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Aquatic Habitat Evaluation Procedures

ARKANSAS RIVER NAVIGATION PROJECT
AQUATIC EVALUATION

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Abstract

An evaluation was conducted to determine aquatic impacts of increasing the depth of the Arkansas River navigation channel from 9 to 12 feet. Field studies were conducted to establish baseline conditions of fish and aquatic habitat. In addition, primary impacts of the project identified by an interagency team of biologists and engineers were evaluated including dike filling rates and associated effects on habitat quality, and the potential of degrading or removing gravel during dredging activities. There are 117 fish species native to the lower Arkansas Drainage. Fish collections from this study area indicate a community that is moderately species-rich (65 species) and representative of most major groups (15 families) within the drainage. Collections were taxonomically dominated by minnows (17 spp.), sunfishes (12 spp.), and suckers (8 spp.). The Arkansas River is inhabited by a high percentage of non-native species five of which were collected in this study: common carp, grass carp, fathead minnow, inland silverside, and striped bass. Gravel bar surveys in proposed dredging locations indicated that 165 acres of gravel could potentially be impacted and would require mitigation by relocating or creating gravel bars. For dike field impacts, the 11-foot channel alternative would result in a loss of 391 average annual habitat units (AAHU) along the entire project length. However, mitigation for the 11-foot alternative resulted in a gain of 494 AAHU. Impacts from the 12-foot alternative would result in a loss of 664 AAHU while approved mitigation projects yielded 108 AAHU. Additional impacts associated with the Verdigris River resulted in a loss of 91 AAHU for both project alternatives. Therefore, the net effect of mitigating impacts, including the Verdigris River channel impacts, was a net gain of 403 and 17 AAHU for the 11- and 12-foot alternatives, respectively. Uncertainty in impacts and mitigation will require a long term monitoring program.

Introduction

The Arkansas River is the fourth largest river in the United States, spanning 1,450 miles. It begins in Colorado, flows through Kansas and Oklahoma, and eventually empties into the Mississippi River. The lower portion of the river is navigable from eastern Oklahoma to the Mississippi River. The McClellan-Kerr Arkansas Navigation system was authorized by the River and Harbors Act of 1946. Construction of the system began in 1949 and was completed in 1970. It spans 445 miles beginning at the mouth of the White River in Arkansas to the Verdigris River in Oklahoma. The navigation channel includes 17 locks and dams, along with hydroelectric facilities at some dams and tributary reservoirs for flood control and recreation. Currently, the authorized navigation channel is 9 feet and is maintained by dredging and dikes.

The Little Rock and Tulsa Districts are evaluating the feasibility of the 12-ft channel. This study, referred to as Phase II of the Arkansas River Navigation Study, will evaluate alternatives and assess impacts of channel deepening by dredging and construction or modification of dikes. The aquatic study was initiated to evaluate potential impacts of channel deepening on riverine habitats and associated fish communities. Coordination with Arkansas Game and Fish Commission, Oklahoma Department of Wildlife Conservation, and U. S. Fish and Wildlife Service identified several areas of concern related to environmental impacts, most notably effects of dredging on gravel substrates and location of disposal areas particularly in dike fields.

A limited field study was initiated in summer 2004 to describe baseline conditions and evaluate impacts. In addition, several interagency meetings were conducted to determine evaluation protocol, agree upon habitat value of dike fields and gravel bars, and discuss mitigation and monitoring needs of the project. The objectives of this report are to:

(a) Describe aquatic habitat and fish communities in representative pools;
(b) Quantify amount and location of gravel bars that could be potentially impacted by dredging;
(c) Quantify amount and relative fishery value of dike fields that will be used as disposal sites to accommodate a deeper navigation channel;
(d) Determine mitigation requirements to compensate for adverse impacts.

Methods

Fish and Habitat Sampling

Of the 17 pools within the project, representative pools were selected for detailed sampling in April and May 2004 (Table 1). In most pools, a minimum of three locations was sampled that corresponded to the lower, middle, and upper reaches. Within each reach, multiple sampling sites were established to incorporate major habitat features (e.g., side channel, main channel, connected backwater, tributary mouths), frequently dredged areas, and dredge disposal sites. This sampling approach provided baseline information and an opportunity to compare

aquatic habitats with different levels of anthropogenic disturbances.

Multiple sampling gears were used to assess three distinct habitats at each site: seining for littoral/shoreline fishes, electroshocking for pelagic/slackwater fishes, and benthic trawls for demersal and main channel fishes. Concurrent with fish collections, physical parameters were measured so that habitat conditions could be described synoptically for all macrohabitats (e.g., littoral zone, channel border, main channel, side channel). Water temperature, conductivity, pH, dissolved oxygen, and turbidity were recorded at a representative position near-shore. Stream width was measured and shoreline position marked so that a representative cross-sectional transect was established. At equidistant intervals, from water's edge to water's edge, depth and velocity were measured. Substrate composition, percent instream cover, and occurrence of major backwaters adjacent to the sampling site were noted.

Comprehensive characterization of the ichthyofauna and aquatic habitats were provided for baseline conditions. Multiple metrics of community diversity were calculated, including indices of species richness and heterogeneity (diversity index). Relative abundance of individual species, including species of special concern (e.g., sturgeon and paddlefish), was summarized. Quantitative relationships between fishes and habitat conditions were developed and used to recommend potential measures of impact prediction. In addition, a complete list of fishes and their distribution within the navigation project were provided.

Gravel Bars

Dredging may alter or remove gravel bars, which are used by a variety of sensitive and protected fishes. A study was initiated to determine the aerial extent of gravel in the project area that could be impacted from channel deepening. Potential gravel bars were identified from a preliminary study, and these locations were later visited by a survey boat to measure substrate composition.

Preliminary estimates of impacts from proposed channel dredging on gravel substrates in the McClellan-Kerr Arkansas River Navigation System were based on both direct observations and indirect indicators from several sources. These sources included current and historical GIS data, Red Hen video footage and observations recorded by field crews during fish sampling. A list of 1-6 mile long sites that were observed to contain or to have a high probability of containing gravel substrates was compiled from these combined sources. The rough area of each site was estimated by multiplying a representative stream width (bank to bank) by the site length.

GIS layers included gravel deposits (obtained from 1981 USGS database, Arkansas Geological Commission and Arkansas Highway and Transportation Department), topographic maps, digital orthophotos and proposed dredging locations (provided by Little Rock District). Locations of current and historical gravel mining operations were used as indirect indicators of possible gravel deposits. Red Hen video footage was collected the week of August 9-13, 2004, during which time stages on the Arkansas River were almost normal. The footage was examined

for exposed gravel bars and areas that, due to surrounding hydrologic and geologic features, might contain gravel substrates.

Substrate observations were made during velocity transects or in the event that a channel trawl yielded gravel in the sample. Velocity transects were taken along a representative cross-section of the channel at ten equidistant points from right bank to left bank, looking upstream. A metal weight carrying a velocity meter was lowered into the water and the flow was measured at the surface and bottom of the water column. When the weight was lowered to the bottom, the operator determined the substrate based on the sensation of the metal striking the river bottom. Substrate was categorized as detritus/woody debris, soft mud, sand, gravel, riprap or bedrock. A 16-foot otter trawl with 1-inch mesh was used to sample benthic fishes of the navigation channel and adjacent areas. Trawls were dragged along the river bottom at 2-5 miles per hour for 10-20 minutes and then hauled in to collect the sample. Any occurrence of gravel in the sample was recorded. GPS coordinates were recorded at each transect and at the beginning and end of each trawl. These locations were incorporated as a layer in the GIS.

The GIS maps were utilized to examine each of the potential gravel sites individually for features that influence substrate composition. These features included channel morphology, channel width, channel depth, scour, adjacent bars, dike fields and size of tributaries. The potential proportion of gravel substrate at each site was estimated as a percent of the stream width. Multiplying the potential proportion of gravel for each site by the site area and summing the resulting acreages approximated total possible amount of gravel along the project length. These estimates assumed simple rectangular site geometry and a normal hydraulic regime with a predictable effect on substrate for each "feature." There was insufficient information to make assumptions about substrate particle size or to differentiate between mixed substrates and "pure gravel." Therefore, these estimates implied that a "gravel substrate" included any substrate containing any amount of gravel of any size.

Little Rock District provided the proposed locations of project dredging in the navigation channel as geo-referenced polygons. The acreage of each of these polygons was calculated by GIS query. Portions of the dredging polygons that fell outside the site range were estimated and the area subtracted from the area of the polygon. These estimates were performed by measuring the total length of the polygon in tenths of miles, then measuring the length of the polygon outside the site range in tenths of miles and dividing the latter by the former to calculate a rough percentage. To estimate area outside the site range, this percentage was multiplied by the total area of the polygon. The resulting area was subtracted from the total area of the polygon to estimate the acres within the site range that could be affected by dredging. For the purpose of simplicity, these estimates assumed that the dredging polygons were rectangular in shape.

In order to verify the quantity of impacted gravel substrate, the potential locations of gravel bars that could be impacted from channel deepening were provided to a hydrographic survey crew with Memphis District. The survey crew visited each potential site to map gravel substrates. A sounding chain was used to identify predominate substrates classified as sand,

sand/gravel mix, and pure gravel. The survey boat established longitudinal transects within the polygon that delineated the dredge cut, and while slowly moving downstream and dragging the chain, each substrate type was mapped and digitally recorded. Maps were transferred to GIS and the actual acres by pool of sand/gravel mix and pure gravel were determined.

Dike Fields and Potential Mitigation Sites

On November 16, 2004, the Little Rock and Tulsa Districts met with biologists from the Engineer Research and Development Center (ERDC), Arkansas Game and Fish Commission (AGFC), Oklahoma Department of Wildlife Conservation (ODWC) and US Fish and Wildlife Service (FWS) at the Corps of Engineers Russellville, AR Project Office to discuss dredge disposal impacts to aquatic habitat in the Arkansas River and compile a list of potential mitigation projects. Aquatic impacts for the Arkansas River Navigation Project were measured in the dike fields and backwater areas using the Habitat Evaluation Procedure (HEP). Red Hen flight video, as well as local knowledge of depth and utilization by fishes, was used to visually assess the habitat value, or existing Habitat Suitability Index (HSI), of each site. AGFC, ODWC and FWS representatives provided valuable local knowledge and suggestions for mitigation. In order to quantify potential benefits from mitigation actions, the participating agencies also provided HSI values for mitigation projects annualized over the project life. These values were based on best professional judgment and experience with similar projects. Acreages for the sites were digitized and provided by the Districts. The result of this inter-agency collaboration was a detailed database containing both qualitative and quantitative information on 180 disposal/mitigation sites in the Arkansas portion and 37 sites in Oklahoma.

Results and Discussion

Fish and Aquatic Habitat

Species composition - Fish collections from the study area indicate a community that is moderately species-rich (65 species) and representative of most major groups (15 families) within the drainage (Table 2). Collections were taxonomically dominated by minnows (17 spp.), sunfishes (12 spp.), and suckers (8 spp.). Gars, herring, catfishes, topminnows, temperate basses, and darters were represented by only a few (3-5) species, but most of these taxa are oligotypic globally or within the drainage (Robison and Buchanan 1988). Bowfin, mooneye, livebearers, silversides, darters, drum, and mullet were each represented by a single species, although all of these taxa are oligotypic or monotypic. The Arkansas River is inhabited by a high percentage of non-native species, five of which were collected in this study: common carp, grass carp, fathead minnow, inland silverside, and striped bass (Cross et al. 1986)

Nine species comprised almost 80% of all fishes collected (Table2). Threadfin shad (35.5%) were the most abundant species and dominated catches made by seining, electrofishing, and trawling. Gizzard shad were also abundant (7.5 %), but only in collections made by

electrofishing. Inland silverside (9.5%) were abundant, but only in seine samples. Red and blacktail shiners, bullhead minnow, and bluegill and longear sunfishes (3-7%) were commonly caught by seining and electrofishing. Blue and channel catfishes were also commonly caught (4%), but only in large numbers when trawling. Twenty species were rare, represented by fewer than 5 specimens (0.03% of total catch).

There are 117 fish species native to the lower Arkansas Drainage (Cross et al., 1986) and previous surveys of the study area (Buchanan 1976) suggest a more speciose fauna for the river (106 spp.). Those data indicate greater diversity for nearly all major groups of fishes including minnows (46 spp.), sunfishes (17 spp.), suckers (17 spp.), catfishes (15 spp.), and darters (24 spp.). The previous surveys, however, were conducted over a greater period of time (7-month period in 1976 versus a 2-month period in 2004), consisted of a greater number of collections (75 seine samples in 1976 vs 33 seine samples in 2004), used disparate techniques (rotenone in 1976, trawling in 2004), and included habitats outside the current project area (clear tributaries). Most of the 45 species reported in 1976 but not collected in 2004 were rare (represented by 5 or fewer specimens). Failure to obtain these was at least partly attributable to their natural rarity in the system and the numerical domination of Arkansas River assemblages by a few species.

Several patterns in fish abundance and distribution were similar in 1976 and 2004. In both surveys, gizzard and threadfin shad were the most abundant species, and inland silversides were common or abundant. Red shiners were the most abundant minnow. River shiner were common upstream from Little Rock, and Mississippi silvery minnow and blacktail shiner downstream from Little Rock. Wetland species, like lake chubsucker, redspotted sunfish, and bantam sunfish were collected only from Merrisach Lake. One important difference between the two surveys is the apparent disappearance of brook silverside – common in 1976 and absent from 2004 surveys. This may be attributable to changes in habitat, but is more likely the result of competitive displacement by the inland silverside, a phenomenon observed previously in impounded rivers (McComas and Drenner 1982).

Fish-Habitat Relationships - Unlike seining and trawling, which could only be done in certain conditions, electrofishing was possible in a wide range of conditions, making it possible to compare fish diversity in a variety of habitats (Table 3). Number of documented species was high ($\geq$ 30 spp.) in dike fields, armored banks, sand bars, and wooded banks; it was moderate (20-26 spp.) in impoundments, aquatic vegetation, and rock outcroppings, and low (< 10 spp.) in other habitats. Sampling effort (number of samples taken to obtain number of individuals) was variable, however, making it impossible to compare number of observed species in an ecologically meaningful manner. To compensate for differences in effort, and to address variation in species-abundance relationships, we used rarefaction (Ludwig and Reynolds 1988; Holland 2003) to estimate the number of species expected for a sample size of 25 randomly drawn individuals from any single habitat. Based on rarefaction, the more diverse or species-rich communities are found on sand bars and in dike fields ($\geq$ 11 spp/25 individuals), and around impoundments, rock outcroppings, wooded or armored banks (approx 10 spp./25 individuals). Species richness is appreciably lower in other habitats (5-7 spp./25 individuals). We believe that

species richness on gravel bars is probably underestimated due to the low number of samples and difficulty of sampling that kind of habitat with a boat-mounted electrofishing setup.

To identify the direction of project impacts on fish communities, we performed a multiple regression analysis. Fish species were classified as: 1) pool-dwelling or backwater species; 2) gravel-associated or channel species; 3) ubiquitous, habitat generalists (excluded from subsequent analysis). Total numbers of fish collected at each site, within each of the two specialist groups, or "guilds," were used as dependent or response variables. Water depth and amount of gravel, which will decrease over the life of the project, were used as independent or predictor variables. Analysis of seining data provided the following statistically significant model for gravel associated species:

$$\text{Number of fish} = 1.27 + 2.72[\text{Pool depth}] + 0.53[\text{Sand and Gravel Acreage}]$$

($N = 31$, $r^2 = 0.19$, $p = 0.055$). Model illustrates a significant positive relationship between fish abundance and the depth of dike pools and the amount of gravel and sand-and-gravel mixture available. It implies that reducing water depth in a dike field and reducing the amount of gravel in the channel will significantly impact those fishes. Analysis of electroshocking data for pool-dwelling fishes did not provide a significant model. This is probably attributable to the prevalence of pool like habitat throughout the system, and insufficient variation in physical habitat for identification of predictive relationships.

Gravel Bars

Gravel bars support a diverse array of fishes, many of which are obligate riverine species and sensitive to habitat degradation and are protected by state and federal regulations. Compared to pools, riffle-oriented fish often have specific requirements for stable, course substrates and low to moderate velocities and many preferentially utilize gravel bars for spawning and foraging. These include sturgeon, paddlefish, suckers, benthic minnows, madtoms, and darters. Resource agencies recognized that impacts to gravel bars needed to be quantified and mitigated if necessary.

Pursuant with the concern about gravel bars, the gravel survey for this project was conducted during the summer of 2005. A total of 28 potential gravel sites were initially identified in the project area ranging from river miles 6.5 - 421.0. The preliminary estimate of total available acres of gravel along the project length was 6,984 acres. However, 96.5 miles of gravel bars, or 23% of the project length, were identified as potential sites that could be impacted by dredging. Estimated total acres of gravel that could be impacted from dredging activities within these 96.5 miles were 967 acres, or 13.8% of the available gravel. These locations, encompassing the 96.5 miles, were provided to the survey boat, and over a 3-week period, the aerial extent and composition of the substrates were measured. These surveys subsequently identified 620 acres of sand/gravel mix, and 165 acres of pure gravel (Table 4).

The survey indicated that sand and sand/gravel mix are relatively ubiquitous throughout the project area. However, pure gravel is a finite resource, and any impacts from dredging will be a primary concern because of the inherent habitat value of gravel bars in riverine systems. Conservation of imperiled species and the overall loss of gravel substrates from anthropogenic disturbances fully justify creation or relocation of gravel bars as a mitigation technique. Studies have reported that created gravel bars are a successful management technique and can provide spawning and rearing habitat for a variety of fishes (Bell 1986; Edwards et al. 1984).

An environmentally conservative assumption is to mitigate gravel bars at a 1:1 ratio, which for this project would be 165 acres. Although gravel bars may not be utilized by all species, those fishes that are found on gravel substrates represent a guild of rare, protected, or commercially important species. Therefore, the goal of the mitigation is to have no-net loss of pure gravel bars either by relocating gravel that is dredged to a nearby, suitable area or transporting dredged gravel to other sites within the project area.

Based on field assessments of gravel bars in the lower Mississippi River basin, environmental guidelines of gravel bar creation are suggested. Design criteria include placement of gravel in relatively high velocity areas to prevent sedimentation such as below dike notches and the tip of dikes. To be functionally equivalent to natural bars, gravel should be of varying sizes (1/8 to 1 inch in diameter). Depth of gravel should be a minimum of 6-12 inches. Preferably, larger grade gravel should be placed first, followed by smaller grade gravel to ensure compactness and reduce loss during placement. Larger boulders and cobble can be initially scattered throughout the restoration site to enhance compactness, minimize loss of smaller gravel, and increase topographic variation of the substrate. Larger stones also collect organic debris that is utilized by madtoms, darters, and other benthic fishes. Variation in gravel size will provide stable substrates for permanent residents that burrow or hide in fine gravel (e.g., darters, macroinvertebrates), species that spawn over a range of gravel sizes (e.g., paddlefish and sturgeon), and fishes that utilize larger gravel for velocity refugia and feeding areas within interstitial spaces.

Impacts and Mitigation Related to Dike Fields

Impacts were directly associated with disposal of dredged material in dike fields. As dike fields become shallower over time, the habitat value to fishes declines. The rate of decline is related to the sediment filling rates associated with dredge disposal and ambient sedimentation rates. Little Rock District engineers met with ERDC on January 6, 2005 and again on April 13, 2005 to discuss dike-filling rates and alternative disposal sites. Limited information was available for dike filling, and realistic numbers are difficult to determine for dynamic and unpredictable processes. Filling occurs based on the specific geomorphology, sediment composition, and flow regime of a particular site. The Arkansas River differs morphologically upstream to downstream within the project area. Therefore, dike filling rates were estimated by Little Rock District for each project alternative and site use (disposal or non-disposal) for Pools 2 through 18 (Table 5). The fill rate (percent per year) was used to estimate percent full at year 50, the life of the project. This value provided a proportion by which the HSI value could be reduced

over the life of the project (with 100% full yielding HSI=0). Figures 1.1, 1.2 and 1.3 illustrate the differences among Navigation Pools 2, 3 and 4. In order to obtain average annual habitat units (AAHU), percent full at time (proportional to HSI) was calculated by multiplying the filling rate during the first 10 years by (10) and using the remaining life of the dike field as the point at which it is 100% full (Figure 2). This two-part linear model is used to annualize the HSI value by: (1) multiplying the average (midpoint) for each linear portion by the beginning HSI value for that part and subtracting the result from the beginning value (i.e. reducing the HSI value by the appropriate amount for that part); and (2) multiplying the results by the number of years for that part, adding and dividing by 50 (time-weighted average) (Figure 3).

Assumptions - Calculation of annualized impacts followed several assumptions. The first was that a dike pool being filled with dredge disposal would gradually become shallower and lose habitat value even though surface acreage may not change appreciably. The rate of change was assumed to follow a two-part linear function (rapid accumulation during the first 10 years and normal accumulation thereafter) to conservatively simplify the naturally dynamic process of sediment accretion behind a dike. Since filling may not affect surface acreage directly, the reduction factor was applied to the HSI value in order to compute impacts to habitat units. The current McClellan Kerr Arkansas River Navigation System (MKARNS) requires maintenance dredging to maintain a 9-foot navigation channel. Since this maintenance activity would likely continue without the proposed deepening, the filling rate for the 9-foot channel was used to calculate "without project" AAHU. The "without project" values, therefore, reflect the continually changing condition of the system rather than a static, "snapshot" of existing conditions typically used in Habitat Evaluation Procedures and referred to as "baseline."

Dike-notching was proposed as a means of minimizing the impacts from this navigation project. Notches in dikes are assumed to cause scour and increase habitat complexity in dike pools. Scour and bathymetric variation add value to aquatic habitat by providing an assortment of microhabitats for different species to exploit. Therefore, it is assumed that the HSI value of the area behind a notched dike will decline 50% less than that of an un-notched dike. Areas with un-notched dikes and other mitigation measures are assumed to fill at the previously specified rates (Table 5). A conceptual model is given in Figure 4 to explain how impacts were calculated under each set of circumstances.

Mitigation projects were proposed to compensate for the potential loss in habitat units from deepening the navigation channel. These measures were organized into three categories: avoid, minimize and compensate. "Avoid" projects entailed avoiding disposal of dredge spoil in an area of high habitat value and moving it to an area of lesser value. In this case, the original location maintains its value and the new disposal area contributes to the overall loss of habitat units. As previously mentioned, notching a dike is assumed to minimize impacts to the dike pool habitat. Proposed dike notches and revetment notches were therefore classified as "minimize" projects and benefits were derived in the form of "reduced impacts." The third category was composed of true compensation measures such as restoring access to backwaters and construction of specific types of habitats. These projects result in actual benefits in that "new"

acres may be added at a higher value, increasing habitat units. A conceptual model is given in Figure 5 to explain how benefits were calculated under each set of circumstances.

Impacts and benefits for each project alternative are given by navigation pool and state in Table 6. Pool 2 (navigation mile 19-50) contained the most proposed dredge disposal areas, but due to higher filling rates, Pools 12 (NM 257-292) and 10 had the greatest aquatic impacts for the 11-ft (-66.1 AAHU) and 12-ft (-112.6 AAHU) alternatives, respectively. Pool 2 also provided for the most benefits of any one pool with 135.3 AAHU gained with the mitigated 11-ft project alternative and 104.3 AAHU gained for the 12-ft alternative. Pool 14 (NM 319-336) and the Post Canal (NM 19 to White River) contained only proposed mitigation and did not contribute to the overall project impacts. For the entire project (Arkansas and Oklahoma combined), the 11-foot channel alternative would result in a loss of 391 average annual habitat units (AAHU) (Table 6). However, mitigation for the 11-foot alternative would result in a gain of 494 AAHU. Impacts from the 12-foot project would result in a loss of 664 AAHU while approved mitigation projects yielded 108 AAHU.

Additional impacts for the Verdigris River were identified. The Verdigris River was straightened and channelized to provide a reliable navigation channel. The channel was shortened from cutoffs, high spoil banks were created on both sides for 50 miles, and the floodplain and associated backwaters became isolated from the river. Isolation of backwaters prevents transfer of organic matter and nutrients between river and floodplain and reduces important spawning and rearing areas for fishes. The navigation channel is 150-ft wide in the Verdigris River compared to a 250-ft channel in the Arkansas River. Therefore, impacts of navigation-related activities have been proportionally greater in the narrow, incised channel of the Verdigris River compared to the wider channel in the Arkansas River. To quantify this impact, the number of acres associated with the navigation channel in Verdigris river pools (i.e., 909.1 acres) was multiplied by an HSI of 0.1, indicating low habitat quality for existing conditions, to obtain impacts of 90.9AAHU for both alternatives. These additional impacts when compared to the mitigation resulted in a net gain of 403 and 17 AAHU for the 11- and 12-foot alternatives, respectively.

Monitoring

The U. S. Fish and Wildlife Service has promoted a long term monitoring program to address the uncertainties in predicting impacts and success of proposed mitigation projects. A monitoring program has been outlined that includes both biological and engineering studies (included as Appendix in EIS). These studies address sediment dynamics in dike fields and backwaters, developing a better understanding of biological responses of fish and other aquatic organisms to dike modifications such as notching, field surveys of gravel bar characteristics and fish utilization, and potential of headcutting and associated impacts to fish in tributaries. A more detailed monitoring program will be developed in cooperation with state and federal agencies to address these topics.

Acknowledgements

Field assistance was provided by Steven George, Bradley Lewis, Bill Lancaster, Phil Kirk, Jay Collins, April Turnage and Neil Douglas. Neil Douglas also identified and curated fishes into the Museum of Zoology, University of Louisiana at Monroe. The interagency team that assisted in evaluated project impacts and mitigation requirements included individuals from Little Rock District, Tulsa District, U.S. Fish and Wildlife Service, Arkansas Game and Fish Commission, and Oklahoma Department of Conservation. Mark Manning and Danny Hunt from Memphis District conducted the gravel survey. ERDC personnel providing input and assistance in evaluating dike fields and gravel bars included Maureen Corcoran, Meg Jonas, David Biendenharn, Julie Kelley and Evelyn Villanueva. Glen Raible (Little Rock District) provided filling rates for dredging impacts to dike fields.

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Table 1. Fish Sampling Sites for the Arkansas River Navigation Project, 2004						
Site #	**Location (pool)**	**Station**	**Mile**	**Seine**	**Shock**	**Trawl**
1	Chouteau	Below Newt Graham L&D 18	420.8	√	√	√
2	Chouteau	Channel near Afton Landing	411.0			√
2.5	Chouteau - bw	Afton Landing backwater	BW	√	√	
3	Chouteau	Above Chouteau L&D 17	402			√
4	Chouteau - bw	Backwater at RM 403.2	BW	√		
5	Pool 16	Below Chouteau L&D 17	401.2		√	√
6	Pool 16 - bw	Falls Park Backwater at RM 398	BW		√	
7	Pool 16	Confluence of AR and Verdigris R.	394.5	√	√	√
7.5	Pool 16 - bw	Sandbar Pool at Confluence	394.5	√		
8	Pool 16	Channel at Coody Creek mouth	389.5	√	√	√
8.5	Pool 16 - bw	Backwater at 389.5 (inside sandbar)	BW	√		
9	Pool 16 - trib	Mouth of Coody Creek	389.5		√	
10	Pool 16 - trib	Mouth of Maynard Bayou	387		√	
11	Neosho	Neosho (Grand) River 4 mi. upst. of AR R.	--			√
12	Pool 13	Island above Trimble L&D 13	293.3	√	√	√
13	Pool 13	Right bank upst. of Trimble L&D 13	293.3	√	√	
14	Ozark	Below Trimble L&D 13	289.5	√	√	√
15	Ozark	Channel at mouth of Mulberry River	272	√	√	√
15.5	Ozark	Channel upst. of Mulberry River mouth	277			√
16	Ozark - trib	Lower mouth of Mulberry River	272		√	√
17	Dardanelle	Below Ozark-Jeta L&D 12	256.5	√	√	√
18	Dardanelle	Rock weir at Rogers Cabin	231.5		√	√
19	Dardanelle	Across from Spadra Park	229.8	√	√	√
20	Dardanelle	Mouth of Cabin Creek at ramp nr. old RR bridge	--		√	
21	Pool 9	Below Dardanelle L&D 10	205	√	√	√
22	Pool 7	Below Toad Suck L&D 8 – pool	155.3	√	√	
22.5	Pool 7	Below Toad Suck L&D 8 – channel	155.3	√	√	√
23	Pool 7	Mouth of Fouche La Fave	146.8	√	√	
24	Pool 7	AR @ Fouche La Fave mouth – rt. bank	146.8	√		√
24.5	Pool 7	AR @ Fouche La Fave mouth – lft. bank	146.8	√		
25	Pool 7	2° Channel at Beaver Dam Island	141.5	√	√	√
26	Terry Lake	Below Murray L&D 7 – main channel	124.3	√	√	√
26.5	Terry Lake	Below Murray L&D 7 – side channel	124.3	√		
27	Terry Lake	AR @ downtown Little Rock	120	√	√	
28	Terry Lake - bw	Willow Bend Cutoff nr. Terry L&D 6	108.4		√	
29	Terry Lake	Above David D. Terry L&D 6	109.8	√	√	√
30	Pool 5	Below David D. Terry L&D 6	107.6	√	√	√
31	Pool 2	Below Joe Hardin L&D 3	49.6	√	√	√
32	Pool 2	AR @ Mud Lake entrance	44.6	√		√
32.5	Pool 2 - bw	Inside Mud Lake entrance	44.4	√	√	
33	Pool 2	Upst. of mouth of Big Bayou Meto	31.7	√	√	√
34	Pool 2 - bw	AR @ mouth of Big Bayou Meto	31.2	√	√	
35	Pool 2	Post Canal at Merrisach Lake	14.4	√	√	
36	Pool 2	Above L&D 2	13.4		√	√
37	Wild AR R.	1 mile dnst. of Wilbur D. Mills Dam – channel	--	√	√	√
37.5	Wild AR R.	1 mile dnst. of Wilbur D. Mills Dam – bw	--	√		
38	Wild AR R.	Below Wilbur D. Mills Dam	--		√	

Table 2. Number of individual fish collected by species and gear type in the Arkansas River below Newt Graham Lock & Dam in 2004. Gear types were 20-foot seine (n=33), electroshock boat (n=35), and 16-foot otter trawl (n=27).

Scientific name	Common name	Seine	Shock	Trawl	All Gear
Family Lepisosteidae					
Lepisosteus oculatus	Spotted gar		16	3	19
L. osseus	Longnose gar	3	4		7
L. platostomus	Shortnose gar		9		9
Lepisosteus spp.	YOY Gar	1			1
Family Amiidae					
Amia calva	Bowfin		1		1
Family Clupeidae					
Alosa chrysochloris	Skipjack herring	6	2	2	10
Dorosoma cepedianum	Gizzard shad	104	1131	59	1294
D. petenense	Threadfin shad	4630	1107	423	6160
Family Hiodontidae					
Hiodon tergisus[1]	Mooneye			1	1
Family Cyprinidae					
Ctenopharyngodon idella	Grass carp		2		2
Cyprinella lutrensis	Red shiner	1123	71		1194
C. venusta	Blacktail shiner	665	99		764
C. whipplei	Steelcolor shiner		1		1
Cyprinus carpio	Common carp	16	21		37
Hybognathus nuchalis	Mississippi silvery minnow	40	7		47
Extrarius aestivalis	Speckled chub	443		3	446
Macrhybopsis storeriana	Silver chub	7		1	8
Notemigonus crysoleucas	Golden shiner	3	1		4
Notropis atherinoides	Emerald shiner	198	60		258
N. blennius	River shiner	509	6	1	516
N. buchanani	Ghost shiner	33			33
N. volucellus[1]	Mimic shiner	1		1	2
Opsopoedus emiliae	Pugnose minnow		4		4
Pimephales notatus	Bluntnose minnow	1			1
P. promelas	Fathead minnow	1			1
P. vigilax	Bullhead minnow	583	51		634
Family Catostomidae					
Carpiodes carpio	River carpsucker	8	138	3	149
C. cyprinus	Quillback carpsucker		5		5
C. velifer	Highfin carpsucker		1		1
Carpiodes spp.	YOY Carpsucker	20			20
Erimyzon sucetta	Lake chubsucker	2			2
Ictiobus bubalus	Smallmouth buffalo		70	4	74
I. cyprinellus	Bigmouth buffalo		10		10
I. niger	Black buffalo		2		2
M. macrolepidotum	Shorthead redhorse		2		2
Family Ictaluridae					
Ameiurus natalis	Yellow bullhead	1			1
Ictalurus furcatus	Blue catfish	30	60	583	673
I. punctatus	Channel catfish	78	38	554	670

(continued)

Table 2. Number of individual fish collected by species and gear type in the Arkansas River below Newt Graham Lock & Dam in 2004. Gear types were 20-foot seine (n=33), electroshock boat (n=35), and 16-foot otter trawl (n=27).

Scientific name	Common name	Seine	Shock	Trawl	All Gear
Noturus nocturnus	Freckled madtom			1	1
Pylodictis olivaris	Flathead catfish		26	2	28
Family Cyprinodonitdae					
Fundulus chrysotus	Golden topminnow	12	1		13
F. notatus	Blackstripe topminnow	2			2
F. olivaceus	Blackspotted topminnow	2			2
Family Poeciliidae					
Gambusia affinis	Mosquitofish	22			22
Family Atherinidae					
Menidia beryllina	Inland silverside	1561	82		1643
Family Moronidae					
Morone chrysops	White bass	28	137	9	174
M. mississippiensis	Yellow bass		25		25
M. saxatilis	Striped bass		38	14	52
Morone spp.	YOY temperate bass	2			2
Family Centrarchidae					
Lepomis cyanellus	Green sunfish	2	39		41
L. cyanellusXspp.	Hybrid green sunfish	1	1		2
L. gulosus	Warmouth	2	20		22
L. humilis	Orangespotted sunfish	4	19		23
L. macrochirus	Bluegill	159	431	8	598
L. megalotis	Longear sunfish	327	415	2	744
L. microlophus	Redear sunfish	16	46		62
L. microlophusXspp.	Hybrid redear sunfish	1	2		3
L. miniatus	Red spotted sunfish	14	10		24
L. symmetricus	Bantam sunfish	4			4
Micropterus punctulatus	Spotted bass	29	35		64
M. salmoides	Largemouth bass	88	212		301
Pomoxis annularis	White crappie	1	34	7	42
P. nigromaculatus	Black crappie	1	7	29	37
Family Percidae					
Percina caprodes	Logperch	6	10		16
P. shumardi	River darter	13			13
Stizostedion canadense	Sauger	1	2	2	5
Family Sciaenidae					
Aplodinotus grunniens	Freshwater drum	33	176	89	298
Family Mugilidae					
Mugil cephalus	Striped mullet		2		2
Total number of species		47	50	23	65
Total number of individuals		10837	4689	1801	17328

[1] *Collected only below Wilbur D. Mills Dam*

Table 3. Number of individual fish collected by species and habitat in the Arkansas River below Newt Graham Lock & Dam in 2004. Gear type for this analysis was electroshock boat (n=35).

Scientific name	Common name	Armored Bank	Bank Without Cover	Open Channel	Dike Field	Eroding Bank	Gravel Bar	Rock Outcrop	Sand Bar	Dam or Weir	Aquatic Vegetation	Wooded Bank
Family Lepisosteidae												
Lepisosteus oculatus	Spotted gar	1	1		2			2		1	4	5
L. osseus	Longnose gar	2			2							
L. platostomus	Shortnose gar	2			3				1	3		
Lepisosteus spp.	YOY Gar											
	TOTAL	5	1	0	7	0	0	2	1	4	4	5
Family Amiidae												
Amia calva	Bowfin	1										
	TOTAL	1	0	0	0	0	0	0	0	0	0	0
Family Clupeidae												
Alosa chrysochloris	Skipjack herring	1					1					
Dorosoma cepedianum	Gizzard shad	160	27	3	326	5	32	33	77	65	182	221
D. petenense	Threadfin shad	131	3	2	29		8	23	30	74	644	163
	TOTAL	292	30	5	355	5	41	56	107	139	826	384
Family Hiodontidae												
Hiodon tergisus[1]	Mooneye											
	TOTAL	0	0	0	0	0	0	0	0	0	0	0
Family Cyprinidae												
Ctenopharyngodon idella	Grass carp				1				1			
Cyprinella lutrensis	Red shiner	1			6			1	36		10	17
C. venusta	Blacktail shiner	2	3		73			4	7	4	1	5
C. whipplei	Steelcolor shiner									1		
Cyprinus carpio	Common carp	5			2				3	1	1	9
Hybognathus nuchalis	Mississippi silvery minnow									7		
Extrarius aestivalis	Speckled chub											
Macrhybopsis storeriana	Silver chub											
Notemigonus crysoleucas	Golden shiner				1							
Notropis atherinoides	Emerald shiner	1			4				1	48		6
N. blennius	River shiner				4				1		1	
N. buchanani	Ghost shiner											

Table 3. Number of individual fish collected by species and habitat in the Arkansas River below Newt Graham Lock & Dam in 2004. Gear type for this analysis was electroshock boat (n=35).

Scientific name	Common name	Armored Bank	Bank Without Cover	Open Channel	Dike Field	Eroding Bank	Gravel Bar	Rock Outcrop	Sand Bar	Dam or Weir	Aquatic Vegetation	Wooded Bank
N. volucellus[1]	Mimic shiner											
Opsopoedus emiliae	Pugnose minnow									2	2	
Pimephales notatus	Bluntnose minnow											
P. promelas	Fathead minnow											
P. vigilax	Bullhead minnow	1	2		2	1		1	16		2	26
	TOTAL	10	5	0	93	1	0	6	65	63	17	63
Family Catostomidae												
Carpiodes carpio	River carpsucker	12			33		2	3	21		6	61
C. cyprinus	Quillback carpsucker	2			2		1					
C. velifer	Highfin carpsucker						1					
Carpiodes spp.	YOY Carpsucker											
Erimyzon sucetta	Lake chubsucker											
Ictiobus bubalus	Smallmouth buffalo	10			10	4		2	6		2	36
I. cyprinellus	Bigmouth buffalo	1			3	1			4		1	
I. niger	Black buffalo				2							
M. macrolepidotum	Shorthead redhorse						1		1			
	TOTAL	25	0	0	50	5	5	5	32	0	9	97
Family Ictaluridae												
Ameiurus natalis	Yellow bullhead											
Ictalurus furcatus	Blue catfish	7		1	33			4	3	8		4
I. punctatus	Channel catfish	3			7	6		3	9	3		7
Noturus nocturnus	Freckled madtom											
Pylodictis olivaris	Flathead catfish	3		1	14			3	1	3		1
	TOTAL	13	0	2	54	6	0	10	13	14	0	12
Family Fundulidae												
Fundulus chrysotus	Golden topminnow	1										
F. notatus	Blackstripe topminnow											
F. olivaceus	Blackspotted topminnow											
	TOTAL	1	0	0	0	0	0	0	0	0	0	0
Family Poeciliidae												
Gambusia affinis	Mosquitofish											
	TOTAL	0	0	0	0	0	0	0	0	0	0	0

Table 3. Number of individual fish collected by species and habitat in the Arkansas River below Newt Graham Lock & Dam in 2004. Gear type for this analysis was electroshock boat (n=35).

Scientific name	Common name	Armored Bank	Bank Without Cover	Open Channel	Dike Field	Eroding Bank	Gravel Bar	Rock Outcrop	Sand Bar	Dam or Weir	Aquatic Vegetation	Wooded Bank
Family Atherinidae												
Menidia beryllina	Inland silverside	18			12			1	4	20	20	7
	TOTAL	18	0	0	12	0	0	1	4	20	20	7
Family Moronidae												
Morone chrysops	White bass	7			58		31		13	16	3	9
M. mississippiensis	Yellow bass				17		1		2	2	1	2
M. saxatilis	Striped bass	1			2		32		2			1
Morone spp.	YOY temperate bass											
	TOTAL	8	0	0	77	0	64	0	17	18	4	12
Family Centrarchidae												
Lepomis cyanellus	Green sunfish	15			13			4	1	3	1	2
L. cyanellusXspp.	Hybrid green sunfish											1
L. gulosus	Warmouth	4			9							7
L. humilis	Orangespotted sunfish	1			3			5	4	2	1	3
L. macrochirus	Bluegill	39	2		87	13	1	17	41	13	68	150
L. megalotis	Longear sunfish	115	11		128	3		22	33	21	6	76
L. microlophus	Redear sunfish	4			12				8	4	14	4
L. microlophusXspp.	Hybrid redear sunfish				1							1
L. miniatus	Red spotted sunfish	6								4		
L. symmetricus	Bantam sunfish											
Micropterus punctulatus	Spotted bass	2			16		1	2	3	4	1	6
M. salmoides	Largemouth bass	40	3		73	2		3	12	14	34	31
Pomoxis annularis	White crappie	7			7		3	2		1		14
P. nigromaculatus	Black crappie				2							5
	TOTAL	233	16	0	351	18	5	55	102	66	125	300
Family Percidae												
Percina caprodes	Logperch	10										
P. shumardi	River darter											
Stizostedion canadense	Sauger								1			1
	TOTAL	10	0	0	0	0	0	0	1	0	0	1
Family Sciaenidae												
Aplodinotus grunniens	Freshwater drum	23	2		31	3	7	1	14	4	14	77

Table 3. Number of individual fish collected by species and habitat in the Arkansas River below Newt Graham Lock & Dam in 2004. Gear type for this analysis was electroshock boat (n=35).

Scientific name	Common name	Armored Bank	Bank Without Cover	Open Channel	Dike Field	Eroding Bank	Gravel Bar	Rock Outcrop	Sand Bar	Dam or Weir	Aquatic Vegetation	Wooded Bank
	TOTAL	23	2	0	31	3	7	1	14	4	14	77
Family Mugilidae												
Mugil cephalus	Striped mullet	1			1							
	TOTAL	1	0	0	1	0	0	0	0	0	0	0
Total number of species		36	9	4	38	9	14	20	30	26	23	31
Total number of families		13	5	2	10	6	5	8	10	8	8	10
Total number of individuals		640	54	7	1031	38	122	136	356	328	1019	958
Sample number (N)		14	3	2	24	1	3	4	12	6	7	19
Total catch per effort		45.7	18	3.5	42.9	38	40.6	34	29.6	54.6	145.5	50.4
Expected number of species for 25 individuals		9.7	7.2	N/a	11.0	8.1	7.0	10.2	11.9	10.5	5.4	10.0

[1] *Collected only below Wilbur D. Mills Dam*

Table 4. Summary of location and amount (acres) of gravel substrate in project area.

Pool	River Mile	Gravel (acres)	Total per pool	Mix sand/gravel (acres)	Total per pool
Pool 5	108	1.6		7.47	
			1.6		7.47
Pool 7	140	0.11		4.94	
	146	3.42		36.45	
	150	17.44		36.88	
	150.5	20.43		1.4	
			41.4		79.67
Pool 9	186	23.36		144.25	
	205	27.8		6.77	
			51.16		151.02
Pool 10	229	0.61		54.15	
			0.61		54.15
Pool 15	361	36.7		154.15	
					154.15
Pool 16	374	1.23		55.81	
	393	0.83		41.06	
	395	3.54		32.93	
			5.6		129.8
Pool 17	402	7.24		32.14	
	421	20.69		11.82	
			27.93		43.96
Total		**165**		**620**	

Table 5. Filling rates by project alternative and site use for each navigation pool.

LOCATION	FILL RATE IN PERCENT AND REMAINING LIFE IN YEARS OF DIKE FIELDS											
	McClellan-Kerr Arkansas River Navigation System											
	EXISTING PROJECT AREAS		PLAN 12' PROJECT AREAS		PLAN 11' PROJECT AREAS		EXISTING DISPOSAL AREAS		PLAN 12' DISPOSAL AREAS		PLAN 11' DISPOSAL AREAS	
	FILL RATE %	LIFE YRS	FILL RATE %*	LIFE YRS	FILL RATE %*	LIFE YRS	FILL RATE %	LIFE YRS	FILL RATE %*	LIFE YRS	FILL RATE %*	LIFE YRS
POOL 18	1.107	90	1.661/1.107	85	1.661/1.107	85	N/A	N/A	N/A	N/A	N/A	N/A
POOL 17	1.107	90	1.661/1.107	85	1.661/1.107	85	N/A	N/A	N/A	N/A	N/A	N/A
POOL 16	1.107	90	1.661/1.107	85	1.661/1.107	85	2.927	34	5.661/3.774	21	4.705/3.136	27
POOL 15	1.786	56	2.679/1.786	51	2.679/1.786	51	2.927	34	5.661/3.774	21	4.705/3.136	27
POOL 14	1.230	81	1.846/1.230	76	1.846/1.230	76	N/A	N/A	N/A	N/A	N/A	N/A
POOL 13	1.667	60	2.500/1.667	55	2.500/1.667	55	N/A	N/A	N/A	N/A	N/A	N/A
POOL 12	1.884	53	2.827/1.884	48	2.827/1.884	48	2.927	34	5.661/3.774	21	4.705/3.136	27
POOL 10	1.088	92	1.632/1.088	87	1.632/1.088	87	1.555	64	3.412/2.275	39	2.545/1.697	54
POOL 09	1.064	94	1.596/1.064	89	1.596/1.064	89	1.518	66	3.163/2.109	42	2.462/1.642	56
POOL 08	1.883	53	2.824/1.883	48	2.824/1.883	48	2.314	43	3.661/2.441	36	3.262/2.326	41
POOL 07	1.716	58	2.574/1.716	53	2.574/1.716	53	2.494	40	4.033/2.689	32	3.607/2.661	37
POOL 06	1.667	60	1.667	60	1.667	60	NC	NC	NC	NC	NC	NC
POOL 05	1.454	69	2.181/1.454	64	2.181/1.454	64	1.717	58	3.647/2.431	36	3.067/2.049	44
POOL 04	1.753	57	2.630/1.753	52	2.630/1.753	52	3.720	27	5.862/3.908	21	5.143/3.750	24
POOL 03	1.148	87	1.722/1.148	82	1.722/1.148	82	1.877	53	3.450/2.300	38	2.934/1.956	46
POOL 02	1.547	65	2.320/1.547	60	2.320/1.547	60	2.108	47	3.307/2.205	40	3.066/2.131	44

- Fill Rate is assumed to directly correlate to the Historical Dredging amounts that averaged 60 percent of total in the first 10 years of the project and 40 percent of the total over the last 24 years for Pools 18 through Pool 7, 60 percent for first 12 yrs for Pool 5 and 60 percent for first 14 yrs for Pools 4 through 2 (Based on 34 years of Dredging Records 1971-2004).
- Pool 18 and 17 project areas are all backwater areas.
- N/A = All Dredge Disposal is Upland.
- NC = No Change as no structures or dredging required except at L&D 7 Lock Approach with disposal just outside of channel.
- *Fill Rate first 10 years/Fill Rate remaining life - Sediment Deposition Increased +50% for 10 years in Project Areas due to Modified Dike Fields

Table 6. Summary of impacts and benefits by state and pool.

All Projects									
	Total Existing HUs	Total HUs with 11-ft Project	HUs Effected by 11-ft Project	Total HUs with Mitigated 11-ft Project	Change in Mitigated 11-ft HUs Relative to Baseline	Total HUs with 12-ft Project	HUs Effected by 12-ft Project	Total HUs with Mitigated 12-ft Project	Change in Mitigated 12-ft HUs Relative to Baseline
Arkansas									
Canal	22.055	22.055	0.000	26.216	4.161	22.055	0.000	26.216	4.161
Pool 2	700.451	653.155	-47.296	836.278	135.827	636.911	-63.540	804.738	104.287
Pool 3	93.142	88.694	-4.447	109.752	16.610	83.238	-9.904	100.374	7.233
Pool 4	108.210	106.455	-1.755	170.057	61.847	105.577	-2.633	169.076	60.865
Pool 5	374.035	322.574	-51.460	391.655	17.620	288.563	-85.471	342.606	-31.428
Pool 6	55.475	55.475	0.000	87.145	31.670	55.475	0.000	87.145	31.670
Pool 7	395.266	337.768	-57.498	431.569	36.303	316.889	-78.376	384.729	-10.537
Pool 8	150.737	130.164	-20.573	161.383	10.647	122.092	-28.644	149.546	-1.190
Pool 9	536.465	494.445	-42.020	558.589	22.123	426.855	-109.610	472.054	-64.411
Pool 10	440.170	394.722	-45.448	526.481	86.311	327.552	-112.618	437.892	-2.278
Pool 12	425.334	359.241	-66.093	399.366	-25.967	318.531	-106.803	350.991	-74.342
Pool 13	24.497	24.497	0.000	38.550	14.054	24.497	0.000	38.550	14.054
Oklahoma									
Pool 13	11.665	11.583	-0.082	24.150	12.485	11.583	-0.082	24.150	12.485
Pool 14	90.845	90.845	0.000	131.529	40.684	90.845	0.000	131.529	40.684
Pool 15	32.269	18.095	-14.174	15.974	-16.295	15.022	-17.247	13.961	-18.308
Pool 16	134.501	117.023	-17.478	160.550	26.049	113.339	-21.162	155.747	21.247
SBC	46.494	23.729	-22.765	29.379	-17.115	18.794	-27.700	23.268	-23.226
Pool 17	127.581	127.581	0.000	164.873	37.292	127.581	0.000	164.873	37.292
Pool 18	11.283	11.283	0.000	11.283	0.000	11.283	0.000	11.283	0.000
Totals									
AR	3325.836	2989.245	-336.591	3737.041	411.205	2728.237	-597.599	3363.917	38.081
OK	454.637	400.139	-54.499	537.737	83.099	388.447	-66.190	524.812	70.174
TOTAL	3780.474	3389.384	-391.089	4274.778	494.304	3116.684	-663.790	3888.729	108.255

Figure 1.1 Effect of fill rates on habitat suitability index over life of project for each project alternative in Pool 2.

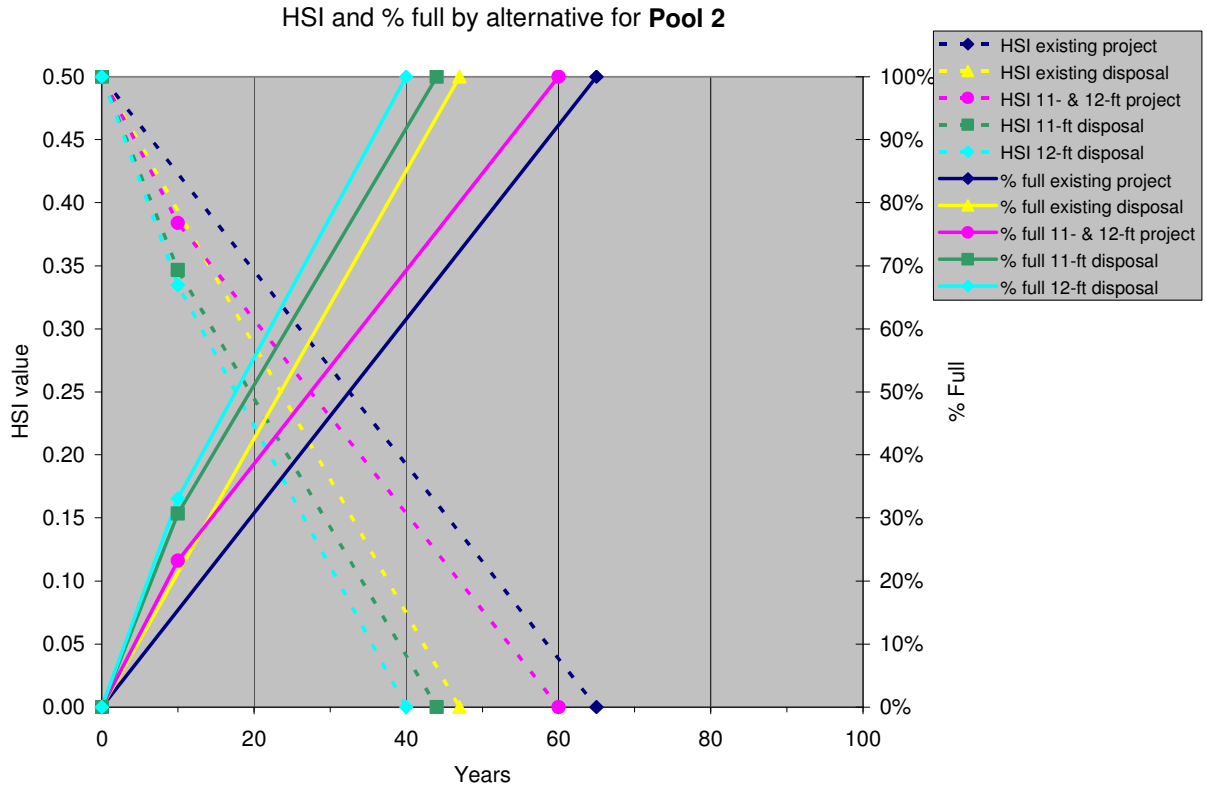


Figure 1.2 Effect of fill rates on habitat suitability index over life of project for each project alternative in Pool 3.

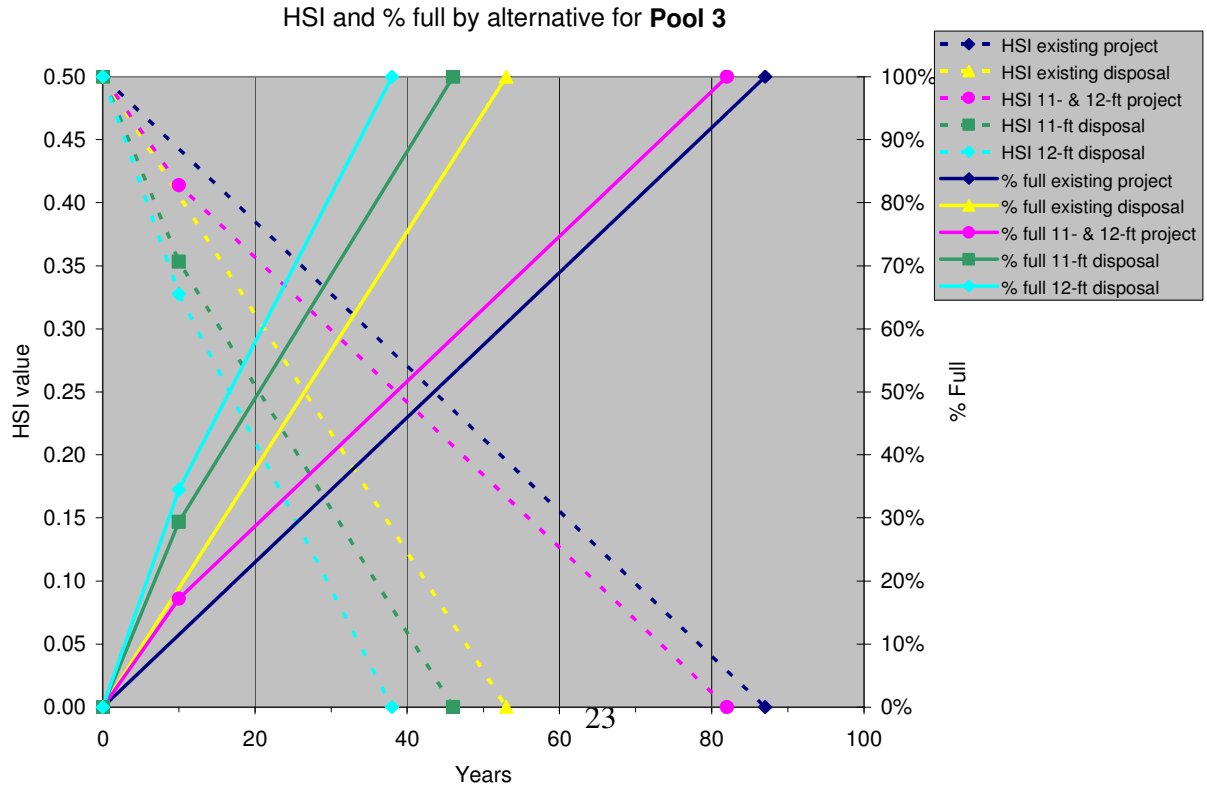


Figure 1.3 Effect of fill rates on habitat suitability index over life of project for each project alternative in Pool 4.

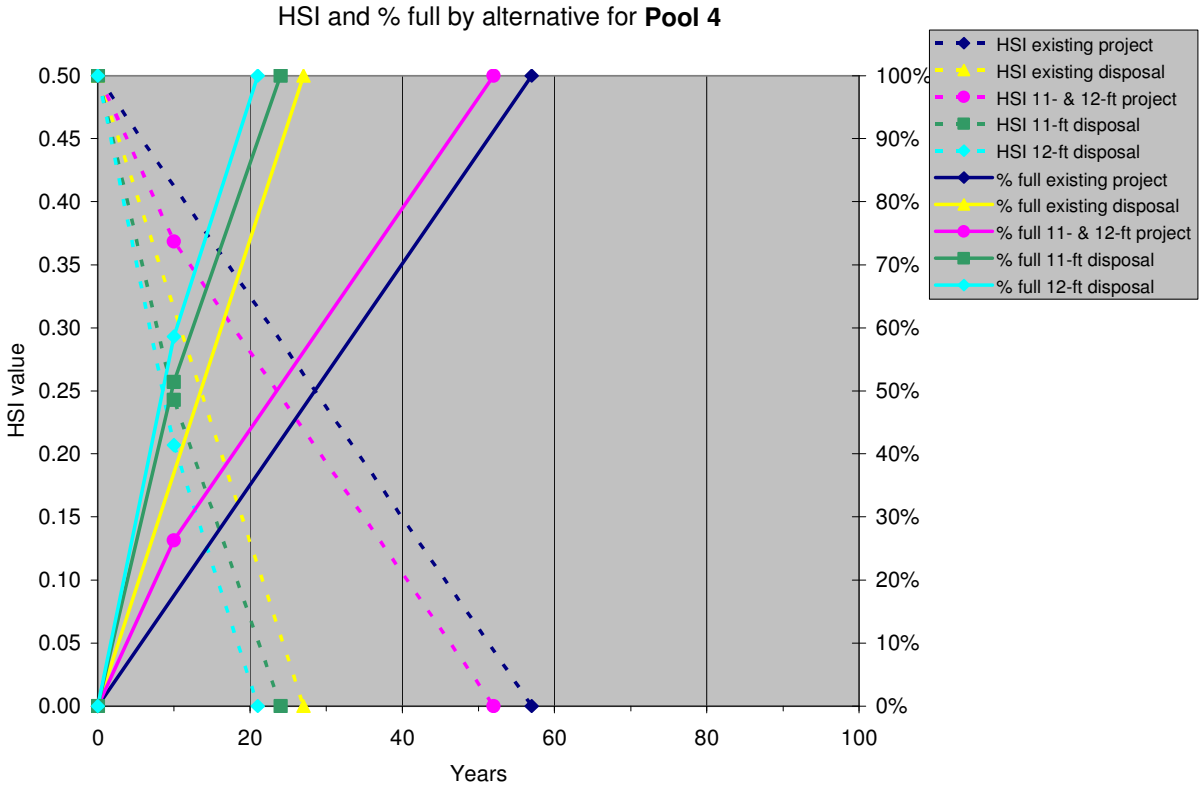


Figure 2. Effect of filling rate (illustrated as % full) on HSI value.

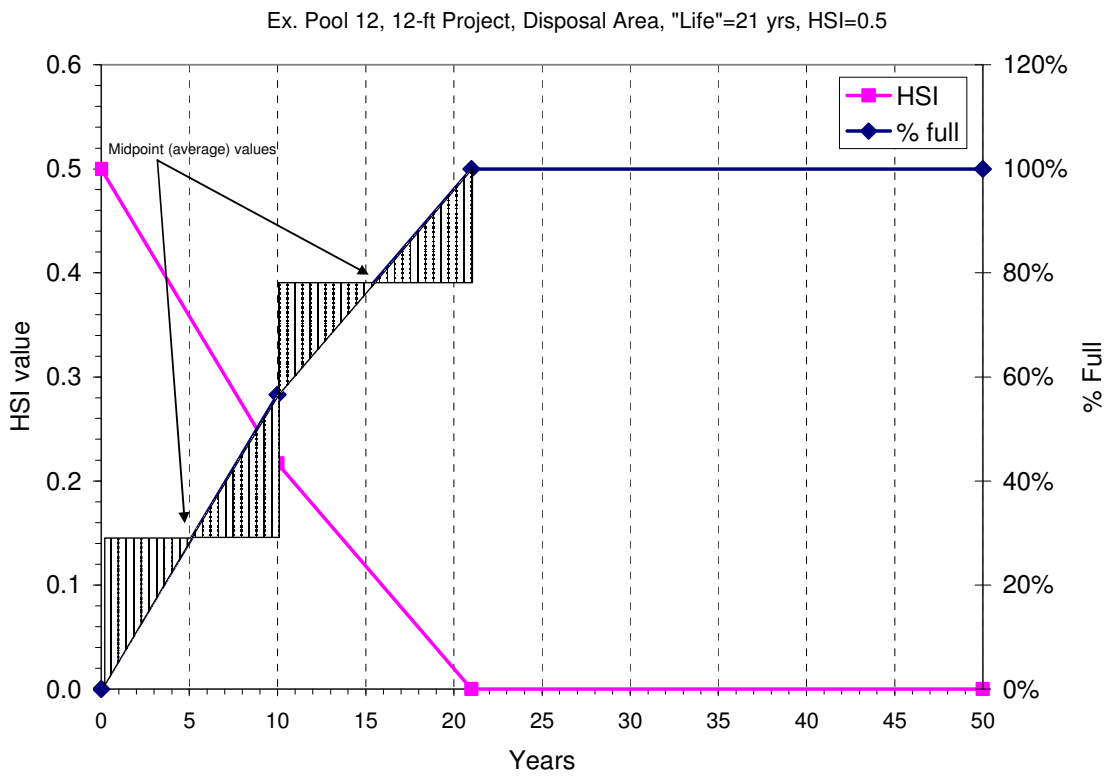


Figure 3. Average annualized HSI value calculation, in general.

$$=((HSI_0-(((FR_{0\text{-}10}/100*10)/2)*HSI_0))*10+((HSI_0-(((FR_{0\text{-}10}/100*10)/2*HSI_0))-((FR_{10\text{-}EY}/100*(EY-10)+FR_{0\text{-}10}/100*10)/2)*(HSI_0-(((FR_{0\text{-}10}/100*10)/2*HSI_0)))*(EY-10))/50$$

$$=((HSI_0-(MidPt_{0\text{-}10})*HSI_0)*10+((HSI_0-(MidPt_{0\text{-}10})*HSI_0)-((MidPt_{10\text{-}EY})*(HSI_0-(MidPt_{0\text{-}10})*HSI_0)))*Y_{10\text{-}EY})/50$$

$$=(HSI_{0\text{-}10}*10+(HSI_{0\text{-}10}-MidPt_{10\text{-}EY}*HSI_{0\text{-}10})*Y_{10\text{-}EY})/50$$

$$=(HSI_{0\text{-}10}*10+HSI_{10\text{-}EY}*Y_{10\text{-}EY})/50$$

$$=HSI_{AA}$$

Where:

HSI = Habitat Suitability Index
FR = Filling Rate
EY = End Year
Y = Years

Figure 4. Conceptual model used to calculate project impacts by alternative.

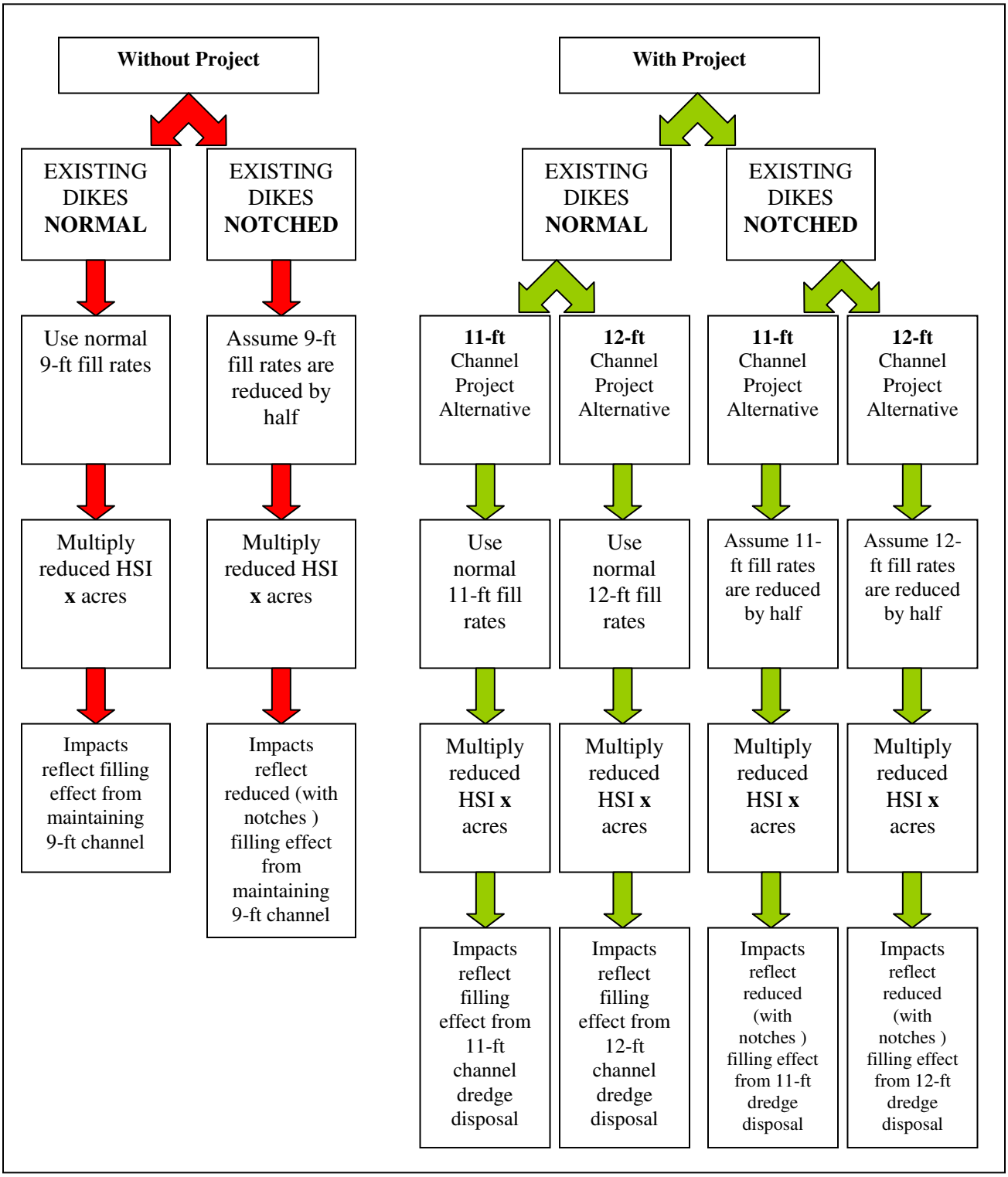
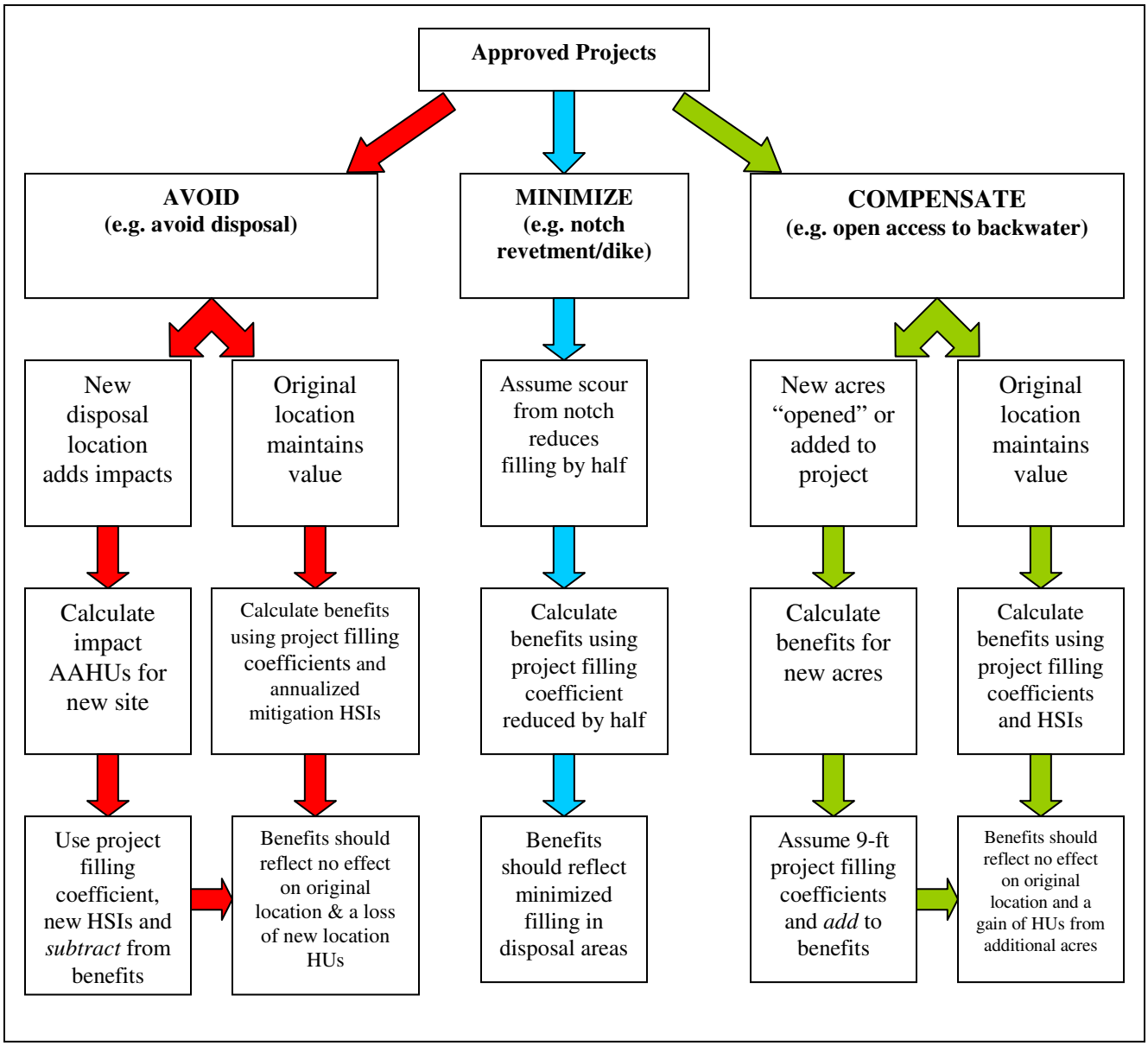


Figure 5. Conceptual model used to calculate project benefits by alternative.



C.7

Aquatic Mitigation Summary

Aquatic Mitigation Summary

Nav. Mile	Mitigation Category	Project Description	Corps Technical Acceptability	Total Existing HUs	HUs Effected by 11-ft Project	Total HUs with Mitigated 11-ft Project	Change in Mitigated 11-ft HUs Relative to Baseline	HUs Effected by 12 ft Project	Total HUs with Mitigated 12-ft Project	Change in Mitigated 12-ft HUs Relative to Baseline
Canal										
15.3R	Compensate	Reconnect Lower Merrisach Lake to Canal with culvert or water control structure for fish passage	Approved	**22.055**	**0.000**	**26.216**	**4.161**	**0.000**	**26.216**	**4.161**
Pool 2										
19.0R	Minimize	Construct island	Approved-recommend constructing on existing island so it will stay	**7.969**	**-0.438**	**7.531**	**-0.438**	**-0.925**	**7.044**	**-0.925**
19.8L	Compensate	Notch existing revetment (1)	Approved	**9.505**	**0.000**	**16.963**	**7.458**	**0.000**	**16.963**	**7.458**
22.8R	Compensate	Maintain entrance to Coal Pile by periodically dredging	Approved	**118.280**	**0.000**	**140.595**	**22.315**	**0.000**	**140.595**	**22.315**
23.6 R	Avoid	Avoid RB disposal	Approved	**3.558**	**-0.196**	**2.321**	**-1.237**	**-0.413**	**0.948**	**-2.610**
23-24L	Minimize	Construct string of islands	Approved	**15.938**	**-0.877**	**19.744**	**3.806**	**-1.850**	**18.468**	**2.530**
23-24L	Minimize	Construct string of islands	Approved	**13.282**	**-0.731**	**16.454**	**3.172**	**-1.542**	**15.390**	**2.108**
24-25L	Minimize	Notch modified revetment (2) and modified dike (1)	Approved-recommend fish notch only in modified dike	**92.917**	**0.000**	**118.441**	**25.524**	**0.000**	**118.441**	**25.524**
27L	Avoid	Avoid aquatic disposal, utilize land	Approved	**2.453**	**-0.660**	**1.793**	**-0.660**	**-0.776**	**1.677**	**-0.776**
27.5-29R	Minimize	Notch modified dikes (4) and existing dike (1)	Approved-10' notches instead of 20' due to narrow channel	**43.173**	**-11.616**	**45.809**	**2.636**	**-13.656**	**42.052**	**-1.120**
27.8-28.5L	Minimize	Notch modified revetment (1) and existing dike (1)	Approved-20' revetment notch, 10' dike notch	**33.116**	**-8.910**	**35.137**	**2.022**	**-10.474**	**32.256**	**-0.859**
31.7-32.8R	Minimize	*Existing tern island – enhance/create islands where feasible and avoid June-August construction, utilize disposal area and extend d/s to NM 31.0R	Approved	**27.474**	**-7.392**	**23.457**	**-4.017**	**-8.690**	**21.941**	**-5.533**
32.2R	Avoid & Compensate	Maintain entrance to backwater channel by avoiding disposal and periodically dredging	Approved-only included entrance channel in surface water acreage	**2.146**	**0.000**	**2.041**	**-0.105**	**0.000**	**2.041**	**-0.105**
32L	Minimize & Compensate	Notch revetment (4) and existing dike (1)	Approved-surface water acreage includes all water inside revetment and dike across small backwater area.	**84.322**	**0.000**	**107.485**	**23.163**	**0.000**	**107.485**	**23.163**
31.8-33.1L	Avoid & Minimize	Avoid LB disposal, utilize RB, notch modified revetment (4) and existing dike (1) across backwater	Approved	**38.022**	**-10.230**	**34.106**	**-3.916**	**-12.026**	**29.703**	**-8.319**
35R	Minimize	Notch modified dikes (2)	Not approved-due to bend and bank erosion, however, engineers stated that this area would not likely fill due to its location.	**6.439**	**0.000**	**6.439**	**0.000**	**0.000**	**6.439**	**0.000**
35.3-36.5L	Minimize	*Existing tern island – enhance/create islands where feasible and avoid June-August construction	Approved	**13.803**	**-0.759**	**30.436**	**16.633**	**-1.602**	**28.469**	**14.666**
36-36.5L	Minimize & Compensate	Notch modified dikes (3) and existing dike (1)	Not approved-due to proximity to bank, engineers agreed that two longest dikes could be notched, but not all four.	**7.727**	**0.000**	**7.727**	**0.000**	**0.000**	**7.727**	**0.000**
36.4-37.0R	Minimize	Extend disposal area u/s to 38.1R, avoid blocking entrance to chute at 36.4R and 38.1R	Approved	**5.692**	**-0.313**	**4.622**	**-1.070**	**-0.661**	**3.434**	**-2.258**
37.5-38.6L	None	Notch raised L-dikes	Not Approved due to short length of dikes	**10.671**	**0.000**	**10.671**	**0.000**	**0.000**	**10.671**	**0.000**
37.8-38.4L	Avoid & Minimize	Avoid disposal, utilize RB.	Approved	**5.692**	**-0.313**	**4.513**	**-1.179**	**-0.661**	**3.203**	**-2.489**
38.8L	Avoid & Minimize	Avoid disposal, utilize RB, notch modified revetment	Approved	**4.269**	**-0.235**	**3.977**	**-0.292**	**-0.496**	**3.652**	**-0.617**
39.8L	Minimize	Notch modified revetment at 39.3L and 39.7L	Approved	**24.469**	**0.000**	**31.190**	**6.722**	**0.000**	**31.190**	**6.722**
38.8-39.6R	Minimize & Compensate	*Existing tern island, notch existing dikes (5) and enhance/construct tern islands where feasible	Approved	**1.755**	**-0.097**	**14.870**	**13.115**	**-0.204**	**13.651**	**11.896**
40R	Minimize	Notch existing revetment/dike (1)	Not approved-erosion problem area	**1.533**	**0.000**	**1.533**	**0.000**	**0.000**	**1.533**	**0.000**
39.8-40.0L	Avoid	Avoid disposal, utilize right bank	Approved	**1.518**	**-0.083**	**1.377**	**-0.141**	**-0.176**	**1.221**	**-0.297**

Aquatic Mitigation Summary

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42.1-42.7L	Minimize	*Existing tern island, use disposal to enhance/construct tern islands, notch backside of existing dikes to maintain flow and islands 42.5L	Approved	5.408	-0.297	7.157	1.749	-0.628	6.259	0.851
42.3-43.3L	Minimize & Compensate	Construct islands and notch existing (3) dikes	Approved	4.743	-0.261	19.521	14.777	-0.551	17.920	13.177
42.8-44.6R	Minimize & Compensate	Notch existing and modified dikes (10-12)	Not approved-this is one of worst depositional areas on river and notches would make short dikes ineffective.	10.671	0.000	10.671	0.000	0.000	10.671	0.000
42.8-43R	Avoid & Minimize	Utilize this disposal area, notch existing and modified dikes (10-12) and extend disposal u/s	Partially Approved-utilizing this area for disposal is approved, but notching dikes is not.	1.423	-0.078	1.345	-0.078	-0.165	1.258	-0.165
43.4-44.1L	Avoid & Minimize	Avoid disposal in LB aquatic areas, utilize land and RB disposal, notch existing dikes/revetments (3)	Partially Approved-avoiding disposal in this area is approved, but engineers only want most d/s part of revetment notched in 1 place rather than 3 places as recommended since this area has an erosion problem.	10.388	-0.571	9.817	-0.571	-1.206	9.182	-1.206
44-44.7R	Minimize	Utilize AR44.3R-D for disposal and extend d/s to 43.0R	Approved	0.854	-0.047	0.807	-0.047	-0.099	0.755	-0.099
44.6L	Compensate	Maintain a 1/2 mile boating lane at the entrance to Little Bayou Meto (44.6L) and 1/2 mile lane at u/s end of Bayou Meto by periodically dredging	Approved	28.100	0.000	33.401	5.301	0.000	33.401	5.301
46.2R	Minimize	Notch modified revetment/dike (1)	Not approved-engineers do not want notches on right bank	0.368	0.000	0.368	0.000	0.000	0.368	0.000
45.4-46L	Avoid	Avoid disposal in aquatic areas of AR45.3L-D, dispose on land or preferably on RB	Approved	8.348	-0.459	6.783	-1.565	-0.969	5.045	-3.304
46.5-46.7L	None	Notch modified revetment (1)	Not approved-see note below	1.227	0.000	1.227	0.000	0.000	1.227	0.000
45.4-47.3R	Minimize & Compensate	Construct islands where feasible in AR46.5R-D, utilize two most d/s cells for disposal first, notch dikes/revetments (4-8)	Partially approved-disposal in this area is approved, but engineers do not want any notches	32.255	-1.774	30.481	-1.774	-3.744	28.511	-3.744
48.7-48.9R	Minimize	Notch modified dikes (4)	Approved	3.496	0.000	4.456	0.960	0.000	4.456	0.960
46.8-49.2L	Avoid & Minimize	Utilize land within cells for disposal at AR48.0L-D, avoid aquatic areas	Approved	11.289	-0.621	10.668	-0.621	-1.311	9.979	-1.311
48.7-50.2R	Avoid & Minimize & Compensate	Utilize land within cells for disposal in 49.4R-D, avoid aquatic areas, notch existing revetments/dikes in two most u/s cells (2)	Approved	5.118	-0.281	9.361	4.243	-0.594	8.593	3.475
49.6-49.9	Avoid	Utilize existing in-channel disposal	Approved	1.044	-0.057	0.986	-0.057	-0.121	0.922	-0.121
Pool 3										
50.9L	Compensate	Maintain entrance to Swan Lake by periodically dredging	Approved	38.463	0.000	42.991	4.528	0.000	42.991	4.528
58.3L	Compensate	Notch revetment at 58.3L	Approved-need to check, there may be another levee inside the revetment	17.112	0.000	28.093	10.981	0.000	28.093	10.981
61.0-62.1L	Minimize	*Probable tern island on RB, avoid aquatic areas in AR61.4L-D, utilize land within disposal cells or enhance/create tern islands on RB	Approved	9.978	-0.980	8.758	-1.220	-2.463	6.913	-3.065
61.5-62.5R	Minimize	Place disposal in string of islands along RB	Approved	3.280	-1.078	1.555	-1.725	-1.441	0.758	-2.521
64-65R	Avoid & Compensate	Avoid disposal in AR64.5R-D, notch existing revetments and/or dikes (3)	Approved	11.677	-1.147	16.964	5.287	-2.882	12.105	0.428
64.8-65.3L	Avoid & Minimize	Utilize AR65.2L-D or in-channel disposal at AR65.5Channel-D	Approved	10.084	-0.991	9.093	-0.991	-2.489	7.595	-2.489

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65.2-65.6	Avoid & Minimize	Utilize AR65.2L-D or in-channel disposal at AR65.5Channel-D	Approved	2.548	-0.250	2.297	-0.250	-0.629	1.919	-0.629
Pool 4										
70.0-70.7L	Minimize	Notch two longest existing dikes (2)	Approved	14.815	0.000	23.203	8.387	0.000	23.203	8.387
70.6L	Compensate	Maintain channel to backwater by periodically dredging	Approved	12.583	0.000	14.939	2.356	0.000	14.939	2.356
71.3L	Compensate	Dredge canals at Island Harbor Estates	Approved	5.618	0.000	7.239	1.622	0.000	7.239	1.622
75.3L	Compensate	Maintain channel to backwater by periodically dredging	Approved	2.022	0.000	2.401	0.379	0.000	2.401	0.379
78.7L	Compensate	Dredge mouth of Pastoria Bend chute and periodically dredge to maintain and notch existing dike (1) if needed to open access to backwater	Approved	11.504	0.000	21.621	10.116	0.000	21.621	10.116
78.9-79.7L	Avoid & Minimize	79.0L - First option - Inquire about upland disposal on Pine Bluff Arsenal property first to avoid any impacts, second option - investigate island disposal upstream on LB at 80.1, third option to place in proposed location and notch modified dikes (4)	Approved-third option (AR79.0L-D) is most likely since there are security issues with disposing on PB Arsenal property and engineers do not want dikes on left bank notched for island construction upstream at 81L.	2.247	-1.253	1.420	-0.827	-1.375	1.243	-1.004
80.0-82.0L	Minimize & Compensate	Place disposal along dike fields to create islands and notch backside of dikes (9) at 80-82L	Not approved-see comment above.	10.786	0.000	10.786	0.000	0.000	10.786	0.000
82.6R	Compensate	Notch existing dike and maintain entrance to backwater at 82.6R by periodically dredging	Approved	18.425	0.000	44.376	25.951	0.000	44.376	25.951
82.5-85.5R	Compensate	Notch existing dikes along RB (14)	Approved	23.570	0.000	37.968	14.398	0.000	37.968	14.398
85.5-85.8R	Avoid & Minimize	Avoid disposal if possible and utilize in-channel disposal	Approved	6.210	-0.470	5.707	-0.502	-1.176	4.952	-1.258
85.9L	Compensate	Construct boat ramp immediately d/s of Dam No. 5 if feasible	Approved-engineers recommended moving to right bank at proposed park location	0.000	0.000	0.000	0.000	0.000	0.000	0.000
85.6-85.8	Minimize	Utilize in-channel disposal	Approved	0.430	-0.033	0.398	-0.033	-0.081	0.349	-0.081
Pool 5										
87.7L	Compensate	Investigate dredging channel into oxbow lake	Not approved-this is highly unlikely due to ownership issues.	69.697	0.000	69.697	0.000	0.000	69.697	0.000
88.2R	Compensate	Maintain entrance to Tar Camp Creek by periodically dredging	Approved	8.987	0.000	10.694	1.708	0.000	10.694	1.708
90.5-91.0L	Minimize	Construct island(s) at 90.5-91.0L behind underwater revetment	Approved	2.673	-0.757	1.916	-0.757	-1.091	1.583	-1.091
91.4-91.7R	Avoid & Minimize	Recommend constructing island downstream at 90.5-91.0L behind underwater revetment, if proposed location must be utilized, place disposal off bank and create island(s) and notch backside of existing dikes	Approved-see comment above, island will be constructed on LB.	29.788	-8.437	35.008	5.219	-12.154	28.207	-1.581
91.5L	Compensate	Bank stab and revetment at 91.5 is needed (current – 0.3)	Approved	2.291	0.000	3.636	1.344	0.000	3.636	1.344
92.6L	Compensate	Notch existing revetment (1) and maintain entrance to backwater by periodically dredging	Approved	3.310	0.000	6.195	2.885	0.000	6.195	2.885
94	Compensate	Notch existing revetment (1)	Approved	1.591	0.000	2.383	0.792	0.000	2.383	0.792
94.3-96.3L	Avoid & Minimize & Compensate	Avoid aquatic disposal in uppermost cells of AR95.5L-D, extend disposal area d/s to create a series of islands for a braided system and terns, notch existing dikes (5) to enhance backwater areas	Approved-note AR95.5L-D is 144 acres, however, with all the islands and notches, the total acreage is approximately 244.	65.750	-13.193	81.262	15.511	-22.342	60.160	-5.591
96.0-98.2R	Minimize	Enlarge and utilize RB disposal, investigate disposing behind modified revetment and dikes, investigate terrestrial disposal if needed	Approved	5.347	-1.514	3.832	-1.514	-2.181	3.165	-2.181
98.5R	Compensate	Notch existing revetment to access backwater (1)	Approved	0.637	0.000	0.953	0.317	0.000	0.953	0.317
99.4L	Compensate	Notch existing revetment to access backwater (1)	Approved-engineers recommended fish notch	0.382	0.000	0.635	0.254	0.000	0.635	0.254
100.3-101.1L	Compensate	Notch existing dikes (2), *Existing tern island on LB, avoid work during nesting season	Partially approved-engineers are okay with notch at 100.3L, but not 101.1L.	39.718	0.000	39.718	0.000	0.000	39.718	0.000
100.6-101.3R	Minimize	Utilize this area as alternative disposal site	Approved	4.710	-1.334	3.376	-1.334	-1.922	2.788	-1.922
102-104R	Minimize	Utilize RB disposal as alternative, construct/enhance tern islands if feasible	Approved	5.283	-1.496	3.787	-1.496	-2.155	3.128	-2.155

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101.5-103.7L	Avoid & Compensate	Avoid disposal, notch existing dikes (10-12) for flow-through and to enhance diversity	Partially approved-engineers approved notching the 6 longest most d/s L-dikes, but not all of the dikes since notching the short ones might cause an erosion problem.	82.702	-16.595	66.107	-16.595	-28.102	54.599	-28.102
105.2-106.0L	Avoid & Compensate	*Existing tern island(s), avoid work during nesting season, construct high water notches in dikes (4) to restore and maintain islands	Approved	2.162	0.000	21.582	19.420	0.000	21.582	19.420
106.5-107.7L	Avoid	Avoid aquatic disposal in AR107.1L, utilize land areas or in-channel disposal	Approved	49.007	-8.133	40.874	-8.133	-15.524	33.483	-15.524
Pool 6										
110.4L	Compensate	Install culvert through land mass at Willow Beach Park to connect backwater to river	Approved	3.263	0.000	5.584	2.321	0.000	5.584	2.321
110.4	Compensate	Install culvert through structure at Willow Beach Lake for fish passage	Approved	27.191	0.000	46.537	19.346	0.000	46.537	19.346
113-114L	Compensate	Notch underwater dikes on backside of islands (4)	Approved	9.040	0.000	14.853	5.813	0.000	14.853	5.813
116.2R	Compensate	Dredge backwater at 116.2R	Approved	0.350	0.000	0.733	0.383	0.000	0.733	0.383
116.6-116.8R	Compensate	Notch existing dikes 116.6 to 116.8R (2) *may have already been done	Approved	2.333	0.000	3.993	1.660	0.000	3.993	1.660
117.1-117.7R	Compensate	Notch existing dikes (3)	Approved	1.750	0.000	3.194	1.445	0.000	3.194	1.445
122.9-123.6R	Compensate	Notch existing dikes (2-4) for flow-through and access	Approved-engineers noted that a lot of bank fishermen use this area, so we need to make sure we do not restrict their access.	4.374	0.000	7.986	3.611	0.000	7.986	3.611
123.7L	Compensate	Notch existing dike for access and fish passage	Approved-engineers recommended a fish notch here	0.875	0.000	1.198	0.323	0.000	1.198	0.323
124.2-124.5L	Avoid	Avoid disposal in AR124.8L-D, utilize in-channel disposal	Approved	3.500	0.000	0.133	-3.366	0.000	0.133	-3.366
124.8-125.1	Minimize	Utilize in-channel disposal at AR124.8 Channel-D	Approved	2.800	0.000	2.933	0.133	0.000	2.933	0.133
Pool 7										
126.7-127.4L	Minimize	Utilize LB for disposal and notch modified dikes (4)	Approved	3.609	-0.299	12.166	8.558	-0.583	10.734	7.125
126.6-127.0R	Avoid	Avoid disposal on RB	Approved	8.220	-0.682	7.538	-0.682	-1.327	6.892	-1.327
131.0L	Compensate	Dredge upper end of Rector Brake to improve habitat	Approved	5.139	0.000	8.136	2.997	0.000	8.136	2.997
131.8-132.5R	Minimize	Notch upper end of modified revetment (1)	Not approved-engineers noted bad erosion problem inside revetment	3.540	0.000	3.540	0.000	0.000	3.540	0.000
132.2L	Compensate	Maintain entrance to Rector Chute by periodically dredging	Approved	13.082	0.000	15.532	2.450	0.000	15.532	2.450
133.5-135.2L	Avoid & Minimize	Avoid aquatic disposal on LB, utilize land disposal on island or construct another island on RB, notch longest existing dike for flow-through (*potential existing tern site)	Approved	23.015	-1.908	27.393	4.378	-3.717	15.561	-7.455
134.2R	Compensate	Notch existing revetment (1) at 134.2R and	Approved	13.247	0.000	22.012	8.765	0.000	22.012	8.765
134.5R	Compensate	Notch existing dike (1) at 134.7R for fish passage and access to Mill Bayou	Appears that dike has a road across it, therefore, we will have to consult real estate to determine if it can be notched or a large culvert installed.	35.402	0.000	35.402	0.000	0.000	35.402	0.000
135-138.2R	Avoid & Compensate	Avoid disposal in aquatic areas, utilize island disposal, (*potential existing tern site), notch two lower dikes	Approved	86.607	-7.181	89.355	2.747	-13.987	81.698	-4.909
139.5-141R	Avoid & Minimize	Avoid disposal from 140R u/s to 141R to prevent blockage of opening between islands, utilize 140R d/s to tip of island	Approved	12.991	-1.077	10.897	-2.094	-2.098	8.912	-4.079
141.5-142.5R	Minimize	Utilize disposal behind raised and extended L-dikes at 142.0R	Approved	6.897	-0.572	0.000	-6.897	-1.114	0.000	-6.897
142.5-143.4R	Minimize	Notch modified dikes (2) at entrance to beaver dam channel for flow-through	Approved	11.991	0.000	18.217	6.226	0.000	18.217	6.226

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143.7-144.2L	Compensate	Construct L-dike or revetment and use disposal to slope and protect bank	Approved	6.509	-2.317	5.589	-0.920	-2.677	5.110	-1.399
145.2-146.2L	Minimize	Notch modified dikes (7)	Approved	17.130	0.000	26.566	9.436	0.000	26.566	9.436
146.5-147.5L	Avoid & Minimize	* Existing tern island – enhance/construct a series of islands along LB where feasible, notch dikes (5), move disposal from LB to RB for excess disposal	Approved	5.448	-0.452	8.758	3.310	-0.880	7.273	1.826
146.3R	Avoid	Avoid disposal in this area	Approved-Note: 3 dikes are already notched in this area, so fill rate should be reduced.	22.218	-2.211	19.581	-2.637	-4.566	16.823	-5.395
146.6-147.8R	Minimize	Utilize land within disposal cells	Approved	4.651	-0.386	4.265	-0.386	-0.751	3.900	-0.751
147.8-150L	Avoid & Minimize	Avoid disposal from 149-150L that would block the entrance to backwater area, utilize disposal area d/s of 149L	Approved	28.322	-10.083	7.184	-21.138	-11.646	5.005	-23.316
148.7-150.4R	Avoid & Compensate	Avoid disposal, notch dike at 149R	Approved	22.383	-7.969	17.351	-5.032	-9.204	13.537	-8.846
150-151.7L	Avoid & Minimize	Avoid disposal from 150-151L that would block side channel and backwater entrance, construct a series of tern islands where feasible, notch existing dike at 150.8L for fish passage and backwater entrance	Approved	62.810	-22.361	88.672	25.862	-25.827	76.463	13.653
154-154.6L	Avoid	Avoid RB disposal, Utilize land disposal within cells at AR154.1L-D	Approved	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155.4L	Miniimize	Utilize land within cell at AR155.4L-D	Approved	0.000	0.000	0.000	0.000	0.000	0.000	0.000
155.6R	Compensate	Notch existing revetment (2)	Approved-engineers recommended not restricting bank fishermen with notches	2.056	0.000	3.416	1.360	0.000	3.416	1.360
Pool 8										
158.8-159.2R	Minimize	Utilize existing island for disposal and/or construct tern islands	Approved	2.382	-0.516	0.547	-1.835	-0.691	-0.076	-2.458
161.2-162.2L	Compensate	Notch existing dikes (3-4) from 161.2-162.2L	Approved-engineers stated that dikes should be notched close to the island-check with Regulatory regarding obstruction	13.337	0.000	20.621	7.284	0.000	20.621	7.284
163.6-165.2R	Compensate	163.6-165.3 - Revetment is needed for bank stabilization	Approved	1.059	-0.229	0.829	-0.229	-0.307	0.751	-0.307
164.2-164.7L	Avoid	Avoid LB disposal, utilize disposal behind revetment on RB	Approved	11.379	-2.466	6.734	-4.645	-3.303	5.157	-6.221
164.5-165.2L	Minimize & Compensate	165 - Notch on upstream end of revetment for flow in and out of Plummerville cutoff, and notch raised dikes (3), maintain entrance by periodically dredging	Approved	29.056	0.000	43.676	14.620	0.000	43.676	14.620
165.5-166.2R	Avoid	Avoid disposal in AR166.0R-D	Approved	22.440	-4.863	15.398	-7.042	-6.513	13.008	-9.432
165.8-167.0L	Avoid & Minimize & Compensate	Avoid aquatic disposal, dispose on land within cells, notch existing revetment (4)	Approved-engineers stated they recommend fish notches only at this location	9.262	-2.007	12.081	2.819	-2.688	10.718	1.456
169.2-169.8R	Minimize	Utilize AR169.4R-D for disposal first, AR169.0L-D second, construct tern islands where feasible	Approved	2.506	-0.102	2.404	-0.102	-0.328	2.179	-0.328
168.7-169.5L	Minimize	Utilize AR169.4R-D for disposal first, AR169.0L-D second, construct tern islands where feasible	Approved	1.426	-0.058	4.641	3.215	-0.186	4.205	2.779
169.4-169.7L	Minimize	Notch raised dikes (4)	Approved	1.799	0.000	2.434	0.635	0.000	2.434	0.635

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169.6-172L	Minimize	Notch raised dike at 170.1L and existing dikes at 170.7L and 171L, utilize land within cells for disposal or create/enhance tern island, (*existing tern island)	Partially approved-engineers approved the notch at 170.1, but not the notches at 170.7 or 171.0	45.727	-9.909	35.818	-9.909	-13.272	32.455	-13.272
174.1-176.7R	Avoid & Compensate	Utilize land disposal on Lentz property, notch existing dikes (4))	Approved	7.943	-0.323	13.879	5.936	-1.039	12.314	4.370
176.2-176.4	Avoid	Avoid disposal in AR176.2L-D, utilize RB land disposal on Lentz property	Approved	2.420	-0.098	2.322	-0.098	-0.316	2.104	-0.316
Pool 9										
179.3-179.7R	Minimize	Utilize disposal at 179.6R behind revetment	Approved	11.010	-2.608	6.108	-4.902	-4.408	2.723	-8.287
180.2R	Compensate	Notch existing dike at 180.2R for fish passage and access to backwater	Approved	15.414	0.000	22.889	7.475	0.000	22.889	7.475
180.4-181.3R	Minimize	Extend disposal area upstream to raised dike at 181.5R and dispose along bank downstream of dike, notch existing dikes (2)	Approved	5.285	-1.252	3.659	-1.626	-2.116	1.344	-3.940
181.8-184.9R	Minimize	Notch existing and raised dikes (8-10) and create a series of islands for braided system and terns	Approved	37.027	-3.600	53.994	16.966	-10.763	36.261	-0.767
185.8-186.4	Avoid & Minimize	Avoid disposal in AR186.2L-D, create artificial gravel bar downstream of dikes from 185L-186L	Approved	7.446	-0.724	6.648	-0.798	-2.164	2.591	-4.855
187.2R	Compensate	Notch long L-dike at 187.2R (2)	Not approved-engineers do not want to notch this dike	82.208	0.000	82.208	0.000	0.000	82.208	0.000
186.9-189.9R	Avoid & Minimize & Compensate	*Existing least tern island - avoid construction during nesting, limited disposal to avoid elevating island and maintain fish access to backwater, notch revetment and dikes (3-6) for flow-through, fish passage and access	Partially approved-disposal will be limited, however, engineers do not want to create a series of notches. They did agree to notch the revetment in two places from 189 to 189.5R.	201.663	-19.609	182.053	-19.609	-58.618	143.045	-58.618
189.2	Minimize	189.2 - Notch revetment and dikes for fish passage and access to backwater	This part approved - See above	67.852	0.000	88.160	20.309	0.000	88.160	20.309
188.9-190.4L	Avoid & Minimize & Compensate	*Existing least tern island, avoid disposal, notch raised revetment (1) and existing dike (1), utilize area upstream at 191R for disposal	Approved-engineers prefer to notch revetment in 2 places	40.705	-3.958	50.444	9.739	-11.832	41.166	0.461
190R	Minimize	Notch Sweeden island dike in chute on RB lowest for fisheries and rec access	Not approved-need to consult with real estate and determine if there are any ownership issues.	0.000	0.000	0.000	0.000	0.000	0.000	0.000
190.5-192R	Minimize	New dredge disposal alternative to 189.5L will create elevated vegetated shoreline on Sweeden Island	Approved	4.918	-1.165	6.697	1.779	-1.969	5.262	0.344
189.9.190.5L	Minimize	Notch modified revetment in two places (2)	Approved	13.525	0.000	10.995	-2.530	0.000	10.995	-2.530
193.6-195L	Compensate	Notch existing dikes (5) in AR194.1L-D	Approved	5.475	-1.297	8.604	3.129	-2.192	7.021	1.546
200.2L	Avoid & Minimize	Utilize land disposal within cells from 200.8L d/s to 200L, avoid disposal u/s of 200.8L	Approved	25.323	-5.997	19.326	-5.997	-10.138	15.185	-10.138
204.6-205.1R	Mimimize	Utilize in-channel disposal (gravel)	Approved	18.615	-1.810	16.805	-1.810	-5.411	13.204	-5.411
Pool 10										
222.5R	Minimize	Construct islands along RB if feasible	Approved-no adverse impact	0.000	0.000	0.000	0.000	0.000	0.000	0.000
225.5L	Minimize	Construct islands along LB if feasible	Approved-no adverse impact	0.000	0.000	0.000	0.000	0.000	0.000	0.000
227.2,229,230,233.5,233.3, 234	Minimize	Construct islands where feasible	Approved-no adverse impact	0.000	0.000	0.000	0.000	0.000	0.000	0.000
232R	Compensate	No adverse impact, bank stabilization is needed at this area	Approved-no adverse impact	0.364	0.000	0.349	-0.015	0.000	0.349	-0.015
233L	Avoid	Utilize land disposal in AR233.0L-D if needed	Approved	0.000	0.000	0.000	0.000	0.000	0.000	0.000

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235-236.8R	Minimize & Compensate	Notch existing dike and raised dike (2-3) in AR236.0R-D, place dredged material on existing islands within disposal area	Approved-engineers approved notches, but only after some channel work has been performed and the channel is moved toward left bank.	105.624	-11.114	131.603	25.979	-35.437	100.346	-5.278
236.6L	Avoid	Utilize this site for disposal	Approved	0.000	0.000	0.000	0.000	0.000	0.000	0.000
238.5-239.9L	Avoid & Minimize	*Existing tern island at 239.5L, avoid disposal in AR238.5L-D, alternately use 240.1-241.0 L, investigate terrestrial disposal, create and/or exend island, notch land side of dikes, do not cut off backwater at 241.1L	Approved	89.120	-9.377	109.053	19.932	-29.900	78.331	-10.790
238.5-241.2	Minimize	Maintain and/or notch existing and modified dikes (3)	Approved	74.279	0.000	96.925	22.646	0.000	96.925	22.646
239.5R	Minimize	239RB-Maintain fish access through revetmetment. Modified revetment along RB will have no adverse impacts	Approved	27.373	0.000	26.266	-1.107	0.000	26.266	-1.107
241.8-242.2R	Minimize	Utilize this site for disposal	Approved	5.685	-0.598	0.000	-5.685	-1.907	0.000	-5.685
242-244.1L	Avoid & Minimize	Avoid disposal in AR242.2L-D at entrance to Hartman Lake, utilize AR241.8R-D and AR244.0R-D if needed, deepen notch in modified revetment	Approved	12.531	-1.318	17.114	4.584	-4.204	9.118	-3.413
243.7-244.2L	Minimize & Compensate	Notch revetment and dike at u/s end to Hartman lake to allow flow-through and fish passage	Approved. Check for road, possible culvert	16.727	0.000	51.738	35.011	0.000	51.738	35.011
244R	Minimize & Compensate	Utilize two downstream cells for disposal if needed and notch two existing upper dikes for fish passage and access	Approved	2.184	-0.543	3.046	0.862	-0.965	2.323	0.139
243.8-246.8L	Avoid & Compensate	Avoid disposal (none currently scheduled) in AR245.6L-D, notch dike d/s of most d/s island at 244.5L	Not approved-engineers do not want dike at 244.5L notched	88.234	-21.945	66.289	-21.945	-39.005	49.229	-39.005
249.7L	Minimize	Alternative disposal site for AR248.0R-D	Approved	0.874	-0.217	0.349	-0.525	-0.386	-0.060	-0.933
254.1-254.5L	Minimize	Alternative disposal site inside closed revetment at 254.1L, no previously approved disposal area indicated on map	Approved	0.728	-0.181	-0.109	-0.837	-0.322	-0.193	-0.921
251.8-253.8L	Compensate	Notch dikes (5-10) on left and right bank up and downstream	Approved	14.982	0.000	22.545	7.563	0.000	22.545	7.563
255.7-256.1R	Avoid	Avoid, use AR256.2L-D for disposal instead of AR256.0R-D	Approved	1.467	-0.154	1.313	-0.154	-0.492	0.975	-0.492
255.9-256.2L	Avoid	Prefer to use this terrestrial area for disposal	Approved	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Pool 12										
271.2-273R	Minimize	Utilize this RB site for disposal	Approved	1.323	-0.616	-0.576	-1.898	-0.763	-1.028	-2.351
273.7-276L	Avoid	Avoid disposal in AR274.0L-D and AR275.0L-D, alternatively use RB disposal to create or enlarge islands,	Approved	6.559	-1.136	5.565	-0.994	-2.264	3.939	-2.621
275-276L	Minimize	Notch modified dikes (3)	Approved	10.157	0.000	13.744	3.587	0.000	13.744	3.587
275.7-276.4R	Minimize	Notch modified dikes (2) that connect to shoreline and extend RB disposal downstream within dike field	Partially approved-engineers do not want dikes notched, constructing islands is approved.	1.913	-0.331	1.582	-0.331	-0.660	1.253	-0.660
275.2-276.6R	Minimize	Notch dikes (2) that connect to shoreline	Not approved-see comment above	31.740	0.000	31.740	0.000	0.000	31.740	0.000
276.0R	Compensate	Maintain entrance to Courthouse Slough by periodically dredging	Approved	7.046	0.000	8.299	1.253	0.000	8.299	1.253
276.8-277.5R	Avoid	Avoid backwater disposal in 277.0R-D, place disposal on land and d/s along bottom end to extend island	Approved	1.162	-0.201	0.960	-0.201	-0.401	0.761	-0.401
278.9-280.3L	Avoid	At AR279.5L-D avoid disposal in aquatic areas, utilize land within disposal area and AR280.0R-D,	Approved	131.189	-22.714	108.475	-22.714	-45.275	85.914	-45.275
279-280.1L	Minimize	Notch modified revetment at 279L and 280.2L to maintain high value for backwater area	Approved	67.644	0.000	91.534	23.890	0.000	91.534	23.890
279-280.1R	Minimize	Utilize AR280.0R-D for disposal and construction of string of islands, notch modified dikes (4) to create and maintain backwater channel	Approved-engineers varied slightly on this, they want to notch the revetment and 3 dikes.	9.737	-1.686	10.665	0.929	-3.360	7.423	-2.314
280.6-280.9	Minimize	280.8L - Notch modified dikes (3)	Approved	11.850	0.000	16.034	4.185	0.000	16.034	4.185

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281.9-283.3L	Avoid	Place disposal on lower end of disposal area on existing sand bars, construct islands where feasible, avoid disposal from 283.2-283.5L	Approved	33.481	-5.797	25.412	-8.068	-11.555	17.398	-16.082
283.1-283.9L	Minimize	283.9L - Notch modified revetment in upper cell (High priority)	Approved	21.579	0.000	41.715	20.135	0.000	41.715	20.135
283.5-284.7R	Avoid	Recommend constructing new disposal at 284R	Approved	1.746	-0.813	0.932	-0.813	-1.007	0.738	-1.007
284.7-287.4	Avoid	Avoid disposal in d/s cells on LB and RB, prefer disposal d/s in new area	Approved	46.658	-21.742	21.661	-24.996	-26.924	15.704	-30.954
285.6-286.2L	Avoid & Minimize	Extend disposal area to 286.2L dike, place disposal behind dikes on LB from 286.2-285.6L to create islands and maintain gravel instream, notch modified (2) and existing (2) dikes	Approved	7.036	-3.279	2.748	-4.288	-4.060	0.974	-6.062
288.4-289L	Avoid	Avoid disposal in AR289.0L-D and place dredged gravel along right bank downstream and extend downstream gravel bar at 289.7R	Approved	7.776	-3.624	0.899	-6.878	-4.487	-0.741	-8.517
288.8-289.8R	Minimize	Utilize this alternative disposal area	Approved	6.348	-2.958	0.136	-6.212	-3.663	-1.345	-7.693
290R	Compensate	Notch existing dike if feasible	Not approved-probably not feasible, appears dike is totally covered	13.490	0.000	13.490	0.000	0.000	13.490	0.000
290.5-291.4R	Minimize	Utilize dry cells in this disposal area	Approved	1.640	-0.284	0.000	-1.640	-0.566	0.000	-1.640
291.8-292.3L	Avoid	Avoid disposal at 292.3L	Approved	5.261	-0.911	4.350	-0.911	-1.816	3.446	-1.816
Pool 13										
305.3-306R	Compensate	Notch revetment at 305.7 and 306R	Approved	24.497	0.000	38.550	14.054	0.000	38.550	14.054
OK										
309.8-310.3	Compensate	Notch 4 dikes for scour	Approved	6.999	0.000	14.700	7.701	0.000	14.700	7.701
310.4	Compensate	Notch parallel dikes (1) for scour	Approved	3.033	0.000	5.972	2.939	0.000	5.972	2.939
311.5-313.7	Minimize	New Dikes, designed to maintain variable habitat (J-hook)	Approved	0.758	-0.038	2.034	1.276	-0.038	2.034	1.276
314.8-315.8	Minimize	New & existing dikes LD recommend J-hook design	Approved	0.875	-0.044	1.445	0.570	-0.044	1.445	0.570
Pool 14										
320-321	Compensate	Notch 3 interior dikes	Approved	14.127	0.000	22.434	8.307	0.000	22.434	8.307
321-323	Compensate	Notch 5 dikes	Approved	23.614	0.000	31.640	8.026	0.000	31.640	8.026
323.7 - 323.9	Compensate	Notch 2 dikes	Approved	2.909	0.000	4.041	1.133	0.000	4.041	1.133
323-324	Compensate	Notch 9 dikes	Approved	33.576	0.000	45.702	12.126	0.000	45.702	12.126
326.7-328.1	Compensate	notch 7 dikes interior/exterior	Approved	16.620	0.000	27.712	11.092	0.000	27.712	11.092
Pool 15										

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336.4	Avoid	NOTE: Site will be avoided to preserve mussel bed	Approved	0.000	0.000	0.000	0.000	0.000	0.000	0.000
336.4		None	Approved	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
348.3		Add to existing island + riprap	Approved	**15.941**	**-7.805**	**4.068**	**-11.873**	**-9.497**	**3.222**	**-12.719**
353.5-354.3		aquatic area converted to terrestrial	Approved	**0.996**	**-0.488**	**0.508**	**-0.488**	**-0.594**	**0.403**	**-0.594**
355	Minimize	Create 3 - 10 acre tern island w/riprap	Approved	**12.011**	**-5.881**	**5.100**	**-6.911**	**-7.156**	**4.039**	**-7.972**
360.6	Compensate	Notch 2 dike	Approved	**3.321**	**0.000**	**6.298**	**2.977**	**0.000**	**6.298**	**2.977**
361-363	Compensate	Relocate gravel to dike field on left descending bank at 360.6. Relocate downstream between rm 360 - 361; monitor & adapt as needed	Approved							
Pool 16										
367.5-367.7	Avoid	No action	Approved	0.000	0.000	0.000	0.000	0.000	0.000	0.000
367.4	Minimize	alternative disposal site for 367.5 - create tern island/w riprap	Approved	**6.310**	**-3.090**	**3.220**	**-3.090**	**-3.759**	**2.551**	**-3.759**
374-375	**Compensate**	**Relocate gravel downstream to rm 373; monitor & adapt as needed**	**Approved**							
379 - 380	Compensate	dredge upper end of oxbow; maintain upper/lower openings	Approved	**89.667**	**0.000**	**127.760**	**38.093**	**0.000**	**127.760**	**38.093**
383.2	Compensate	Dredge mouth of Hopewell Creek	Approved	**0.221**	**0.000**	**0.210**	**-0.011**	**0.000**	**0.210**	**-0.011**
392.1-393.0	Minimize	Notch dikes, create tern island in middle cell	Approved	**13.284**	**-6.504**	**6.545**	**-6.739**	**-7.914**	**5.126**	**-8.158**
393	Compensate	Relocate gravel to dike fields created on Right descending banck at rm 392.1-393.0; monitor & adapt as needed	Approved							
393.2 - 394.1	Avoid & Minimize	1st priority dispose in terrestrial cell, notch internal & lower end dikes; 2nd priority dispose in dike cell above and below bridge. I	Approved	**15.111**	**-7.399**	**12.518**	**-2.593**	**-9.003**	**9.804**	**-5.307**
393.8-394.6	Minimize	Notch added dikes to avoid fill,design to minimize fill (J-hook)	Approved	**9.686**	**-0.485**	**10.033**	**0.347**	**-0.485**	**10.033**	**0.347**
395	Compensate	Relocate gravel to dike fields on left descending bank at rm 393.8; monitor & adapt as necessary	Approved							
sbc 0.4	Minimize	aquatic disposal; create HQ marsh; variable depth 6-in - 2 ft; mussels will be protected from impacts resulting from disposal	Approved	**22.140**	**-10.841**	**16.949**	**-5.191**	**-13.191**	**13.424**	**-8.716**
sbc.4.8	Minimize	**NOTE: site will be redesigned to preserve mussel patch.aquatic disposal will only occur if mussels won't be impacted; create HQ marsh; variable depth 1 - 2 ft;**	**Approved**	**19.926**	**-9.756**	**10.170**	**-9.756**	**-11.872**	**8.054**	**-11.872**
sbc 6.6	Avoid & Minimize	**expand island, design to avoid impacts to mussels; height of disposal will be 1 - 2 ft below water surface**	**Approved**	**2.214**	**-1.084**	**1.130**	**-1.084**	**-1.319**	**0.895**	**-1.319**
sbc 6.9	Avoid & Minimize	**expand island, design to avoid impacts to mussels; height of disposal will be 1 - 2 ft below water surface**	**Approved**	**2.214**	**-1.084**	**1.130**	**-1.084**	**-1.319**	**0.895**	**-1.319**
398.8	Compensate	dredge upper/lower end Okay oxbow install culvert structure	Approved	**0.221**	**0.000**	**0.263**	**0.041**	**0.000**	**0.263**	**0.041**
Pool 17										
402	Compensate	Relocate gravel upstream to rm 403.5 - 404; monitor & adapt as necessary	Approved							
407	Compensate	Dredge Upper/lower end Tullahassee Loop; rework culvert structure	Approved	**0.289**	**0.000**	**0.347**	**0.058**	**0.000**	**0.347**	**0.058**
408.8	Compensate	Dredge mouth of Strawberry Creek	Approved	**6.654**	**0.000**	**7.977**	**1.323**	**0.000**	**7.977**	**1.323**

Aquatic Mitigation Summary

Nav. Mile	Mitigation Category	Project Description	Corps Technical Acceptability	Total Existing HUs	HUs Effected by 11-ft Project	Total HUs with Mitigated 11-ft Project	Change in Mitigated 11-ft HUs Relative to Baseline	HUs Effected by 12 ft Project	Total HUs with Mitigated 12-ft Project	Change in Mitigated 12-ft HUs Relative to Baseline
408.9	Compensate	dredge mouth of Billy Creek Cutoff	Approved	**39.923**	**0.000**	**57.432**	**17.508**	**0.000**	**57.432**	**17.508**
414.7	Compensate	Dredge at culvert structure	Approved	**25.169**	**0.000**	**30.172**	**5.003**	**0.000**	**30.172**	**5.003**
416.7	Compensate	Dredge/rework culvert structure	Approved	**35.295**	**0.000**	**42.311**	**7.016**	**0.000**	**42.311**	**7.016**
418.8	Compensate	Dredge/rework culvert structure	Approved	**10.415**	**0.000**	**12.485**	**2.070**	**0.000**	**12.485**	**2.070**
419.5	Compensate	Dredge mouth of Bull Creek	Approved	**9.836**	**0.000**	**14.150**	**4.314**	**0.000**	**14.150**	**4.314**
421	**Compensate**	**Relocate gravel to rm 417-418.5; monitor & adapt as needed**	**Approved**							
Pool 18										
426.7	Compensate	Dredge mouth of Commodore Creek	Approved	**2.604**	**0.000**	**2.604**	**0.000**	**0.000**	**2.604**	**0.000**
439.7	Compensate	Dredge lower end of oxbow	Approved	**2.314**	**0.000**	**2.314**	**0.000**	**0.000**	**2.314**	**0.000**
442	Compensate	Dredge lower end of oxbow	Approved	**6.365**	**0.000**	**6.365**	**0.000**	**0.000**	**6.365**	**0.000**

C.8

Long Term Monitoring and Adaptive Management

C.8 Long Term Monitoring and Adaptive Management

C.8.1 Purpose

Large river riparian, wetland, and aquatic ecosystems are complex and dynamic. Our understanding of the Arkansas River Ecosystem and our ability to predict how the river will respond to management actions is limited. These knowledge gaps lead to uncertainty over how best to implement mitigation measures to achieve the desirable outcome. Despite these uncertainties, the U.S. Army Corps of Engineers (USACE) must make decisions and implement plans. The purpose of this document is to develop the process framework for monitoring and managing the biological mitigation measures. The McClellan Kerr Arkansas River Navigation System (MKARNS) adaptive management plan will serve as a template for task requirements to achieve defined goals and measurable objectives to accomplish mitigation results. It is the ultimate goal of the USACE to achieve a functioning, self-sustainable ecosystem by mitigating for impacts as a result of the navigation deepening and flow modification project.

C.8.2 Goals and Objectives

The goals and objectives for the adaptive management plan include:

- Form a multi-agency Executive Committee and a scientific advisory review panel.
- Determine the relevant questions that need to be answered by monitoring and scientific research studies.
- Develop standardized monitoring procedures that will be used to determine long term changes in the river and to quantify impacts of the navigation project.
- Develop measurable parameters to determine if mitigation has been adequate to offset losses to fish and wildlife habitat and populations.
- Evaluate long term trends for habitat and fish and wildlife populations using monitoring data
- Based on analysis and recommendations of committee members, modify the adaptive management plan to achieve goals
- The USACE will fund and implement additional mitigation if monitoring information suggests that mitigation was not sufficient or if project impacts are more severe than anticipated.

C.8.3 Adaptive Management Process

C.8.3.1 Executive Committee Composition

A committee charged with implementation of the adaptive management plan should be composed of representatives from the following agencies: USACE, U.S. Fish and Wildlife Service (USFWS), Oklahoma Department of Wildlife Conservation (ODWC), and Arkansas Game and Fish Commission (AGFC). The panel should be charged with responsibilities of

evaluating adequacy of monitoring plans, reviewing monitoring data, predicting future-conditions, calling on needed resources (e.g. subject matter experts) for assistance, and evaluating and recommending corrective measures if needed. Multi-agency membership on the committee should take advantage of various areas of expertise and agency perspective for a balanced evaluation of the Arkansas River Watershed.

USACE responsibilities should include convening and organizing panel meetings, funding and conducting monitoring studies, preparing reports, summarizing monitoring activities, conducting panel briefings on monitoring\results and implementing corrective measures and any associated studies as recommended by the committee. While committee meetings could be convened at the request of any member or as warranted by changing conditions, it is anticipated that the committee should initially meet once annually or more frequently as new data area available for review.

An independent scientific review panel would be developed from local, regional, and national experts for each major area of study to ensure scientific rigor of the long term monitoring studies.

C.8.3.2 Committee Decision and Recommendations

Committee decisions and recommendations should be by consensus of committee members. If consensus cannot be reached on any subject matter, it is likely that this process should provide the advantage of generating the necessary information and scientific data (based on input from all agencies) to facilitate science based resolution of these matters in the most appropriate forum. In the event a consensus cannot be reached, the scientific review panel will be consulted for their opinion.

C.8.4 <u>Baseline Development</u>

C.8.4.1 General

Baseline data would be collected from four sites within each identified trend pool. The trend pools and representative sites within each trend pool would be selected by the Executive Committee. Stratified random sampling should be performed so ensure scientific rigor. The sites to be sampled would include proposed mitigation backwater areas and tributaries, representative notched dike fields compared to reference sites and comparison of natural to mitigated gravel bars. Sites sampled would include replicated areas where dikes will be raised and where dredge spoil will be placed in the dike field.

The goal of gathering baseline data would be to document pre-project conditions before the navigation project is implemented, so that meaningful comparisons can be made to post-project conditions. These data would allow us to better assess how stream flow quantity (hydrology) and stream flow quality (water quality) factors affect ecosystem components of the Arkansas River Basin. It is also needed to compare to long-term data to assess impacts related to MKARNS deepening project. However, we are aware that because of natural variations in

hydrology and biological populations that several years of pre-project monitoring would be required to make scientifically rigorous decisions.

Biological evaluation criteria used would include:

- species composition
- relative abundance of species
- distribution of species
- sportfish stock descriptors
- water quality factors that affect biotic communities
- water quality and flow regime factors that affect biotic communities
- habitat substrate, depth, velocity, and woody structure
- determination of appropriate sampling times, locations and efforts

Sampling sites would be selected based on the following criteria

- Stratified random sampling with replication to ensure scientific rigor.
- long-term availability and access for sampling
- likelihood of consistently obtaining samples that adequately reflect fish communities within the reach
- diversity of habitat types within the site location

Replicated sample sites would be randomly selected to complement the collection of data for other components of the biological community. Repeated-measures statistical designs will be evaluated since they may allow for more consistency in sample sites, and it would allow greater determination of the relationships of the fish community structure to other ecosystem components including the benthic invertebrate community, the aquatic macrophyte community, in-stream habitat and water quality.

C.8.4.2 Methodology

All sampling methods will be agreed upon before sampling is initiated by the Executive Committee, and committee members may request a review by the Independent Science Review Panel. Sampling methods may need to vary depending upon the physical characteristics of sampling reaches and stations and microhabitats present. Sampling methods and effort would be standardized within each sample site and would remain consistent, when possible, throughout both the baseline and long-term sampling periods. Sampling effort would be recorded for determination of catch-per-unit effort. All sampling would generally follow the protocol contained in the USGS's National Water-Quality Assessment Program (1993 Open File Report 93-104), *"Methods for Sampling Fish Communities as a Part of the National Water-Quality Assessment Program"*.

I believe that a review of the Upper Mississippi and Missouri monitoring protocols is needed before we can agree to use USGS protocols. This is going to depend on study questions.

C.8.5 Long Term Monitoring

The long term monitoring program would be used to detect ecosystem changes attributable to the MKARNS deepening project. Long term monitoring data would be evaluated in the context of baseline data.

Study questions that are important must first be identified before any study design or methods are discussed.

C.8.6 Aquatic

Some questions concerning aquatic resources include:

1. How much surface acreage of water would be converted to terrestrial land by the project.
2. What is the measured dike-filling rate for each pool and how does that compare to previous model predictions?
3. How many major new dredge areas develop in the main channel after project completion, and what habitat impacts are realized from dredging those areas?
4. How many new unanticipated dikes and revetments are constructed?

C.8.6.1 Sediment Dynamics

Monitoring would be conducted on representative pools of the river throughout the navigation system at replicated sites. Monitoring parameters would include bathymetry, substrate (faces) sampling, LIDAR and GIS. The sedimentation analysis would be used in conjunction with the habitat quality to determine if mitigation measures are effective. Sedimentation analysis would determine if the dike filling coefficient is realistic and how much additional aquatic habitat is converted to terrestrial habitat by the project.

C.8.6.2 Quality of Habitat

Some questions concerning quality of habitat include:

1. What is the impact of the project on woody debris abundance and distribution?
2. What is the fish community response to reduced habitat volume in dike field that are raised or aquatic areas where dredge spoil is deposited?
3. How does opening the mouth of the backwater influence water quality and the fish community?
4. Do artificial gravel bars persist and function like natural gravel bars?
5. Do mussel recovery efforts lead to sustainable mussel populations in the impacted areas and outside of impacted areas?
6. Are state water quality standards met by the project?

(1) Backwaters and Tributary mouths - Monitoring would include substrate sampling and water quality parameters. Representative sites would be re-evaluated for HSI values to determine if projected habitat values are achieved from opening backwaters. Fish samples would

be taken. Emphasis on tributary mouth is important because the transition zone facilities high diversity.

GOAL: Improve habitat value. This is a habitat goal and objective vs. a study objective, so we should state that or it becomes confusing.

OBJECTIVES: Improve HSI value and maintain current fish diversity.

(2) Gravel bars – Baseline data would be gathered from gravel bars identified to be impacted by the deepening project. Baseline core samples would be obtained to determine depth of gravel beds and classification for heavily impacted large gravel beds. USACE H&H staff would model current location of gravel bars to determine site characteristics and velocities and select new sites for relocating the gravel to based on those characteristics. Representative relocated gravel beds and reference (non-impacted) gravel beds would be monitored to determine changes to substrate and quality of habitat.

GOAL: No net loss of gravel bar habitat.

OBJECTIVES: Status quo of function and value of gravel bar habitat as compared to baseline conditions.

(3) Dike fields – Monitoring would include seasonal and nighttime sampling of fish to determine presence, relative abundance, and diversity. Bathymetry and LIDAR data would be used for general analysis and trends. Comparison of replicated notched and un-notched dike fields, with and without dredge spoil placement and dike raising would be made to determine if assumptions and predicted HSI values were correct.

GOAL: Active Disposal – Minimize impact to habitat quality
Non-Active Disposal - Improve habitat quality and diversity.

OBJECTIVES: Active Disposal – Minimize acceleration of sedimentation through notching;
In-Active Disposal – achieve higher HSI values through greater fish diversity, and improved water quality.

Raised dikes - ??

(4) Mussel Patches and Beds - Relocated mussels would be monitored in their new location once a year for three years and then every other year for a maximum of 10 years of monitoring. Monitoring would be conducted during disposal operations (OK/AR) to determine if existing mussel populations are adversely impacted. Monitoring of relocation sites would be conducted to ensure sustainability of new populations.

GOAL: Minimize impacts to population and maintain species diversity through re-establishing in decimated areas.

OBJECTIVES: 75% survival rate of relocation population and eventual sustainability.

(5) Physical and Chemical Quality of Water – Monitoring will occur throughout the system and used as an overall indicator of healthy and sustainability of the target habitats. Parameters and methodologies include temperature, dissolved oxygen, turbidity, and suspended solids.

GOAL: Minimize impacts.

OBJECTIVES: Obtain state water standards for all parameters, and where possible improve water quality.

C.8.7 Terrestrial

C.8.7.1 Quality of Habitat

1. Bottomland Hardwoods – The ODWC would maintain the mitigation areas. Anticipated HSI values were calculated to create expected objectives on diversity and health of ecosystem. Sustainability of the area is the ultimate goal. Performance standards may include: achieving a survival rate of installed trees and shrubs exceeding 75 percent after 3 years, achieving a stems per acre count for bare-root seedling reforestation of greater than 300 individuals of native species surviving after 5 years, and species diversity of plantings and volunteer recruitment with no single species constituting greater than 30 percent of the individuals at the end of the monitoring term.

2. Marshlands – The ODWC would maintain the mitigation areas. Anticipated HSI values were calculated to create expected objectives on diversity and health of ecosystem. Hands-on management of the system by ODWC is anticipated to achieve restoration goals. Performance standards may include: achieving percent ground cover rate with desirable wetland or aquatic plant species exceeding 80 percent at 3 years, species diversity of plantings and volunteer recruitment with no single species constituting greater than 30 percent of the individuals at the end of the monitoring term.

C.8.7.2 Monitoring

Monitoring would generally require a minimum of three inspections each year, all during the growing season for three years and then 3 additional periods every 5 years for a total of 6 years of monitoring. These inspections should be scheduled to correspond to the spring, summer, and fall seasons. The information gathered during site inspections should focus on the performance standards developed by the executive committee. Monitoring activities would include assessment of the hydrologic, vegetative, and physical features of the mitigation site. Depending on the vegetative plan for the site and the plans performance standards, herbaceous, shrub, and tree strata would likely require independent assessment. Hydrologic monitoring may include the installation and monitoring of wells or staff gauges, observation and recording of water levels, and documentation of interactions with adjacent aquatic areas (in-flow and out-flow). Vegetative assessment should include identification of dominant plants to the species level, size, density, and condition of growth (health and vigor). Physical feature monitoring includes such aspects as

the stability of construction disturbed soils, condition and stability of constructed features, adequacy of soil compaction or preparation, influences from adjoining lands, etc. Appendix A is a summary of the project timeline and costs for long-term monitoring.

C.8.7.3 Threatened and Endangered Species

1. Interior Least Tern – Monitoring would be conducted in accordance with USFWS Biological Opinion.

2. American Burying Beetles – Prior to construction of terrestrial disposal sites in potential habitat areas baseline surveys would be conducted to determine presence of species. Standard procedures would be implemented to bait and avoid any impact during construction.

In addition to basic monitoring described above, the committee could recommend and oversee additional monitoring efforts as appropriate. Responsibilities for funding and implementing all monitoring studies should rest with the USACE though other agencies could participate in sample collection or other monitoring activities as desired. Initial estimates of frequency of monitoring data collection are provided in the adaptive management plan but could be altered by recommendation of the committee.

C.8.8 Adaptive Management

C.8.8.1 Aquatic

1. Sediment Dynamics – Sediment dynamics would be affected by dike notching, dredging, dredge disposal, and constructing or modifying river training structures. Monitoring data of sedimentation and habitat quality would be compared to baseline data and assumptions to determine if changes should be made to any of the above features to achieve higher habitat values.

2. Quality of Habitat

(1) Backwaters and Tributary mouths – Maintenance dredging of backwater areas would occur periodically during routine operations and maintenance of the navigation channel. If through monitoring, the projected HSI values are not being achieved additional dredging or other innovative measures would be investigative and implemented. .

(2) Gravel bars – If relocation of gravel does not achieve the anticipated results, additional analysis and re-modeling would occur to determine more sustainable locations for gravel beds.

(3) Dike fields – It is anticipated that dike notching and modification to training structures would positively affect habitat quality in the dike fields where disposal is not anticipated. . Notching is anticipated to reduce the filling rates of the dike fields and increase habitat diversity. If fish sampling, water quality, and sediment analysis do not indicate predicted

HSI values have been realized, additional dredging and habitat creation would be evaluated and implemented.

(4) Mussel beds – If relocated populations are not thriving alternate sites would be evaluated. If monitoring indicates mussel beds are being adversely affected from in-stream disposal then disposal techniques would be re-evaluated and new methodologies would be implemented.

C.8.8.2 Terrestrial

Quality of Habitat. Hardwoods and Marshlands – ExHEP monitoring is used as an indicator of the expected health and sustainability of the ecosystem. If monitoring indicates degradation or system failure based on predetermined criteria, the reasons for the failure would need to be evaluated and measures taken to achieve the stated goals. This may include operational and maintenance changes or additional plantings.

C.8.8.3 Threatened and Endangered Species

1. Interior Least Tern – Not evaluated for adaptive management as part of the project. However, compliance and requirements of the ESA dictate requirements and adjusted would be made in consultation between USACE and USFWS.

2. American Burying Beetles – Not required.

APPENDIX A – SUMMARY LONG TERM MONITORING

MONITORING TASK	TARGET PARAMETERS	SAMPLING
SEDIMENT DYNAMICS		
Bathymetry	Trends – Depth changes over time	Select areas at the following times (baseline, 4 water years with an attempt at one each low, medium, high)
Backwater & Tributary Mouth	HSI values	Reduce excessive sedimentation that is degrading aquatic habitat through dredging.
Substrate Sampling	Classification and diversity of river bottom habitat	Select areas to include dike fields and backwaters, four sampling periods for comparison, sites determine by executive committee for appropriate representation.
LIDAR/GIS	General Trends of deposition and vegetation growth; Aquatic habitat volume and acreage.	Entire river (3 time periods: preconstruction, immediately following construction, post construction)
AQUATIC HABITAT		
Backwater reevaluations	HSI values from mitigation measure assumptions – Based on 11 year target	Delphi committee re-evaluates some reference areas and dredged areas – baseline and 3 times post baseline
Tributary Mouths	Diversity and Presence	Delphi committee re-evaluates some reference areas and dredged areas – baseline and 3 times post baseline
Gravel Modeling	Areas of sustainable substrate	Baseline models
Gravel Monitoring	Habitat quality and diversity	Baseline core sampling for depth and classification, invertebrate presence/absence (baseline / two post construction). Fish use of the gravel habitat
Fish Sampling	Diversity, relative abundance, presence, and sportfish stock	Backwaters and Dike fields (baseline season and 3 water years varied)

	descriptors	
Mussel Bed Monitoring	Sustainability of relocated populations and turbidity at mussel beds during in-stream disposal operations adjacent to known large populations	Patch will be sampled before dredging, 6 mo and 1 yr after dredging This appears to be differerent from what was said above.
TERRESTRIAL HABITAT		
Hardwoods	Habitat Quality and Sustainability	EC re-evaluates using ExHEP protocol on new sites. Monitoring 3 inspections/yr for 3 years and then 3 additional survey cycles on 5 year intervals for a total of 6 years.
Marshlands	Healthy functions and values	EC evaluates site using exhep protocol. Monitoring includes 3 inspections/year for 3 years and then 3 additional cycles on 5 yr intervals for a total of 6 years.
PHYSICAL AND CHEMICAL WATER PARAMETERS		
Water Quality (all Gravel beds, representative backwaters, representative dike fields)	Dissolved Oxygen, Turbidity, Temperature, …	Baseline, plus 3 water years

APPENDIX B – SUMMARY ADAPTIVE MANAGEMENT

HABITAT	TARGET PARAMETERS	ADAPTIVE MANAGEMENT
Backwater & Tributary Mouth	Improve HSI values over baseline	If degradation of aquatic habitat is occurring from sedimentation, then dredging would be implemented
GRAVEL BARS	No net loss	If gravel bars are not able to be relocated additional modeling and relocation activities will be implemented
DIKE FIELDS	HSI values minimize sedimentation	If desired results are not achieved, additional notching would occur or exploration of advanced techniques. Other aquatic mitigation measures would need to be identified and

		implemented.
MUSSEL BEDS	Re-colonization	If relocated mussels are not thriving habitat improvement and additional relocations would be implemented
Terrestrial	HSI value goals	If desired results are not achieved, additional plantings and adjustment to management techniques would be implemented.