REGULATORY
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Report on the

Cumulative Impacts of Commercial Dredging on the Kansas River

A Social, Economic and Environmental Assessment

Kansas City District, Corps of Engineers
DACW 41-79-C-0017

1982

79-801-4-003

Burns & McDonnell
ENGINEERS - ARCHITECTS - CONSULTANTS

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May 25, 1982

Mr. Robert Ruf
Corps of Engineers-Kansas City District
624 Federal Building
601 East 12th Street
Kansas City, MO 64106

Cumulative Impacts of Commercial Dredging
on the Kansas River
Contract No. DACW 41-79-C-0017
Our Project No. 79-801-4-003

Dear Mr. Ruf:

Pursuant to your Authorization, we submit the final Environmental Assessment, "Cumulative Impacts of Commercial Dredging on the Kansas River, A Social, Economic and Environmental Assessment."

We wish to express our thanks to you for your assistance and consultation during the preparation of this report.

We are available at your convenience to discuss the details of this report with you.

Respectfully submitted,

BURNS & McDONNELL

Arthur Murphy

Arthur Murphy, P.E.
Project Manager

AM/kmc

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INTRODUCTION

INTRODUCTION

The purpose of this study is to identify and evaluate the social, economic and environmental aspects of commercial dredging operations on the Kansas River and to examine possible alternatives to current dredging operations.

The general study area for considering environmental aspects includes the Kansas River channel and adjacent banks from river mile 0-153. A corridor measuring approximately 1,000 feet from mid-channel to either side of the Kansas River was investigated. Kansas River miles 0-51 were investigated in greater detail because of the more intense dredging activity that occurs in that reach. Some analysis of the dredging that occurs upstream of river mile 51 and downstream into the Missouri River is included in this report.

Investigation of the social and economic elements includes a survey of the Kansas River commercial dredging operations, an industry analysis, a review of labor and other economic markets affected by the dredging operations, and an analysis of the planning considerations and policy implications involving present dredge sites and the locating of new sites in the region.

Section I of this report discusses dredging alternatives. Initially reviewed are those alternatives removed from further study because they were either infeasible or their implementation would not be beneficial. Following this review is a brief assessment of the alternatives considered in detail throughout the remainder of the report. A detailed assessment matrix (Table I-3) summarizes the impacts expected to result from the Kansas River commercial dredging alternatives.

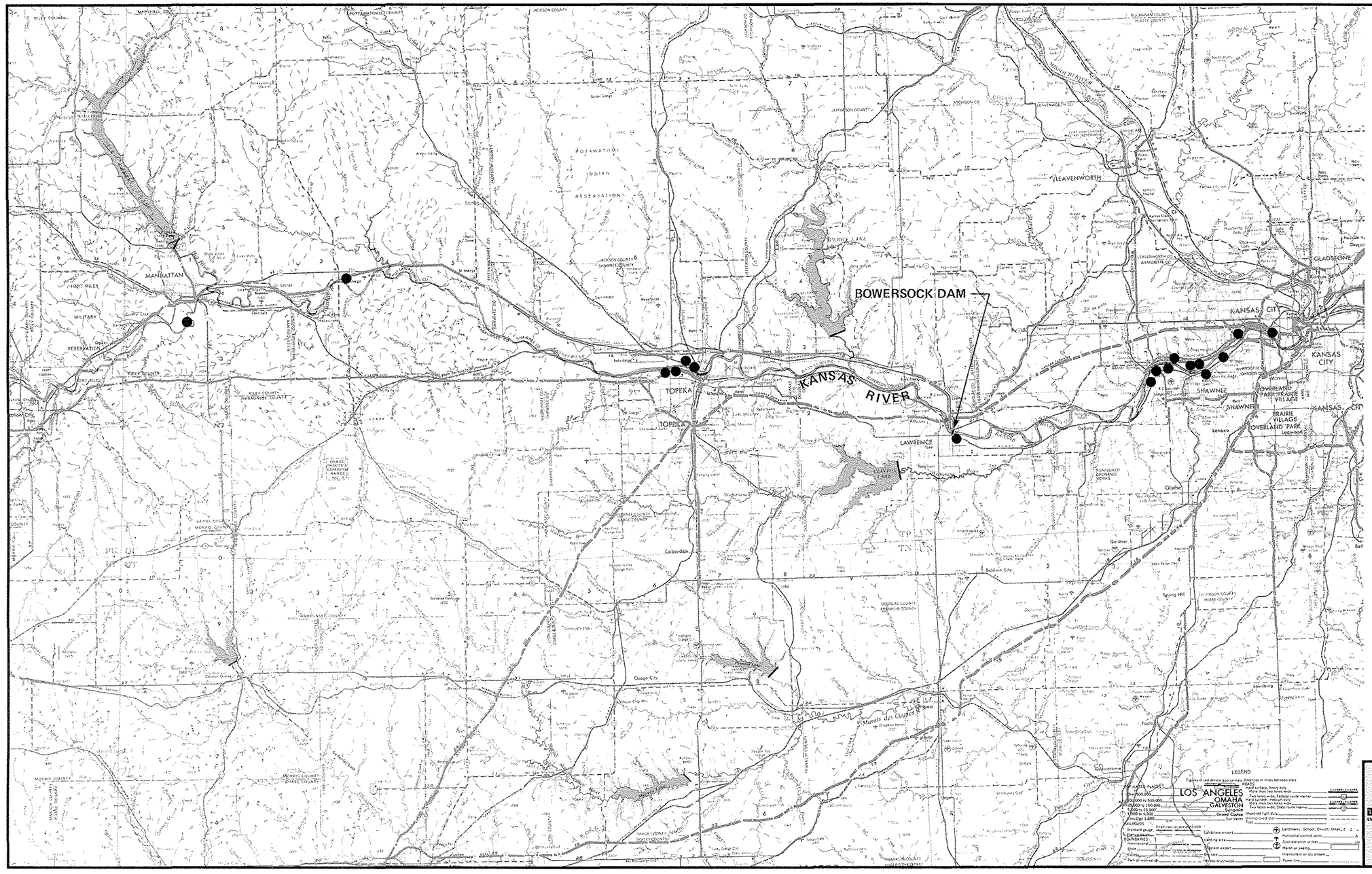
Section II reviews in detail the affected area's social, economic and environmental baseline conditions.

Section III examines in detail the environmental consequences of the alternatives considered in this report.

Supporting data has been included in the appendices of this report.

Figure IN-1 identifies the Kansas River commercial dredging study area and locates each of the commercial dredging sites along the Kansas River.

* * * * *



LEGEND

- Kansas River and Tributaries
- Lakes
- Commercial Sand and Gravel Dredging Operations

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Scale in Miles

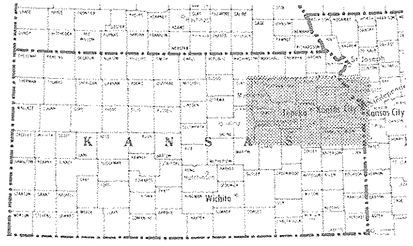

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Figure IN-1
KANSAS RIVER COMMERCIAL DREDGING STUDY AREA

PART I – ALTERNATIVES

PART I
ALTERNATIVES

A. ALTERNATIVES ELIMINATED FROM FURTHER STUDY

1. REDUCED AND/OR RESTRICTED DREDGING SEASON

This alternative was examined in response to concerns about the impacts of existing sand and gravel dredging operations on the aquatic biota (especially fishes) of the Kansas River during critical life periods and stages. The alternative does not imply a reduced quantity of material extracted, since the amount dredged depends on the daily or monthly length of time a dredge operates.

Present sand and gravel dredging in the Kansas River is restricted to the period of ice-free flows which generally encompasses the months of March through November. Due to variability between yearly water temperatures, dredging may also occur for a short time during the months of December and February.

An analysis of the reduced and/or restricted dredging season alternative must include an examination of the physical, chemical, and biological effects resulting from dredging and the significance of these effects during a time period when the impacts on the biota of the river are specific or magnified.

The most important time period for fish populations inhabiting the Kansas River is the general period of April through July when most spawning activity takes place and potential food sources are at a maximum. This season is based on information contained in Cross (1967) and water temperatures by month for the Kansas River (Table I-1). Several species, principally minnows and sunfishes, may spawn in the month of August and walleye (*Stizostedion vitreum*) and sauger (*Stizostedion canadense*), may spawn in March.

The primary direct impacts to fish spawning success in the Kansas River resulting from dredging, if they occur, are related to water quality changes, primarily turbidity and siltation, and direct habitat modification. Preliminary water quality data of the Fishery-Dredging Study and data provided by the Kansas Department of Health and Environment and United States Geological Survey suggest that water quality degradation resulting from operating dredges is not significant (see Section III.A.4). Operating dredges do contribute to increased turbidity immediately below the effluent outfall pipe (Table 5 of Appendix C), however several factors mitigate the overall impact of this increased turbidity and siltation.

Table I-1
MEAN KANSAS RIVER WATER TEMPERATURES BY MONTH
AT BONNER SPRINGS, KANSAS[1]

Month	Temperature (degrees C) Mean	Maximum	Minimum
January	1.3	9.5	0.0
February	1.9	6.0	0.0
March	8.7	24.5	1.5
April	13.9	20.0	7.0
May	20.0	26.0	10.5
June	22.9	29.5	16.5
July	25.1	30.0	21.5
August	26.1	33.0	23.0
September	22.3	27.0	19.0
October	16.4	22.0	10.5
November	8.1	14.5	1.0
December	2.1	4.5	0.0

[1] Spot observations during period July 1950 to September 1972.

Source: Burns, C. V. 1975. Temperature of Kansas Streams, Technical Report No. 12, Kansas Water Resources Board.

Elevated turbidity resulting from the return of excess water to the river via the outfall pipe affects only a small portion of the river cross-sectional area. Recent sampling indicates that the turbidity resulting from the effluent does not seem to influence downstream conditions. High background levels of turbidity are associated with high river flows (Kansas Department of Health and Environment, 1978). These high flows overlap much of the period of maximum fish spawning activity, the spring and early summer months. This point is illustrated by Table I-2. The small increase in turbidity and siltation resulting from the outfall pipe effluent is insignificant in comparison with the seasonal high turbidity and flows of the Kansas River.

Fish spawning habitat in the study area occurs in the Kansas River and its tributaries. Spawning generally occurs in shallow-water areas, but this depends on the species. Spawning areas include quiet backwaters, tributary mouths, and the filling banks of the Kansas River. Macroinvertebrates occur in shallow and deep water areas depending on the species. Some of the quiet, shallow water habitat contains larger amounts of silt and other organic material which are unprofitable to mine. Habitat alternation by operating dredges benefits some species and is unfavorable to others. However, dredging does not appear to directly affect, to a significant degree, fish spawning success in the river. This conclusion is based on the densities of young fishes captured in the dredging areas versus the control areas during 1979 and 1980 (see discussion in Section III.5.a.).

Table I-2
MEAN, MAXIMUM AND MINIMUM DISCHARGES BY MONTH OF THE KANSAS RIVER FOR A RECENT PERIOD OF RECORD [1,2,3]

Month	Discharge (cfs) Mean	Maximum	Minimum
January	4,746	14,389	856
February	6,383	18,520	1,135
March	9,125	36,561	1,117
April	10,709	43,567	1,116
May	11,575	24,401	3,412
June	13,292	22,829	3,783
July	7,309	13,366	2,745
August	6,109	19,766	1,475
September	8,044	27,233	999
October	8,593	51,626	1,248
November	8,401	42,320	1,031
December	5,427	21,939	947

[1] Period of Record 1968 through 1977.
[2] Gaging station at Bonner Springs, Kansas through September 1973, gage moved to DeSoto, Kansas October 1973.
[3] Derived from discharge records found in the United States Geological Survey's Water Resources Data for Kansas, water years 1968 through 1978.

Current dredging operations take advantage of the high streamflows prevalent in the spring of the year. These flows carry larger amounts of mineable materials which are "trapped" in the "pit" created by an operating dredge. A greater percentage of the yearly sand needed to supply the market can be removed during this time. To restrict dredging during this period could result in inefficiency of removal and therefore, higher costs, and direct environmental effects encompassing a greater period of time than that resulting from concentrating dredging activity during high flows.

Reducing and/or restricting the length of the dredging season also does not address or control the problem of sand removal above the replenishment rate.

For these reasons, this alternative was not considered as a viable alternative to existing dredging operations.

2. MODIFICATION TO EXISTING DREDGING EQUIPMENT AND TECHNIQUES

This alternative was examined to determine if any change in existing dredging equipment and methods is a viable economic and environmental alternative to existing dredging operations. The alternative does not presuppose movement of dredging operations off of the Kansas River or a change in the quantity of material extracted.

The two basic types of dredges in use in the United States are mechanical and hydraulic (Morton, 1977). The mechanical types, which resemble excavation machines seen on land, include bucket, clamshell, orange peel, and dragline dredges. The dredges are usually operated in conjunction with a barge which is either onboard or operated as a separate vessel. The dredged material is processed onboard or transported to a processing area on shore. Several of these types of operations are or have been in use on the Allegheny river, Ohio River, Tennessee River, and Brazos River in Texas (U.S. Army Engineer District, Pittsburgh, PA, 1978, 1980; Smalley et al., 1974; Forshage and Carter, 1973). The principal disadvantage of mechanical dredging is the excessive turbidity that is developed (Morton, 1977; Forshage and Carter, 1973); the advantage of this method over hydraulic dredging is the reduced interaction between the sediment and water column (Morton, 1977).

Hydraulic dredges mix large volumes of water with the sediments to form a slurry which is sucked from the bottom and pumped either through a pipeline or into a hopper bin to be carried to shore for processing.

Current dredging operations on the Kansas River utilize floating, hydraulic "suction" type dredges. The one feature that differs between dredges is the type of device used to loosen the sand and gravel bed, prior to its entry into the suction tube. Most dredges use a "chain-ladder" device, but several have special cutter heads. The latter allows the dredge tube to work deeper in the sand layer and in one instance eliminated the infrequent problem of fish being sucked into the dredging equipment. One dredge uses a small water jet mounted on the suction tube and another uses a hydraulically operated arm which moves back and forth in front of the tube. The dredged material is transported by a pipeline mounted on pontoons to a riverbank processing area where it is cleaned, sorted, sized and distributed to appropriate storage piles.

This alternative was eliminated from further consideration primarily because any changeover in the type of equipment used to dredge and process sand and gravel would be expected to increase the cost of the aggregate, while no significant environmental benefits would be realized. Present suction dredges are preferable to mechanized dredges because of their minimal influence on stream turbidity levels during operation. The source of most of the turbidity resulting from dredging operations is the excess-water stream discharged through the onshore outfall pipe below the dredge. The finest fraction of the dredged material, the silt and clay, is returned to the river via this water stream. The turbidity plume resulting from this discharge is in all cases small and disposal of this water by other methods does not appear to be warranted. Available evidence also indicates that resuspension of toxic substances by suction dredge operation may not be a problem (see discussion in Section III.4.a) and existing dredging methods and techniques (length of operation, areas dredged, depth of withdrawal) do not significantly impact the biota of the river.

This alternative also does not control the problem of sand removal above the replenishment rate and its possible concomitant effects on river hydrology and ecology.

For these reasons, this alternative was not considered as a viable alternative for commercial sand and gravel production in the study area.

3. ALTERNATIVE MATERIALS FOR DREDGED MATERIAL PRODUCTS

The question of finding materials which can replace natural sands and gravels is potentially very complex and in fact could be the subject of a separate research study. This section will briefly survey the principal synthetic substitutes for aggregates which have come into use. Some economic ramifications will also be discussed.

One major category of synthetic materials consists of the lightweight aggregates. The bulk of these is produced by the heat treatment of suitable shales, clays and slates. These materials are bloated in rotary kilns at temperatures usually in the range of 1800 degrees to 2200 degrees F. Gases within the mineral cause numerous cells to be formed, considerably expanding the volume. Another process is sintering, in which raw materials like those already mentioned as well as fly ash are crushed, screened and distributed evenly over a grate. The mass is then combusted, causing particle surfaces to fuse into a sintered cake. This can then be crushed and graded. In the case of fly ash, which is a furnace residue accumulated in coal-fired power plants, the material is first pelletized by spraying it with water. Carbon remaining in the ash will usually support the combustion for sintering.

Two by-product materials have found some use as lightweight aggregates. Cinders derived from the combustion of coal or coke are sometimes used in concrete blocks. Blast furnace slag is expanded and crushed to produce an acceptable aggregate. The use of this material is necessarily restricted to areas of steel production.

Two ores, vermiculite and perlite, are expanded to make a very lightweight aggregate for insulating concretes. (The preceding information is summarized from "Concrete Products," editors, 1963; Fondriest and Snyder, 1964; Marek, 1972; Portland Cement Association, 1977.)

All of these materials have been used in situations in which a lightweight concrete has been desired. The properties of these aggregates vary greatly, but in general they do not have the strength of conventional aggregates. The suitability of using these materials in structural concrete varies with the engineering requirements of each job. A salient point, however, is that an adequate degree of workability with lightweight concrete often requires a considerable amount of the finer, heavier aggregate size fractions (Bush, 1967. In Mineral and Water Resources of Missouri). In practice, this is often accomplished by the use of natural sands. Whether or not the synthesized aggregates can at certain gradations be substituted for

natural sands is never made clear in the literature which was reviewed. Consequently, a critical consideration in the question of substitutability remains uncertain.

The recycling of old concrete is a technique which is coming into use as a source of aggregate for road bases and paving concrete. While the crushing and recycling of worn pavement is a promising technique, the use of this material for pavements raises questions of mix design and workability. Again it seems that the addition of a substantial quantity of natural sand is often necessary (Halstead, 1979; Ray, 1977).

Other emerging technologies include waste utilization and the chemical and thermochemical processing of raw materials (Fondriest and Snyder, 1964; Marek, 1972). In areas in which combustible solid wastes are reduced by incineration, considerable quantities of ash are produced. This can be treated to form aggregates in a manner similar to fly ash. Solid wastes can also be used directly as aggregates. Besides recycled concrete, rubber, scrap steel and ceramic wastes are among the materials which have been used. These wastes sometimes require only simple mechanical processing and sometimes more elaborate procedures. The nature of these materials would seem to confine them to the larger size gradations.

Chemical and thermochemical processing can be used to create various types of synthetic aggregates. Chemically active ingredients such as lime, phosphate, silicate or cement can be mixed with reactive earthen substances such as sand, clay and soil. These mixtures can be pelletized to aggregate-size agglomerates. Low-quality aggregates produced in this manner can be beneficiated to the desired quality. Beneficiation may also apply to low-grade conventional aggregates that might be considered waste by producers. Techniques of beneficiation include mechanical treatment such as crushing and separation and upgrading by blending with materials having specific characteristics. Low-quality aggregates can also be coated to increase resistance to wear or encourage other properties. These processes result in products which are suitable for lightweight aggregates, filler and other undemanding uses, but they are not usually expected to match the performance of natural aggregates.

Aside from unanswered technical questions, complicated economic issues arise in considering the substitution of synthetic aggregates for alluvial material. None of the synthetics mentioned here are known to be produced in the study area, with the exception of an Ottawa, Kansas firm that produces a ceramic-coated expanded shale aggregate. The large-scale production of any substitute would necessitate the establishment of an entirely new industry. It seems unlikely that the dredging operators, whose experience and expertise obviously lies with dredging, would want to attempt this type of production. Whether or not concrete producers or other businesses would consider this an attractive investment venture is difficult to predict, so no information is available on the costs of these techniques. Based on qualitative

discussions in the aforementioned sources, it appears that synthetic aggregates are likely to be priced well above prevailing values for natural aggregates. Synthetics could become competitive if natural materials experience sharp increases in price, which would occur if the supply were severely restricted.

The technology required for most of the processes mentioned above is neither sophisticated nor unfamiliar, so that this is not a major barrier for potential entrepreneurs. A more critical problem is the lack of an infrastructure to support the production or processing of unconventional aggregates. For example, there is currently no large-scale recovery of solid wastes in the study area, nor are expandable ores being mined in any quantity. It would require a very large investment to create such a supportive infrastructure and this would not occur except in the face of a very high demand for these materials.

Since it is doubtful that any synthetic aggregate could be substituted for the fine, heavy sands that comprise the bulk of Kansas River production, and because of the obstacles to large-scale production, it appears unlikely that synthetics are a viable alternative to current dredging.

4. MOVEMENT OF EXISTING DREDGING OPERATIONS UPSTREAM

On first examination, the implementation of this alternative would lessen bed degradation and its associated effects in the lower Kansas River. The existing concentration of dredging operations in the Bonner Springs--Turner Bridge reach (river miles 22.0 to 9.3) localizes the effects on river channel morphology within the reach.

Though it is unclear whether there is any regulatory authority to authorize such a move, the implication is that any negative effects of dredging would be transferred to another area of the river. The socioeconomic and land use implications of such a move are discussed in Section III.A.6. From an environmental standpoint, this alternative would result in the commitment of additional streambank habitat and/or agricultural land resources along the river, unless previously disturbed sites are utilized. Abandonment of existing sites would not result in any significant benefits to agricultural, park, or wildlife land uses, unless the sites were restored and revegetated. Abandoned riverbank commercial dredging sites are relatively small, sandy, xeric waste areas which appear to have long recovery times for riparian vegetation. Except in areas where the site is protected by flood control levees, industrial or other commercial uses of abandoned sites do not seem feasible due to the possibility of flooding and other natural hazards along the riverbank.

Strategic spacing of commercial sand and gravel dredging operations would avoid concentrating dredging and its environmental effects in a local area, although the aggregate impact would continue. A major consideration is the implementation of this plan. Several serious problems with no simple solution are apparent. First and foremost is

the question of whether there is any legal or regulatory authority which can site commercial sand and gravel dredging operations. Secondly, to be effective, the distances between dredging operations would have to be substantial in order to realize any significant long-term benefits. This raises the question of which firm or firms will take the furthest downstream position and hence enjoy a competitive advantage insofar as transportation costs to the Kansas City Metropolitan Region market are concerned.

These considerations make the movement of existing dredging operations upstream by regulatory means an unrealistic alternative to existing operations.

5. COMBINATION

In the early stages of this analysis, combination plans involving various alternative sand and gravel production methods were examined to determine if such combinations were a viable option to existing dredging operations.

Varying scenarios of this plan include existing river operations and land mining (one firm does this), existing operations and alternate stream sources (two firms presently operating on the Kansas River also operate on the Missouri River), land mining and alternative stream sources and many others.

Implementation of this alternative appears to be infeasible due to economic reasons. Most dredging firms presently in operation on the Kansas River are not large enough to invest in and maintain separate sand and gravel production facilities (see further discussion in Section III.A.6.). Should regulatory actions force existing operations off of the river, it is likely that most firms would convert only to a new operation somewhere else. Reducing the quantity of sand and gravel extracted to the replenishment rate will also effectively force existing operations out of business at existing sites (again see discussion under Section III.A.6.). Therefore, no combination alternative involving existing dredging operations and any other source appears plausible for individual dredging firms. Any option which considers the movement of some operations to an alternate source while allowing others to remain on the river may be outside the legal authority of regulatory agencies.

For these reasons, the environmental consequences of a combination alternative were not considered in detail.

B. ALTERNATIVES CONSIDERED IN DETAIL

1. NO ACTION

Existing dredging operations have an insignificant local effect on air quality. This effect is associated with dust from haul truck traffic on access roads to individual dredge sites. Increased noise levels in the immediate vicinity of a sand and gravel dredging site can be expected

but these are judged insignificant in comparison with background conditions.

Surface water quality is apparently not affected to any significant degree by existing dredging operations. The excess water stream discharged through the effluent pipe has higher turbidity levels than the river but this apparently does not affect downstream conditions. Though the character of the riverbed sediments suggests little resuspension of toxic material by dredging, a definitive conclusion cannot be reached until more data is available from the Fishery-Dredging study of the lower Kansas River.

Temperature may slightly increase due to decreasing river depth as a result of bed degradation, but this should not be different from conditions found throughout most of the stream's length.

Slight decreases in primary productivity may be a consequence of existing dredging operations; however, other short-term events such as reservoir release patterns and floods appear to have similar effect.

At the present time, dredging apparently has not negatively affected aquatic macroinvertebrate diversity or densities in dredged segments of the Kansas River. It is plausible that increased habitat diversity has resulted from dredging with a parallel increase in the diversity and density of benthic organisms. This same case may be made for the fish population which apparently is not negatively affected by dredging. The greater habitat diversity in the dredged portions of the river has benefited some species and negatively affected others such as the sand shiner. Overall quality of the fish population has not been affected. However, it is inferred that with no replenishment of appreciable amounts of sand below Bonner Springs, the river could be modified into a deep channel over the long-term. Such a change would constitute monotonous habitat conditions for aquatic organisms. This is a net negative impact when compared to the predredging original sandy, shallow habitat conditions. Presumably, this is a result of a decrease (in the dredging area) of the shallow, sandy habitat preferred by some fishes.

There are no apparent impacts on threatened or endangered aquatic life resulting from dredging. However, the lack of life history information and the uncertainty of whether certain species (pallid sturgeon and sicklefin chub) occur in the river precludes a definitive answer.

It is inferred that bed degradation causes a parallel decline in surface and groundwater levels and consequently accelerates the aging process of existing wetlands along the Kansas River. However, wetlands along the river are in many cases not permanent and other factors are possibly involved in bed degradation in the lower Kansas River. These considerations make the impact on wetlands from existing sand and gravel dredging difficult to describe or measure.

Whoa!

Dredging may have an indirect effect on terrestrial vegetation and streambank habitats due to bank erosion. Bank erosion results in the loss of wildlife habitat occurring along the river, although this habitat is primarily cropland which is not as important as other habitats such as riparian timber. Mammals, birds, and amphibians and reptiles may be affected to a small degree from this habitat loss. At this time it appears that existing commercial sand and gravel dredging has no detrimental effects on threatened or endangered terrestrial species.

Numerous stresses and other confounding factors influence the environmental quality of the Kansas River. These stresses include urbanization, industrialization, point and nonpoint source pollution, and consumptive water use. Sand and gravel dredging is only one source of additional stress to the ecosystem and by itself, has not appeared to significantly impact the aquatic environment of the Kansas River up to this point in time.

Few impacts on the socioeconomic environment are expected from the no action alternative with the exception of three elements. Agricultural land use, recreational fishing and aesthetic features are expected to be the only items affected.

A moderate impact on agricultural land use along the Kansas River is anticipated should dredging proceed with no additional restrictions. Kansas River bank erosion, caused in part by dredging, would probably continue to consume farmland adjacent to the river. Recreational fishing may actually improve somewhat in the short term because of continued dredging providing increased diversity for fish habitat (actual degree of impact is uncertain), however long-term effects may be significant. The aesthetic features along the river may become less attractive with continued severe bank erosion.

No additional impacts are anticipated for the remainder of the socioeconomic elements should Kansas River commercial dredgers continue their current operational procedures.

2. CESSATION OF DREDGING

The abandonment of sand and gravel dredging on the Kansas River may cause a slight improvement in local particulate levels due to decreased haul truck traffic on access roads. This same conclusion may be reached for noise levels. However, in comparison to background levels, slight overall improvement in both of these elements is expected.

Surface water quality will improve with the implementation of this alternative, though this will not represent a significant improvement.

Primary productivity and plankton densities may also increase though existing dredging operations are not a primary limiting factor for these elements. The diversity and density of macroinvertebrates and fish may return to levels found throughout most of the river's length owing to

decreased habitat diversity. However, this may be beneficial over the long-term in that modification of the river into a deep channel monotonous habitat below Bonner Springs will not occur.

The accelerated aging process of existing wetlands may decrease, though the degree of this improvement is difficult to measure because of other impacting factors.

Terrestrial biological resources are expected to be slightly improved with the implementation of this alternative because of decreased bank erosion and its impact on habitat.

The overall environmental quality of the lower river is expected to improve although it may not be noticeable because of other present stresses on the river and its resources such as urbanization, industrialization, point and nonpoint source pollution, and consumptive water use.

For the most part, land use impacts from the cessation of dredging alternatives are expected to be short term and insignificant for the residential, commercial, industrial, and mining/quarrying elements. This impact would be caused primarily by higher prices for sand and gravel which would increase construction and site development costs. The end result would likely be a slight reduction in future land development demands in the above land use categories. With reduced streambank erosion a positive benefit would probably be realized for agricultural land due to greater bank stability. Property values would most likely continue to appreciate along the Kansas River corridor and may increase slightly near dredge operations which are no longer functioning.

Fishing along the Kansas River may be impacted slightly by the removal of dredges. As the river channel would attempt to return to its pre-dredging conditions, some fish habitat areas may fill in with sediment, reducing the number of game fish in the stream.

It is difficult to estimate what effect the cessation of dredging alternative may have on the aesthetic features of the study area. Reduced levels of bank erosion would reduce the deterioration levels of the river banks. The removal of dredges from the stream would be seen by many as an improvement in local aesthetic features. However, unused dredge sites are often viewed as unaesthetic and considered a negative impact.

Substantial negative impacts are expected to occur in several socioeconomic elements. These include the employment/labor force, income, aggregate price, housing, and construction industry elements. There would be a large reduction in the sand and gravel industry labor force. Serious primary and secondary impacts would be felt in the local and regional industries dependent upon Kansas River aggregate, resulting in a rise in unemployment.

There would be substantial income losses as a result of the cessation alternative for the sand and gravel industry employees and operators. This is also the case in the local and regional income sectors because of similar market dependencies upon the ready supply of aggregates.

The price of aggregates would be expected to increase substantially due to sudden changes in the transportation and supply mechanisms.

Housing market conditions as well as construction industry conditions would be affected greatly both locally and regionally because of large increases in construction costs and a probable reduction in demand for new construction.

The local and regional population may decline slightly because of impacts from reduced aggregate production, reduced employment, and higher construction costs which would have a slight affect on migration patterns into and out of the area.

Services in the study area would also be negatively affected by the cessation of dredging alternative. Tax revenues would be reduced slightly because of lower state corporate and excise tax revenues. Public services would probably be moderately impacted because of an increased demand for social services and fewer funds to support those demands. A severe impact is anticipated on the regional transportation network. This would be caused by increased highway construction costs, reduced highway maintenance and an increase in highway shipments of sand and gravel. Local schools would be affected by the slight changes in area population and the higher construction costs for school expansion and new facilities.

Neighborhood cohesion would be only slightly affected by short-term changes in neighborhood equilibria caused by social and economic adjustments to the effects noted previously.

Substantial inflationary strains would be felt in the local and regional economy with the implementation of this alternative. This is especially true in the employment, income, housing, construction, and aggregate price elements as identified in the alternatives assessment matrix (Table I-3) and above text. It is estimated that a slight impact would be felt nationally for a short period of time after implementation of the cessation of dredging alternatives because of the size of the study area's economy relative to the national economy.

3. REDUCED QUANTITY OF MATERIAL EXTRACTED

Local air quality and noise levels will be slightly improved owing to a reduction in machinery operation and haul truck traffic.

Insignificant improvements in Kansas River water quality will be a result of reducing the amount of sand and gravel dredged. This will primarily be a consequence of reduced turbidity and sedimentation from the effluent outfall pipe.

Primary productivity and river plankton may improve, though this will not be significant because of other limiting factors such as high river flows and pollution from agricultural runoff and industrial sources. The diversity and density of macroinvertebrates and fish may return to pre-dredging conditions. The overall diversity of these organisms may decline because of decreased habitat diversity, but this would be less severe than mining the river below Bonner Springs until a deep monotonous channel is created.

The few existing wetlands along the Kansas River are expected to benefit from this alternative since deceleration of bed degradation will benefit standing water areas. However, the degree of this improvement is unknown due to other impacting factors.

Terrestrial biological resources are expected to be slightly improved because of decreased bank erosion and habitat loss.

In comparison with existing sand and gravel dredging on the Kansas River, reducing the quantity of material extracted would result in a significant improvement in overall aquatic environmental quality, but will have a moderate to singificant effect on channel morphology. However, this alternative, for all practical purposes, is the same as the cessation of dredging alternative. Reducing the material extracted to the replenishment rate could force existing operations out of business due to economic reasons.

Socioeconomic impacts experienced in the reduced quantity of material extracted alternative are anticipated to be quite similar to those impacts in the cessation of dredging alternative. This condition is evident in Table I-3. The primary reason for this similarity is that local and regional impacts, caused by a major change in the sand and gravel extraction process, are the result of similar reliance of the Kansas River dredging industry.

The specific differences in estimated impacts between these two alternatives are due to the assumption that this alternative would most likely result in greater constraints on the dredging operations downstream of the Bowersock Dam in Lawrence, Kansas. Should this occur, less impact would be felt in the upstream reaches where approximately 25 percent of the sand and gravel aggregate is extracted. In all seven elements where impacts are dissimilar, the environmental effect is reduced from substantial to moderate because of much lower impacts being felt in the upstream areas along the Kansas River. These seven elements are the local and regional labor force, the local and regional income levels, the local housing market and construction industry, and the local economy.

4. ALTERNATIVE STREAM SOURCES FOR DREDGED MATERIALS

Since movement of an existing sand and gravel dredging operation to a new stream source is expected to involve similar equipment and operation practices, air quality and noise impacts will be slight. While

operation on the Missouri River necessitates diesel dredges which emit air pollutants and are noisier, this should not be significant in comparison to background conditions.

Surface water quality will be little affected by dredging on the Missouri River. This conclusion is based on background conditions including river flow.

Aquatic biological resources such as plankton, periphyton, benthic organisms and fish are also expected to be insignificantly affected by sand and gravel dredging on the Missouri River. Again, the basis for this conclusion is that dredging operations will have very local impacts on an ecosystem which is also impacted by other factors. A slight improvement in habitat diversity is possible from Missouri River dredging.

The impact on wetlands from this alternative cannot be determined without prior knowledge of site locations.

The impact on vegetation and wildlife depends on the areas chosen for relocation. Certainly, vegetation and wildlife will be displaced by bank material storage areas and lignite processing equipment. The magnitude of this effect depends on the quality of the habitat removed. For instance, the removal of cropland or previously disturbed habitats is less severe than the removal of riparian timber. It is anticipated that the relocation of a dredging operation to a Missouri River site will be in an area which requires the least amount of clearing and development costs, i.e., cropland or other previously disturbed land.

Effects on threatened or endangered species cannot be determined with absolute confidence. It is possible that disturbance to these species may result from human activity in a new area. However, should a new site be located in the Kansas City metropolitan region, the likelihood of impacting threatened or endangered vertebrates is rare.

Dredging on an alternative stream source such as the Missouri River is anticipated to have no significant negative impacts on overall environmental quality.

Alternative stream sources, as discussed in this section, refer to the Missouri River system in or near the Kansas City metropolitan area. Environmental effects are not considered for the Kansas River area since implementation of Missouri River dredging would probably be the result of reduced or eliminated Kansas River dredging as discussed in the two previous alternatives.

The anticipated socioeconomic impacts from the alternative stream sources alternative would be considerably lower than in the cessation of dredging or the reduced quantity of material extracted alternative. In several of the economic sectors, specifically employment and income, the environmental effect is projected as a positive impact.

The only expected land-use impact from this alternative would be a slight increase in industrial land use along the Missouri River because of the increase in dredge sites.

No impacts are anticipated on local parks or recreational fishing because of this alternative.

Some short-term effect on local aesthetics may result from new site development along the Missouri River.

Positive employment/labor force impacts would be felt from a considerable increase in the Missouri River sand and gravel industry, which also requires more labor per dredge operation. The local and regional labor forces would increase slightly because of some local industry growth. Similarly, income levels in these areas would increase slightly because of their direct relationship to labor increases in the Missouri River dredging industry and local markets.

Significant short-term fluctuations in the price structure of sand and gravel aggregates will probably follow changing market conditions. This is expected to level off to a long-term moderate price increase due to more expensive operations.

No impact on local or regional population is anticipated.

Higher production and construction costs would have a moderate negative impact on the local and regional housing markets.

Substantial short-term impacts on the local and regional construction industry are expected from this alternative until the industry stabilizes.

Services will only be slightly affected by this alternative. The effect on tax revenues is unknown and is dependent upon market conditions.

Public services will probably realize a short-term impact because of lost production revenue during the changeover period and a slight increase in demand for social services. There could possibly be a moderate impact on transportation services with the alternative stream sources option. Higher costs for highway maintenance and construction along with additional truck traffic in the new site areas would add to the wear and tear of the roads in the region.

No impacts are expected to be felt by local schools and no disruptions affecting neighborhood cohesion should occur.

The overall local and regional economy, it is estimated, would receive moderate short-term impacts until the sand and gravel industry and secondary markets stabilize. The national economy is not likely to experience any noticeable impacts caused by this short-term regional market condition.

5. LAND MINING

Land mining for sand and gravel is expected to have an insignificant to significant local effect on air quality and noise levels. If mining is from a floodplain pit (the most likely possibility), particulate levels may be significant for only a short time during overburden removal. If the aggregate is extracted dry from an upland site, continued degradation of local air quality can be expected. Noise levels should not be increased to any significant degree. The impact of noise from land mining would be most significant if the aggregate is excavated dry and the site is in close proximity to a residential area.

Floodplain sand and gravel dredging could have a slight negative effect on ground water quality particularly if spills or oil or grease from the dredge or other on-site operations runoff into the dredge pit.

Aquatic biological resources will increase with the creation of a flooded pit.

The potential impact of land mining, especially in floodplain areas, on wetlands cannot be determined without prior knowledge of land mining relocation sites. Land mining would have a significant impact on wetlands only if the mining site chosen is within an existing wetland.

The land requirements for a land mining operation are substantial and in the magnitude of 40 to 50 acres per year to replace existing lower Kansas River production. The removal of this land will displace vegetation and wildlife throughout the life of the operation. Of course the severity of this impact on vegetation and wildlife resources depends on the quality of habitat removed. The removal of cropland or other previously disturbed habitats is less severe than the removal of floodplain and riparian timber. Consequently, the impact of land mining on terrestrial biota may range from insignificant to severe depending on the area mined. It should be pointed out that cropland or other previously disturbed areas would be less costly to clear and develop and these may be the most likely candidates for a land mining site.

Unless the spoil resulting from overburden removal is transported off site, this material may also represent an impact on terrestrial biota due to the displacement of habitat. Mitigation possibilities such as use of the overburden material as filler material or landfill or grading and revegetation may minimize the effect of spoil disposal.

In this alternative, many of the impacts on various socioeconomic elements are similar to those effects experienced in the alternative stream sources option. Though it is obvious that the operations involving river dredging are quite different from land mining operations, the environmental effect in many cases is the result of similar siting and/or market considerations.

For example, as in the previous alternatives, proper siting procedures would eliminate any potential impacts on historical or archaeological sites in the area. The price of aggregate, the housing market, and the service sector elements would experience similar impacts as in the alternative stream sources option because of comparable market conditions in an industry undergoing change. These similarities between the stream sources and land mining alternatives also hold for the impacts on the local, regional, and national economy.

The land mining alternative impacts all of the land use elements considered in the assessment matrix (Table I-3). The impacts on agricultural land would probably be moderate to severe, depending on the types of land utilized for this activity. Residential, commercial and industrial land use may be negatively impacted because of higher aggregate costs resulting in higher construction costs. Mining and quarrying land use would increase relative to market demand. Property values near land mining sites may be negatively affected. Again, this depends on the location of the mine sites.

Also site specific is the impact, if any, land mining may have on local parks. This impact is unknown.

There would be a substantial long-term effect on local aesthetic features of the land because of significant development and operation impacts. This would be especially true should agricultural land be mined.

Employment and income in the sand and gravel industry would be impacted somewhat, but the extent is unknown. Depending upon market conditions, many of the employees from the river dredging operation may simply transfer to the land mining operations as they are developed. In the area near the land mining, some increase in industry labor is anticipated. No regional impacts are expected, however.

Local and regional income levels would not experience any noticeable effect from the land mining alternative. The probable shift of labor and income from river dredging to land mining would neutralize any effect.

The local construction industry impact is seen as moderate and short term, caused by an attempt to return to a state of equilibrium. However, the study region is likely to receive significant short-term impacts because of the regional reliance on Kansas River aggregate and a temporary instability in the sand and gravel industry.

Some slight disturbance in neighborhood cohesion may be caused by industry and socioeconomic conditions related to the establishment of land mining in an area.

C. COMPARATIVE IMPACTS OF ALTERNATIVES

1. MATRIX SUMMARY

The Kansas River Commercial Dredging Alternatives - Assessment Matrix, Table I-3, summarizes the impacts discussed in the previous section (I.B.). The expected environmental effect on each environmental element is identified for the five alternatives considered in detail. Those alternatives are: A) no action, B) cessation of dredging, C) reduced quantity of material extracted, D) alternative stream sources, and E) land mining. Comments in the matrix are made on those items needing some qualification. As noted above, further discussion of these impacts can be found in Section I.B. and described in detail in Section III of this report.

Environmental effects assessed in this matrix under the elements of physiography and geology, hydrology, and facilities and structures have been identified for two separate reaches of the Kansas River. Current information suggests that river channel characteristics above DeSoto, Kansas are not yet affected by dredging activity. This is not the case along the Kansas River below DeSoto, Kansas. Therefore, the above specified environmental elements were assessed separately on the river reaches above and below DeSoto, Kansas.

The atmospheric, aquatic, terrestrial, and environmental quality elements assessed in Table I-3, describe impacts that are expected to occur along the Kansas River downstream of DeSoto, Kansas. As mentioned previously, dredging activity does not appear to be a major influence upstream of DeSoto. Upstream dredging operations will have only insignificant effects on the atmospheric, aquatic, and terrestrial elements or the overall environmental quality of the upstream ecosystem. In instances where impacts on the above elements may occur upstream, this has been noted in the report text.

Due to the characteristics of the socioeconomic elements, most of the impacts discussed apply to the entire economic and social study area, unless otherwise noted in the matrix.

Table I-3
KANSAS RIVER COMMERCIAL DREDGING ALTERNATIVES — ASSESSMENT MATRIX

Environmental Elements	A No Action	B Cessation Of Dredging	C Reduced Quantity Of Material Extracted	D Alternative Stream Sources	E Land Mining	Comments
KANSAS RIVER ABOVE DESOTO, KANSAS						
Physiography and Geology						
Channel Morphology (width, depth & location of channel)	I	I	I	I	I	A, B, C, D. There is no substantial evidence that dredging is the cause of instability anywhere in the designated reach. (See section II.A.4.) E. Unless located close to the present river channel or in the path of some future channel migration, sandpits cannot affect stream morphology.
Mineral Resources	I	I	I	I	I	A, B, C, D. Sand from the original primary Kansas River source is cut off by federal lakes and reservoirs, but normal river action is adequate to sustain sand production at upstream dredging locations.
Soils	I	I	I	I	S	E. Soils are stripped prior to mining. On flood plains, sandpits remain as lakes after the sand is extracted and the site abandoned.
Land Usage	I	I	I	I	S	E. Agriculture not possible during or after pit mining. Lakes become sites for housing developments, park locations, or simply remain as lakes or ponds on the floodplain. In some instances abandoned sandpits have become city dumps.
Compaction and Subsidence of River Substrate	I	I	I	I	I	A, B, C, D, E. Dredging activities are permitted only in a small percentage of the total river area.
Bank Slope Stability	I	I	I	I	I	A, B, C, D, E. Bank slope stability appears to depend upon factors other than dredging in the reach of the Kansas River above Desoto.
Construction Material	I	S	S	S	M	B, C, D. The Kansas River and its flood plain are the sole source of fine aggregate in Wamego, Topeka and Lawrence areas. E. Land mining (if possible at all) is more expensive than river mining because of stripping operations and resource depletion.

Table I-3 (continued)

Environmental Elements	A No Action	B Cessation Of Dredging	C Reduced Quantity Of Material Extracted	D Alternative Stream Sources	E Land Mining	Comments
KANSAS RIVER ABOVE DESOTO, KANSAS						
Hydrology						
Flood Carrying Capacity of Channel	I	I	I	I	I	E. Greater depth at sand pits will increase flood plain storage slightly. Stockpiles and equipment would reduce capacity of flood plain to carry water.
Ground Water Quantity	I	I	I	I	I+	E. Recharge to the aquifer at sand pits is increased slightly by rain falling on the water surface. Surface drainage can also be diverted to abandoned sand pits with a slight increase in recharge to the aquifer.
Surface Water Quantity	I	I	I	I	I	Impact is considered insignificant since no evidence is available that dredging is influencing river morphology in the upper Kansas River.
Facilities and Structures						
Flood Control Structures	I	I	I	I	I	A, B, C, D, E. Dredging activities in the upper reach of the Kansas River cannot be positively correlated with river instability. (This presumes that dredgers operating in both the river and sand pits will operate their dredges in the future at distances from these structures and physical features as required by present regulations.)
Bank Stabilization	I	I	I	I	I	
Water Intake Structures	I	I	I	I	I	
Dams	I	I	I	I	I	
Bridges	I	I	I	I	I	
KANSAS RIVER BELOW DESOTO, KANSAS						
Physiography and Geology						
Channel Morphology (width, depth & location of channel	S	M+	M+	I	I	A. The Kansas River channel in this reach is presently widening and degrading. Alternatives which eliminate or curtail Kansas River dredging cannot eliminate *all* instability. Continuation of dredging at current levels however will accelerate degradation and widening.
Mineral Resources	S	S+	S+	I	S	E. Land mining depletes sand resources at a specific location since *none* of the quantity removed is replaced by river action.

Table I-3 (continued)

Environmental Elements	A No Action	B Cessation Of Dredging	C Reduced Quantity Of Material Extracted	D Alternative Stream Sources	E Land Mining	Comments
KANSAS RIVER BELOW DESOTO, KANSAS						
Physiography & Geology (continued)						
Soils	S	S+	S+	I	S	A. Soils are now being lost by river widening. This will not cease completely if dredging is halted or curtailed (Missouri River degradation) but should be slowed. E. Sand pits necessitate flood plain soil removal prior to mining.
Land Usage	S	S	M	I	S	A. Land lost to the river cannot be used at all. B. Dredging firms would relocate. Land usage would change. E. Pit Mining destroys the flood plain.
Compaction and subsidence of substrate	U	U	U	U	U	Compaction of substrate, unknown.
Slope Stability	S	M+	M+	I	I	A. Present extraction rate is accelerating bank and bed erosion. Because part of the instability may be caused by degradation on the Missouri River, it is not believed that instability will be halted with total cessation or curtailment of dredging.
Construction Material	I	S	S	S	S	Any dislocation of dredging activity will increase the costs and possible decrease the supply of fine aggregate in the Kansas City area.
Hydrology						
Flood Carrying Capacity of the Channel	S+	M+	M+	I	I+	The river channel is presently increasing in capacity. Cessation or reduction of dredging will slow, but not stop this action. E. Land mining will increase storage on flood plain a small but insignificant amount.
Ground Water Quantity	M	M	M	M	I	A, B. Water surface in the Kansas River in the reach considered here are presently declining for all levels of flow. This would produce corresponding (but not direct) declines in water wells adjacent to the river. Some additional energy would be required to lift the water the additional height. Of more concern is the physical threat to the well locations themselves. (See Facilities and Structures.) Water levels are unlikely to return to previous levels even after total cessation of dredging because of continued degradation of the Missouri River.

Table I-3 (continued)

Environmental Elements	A No Action	B Cessation Of Dredging	C Reduced Quantity Of Material Extracted	D Alternative Stream Sources	E Land Mining	Comments
KANSAS RIVER BELOW DESOTO, KANSAS						
Hydrology (continued)						
Surface Water Quantity	S	M+	M+	M+	M	A. Present dredging practice is accelerating bed degradation and lowering water surface profiles. Johnson Co. Water District #1 intake presently requires a jetty to maintain adequate water levels to operate. Cessation of dredging or curtailment will slow the degradation process but may or may not stop it. "Healing," of the river by accretion of sediments and revegetation is uncertain and it is not known if water stages will return to their former levels.
Facilities and Structures						
Flood Control Structures	I	I	I	I	I	Flood control structures in the designated river reach are downstream of most of the dredging operations.
Bank Stabilization	S	M+	M+	M+	M+	A. Will ensure continuation of bridge foundation element exposure, lowered water surface levels, and bank erosion. B, C, D, E. The river is presently becoming wider and the bed is degrading. Cessation of dredging or reduced quantities will slow, but will not halt this action, since the Missouri River is also degrading its bed.
Water Intake Structures	S	M+	M+	M+	M+	A. Bed degradation has forced Johnson Co. Water District #1 to construct a jetty across the Kansas River at their intake in order to continue operations. B, C, D, E. Cessation of dredging or reduced quantities will slow, but may or may not stop this degradation since the effect of the Missouri River degradation is unclear.
Dams	S	M+	M+	M+	I	A. Will ensure continued severe impacts. B, C, D. Slowing the process of degradation will allow Johnson Co. Water District #1 to construct a more stable jetty or new intake structure. Johnson Co. Water District #1 jetty is the only "dam" in the reach.
Bridges	S	M+	M+	M+	I	A. Will ensure continued severe impacts. B, C, D. Slowing the process of bed degradation and river widening will prolong the life of bridge structures and foundation elements.

Table I-3 (continued)

Environmental Elements	A No Action	B Cessation Of Dredging	C Reduced Quantity Of Material Extracted	D Alternative Stream Sources	E Land Mining	Comments
KANSAS RIVER BELOW DESOTO, KANSAS						
Atmospheric						
Air Quality	I	I+	I+	I	I/M	A. Insignificant local effects. B, C. Insignificant improvement due to decreased haul truck traffic. D. Insignificant local effects. E. Initial impact during overburden removal, insignificant during operation phase, except if aggregate is extracted dry.
Noise	I	I+	I+	I	I	A, E. Insignificant effect in comparison with background conditions. B, C. Slight improvement. D. Elevated levels from diesel dredge operation, but insignificant due to background levels and anticipated location.
Aquatic						
Water Quality Surface Water	I	I+	I+	I	N	A, D. Insignificant effect in comparison with background conditions. B, C. Slight improvement. E. Only impact would be from runoff if site is near a drainage.
Ground Water	N	N	N	N	I	E. Only if runoff into dredge pit.
Temperature	N	N	N	N	N	A. Insignificant increase from bed degradation and decreasing depth.
Primary Productivity	I	I+	I+	I	N	A, D. Insignificant effect. B, C. Slight improvement. Note: Dredging is not a primary limiting factor.
Plankton	I	I+	I+	I	N	A, D. Insignificant effect. B, C. Slight improvement. Note: Dredging is not a primary limiting factor.
Macroinvertebrates	I+*	I*	I*	I	N	A. Appears to have had a positive effect by increasing habitat diversity. B, C. Short-term effect by decreasing habitat diversity. D. Insignificant effect.
Fish	I+*	I*	I*	I	N	A. Appears to have had a positive effect by increasing habitat diversity. B, C. Short-term effect by decreasing habitat diversity. Some species i.e. sand shiner may benefit. D. Insignificant effect.

Table I-3 (continued)

Environmental Elements	A No Action	B Cessation Of Dredging	C Reduced Quantity Of Material Extracted	D Alternative Stream Sources	E Land Mining	Comments
KANSAS RIVER BELOW DESOTO, KANSAS						
Aquatic (continued)						
Habitat/Migration Areas	M+	I*	I*	I+	N	A. Appears to have had a positive effect for fish and benthic organisms by increasing habitat diversity, however, see long-term effects below. B, C. Insignificant short-term effect by allowing habitat diversity to decrease. D. Slight improvement in habitat possible.
Threatened/Endangered Species	I	N	N	N	N	A. No apparent detrimental effects. Possible minimal effect on pallid sturgeon and sicklefin chub if they occur.
Long-Term Habitat Effects	M/S	M+	M+	N	N	A. Moderate to substantial impact on fishery if area is mined out and a deep channel monotonous habitat results. B,C. Moderate positive long-term impact by avoiding significant habitat alteration below Bonner Springs.
Wetlands	I/M	I/M+	I+	U	U	A. Insignificant or moderate effect by contributing to bed degradation and possible wetland aging process, though other factors contribute to bed degradation. Note: Wetlands as a year-round resource in the study area are rare. B, C. Will slow down the accelerated aging process of existing wetlands.
Terrestrial						
Vegetation	I	I+	I+	I	I/M/S	A. Insignificant effect due to bank erosion, riparian timber not as prone to loss due to bank erosion. B, C. Slight benefit to streambank vegetation due to decreased bank erosion. D, E. Possible vegetation removal for site.
Mammals	I	I+	I+	I	I/M/S	A. Insignificant effect due to habitat loss through bank erosion and bed degradation's effect on wetlands. B, C. Slight improvement possible from decelerating bed degradation and habitat loss due to bank erosion. D, E. Slight to severe effect possible from habitat removal, disturbance due to human activity.

Table I-3 (continued)

Environmental Elements	A No Action	B Cessation Of Dredging	C Reduced Quantity Of Material Extracted	D Alternative Stream Sources	E Land Mining	Comments
KANSAS RIVER BELOW DESOTO, KANSAS						
Terrestrial (continued)						
Birds	I	I+	I+	I	I/M	Comments same as for mammals.
Herpetofauna	I	I+	I+	I	I/M	Comments same as above.
Threatened/Endangered Species	N	N	N	N/I	I/M	D, E. Possible disturbance from human activity and locating in a new site.
Environmental Quality	I	I+	I+	I	I/M	A, D, E. Insignificant to moderate effect on overall quality. B, C. Slight improvement but may not be noticeable due to other factors.
Socioeconomic						
Land Use						
Agricultural	M	M+	M+	N	M to S	A. Continued bank erosion caused in part by dredging. B, C. Reduced bank erosion. D. Missouri River banks highly controlled. E. Prime farmland impacts.
Residential	N	I*	I*	N	I	B, C. Affected primarily by sand & gravel price increases.
Commercial	N	I*	I*	N	I	E. Potential negative impact on land development due to higher aggregate costs.
Industrial	N	I*	I*	I+	I	B, C, E. Same as Residential and Commercial elements. D. Industrial expansion along the Missouri River.
Mining/Quarrying	N	I*	I*	N	M+	B, C. Same as residential and commercial. E. Increased land use relative to market demand.
Property Value	N	I*	I*	N	I	B, C. May result in slight increase in nearby property values where dredging stops. E. A negative impact on nearby land values.
Recreation						
Parks	N	N	N	N	U	E. Determined by locations of new sites.

Table I-3 (continued)

Environmental Elements	A No Action	B Cessation Of Dredging	C Reduced Quantity Of Material Extracted	D Alternative Stream Sources	E Land Mining	Comments
Recreation (continued)						
Fishing	I* + to M* +	I	I	N	N	A. Increasing diversity in fish habitat due to dredging. B, C. Habitat diversity returns to pre-dredging conditions. D. No additional impact on the Missouri River.
Aesthetic Features	I	U	U	i*	S	A. Dredging contributing in part to continued bank erosion. B, C. Unused sites may be considered unaesthetic. Reduction in levels of bank erosion would improve river features. D. Some disturbance during new site development. E. Long-term disturbance.
Historical/ Archaeological	N	N	N	N	N	No expected impact.
Employment/Labor Force						
Sand & Gravel Industry	N	S	S	M+	U	B, C. Massive reduction in labor force. D. Considerable increases in those employed in Missouri River dredging. E. Dependent upon market factors.
Local	N	S	M	I+	I+	B. Primary and secondary impacts causing rise in unemployment. C. Not as great an impact as in cessation of dredging alternative. D, E. Slight additions due to local industry growth.
Regional	N	S	M	I+	N	Very similar conditions as in local element because of regional reliance on sand and gravel sources.
Income						
Sand & Gravel Industry	N	S	S	M+	U	B, C. Losses in income as a result of reduced production. D. Directly related to Missouri River dredging increases. E. Dependent upon market factors. Most likely to increase.
Local	N	S	M	I+	N	B. Primary and secondary effects from discontinued dredging. C. Effects similar to but less severe than alternative B.

Table I-3 (continued)

Environmental Elements	A No Action	B Cessation Of Dredging	C Reduced Quantity Of Material Extracted	D Alternative Stream Sources	E Land Mining	Comments
Income (continued)						
						D. Slight increases caused by additional Missouri River dredging. E. Probable shift of labor and income from river dredging to land mining not felt in local income.
Regional	N	S	M	I+	N	Similar to local income element above because of like local and regional relationships to sand & gravel industry.
Price of Aggregate	N	S	S	S* to M	S* to M	B, C. Substantial price increases. D, E. Significant short-term fluctuations with changing market. Long-term moderate raise from more expensive operations.
Population						
Local	N	I	I	N	N	B, C. Some decline from reduced production and employment and higher construction costs affecting migration patterns.
Regional	N	I	I	N	N	Similar conditions as in local population impacts.
Housing						
Local	N	S	M	M	M	B. Market conditions from cessation would cause large increases in housing costs and reduction in demand. C. Not as great an impact as in cessation because of lesser restrictions expected to be placed on upstream dredgers. D, E. Higher production costs would have a noticeable effect on housing market.
Construction Industry						
Local	N	S	M	S*	M*	B. Large impacts on Kansas River region construction industry. Reduced supplies, higher costs. C. Likely to be less serious upstream but still a noticeable impact overall. D. Substantial short-term impacts until industry stabilizes. E. Moderate short-term impacts caused by changing industry.
Regional	N	S	S	S*	S*	B, C. Substantial impacts throughout the economic study area. D, E. Significant short-term impacts until industry stabilizes.

Table I-3 (continued)

Environmental Elements	A No Action	B Cessation Of Dredging	C Reduced Quantity Of Material Extracted	D Alternative Stream Sources	E Land Mining	Comments
Services						
Tax Revenues	N	I	I	U	U	B, C. Slight reduction state corporate and excise taxes. D, E. Dependent upon market conditions.
Public Services	N	M	M	I*	I*	B, C. Greater demand for social services and lower funds to support them. D, E. Short-term lost revenue and increased demands.
Transportation	N	S	S	M	M	B, C. Increased highway costs, reduced maintenance and construction, more numerous highway shipments. D, E. Higher costs in highway maintenance and construction and additional truck traffic in new localities.
Local Schools	N	I	I	N	N	B, C. Slight changes in population and higher costs for school building and expansion.
Neighborhood Cohesion	N	I*	I*	N	I*	B, C. Short-term changes in neighborhood equilibrium caused by social and economic adjustments. D, E. Some disruptions in neighborhood stability caused by industry and socioeconomic conditions.
Economy						
Local	N	S	M	M*	M*	B, C. Substantial strains expected on the local economy. Fewer impacts upstream in C. D, E. Moderate short-term impacts until industry and secondary markets stabilize.
Regional	N	S	S	M*	M*	Very similar to local economy because of like local and regional relationships.
National	N	I*	I*	N	N	B, C. Slight impact on national economy for a short period after cessation or reduction occur. D, E. No expected impact on the national economy.

Source: Burns & McDonnell
*Environmental Effect: I – Insignificant, M – Moderate, S – Substantial, U – Unknown, N – No expected impact, * – Indicates a short-term impact, + – Indicates a positive impact.*

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PART II – AFFECTED ENVIRONMENT

PART II
AFFECTED ENVIRONMENT

A. GEOLOGY AND GEOMORPHOLOGY OF THE KANSAS RIVER BASIN

1. PHYSIOGRAPHIC PROVINCES OF THE KANSAS RIVER BASIN

The Kansas River drainage system includes not only the Kansas River proper but that of the Smokey Hill and Republican rivers and their tributaries. The following description applies to the total drainage area and is abstracted from Frye and Leonard (1952).

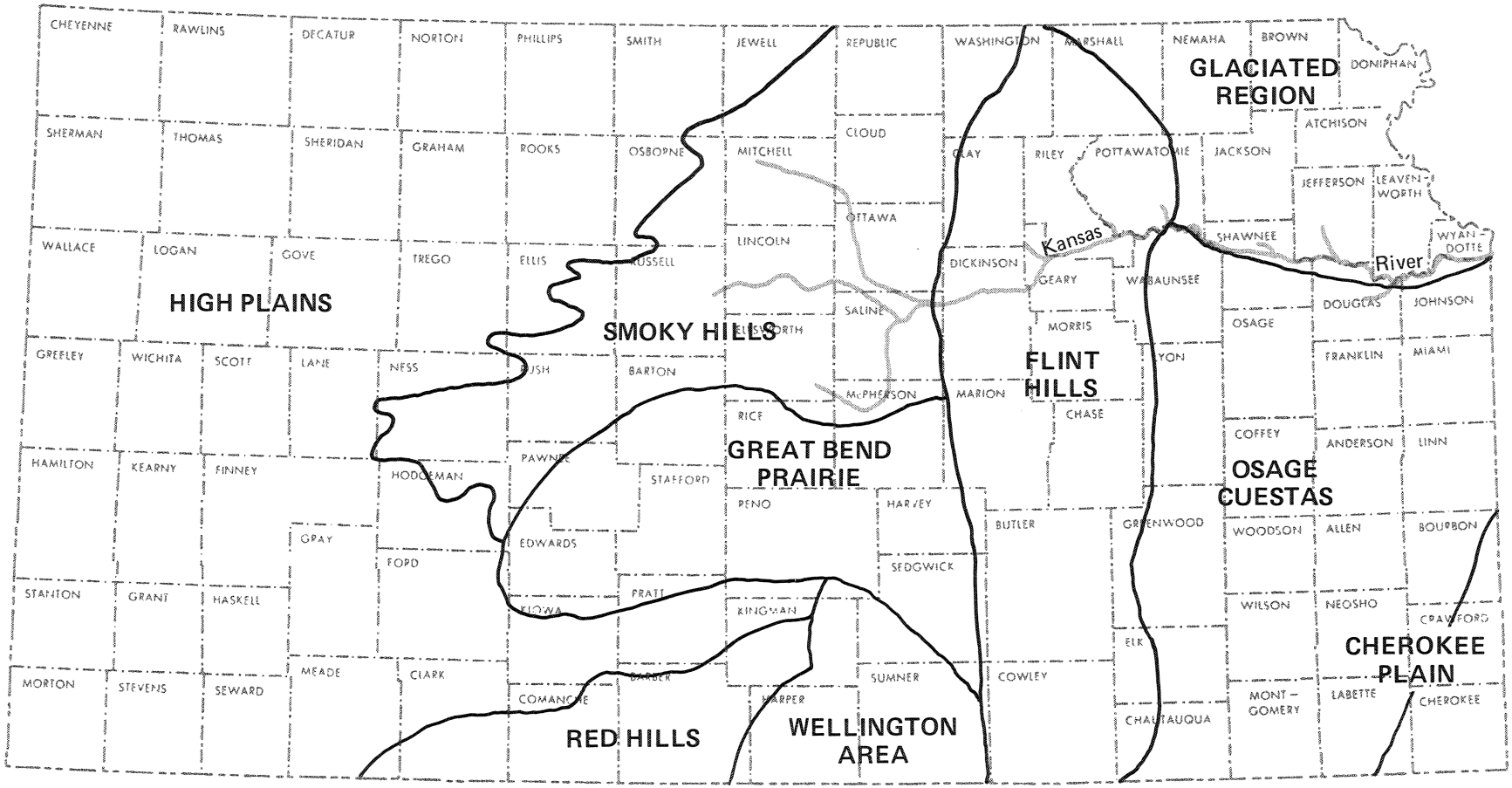
The surface of the state of Kansas in general slopes upward from elevations of 700 to 1,000 feet above sea level in the east to elevations exceeding 4,000 feet in the west near the Colorado state line. The rainfall belts also show a gradation from east to west with the normal rainfall being more than 40 inches per year in the southeast and 15 to 20 inches per year in the west. The pre-Pleistocene area geology changes from Pennsylvanian and Permian rocks in the east, through Cretaceous rocks in the central region, to Pliocene rocks in the western region. The several physiographic, or topographic, provinces of Kansas are also general north-south belts that change in character toward the west (See Figure II-1).

The High Plains include approximately one-third of the area of Kansas; they occur in the western part of the state and extend into contiguous parts of Oklahoma, Colorado, and Nebraska. The High Plains constitute a plateau bounded by distinct scarps on the east and west. Their eastern limit is defined by the prominent scarp of the Fort Hays limestone (Niobrara formation, Cretaceous) for 150 miles northeastward from Finney County.

The topography of the broad interfluves in the High Plains section is monotonously regular with a regional eastward slope of about ten feet to the mile. In much of the region the surface is underlain by late Pleistocene silt deposits and locally by wind-blown sand resting on earlier Pleistocene deposits or Pliocene Ogallala formation. Much of the High Plains upland surface is not drained by integrated surface channels, and two sizable drainage systems (Whitewoman Creek and Bear Creek) are not integrated with any through-flowing stream.

The Arkansas River is the only Kansas stream that completely crosses the High Plains region from a source in the Rocky Mountains but its level is only slightly below the upland surface. In striking contrast, the Smoky Hill River, which originates on the plains surface in Colorado, occupies a valley 15 to 20 miles wide cut in Cretaceous bedrock.

Erosion by lateral stream planation is effective in a very small part of the region and, since much of the upland surface lacks integrated surface drainage, erosion along defined stream channels is small. On the flat uplands, even sheet erosion is of relatively small importance



Source: Museum of Natural History, University of Kansas, "Amphibians and Reptiles in Kansas," 1974.

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Figure II-1
PHYSIOGRAPHIC PROVINCES OF KANSAS

and the persistent mantle of wind-blown silt is subject to shifting during periods of excessive drought.

The Smoky Hills section in the north-central part of the state flanks the scarp of the High Plains on the east. The topography of the eastern part of the section is dominated by irregular hills held up by discontinuous lenticular sandstones in the Cretaceous Dakota formation. This area is well-drained moderate to coarse-textured mature topography, and stratigraphic evidence suggests that dissection has proceeded throughout Pleistocene time.

The Flint Hills Upland, extending in a north-south belt across the state from the Oklahoma state line in Cowley County to the Nebraska state line in Marshall County, effectively separates the Central Lowlands from the Great Plains. The Flint Hills are classed within the Central Lowlands because of their genetic and geologic similarities to the Osage Cuesta Plains to the east. In fact the Flint Hills can be described as a series of prominent cuesta scarps and dip slopes developed on resistant cherty limestones of early Permian age (primarily Wreford, Florence, Fort Riley, and Herington). The east face of the upland typically consists of a series of stratigraphically controlled benches, and the western part of the upland in some places is a relatively smooth series of dip slopes on the Florence, Fort Riley, and Herington limestones that terminate westward under alluvial veneer. The western limit of this upland is drawn at the termination of the dip slope where it joins the plain developed on Permian shales or Tertiary, Quaternary, or Cretaceous sediments.

In strong contrast to the Great Plains of central and western Kansas, the Flint Hills have been a positive element of the topography, subject to subareal erosion since mid-Tertiary time or earlier.

The Kansas River is the only through-flowing stream that crosses the Flint Hills Upland. Its course is the result of Kansan glaciation.

The Osage Cuesta Plains include the region south of the Kansas River Valley, east of the Flint Hills, and northwest of the scarp of the Fort Scott limestone. This scarp marks the westward limit of the Cherokee Plain. The cuestas of the Osage section have much similarity to the Flint Hills except in magnitude. They are developed on limestones of Pennsylvanian and earliest Permian age and are separated by plains developed on the intervening shales.

The Dissected Till Plains in the northeast present a topography unlike any other part of the state. This section presents a view quite similar to adjacent parts of Missouri and Nebraska and southern Iowa. The section is bounded on the south by the broad and distinctive Kaw Valley which marks the general southern limit of the Kansas till, and on the west by the sharp diminution in thickness of Kansas till at the edge of the Flint Hills. In northern Marshall County the Dissected Till Plains transgress the Flint Hills Upland and contact the Great Plains section

at the Nebraska state line. Here, thick Kansas till overlaps the Flint Hills belt from the northeast, and from the west Cretaceous sediments overlap the Permian rocks as far as the Herington limestone. Except in some divide areas the topography of the Dissected Till Plains section is well drained, moderately fine-textured, mature, and is a well-rounded rolling surface. For the most part it is developed in glacial till with Pennsylvanian or Permian rocks exposed along the lower parts of the deeper valleys. In northeastern Doniphan County thick loess deposits impart a distinctive character to the topography, but elsewhere in the section the thin loess deposits veneer rather than modify the surface developed on Kansas till.

2. GEOLOGY OF THE KANSAS RIVER BASIN

a. Geologic Structure

The Kansas River Basin is located predominantly on the eastern flank of a syncline. This structure, which was formed by the downwarping of a great thickness of sedimentary rocks, stretches from Canada to Texas and from approximately the Mississippi River to the Rocky Mountains. Due to this structure, rock units which are exposed at the surface near the mouth of the Kansas River are covered by younger sediments as one moves upstream and can be found only at great depths in western Kansas. These same rock units, however, are again exposed at the surface just in front of the Rocky Mountains, indicating that the geologic structure is composed of two limbs which dip in opposite directions. The topographic surface of the Kansas River Basin, in contrast to the attitude of the underlying rock layers slopes to the east.

Despite their participation in the mid-continent syncline, rock layers in the Kansas River Basin are not greatly disturbed. The strata dip to the west at rates of 20 to 60 feet per mile. An observer at an individual outcrop would describe the strata as essentially horizontal. The area for the most part is seismically stable and surface faults are a rarity.

The geologic structure has its greatest influence on the pattern of bedrock exposures, which in turn influences the physiography of the basin. Outcrops of rock units are parallel to the synclinal axis which is oriented in a north-south direction. Consequently, the bedrock outcrop pattern of the Kansas River Basin resembles a series of north-south trending bands. Physiographic provinces generally follow a similar trend.

The syncline was formed at the same time as the Rocky Mountains and the rock layers disturbed at that time have been relatively stable throughout the succeeding geologic periods. Rock units younger than Mesozoic are not involved in the folding. These younger units are the Ogallala formation, which forms the High Plains section of western Kansas, and the Pleistocene deposits which can be found throughout the Kansas River Basin, but which dominate the landscape

in northeastern Kansas. These units overlie the older rocks without regional dip or folding.

Superimposed on the eastern flank of the syncline in the subsurface and represented on the surface by the Flint Hills physiographic section, is a local anomaly termed the Nemaha Arch. The Nemaha Arch was formerly presumed to be a buried mountain range, but more recent theories assume it is a fault or "suture" zone. The area overlying the arch has been a positive (rising) element in the Kansas landscape since Mississippian times. The area is still active today as shown by microseismic and earthquake studies. The Flint Hills Area, in consequence, is listed in the Uniform Building Code as an "Area 2," in which "moderate" earthquake damage can occur. The remainder of the Kansas River Basin is listed as an "Area 1" in which earthquake damage will be "minor." It is probably no coincidence that the widest portion of the Kansas River Valley occurs near Wamego where the river crosses the axis of the Nemaha Arch, and where, in theory, the river would be forced to cut laterally in response to minor uplifts along the axis.

b. Stratigraphy

The oldest rocks exposed in the Kansas River Basin are Pennsylvanian in age. These rocks form the surface in most of the eastern one-fourth of Kansas and underlie the glacial drift in northeastern Kansas. The individual lithologic units which comprise the Pennsylvanian rocks are normally less than 25 feet in thickness and are found in more or less uniformly alternating sequences of shale, limestone, sandstone and coal (53 seams) termed "Cyclothems." The aggregate thickness of Pennsylvanian rocks in Kansas is about 3,100 feet.

Rocks of Pennsylvanian age, in normal sequence, are overlain by those of Permian age. The outcrop of Permian age rocks coincides with the Flint Hills section and lies west of and parallel to the Pennsylvanian outcrop. Permian rocks form the valley walls of the Kansas River proper from approximately the western Shawnee County line to the confluence of the Smoky Hill and Republican rivers at Junction City. The lower portion of Permian age rocks resembles the Pennsylvanian except that they contain fewer coals. The upper rock layers of the Permian sequence, however, contain salt and gypsum beds. Both gypsum and salt are mined in Kansas. Salt from upper Permian beds is the most common source of chlorides in rivers of the Kansas River drainage basin.

West of the Permian Outcrop in central Kansas and southern Nebraska is the exposure of Cretaceous rocks which directly overlie the Permian. Rocks of Jurassic and Triassic periods are missing over large parts of the area due to nondeposition or erosion. Cretaceous rock units consist of vari-colored clays, siltstones and sandstones of the Dakota formation and alternating beds of limestone, chalk and shales assigned to other formations. Cretaceous Rocks are about

2,750 feet in aggregate thickness and have been divided into eight formations. The Dakota serves as a groundwater reservoir (aquifer) in areas as far separated as North Dakota and Oklahoma. The Chalk and Limestone formations, particularly the Niobrara have yielded especially fine specimens of fossil reptiles.

The last known invasion of marine water occurred during Cretaceous time. The Laramide Revolution which formed the Rocky Mountains occurred at the end of the Cretaceous period. Consequently, rocks younger than the Mesozoic-Cretaceous period are continental in origin and do not participate in the mid-continent synclinal structure.

Rocks of Tertiary age in the Kansas River Basin are confined to one formation, the Ogallala. The Ogallala formation is composed of massive to cross-bedded, gravel, sand and silt, locally cemented with calcium carbonate. The Ogallala covers the western one-third of the state of Kansas and the eastern one-half of the Colorado plains. It extends as well from the Texas Panhandle to Nebraska. The formation has been greatly reduced by erosion since its initial deposition and is thought to have originally extended from the foot of the Rockies to the Flint Hills of eastern Kansas in one, continuous, tabular mass.

Geologic materials of Pleistocene age are widely distributed but discontinuous across the Kansas River Basin. The deposits are nonmarine in origin and include glacial, lacustrine (lake), fluvial (river) and eolian (wind) deposited sediments. Ice-transported sediments occur only in northeastern Kansas, whereas stream-laid deposits occur generally throughout the state in stream valleys. Wind-laid deposits occur throughout the state, also, but are most extensive in northern and western areas. Wind-blown silt, called loess, is the most widespread deposit and forms the immediate surface material over approximately one-half the area of the basin. Much of the fertile topsoil has been developed from Quaternary alluvium and loess. Lacustrine deposits are most commonly associated with the ice-lain deposits in northeastern Kansas.

c. Geologic History of the Kansas River Basin

The oldest rocks in the study area are of Pennsylvanian age. These were laid down in shallow inland seas which experienced geologically rapid, but apparently systematic fluctuations in water level. The sediments left behind are thin sequences of limestone, shale, sandstone and coal which occur in more or less orderly patterns (Cyclothems).

Cyclothemic deposition did not end with the Pennsylvanian period but continued to form those rocks assigned in age to the early part of the next period, the Permian. These rocks are light gray to cream-colored limestones, many of which contain an abundance of

chert and which are interlayered with shale and minor amounts of sandstone.

The major sea-level fluctuations ended sometime in the early Permian and the seas began to dry up. Above the Cyclothemic deposits is found a sequence of siltstones, sandstones and shales which contain abundant evaporites (gypsum and salt). About 1,900 feet of this material is found within and immediately west of the study area. The salt members are found only in the subsurface, since they were long ago dissolved and carried away by rainwater near their outcrops.

Major Mesozoic deposition took place in the Cretaceous period when seas again encroached upon the North American continent. This was the last time in geologic history that marine environments were present in the interior of the continent. Cretaceous deposition is in part continental (parts of the Dakota and Cheyenne formations) which is predominantly sandstone, but most of the rocks of this age are marine in origin and consist of limestones and shales.

At the end of the Cretaceous Period and the Mezozoic Era, the ancestral Rocky Mountains were formed (the Laramide Revolution) and rock layers in the west-central United States were deformed into an immense downward fold. This feature, the mid-continent Syncline, extends from Canada to Texas and from the Mississippi River to the Rockies. It is this folding that causes all rocks in the study area, younger than Cenozoic, to dip gently downward to the west. The Kansas River system flows from near the western limb of the syncline completely across it to the eastern limb (via the Missouri).

The Cretaceous Period and its ending saw the formation of the general features of the mid-continent area: an eastward slope from the Rocky Mountains and the creation of the mid-continent syncline. The next geologic era, the Cenozoic which includes the present, saw the formation of the details of our present landscape: the rivers, hills and valleys.

At the beginning of the Cenozoic Era, the area now known as the High Plains and Rocky Mountains were considerably lower relative to sea level than at present. Much of the regional movement that raised the base of the mountains and adjacent plains area occurred in late Tertiary and until then stream gradients were less steep than today. At any rate, no deposits of early Tertiary Age are known in western Kansas. Deposits of late Tertiary age (Pliocene) which indicate a western sediment source cover the entire western one-third of the state of Kansas and extend into Colorado. This deposit is thought to have originally extended from the Rockies to the Flint Hills, but has been eaten away in both the east and the west by erosion. The upper surface of the Ogalalla, as the formation is known, forms the physiographic section known as the High Plains. The main

tributaries of the Kansas, the Smoky Hill and Republican rivers, rise at the extreme western edge of the High Plains and flow eastward across the width of the Ogalalla Outcrop. Streams ancestral to the present rivers were probably instrumental in removing the Ogalalla from central Kansas.

Beginning about one million years ago, for reasons unknown, the entire world was subjected to a series of prolonged thermal minima which caused continental glaciers to form and move southward for tremendous distances. Four glacial advances are recognized.

Glaciation resulted in worldwide lowering of sea levels and cycles of erosion and deposition on the continents. At the beginning of each glaciation, there was a sharp reduction in both chemical weathering and soil formation and a pronounced acceleration of stream erosion. From approximately the mid-glacial to the early part of the next interglacial stage, a cycle of deposition occurred, marked by a sequence of coarse to fine-grained sediments in the stream valleys. The glaciers themselves transported huge amounts of heterogeneous materials and left it as a blanket, often several hundred feet thick, over the landscapes from which they retreated.

The effects of glaciation extended far beyond the actual limits of the glaciers themselves since one of the characteristics of glacial periods is a general increase in precipitation. In addition, melt waters from the glaciers carried large volume of sand, silts, and gravels into the regional drainage systems to be deposited many miles from the source. Many of these deposits are extant today.

Continental glaciers actually reached into the study area only during the two earliest glacial periods, but erosion and depositional features are found in the study area which are distinctive to all of the glacial stages.

The Kansas Basin landscape is for the most part a product of erosion and deposition during Pleistocene time and has evolved to its present aspect by pulses of accelerated erosion and sedimentation during each of the glacial ages of the Pleistocene. In Tertiary time the Kansas River Basin was truly a plain. Early in Pleistocene time, valley deepening occurred along major streams in all parts of the study area. The relative incompetence of streams in the western third of Kansas left broad areas undissected but in the eastern part virtually all the area was eroded and in central Kansas valley deepening exceeded 200 feet. In the Flint Hills Upland and Osage Cuesta Plains each succeeding glacial age produced an episode of downcutting of diminishing intensity.

In the Dissected Till Plains section the influence of glaciation overpowered all other factors. The post-glacial history of this region has been primarily dissection of glacial till, deepening of valleys, and relatively minor alluviation of valleys.

The net effect of Pleistocene events on the Kansas Basin landscape has been a strong increase in topographic relief and the placement of deposits that contain large supplies of ground water, sand and gravel, volcanic ash, and some of our ceramic raw materials. The surface soils, the most valuable single mineral resource in the study area, are almost entirely a product of processes operating during Pleistocene time.

d. Soils

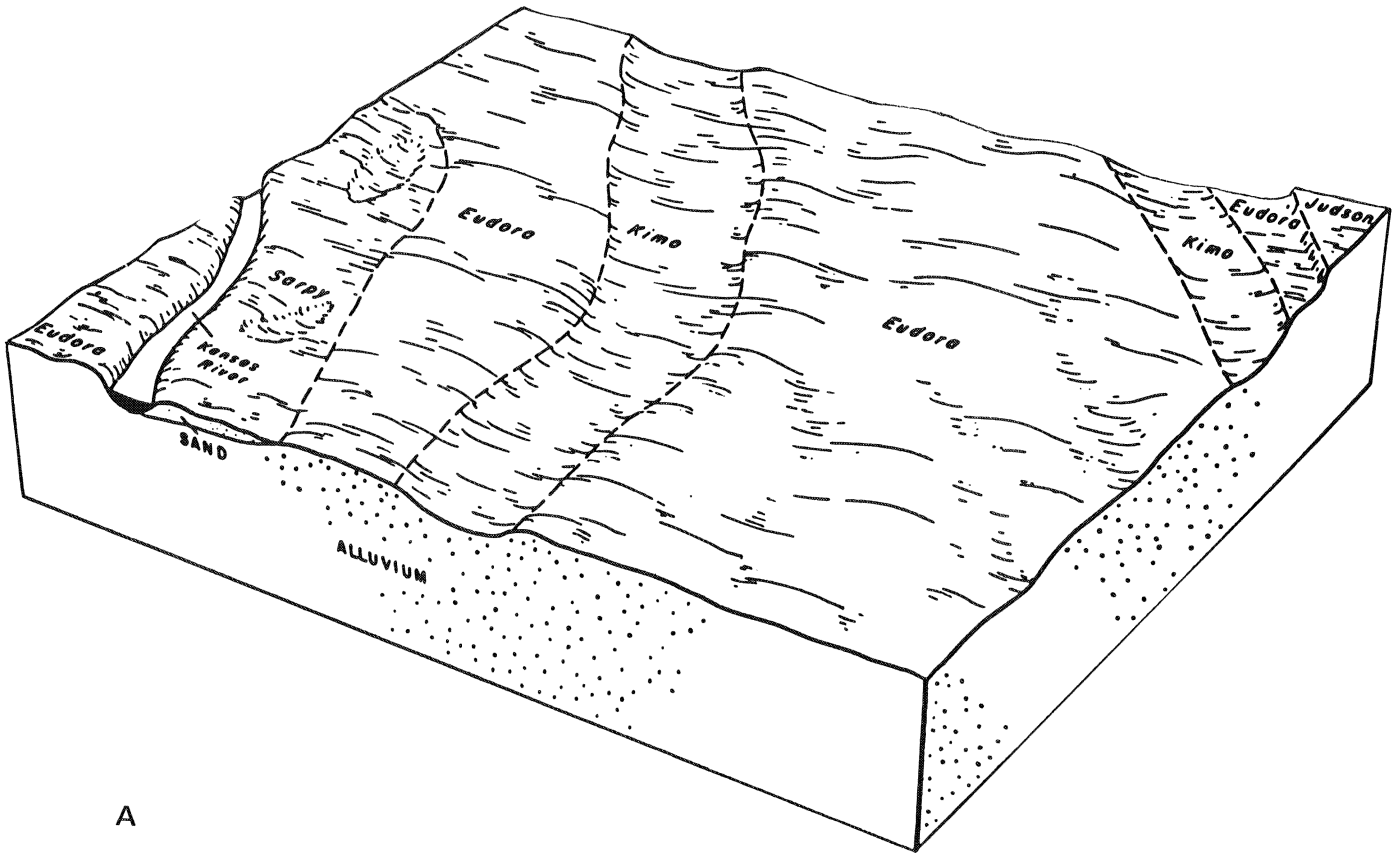
Floodplain soils associated with the Kansas River and its tributaries are derived from alluvium. The alluvium consists of water-laid deposits of silt, clay, sand and gravel and has been modified in the past by natural phenomena such as channel migration and flooding. Other soils in the project area include those formed from the weathering of local parent material and eolian deposits transported to the area by wind.

Soils of the Kansas River Valley consist of sandy riverwash in and immediately adjacent to the river channel and the deep, nearly-level silt and sandy loams of the first and second bottoms in the floodplain. The first bottom is next to the stream and is subject to periodic inundation, sometimes more than once a year. The second bottom represents the higher terraces above the first bottom which are less frequently inundated. Soil associations of the valley are primarily the Eudora-Kimo in the eastern reach (e.g., Johnson and Douglas Counties) and Eudora-Haynie-Sarpy types in the western reach (e.g., Riley and Geary Counties). Generalized soil patterns of the Kansas River Valley are shown in Figure II-2.

The floodplains and low terraces of the eastern Kansas River tributaries (Wakarusa and Delaware rivers, and Soldier Creek) have deep, nearly-level silty clay loam soils of the Kennebec-Wabash-Reading association. Soils of the near-western Kansas River tributaries (Big Blue and Republican rivers) again are of the Eudora-Haynie-Sarpy type with the Sarpy series being very common in the first bottoms. Riverwash is also found in these areas, especially in the Republican River corridor.

The floodplains of the far-western Kansas River tributaries, the Smoky Hill, Saline, and Solomon rivers, are characterized by the deep, nearly-level calcareous silt and clayey loams of the Humbarger-Muir and Roxbury-New Cambria-McCook soil associations with the latter occurring mostly along the Solomon River. The soils of these areas are generally less sandy than those found in the Kansas River corridor.

In upland areas of the Kansas River corridor, more shallow, sloping, clayey soils will be found. The Flint Hills area in portions of Riley, Geary, Pottawatomie, and Wabaunsee Counties is covered with cherty limestone soils of the Sogn, Summit, and Florence types.



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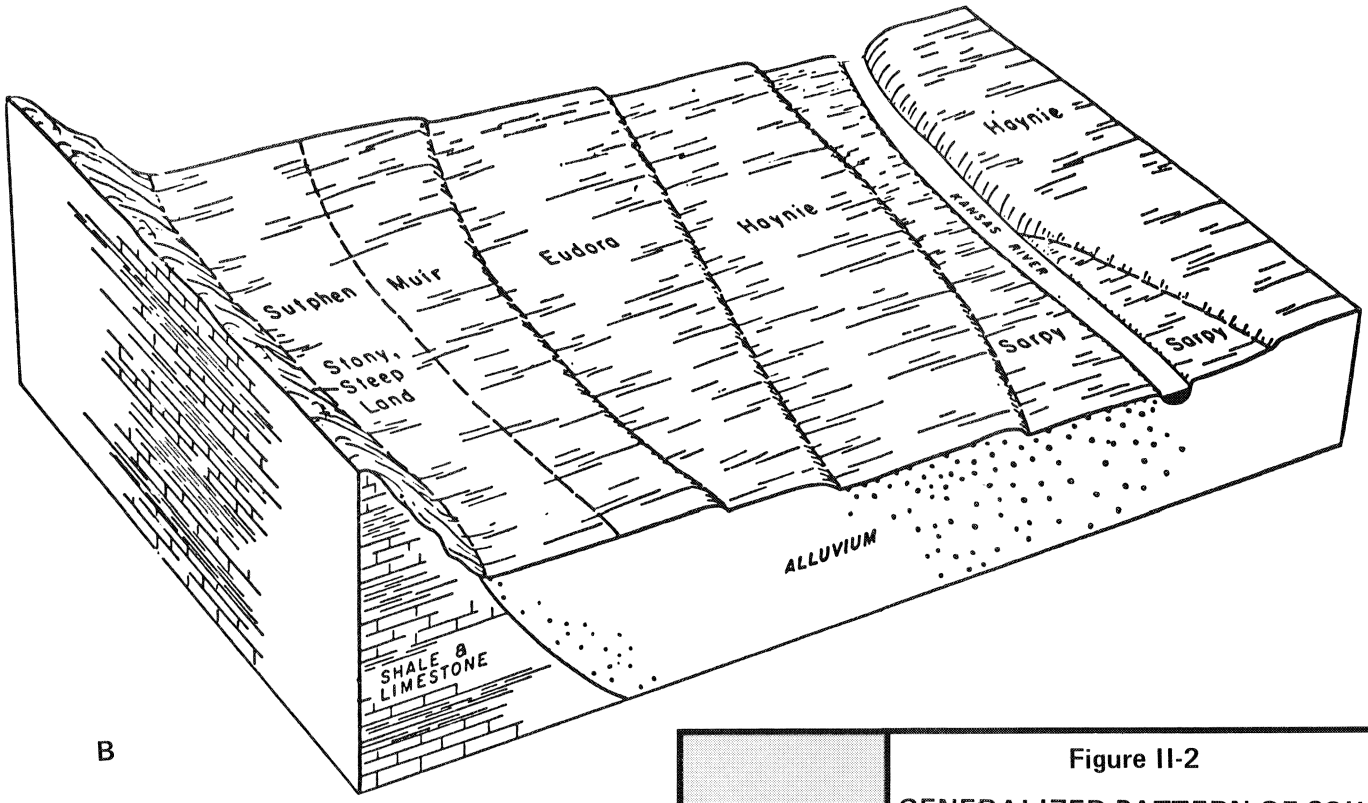

B

Source: U.S. Department of Agriculture, Soil Conservation Service, Salina, Kansas.

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Figure II-2

GENERALIZED PATTERN OF SOILS AND UNDERLYING MATERIALS IN THE KANSAS RIVER VALLEY A-EASTERN REACH, B-WESTERN REACH

In the study area, specific information on the soils of Wabaunsee and Pottawatomie Counties is lacking owing to incomplete soil surveys.

Several factors influence the type of land use practiced on the various soil types in the study corridor. Drainage, slope, permeability, water-holding capacity, fertility, shrink-swell potential, and location determine the use to which a given soil type will be put.

The very sandy, unstable riverwash soils and steeply sloping soils adjacent to and occurring on the streambanks are best used to support native vegetation and develop wildlife habitat. Low-lying, poorly drained, clayey soils typical of old meander scars have limited agricultural potential and are also more suited for native vegetation. Floodplain alluvial soils of the first and second bottoms having sandy silt, silt-loam profiles, can be cultivated and when irrigated, high crop yields are possible. These soils are well suited for tree growth and wildlife development in areas where periodic inundation hinders agricultural uses.

3. HYDROLOGY AND FLUVIAL GEOLOGY OF THE KANSAS RIVER

a. Drainage History

The Quaternary period saw the major development of the Kansas River Basin landscape and drainage. This period includes about the last one million years of geologic history. The Quaternary period includes both the Pleistocene epoch, (popularly known as the "Ice Ages") and the Recent. Pleistocene time was characterized by world-wide, climatic fluctuations, which caused continental ice sheets to move south into the Interior Plains and subsequently to be melted back to the north. Four ages of continental glaciation and four interglacial ages are recognized. These are named from oldest to youngest:

Glacial Age	Interglacial
Nebraskan	Aftonian
Kansan	Yarmouthian
Illinoian	Sangamon
Wisconsin	Present

The present drainage pattern of the Kansas River is intimately related to the cycles of Pleistocene erosion and deposition. The evidence indicates (Frey & Leonard, 1952) that by late Nebraskan times, the Flint Hills served as a drainage divide and all streams west of that area flowed southeast to drain into Oklahoma, while those to the east flowed east and southeast. The ancestral Kansas River flowed east of the divide. The Nebraskan Glacier reached only into extreme northeastern Kansas and produced little changes in drainage. But, during the advance of the Kansan ice sheet, which extended from Northern Canada to just beyond the present course of

the Kansas River, the Big Blue and the lower course of the Republican rivers were formed as ice-marginal streams which carried melt water away from the glacier. Originally these streams emptied into the ancestral Kansas River, but when the Kansas itself was overridden and ice-blocked, the streams were ponded and melt waters spilled over the Flint Hills divide to flow westward to near the site of the present city of Salina, where they joined the ancestral Smoky Hill to flow south into the Arkansas River. In the same manner, melt water south of the glacier spilled from the Kansas Valley near Topeka into the Wakarusa drainage.

With the retreat of the Kansas glacier, the Flint Hills divide was once again reestablished, but the spillway across the divide had been cut several hundred feet below its former level and moved to the west, probably to near the present site of Junction City. Slow, headward cutting by the Kansas River during succeeding ages, eventually allowed the river to capture the Smoky Hill drainage in early Wisconsin time. The overall pattern of drainage within the Kansas Basin has remained relatively constant since that time.

Beginning in early Pleistocene time stream valleys in the Central United States began downcutting within their valleys. Periods of deposition were followed by renewed erosion which partially removed the earlier deposits. Since each erosion cycle cut generally deeper than the preceeding one, the remnants of older deposition usually occur at higher elevations than the newer. Such erosional remnants are termed "terraces" since they are normally separated from adjacent valley land by a prominant scarp. Terraces are the remnants of former floodplains and their upper surfaces are generally flat. Aerial photographs reveal meander scars (see Appendix D, "Explanation of Terms") on the older surfaces just as on the modern floodplain. Five terrace levels are generally recognized, but Dufford (1958) has "lumped" two of these together as the "Intermediate Surface Complex" and his nomenclature is used here:

Name	Age	Elevation Above Present Floodplain
Menokan	Kansan	80-100 feet
Buck Creek	Kansan	±35 feet
Newman	Illinoian	8- 10 feet
Intermediate Surface Complex	Wisconsin(?) and Recent(?)	5- 7 feet

The Menoken Terrace occurs as almost continuous remnants on the north bluff of the Kansas River from Lawrence to Bonner Springs. Less continuous remnants are found south of the river. These deposits are thought to represent glacial outwash deposits formed in existing drainages during retreat of the Kansas glacier. Where they are far enough removed from the valley bluff the Menoken Terrace

deposits are generally 80 to 100 feet above the modern floodplain and are therefore not considered further in this report.

The second highest terrace, the Buck Creek level, occurs in the Kansas Valley as small remnants at the mouths of large tributary streams such as Mud and Stranger Creeks. The Terrace was destroyed by erosion in the valley of the Kansas proper by later cycles of cut-and-fill. This terrace is thought to be associated with the period of time when the Kansas River cut through the Flint Hills divide and captured some of the western drainage. The bedrock floor beneath the valley was cut at least twenty feet deeper than during Menoken times and was subsequently backfilled with more than 55 feet of silty material.

The bedrock floor was again deepened in Illinoian time and again backfilled with sediments. This subsequent filling resulted in a floodplain surface, termed the Newman terrace that is generally 8 to 10 feet above the modern floodplain.

Between the Newman Terrace and the modern floodplain are a series of sediments which are of fairly recent origin as demonstrated by meander scars, but which are older than the modern floodplain. These deposits contrast markedly with the Newman Terrace in surface configuration and soil development. There is little difference in elevation however. The Newman Terrace is a minimum of three feet above the younger sediments. These younger materials were described by Dufford (1958) from his work between Lawrence & Bonner Springs and titled, "The Intermediate Surface Complex". He suggests that they may actually be two surfaces which correlate with (1) an extensive terrace near Manhattan, Kansas and (2) with a terrace (named the "Holiday" terrace) which has been mapped west of Lawrence, KS. Surface scrolls on the Intermediate Surface Complex show meander scars with much shorter radii of curvature than those found on the modern floodplain. Agricultural soil scientists have differentated five different types of soil in the Kansas Valley which probably conform to the five erosion levels; (1) Buck Creek Terrace (2) the Newman Terrace (3) and (4), the two terraces of the Intermediate surface complex and (5) the modern floodplain. This relationship, however, has not been worked out in detail.

The major portion of the Kansas Valley in the Kansas City-Lawrence reach is composed of materials deposited as part of the modern floodplain. The modern floodplain can be distinguished on aerial photographs from the terraces, described above, by the nature of the meander scars left upon it. The scars are generally parallel to and upstream of the present river bends and indicate that the present river meanders are moving downstream in a systematic fashion.

The sweep (see "explanation of terms") of Kansas River meanders has progressively eroded the sediments deposited during previous geologic cycles, so that the modern floodplain occupies most of the

area of the narrower sectors of the valley such as the Eudora-Kansas City reach. The valley of the Kansas River, in contrast to most, is wider between bluffs as one moves upstream. For this reason, the percentage of the river plain occupied by the modern floodplain is generally less as one moves upstream.

The age of the modern floodplain is unknown. The floodplain is at least 140 years in age and is "Modern" only in the sense that it is the latest of all the depositional levels within the Kansas River Valley. The fact that erosion during the present cycle has not completely removed all the older terrace levels indicates that either the present river regime is fairly young or that meander sweep within the Kansas Valley has been a relatively slow process.

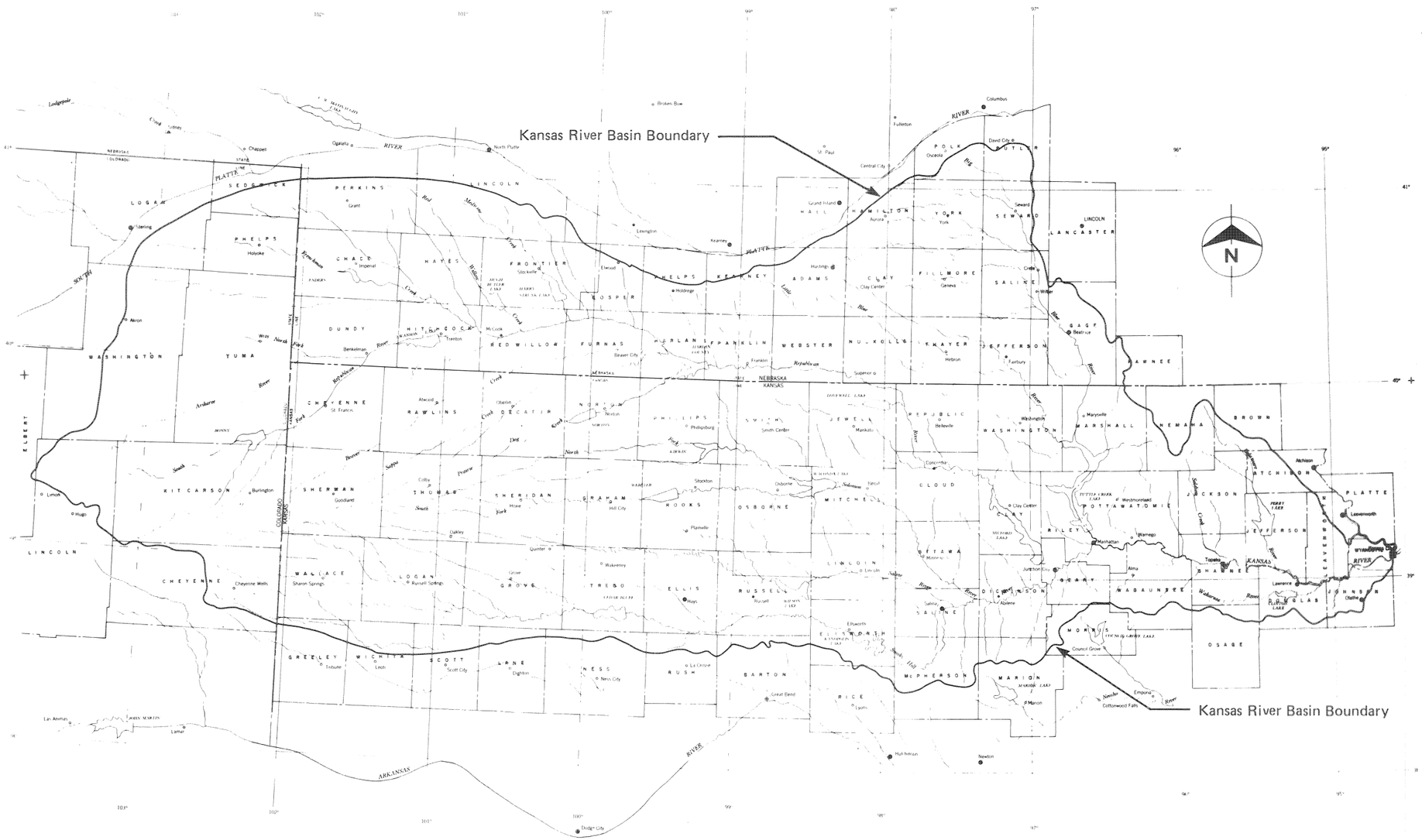
b. The Present Kansas River

The Kansas River Basin occupies portions of northeast Colorado, southern Nebraska and nearly all of the northern half of Kansas (See Figure II-3). The Kansas Basin lies between the Platte and Nemaha basins on the north and the Arkansas and Marias de Cygnes (Osage) basins on the south. The total drainage area of the Kansas Basin is approximately 61,440 square miles. It is approximately 480 miles long and averages about 140 miles in width with the major axis of the basin orientated in an east-west direction (Kansas Board of Agriculture, 1944).

The Smoky Hill and Republican rivers join at Junction City, Kansas to form the Kansas River proper. The Kansas flows easterly for a distance of approximately 170 miles to join the Missouri River at Kansas City, Kansas. The principal tributary, in addition to the Smoky Hill and Republican rivers, is the Big Blue River, which, unlike either of the former rivers, has its origin in southern Nebraska rather than eastern Colorado. The Big Blue joins the Kansas River near Manhattan, Kansas. Other, smaller tributaries, which enter the Kansas River below Manhattan are Vermillion Creek, near Wamego; Cross and Mill Creeks, near Rossville; Soldier Creek at Topeka; Delaware River, near Perry; Wakarusa River, at Eudora; and Stranger Creek near Linwood.

Elevation of the river bed near the mouth at Kansas City, Kansas is approximately 690 feet. Elevation of the plains at the extreme western edge of the Kansas Basin is about 5,500 feet.

The term "Valley" in this report will be used to designate the area that lies between the bedrock bluffs generally exposed on both sides of the river. The valley is a product of millenia of erosion and contains not only the river, but also the floodplain, terraces, agricultural land, highways, railroads and portions of several cities. The river "Channel" on the other hand contains only the river and is the "ditch" cut into the floodplain by the present stream. The channel is changing its width, depth and location continuously.



Source: Corps of Engineers - Kansas City District 1977.

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Figure II-3
KANSAS RIVER
DRAINAGE BASIN

The valley of the Kansas River is unusual in that its widest portion is not near the mouth at Kansas City, but near river mile 120 where the width is approximately 3.5 miles. The narrowest point between Kansas City and Manhattan is at Kansas City, Kansas, near river mile 10.5 where the valley is about 0.9-mile wide.

Average annual rainfall increases across the basin from about 15-inches in the western portion to 36-inches near the mouth. As a consequence the eastern portion of the basin contributes more runoff than the western. This is demonstrable by comparison of average annual flows as recorded at the Ft. Riley river gage (2,085,000 acre-feet in 1975) at river mile 168.9 with the DeSoto gage (5,024,000 acre-feet) at river mile 31.0. Approximately 75 percent of the Kansas River drainage basin upstream of DeSoto lies above the Ft. Riley gage, but the average annual flow at Ft. Riley is only about 41 percent of that at DeSoto. The 25 percent of the Kansas Basin that lies downstream of Ft. Riley therefore contributes almost 60 percent of the runoff measured at the DeSoto gage.

In an analogous manner, the major portion of suspended sediment found in the Kansas River also comes from the downstream portion. Not only is rainfall more abundant in the eastern portion of the basin, but the Dissected Till Plains of northeastern Kansas, is also an area of relatively steep slopes and easily erodeable soils (Collins, 1965). In consequence both the sediment concentration (see "Definition of Terms") and the sediment yield (see "Definition of Terms") increase in a downstream direction in contrast to the action of most rivers.

Suspended sediment in the Kansas River is primarily of silt and clay-sized particles. Osterkamp (1981) noted that at Wamego, there appeared to be a coarsening of sediment after reservoir construction, but he did not find this to be of significant magnitude.

Sand comprises a relatively small portion of the total sediment in the Kansas River. The ultimate source of sand to the present stream appears to be the upland terrace deposits of Nebraska and only those streams which flow through or from Nebraska (the Republican and Big Blue) are "Sandy" streams (Schumm, 1960). However, the route of all sediments from source to the sea is not a direct, continuous flow. Sand or other size particles may be deposited along the channel at any point and may remain at that position from minutes to thousands of years only to be picked up and moved to some new position by the river. Consequently, sediments, including sand, are stored in the bed and banks of the Kansas River and these can be released by normal river action.

Five river gages have been maintained on the Kansas River long enough for the accumulation of significant periods of record.

Gage	Year Installed (calendar year)	Location River Mile	Avg. Annual Discharge (C.F.S.)	Drainage Area (Sq. Miles)
Ft. Riley	1963	168.9	2,878	44,870
Wamego	1919	126.9	4,921	55,280
Topeka	1904	83.1	5,468	56,720
Lecompton	1936	63.8	7,062	58,460
Bonner Springs -Desoto	1917	31.0	6,935	59,756

The gage at Bonner Springs (river mile 20.3) was moved to DeSoto (river mile 31.0) in 1973.

The U.S. Geological Survey is the agency charged with the responsibility of maintaining the river gages and publishing the accumulated records.

The maximum discharge recorded on the Kansas River was in July 1951. At Bonner Springs this occurred on July 13. Flow was estimated at 510,000 cubic feet per second. At that time the Kansas Valley was covered with water from "wall to wall". The second highest flood since at least 1844, was the flood of 1903, which was about three feet lower at the Bonner Springs gage than that of 1951. Other floods of record occurred in 1902, 1904, 1908, 1915, 1923, 1927, 1935, 1941 and 1943. The flood of 1935 took 105 lives.

The minimum flow of record at Bonner Springs was 160 cubic feet per second which occurred October 11, 1956.

A flood control study of the Kansas River was authorized by Congress in 1928. In 1933, the results of the study were submitted to Congress. Several reservoirs were proposed in the study which were subsequently built. Kanopolis Lake was the first of these. It was begun in 1940 and completed in 1948. A number of other lakes followed:

Lake	Tributary	Storage Began
Kanopolis	Smoky Hill	Feb. 1948
Harlan Co. (Nebr.)	Republican	Nov. 1952
Kirwin	Solomon	Sept. 1955
Webster	Solomon	May 1956
Lovewell	White Rock Creek	May 1957
Tuttle Creek	Big Blue	March 1962
Wilson	Saline	Dec. 1964
Milford	Republican	Jan. 1967
Glen Elder	Solomon	Oct. 1967
Perry	Delaware	Mar. 1969
Clinton	Wakarusa	Nov. 1977

Reservoirs tend to trap sediment that would otherwise move downstream. The water released by the reservoirs is relatively

sediment-free and is able to suspend sediment particles from the bed and banks of the river. A number of studies indicate that scouring normally occurs downstream of a major reservoir and in some cases bank instability also (Corps of Engineers, April 1980).

Osterkamp (1981) infers that the Kansas River, as a result of reservoir construction, is becoming braided and "Unstable", in part. Braiding is the process in which more sediment is brought to a part of a stream than it can remove, the building of bars becomes excessive, and the stream develops a network of interlacing channels. Osterkamp defines as "Unstable" any reach of the river in which the channel width is more than 25 percent greater than that which would be predicted by power-function equations based upon measurements previously analyzed for midwestern streams similar in discharge and sediment characteristics to the Kansas River. Oster Kamps notes the tendency of "Unstable" reaches to coincide with historically active reaches. The quantity of sediment in the Kansas River has also been reduced by reservoir construction. Kansas River sediment loads have been sampled at two locations. Continous sediment data has been collected at Bonner Springs - DeSoto, and at Wamego, Kansas since 1958. The annual suspended sediment and discharges are listed below: (Corps of Engineers; 1965, 1970, 1975, 1980.)

ANNUAL DISCHARGE AND SUSPENDED SEDIMENT BY WATER YEAR

	Water Discharge ac-ft (millions)		Suspended Sediment-Tons (millions)	
Year	Wamego	Bonner Springs	Wamego	Bonner Springs
1958	4.75	6.76	17.36	29.30
1959	3.41	4.99	12.76	19.68
1960	6.24	7.69	19.78	36.16
1961	4.78	6.74	13.26	28.68
1962	5.67	8.50	14.58	42.83
1963	2.02	2.68	1.91	3.55
1964	1.59	2.68	1.73	3.78
1965	3.72	5.89	6.07	19.83
1966	2.05	2.83	1.06	2.94
1967	2.69	5.10	5.88	19.24
1968	2.20	4.42	1.73	8.30
1969	5.75	8.08	5.76	17.90
1970	2.24	3.58	1.10	6.02
1971	3.53	4.36	4.19	6.32
1972	1.82	2.77	1.22	3.80
1973	7.63	12.79	10.34	34.92
1974	8.95	12.85	14.59	25.78
1975	2.84	4.53	1.98	10.28

4. EROSION ON THE KANSAS RIVER

a. Historical River Changes

The purpose of this section is to outline the history of changes in the Kansas River Basin and to determine, where possible, the nature and extent of adjustments in channel geometry resulting from those changes. Particular emphasis will be placed on the last forty years of the river's history and on the lower 51 miles of the river channel.

The Kansas River Basin, in a process that began about 140 years ago, has been changed from a pristine, largely prairie, environment to a settled and intensely developed farm and urban area. The process of settlement itself involved virtually complete conversion of land usage within the basin. Subsequent developments, including urbanization, dam construction, commercial sand and gravel dredging, flood control measures, railroad, highway and bridge construction, have placed additional stresses on the river, to which it is now in the process of adjustment.

Dort (1980) prepared a study for the Corps of Engineers in which he and his co-workers examined all available maps and aerial photos available to them. They were able to map the Kansas River channel as it was shown on contemporary maps at various times in the past back to about 1850. They were also able to determine the areas (but not the channels) which the Kansas River has occupied in the last several thousand years and to show those portions of the Kansas River Valley which the Kansas River has not disturbed for several millenia.

Dort's work has been summarized and expanded by Osterkamp (1981), who assembled more than 150 channel measurements from field surveys of the USGS and the Corps of Engineers for various gaged and ungaged sites on the Smoky Hill and Kansas rivers. Field data was supplemented by a large number of channel width and gradient measurements determined from low-altitude aerial photographs and topographic maps. Based upon empirical relationships developed for unregulated streams within the Missouri Basin which allows comparison of streams of similar mean discharge and channel-sediment characteristics, Osterkamp developed the following nomenclature: Those reaches of the Kansas River which, since approximately 1850, have demonstrated relatively rapid changes in channel locations he terms as "active." Those which presently exhibit channel widths more than 25 percent greater than would be anticipated by comparison with the empirical relationship of width and discharge determined for similar streams of the Missouri Basin, he lists as "unstable." Under this terminology, a river reach can be "active" but "stable." The reach can have been in the process of rapid channel migration for some years (active), but if migration is not also accompanied by widening of the river channel the reach is considered "stable."

Reaches of interest on the Kansas River are:

River Reach	Classification	River Miles from	to
KCK-Lawrence	Inactive	0	51
	Unstable	14	42
Lawrence - Mile 60	Active	53	60
	Unstable	55	60
Mile 69 - Mile 72	Inactive	60	72
(midway Topeka to Perry)	Unstable	69	72
Mile 72 to Topeka	Active	72	82
	Stable	72	82
Mile 101 - Mile 120	Active	101	120
(Bellvue-Rossville)	Unstable	99	123
Manhattan-Junction City	Active	140	170
	Unstable	147	163

Areas considered as historically inactive and presently stable are not included in the listing.

Areas of interest to this study are those which are considered as historically "inactive" but presently "unstable," particularly in the Kansas City, Kansas to Lawrence reach. In this light, it should be noted that although that reach has been historically "inactive," it is presently "active" from near Lawrence (river mile 49) to near DeSoto (river mile 35).

Osterkamp (1981) also investigated the stage-time relationships of gages on the Kansas River. Since the channel cross-sections at the locations of river gages are surveyed at regular intervals, they represent a historical record of channel changes in the vicinity of the gage. By selecting representative flows, it is possible to determine changes in the stage-discharge relationship at any one gage and to compare that relationship to the records of other gages.

Because the volume of flow increases downstream in most rivers, it is inappropriate to compare gages on different river reaches by considering the same numerical value of discharge at every gage. Osterkamp elected to use comparable flows based upon percentage frequency of certain flows. After selecting the appropriate volume of flow at each gage, the stage of those flows was plotted against the time when the stage-discharge relationship for that volume of flow was pertinent. Any persistent changes in the stage-time relationship indicates changes in channel geometry in the reach which affects the gage.

Osterkamp chose to investigate those flows which are associated with (1) the "active-channel width" which he defines as discharge rates equalled or exceeded 25 percent of the time and (2) the "bankful" stage which is that flow which is equaled or exceeded 10 percent of the time. Osterkamp (Osterkamp & Hedman, 1977, p. 256) describes the active channel width as "...short-term geomorphic feature subject to change by prevailing discharges. The upper limit is defined by a break in the relatively steep bank slope of the active channel to a more gently sloping surface beyond the channel edge. The break in slope normally coincides with the lower limit of permanent vegetation so that the two features, individually or in combination, define the channel reference level. The section beneath the reference level is that portion of the stream entrenchment in which the channel is actively, if not totally, sculptured by the normal process of water and sediment discharge."

"Bankful" stage of most streams roughly coincides with the stage for a flood event with a two-year recurrence interval. Geometry measurements taken from this level are inferred to be indicative of infrequent discharge events that occur in a stream." (Osterkamp, 1981)

"The 25 percent flow-duration stage is indicative of aggradation or degradation of the channel bed, although it can change also in response to change in active channel width; this stage generally is similar to both the active channel level and the stage of mean discharge for regulated Kansas streams. Changes in the 10 percent flow duration stage can suggest channel and conveyance changes above the active channel level." (Osterkamp, 1981.)

A number of other channel levels or stages can be studied in a manner similar to that proposed by Osterkamp and which may yield different estimates of channel geometry changes. Dr. Osterkamp's work is reported here, however, as the most complete and detailed examination of stage-time relationships on the Kansas River. The stage-time relationship corresponding to 25 percent and 10 percent flow-duration for selected Kansas River gages are included in Appendix E of this report. Individual gage records will be discussed in the body of this report.

The plan of this section is to discuss the stage-time relationship of each river gage for which records are available, beginning on the Missouri River, 1.7 miles downstream of the confluence of the Kansas with the Missouri River, and proceeding upstream on the Kansas to Junction City--a distance of over 170 miles. Combined with the discussion of river gages will be a discussion of additional information obtained from other sources, which might be germane to the river reach being discussed. Such information might include available maps, cross sections and data from local officials.

Osterkamp's data for the Missouri River at Kansas City, Missouri is presented in Figure E-17 of Appendix E. Records for the Kansas City gage are available from 1897 to the present. Daily stage and discharge records are available from 1900 to the present.

The Kansas City gage is located on the downstream side of the Chicago, Burlington and Quincy Railroad bridge in Kansas City, Missouri and 1.4 miles downstream of the confluence of the Kansas and Missouri rivers.

Osterkamp's data for the Kansas City gage (Figure E-17) indicates that since 1943, the year he elects to begin, the stage-time relationships corresponding to the 25 percent and 10 percent flow-duration rates both demonstrate a decline in elevation. In the 30-year period investigated, the stage of the 25 percent flow-duration rate (60,000 cfs) has declined approximately 3.0 feet (calculated from beginning point, 1943, to end point, 1973) for an average of 0.1-foot per year. Lines connecting local maxima (1947, 1957 and 1962) or local minima (1946, 1952 and 1968) also have slopes of approximately 0.1-foot per year on the 25 percent graph.

The stage of the 10 percent flow-duration rate (86,000 cfs) has declined about 2.5 feet (measured from the beginning point, 1943, to the end point, 1973) for an average of about 0.08-foot per year. A line connecting local maxima (1947, 1957 and 1972) has a slope of approximately 0.07-foot per year. A line connecting local minima (1952, 1962, and 1970) has a slope of approximately 0.03-foot per year. The lines connecting the maxima and minima of the 10 percent flow-duration rate tend to converge, indicating that, with time, fluctuation about some common mean slope has decreased. The common mean slope would be 0.05-foot per year which probably describes the rate of change in stage of the 10 percent flow-duration rate better than other calculated values.

The physical significance of the stage-time relationships shown for the Kansas City gage is that the river channel below the "active channel" level has increased in storage capacity, probably by degradation. The width of the "bankful" level has decreased in compensation, but at a slower rate of change than that indicated by the "active channel" level. "Perfect" compensation at the "bankful" level for changes in capacity below the "active-channel" level would have resulted in a 10 percent stage-time graph which would demonstrate fluctuations about a common mean line with a slope of zero. If no changes occurred at the "bankful" level the mean slope of the graph would be the same as that of the "active channel" level, 0.10-foot per year.

Not indicated in Figure E-17, but available from older records, is the fact that degradation has been occurring in the Kansas City reach for some time prior to 1943.

Normal riverine action generally causes major degradation in a stream channel to be propagated in an upstream direction. One would then anticipate that any lowering of bed elevations in the vicinity of the Kansas City gage would be extended upstream in both the Missouri and Kansas River. On the Kansas River, this effect would be noted first at the mouth and with time would progress up the river causing declines in the stage-time relationships at progressively more distant river gages.

The presence or absence of upstream propogation of major degradation is difficult to assess for a number of reasons, but primarily because rivers are in a continuous process of adjustment to general climatic factors. Rivers tend to aggrade their channels during periods of low stream flow and to degrade them during periods of higher flows. In the midwestern U.S., climatic conditions are relatively uniform over very large areas and two streams such as the Missouri and Kansas may both experience channel degradation, not because one is influencing the other but because both are reacting to the same stimulus, increased discharge during periods of higher runoff.

The Bonner Springs gage location is the first encountered as one progresses upstream from the mouth of the Kansas River. Records are available for this location from 1917 to 1973 when the gage was removed to DeSoto. The gage was located at various bridges in the Bonner Springs reach during the period of record. The last location, from 1961 to 1973, was on the Kansas Highway 7 bridge at river mile 20.3. The stage-time relationship for 10 percent and 25 percent flow duration rates is shown on Figure E-16.

Figure E-16 indicates that the stages for both the 10 percent and 25 percent flow-duration rates have declined. From the beginning of records to 1973, the stage for the 25 percent flow duration rate (9,500 cfs) declined 11.1 feet. The stage of the 10 percent flow-duration rate (20,000 cfs) declined about 10.8 feet in the same time period. Unlike the Kansas City records, the Bonner Springs data does not indicate a singular trend throughout the period of record. In the stages of the 25 percent flow duration rate, there appear to be three separate trends: (1) from 1917 to 1942, 0.9-foot (decline); (2) 1942 to 1962, 4.6 feet (decline); (3) 1962 to 1973, 5.1 feet (decline). The common trend is downward, but at an accelerated rate in recent years.

A reasonable estimate of an average rate of stage decline for the 25 percent flow-duration rate from approximately 1939 to 1961 is 0.15-foot per year, which is the mean of the slope of lines connecting respectively, the local maxima (0.1) and local minima (0.2). The average slope of the graph after 1962 is about 0.46-foot per year.

The graph indicates that gross changes developed in channel storage capacity below the "active channel" level some time in the period from 1958 to 1962 because the average slope of the graph can be calculated at 0.15-foot per year prior to that period and at 0.46-foot per year afterwards. The change in the rate of change of the stage-time relationship is slightly more than a three-fold increase.

The stage-time relationship of the 10 percent flow duration rate (20,000 cfs) is similar to that of the 25 percent flow-duration rate. A reasonable estimate of the average decline of stage for the 10 percent flow-duration rate between about 1938 and 1961 is 0.16-foot per year which was calculated as the mean of the slopes of the lines connecting, respectively, the local maxima and minima of the graph in the 1938-1961 segment. As in the case with the stage-time relationship of the 25 percent flow-duration rate, the 10 percent rate also indicates a major change in channel storage capacity in the period from 1958 to 1962. Since the average slopes of both the 25 percent and 10 percent graphs both before and after the period 1958 to 1962 are very similar, it is assumed that the "bankful" (10 percent) level remained fairly constant in width and that changes in the graph for stages of the 10 percent flow-duration rate are due to increases in channel capacity developed below the "active channel" level (25 percent). The changes appear to be due primarily to degradation of the river bed at the gage location.

In the stages of the 25 percent flow duration rate there appears to be three separate trends: (1) from 1917 to 1942 there was 0.9-foot decline (2) from 1942 to 1962 there was 4.6 of decline and from 1962 to 1973 (the end of records) there was 5.1 feet of decline. Rivers, in general, tend to aggrade during periods of low flows and to be degraded during periods of high flows. Trends, 1 and 2 above can be explained in these terms. The 60-year average annual flow past the gate is approximately 5,000 acre feet per year. In the perior 1917 to 1942, that average was exceeded only three times, (1927, 1929, and 1935). The stage-discharge relationship for the 25 percent flow duration declined at approximately those times. The gage declined about 0.9 a foot during the 1917-1942 period, 0.6 of which occurred in 1929-30 and 0.3 of which occurred in 1935-36.

During the period 1942 to 1952, the average annual flows generally exceeded the 60-year average and one would expect gage heights for equivalent flows to decline. Figure E-17 indicates that a decline, in fact, does occur. The wet years of 1942-52 were followed by the severest drought of record (1953-57) when stream flows were less than 60-year average. The gage heights for both the 25 percent and 10 percent flow duration rates begin to climb upward during that period. In the time period 1958 to 1962, the annual discharge was again greater than the 60-year average and gage heights again begin to fall. In the five-year period after 1962, the annual stream flow was less than that of 1958-62 and one would expect the gage heights

to rise or stablize. In fact, the gage height begins a sharp drop after 1962 and shows no correlation at all with annual stream flows during the period 1963-73.

The action of the 25 percent and 10 percent flow duration curves indicate that the Kansas River in 1943 began a change in dominant flow regimes from a dominant low-flow regime in the period 1917-42, to a dominant high-flow regime in the period after 1942. The dominant high-flow regime in the 1942-62 period was interrupted by the 1953-57 drought, but subsequent annual flows (1958-62) exceeded the 60-year average and the river apparently has never returned to a low-flow regime. At the Bonner Springs gage, the gage heights shown in Figure E-17 has declined steadily since 1958, but it is only after 1962 that these declines cannot be correlated with average annual flows, i.e., some factor or factors began to influence the Bonner Springs reach after 1962 which completely obscures the relationship of annual flows and gage heights which is apparent in the records prior to 1962.

Changes in the stage-time relationship at the Bonner Springs gage after 1962 are intrinsically different from those at the Kansas City gage. The changes at Bonner Springs are greater in magnitude and are occurring at a faster rate than those at Kansas City. These facts indicate that the changes at the Bonner Springs gage location are not all due to general degradation on the Missouri River system (though a portion might be). Since the magnitude of changes in channel geometry at Bonner Springs is greater than those at Kansas City, some local stress on the Kansas River is indicated.

The Bonner Springs gage is influenced by a relatively short reach of the Kansas River. Examination of gage records will produce evidence of changes in channel morphology at the river cross section where the gage is located and probably also of changes in channel cross section a short distance downstream, but gage records by themselves cannot delineate the total length of the river in which changes are taking place.

The U.S. Army Corps of Engineers in March of 1977 surveyed a series of cross sections in the Bonner Springs-Kansas City, Kansas reach of the Kansas River. Field surveys by the Corps of Engineers were also available from the years 1956 and 1962, some of which matched the locations of some of the 1977 field surveys. This field data was augmented by the Corps of Engineers with cross sections constructed from uncontrolled aerial photography. A Kelsh Plotter was used to construct these latter cross sections. The aerial surveys of 1954, 1970 and 1971 which were used to construct the cross sections were uncontrolled; no data points were surveyed and marked on the ground surface prior to the actual photography. In order to determine cross sections, horizontal control for those years was established by locating on the older photographs the position of range monuments established by the 1977 survey. The known distance between these

monuments was then used to set the horizontal scale. Vertical control on the uncontrolled photographs was established by using overbank elevations from the 1977 surveyed cross sections. It is extremely difficult to determine the elevation of a water surface with the Kelsh Plotter. For this reason, the water surface elevations shown for the cross sections constructed from the aerial photography of 1954, 1970 and 1971 may be subject to error. The cross section of those years should be used only for comparison of channel widths. The Corps of Engineers' cross sections are appended to this report, Appendix E, Figures E-1 to E-11.

The cross sections represent surveys within the reach from river mile 9.5 (Turner Bridge) and river mile 31.7 (above DeSoto). Of the 11 sections, however, ten are within the reach between river miles 9.5 and 23.7 (about 3.5 miles upstream of the Bonner Springs gage location).

Range 21 (river mile 21.00), shown on Figure E-5, is 0.7-mile upstream of the 1973 location of the Bonner Springs gage (20.3) and is approximately at a former location of the gage, the Old Highway 7 bridge, which was destroyed in 1961. Range 18 (river mile 19.74), shown on Figure E-6, is 0.56-mile downstream of the 1973 location of the Bonner Springs gage. These cross sections demonstrate the changes in channel morphology which in turn produced the changes in the stage-time relationships at the Bonner Springs gage.

Comparisons of the older surveys, shown on Figures E-5 and E-6, with those of 1977 indicate that the elevation of the river bed has been lowered both immediately upstream and immediately downstream of the last location of the Bonner Springs gage while channel widening has been minor, about 30 feet at Range 21 and a net increase of about 25 feet at Range 18. The channel at Range 18 has shifted to the left about 85 feet (measured at elevation 765) since 1971 but about 60 feet (at elevation 765) of filling has occurred on the right bank. The City of Bonner Springs stabilized the left bank of the river from river mile 20 to 20.5 in 1968.

The changes in the stage-time relationships for the 10 percent (20,000 cfs) and the 25 percent (9,500 cfs) flow duration rates indicated by the records of the Bonner Springs gage are in agreement with the changes in channel geometry demonstrated by the Corps of Engineers' cross sections for Range 21 and Range 18. Major changes in channel capacity have occurred below the "active channel" level (approximately elevation 769 at Range 21 and 763 at Range 18) while only minor changes have occurred at the "bankful" level. Most of the changes in the stage-time relationship shown at the Bonner Springs location are therefore due to channel degradation at the gage location rather than channel widening.

Additional Corps of Engineers' cross sections, also contained in Appendix E, demonstrate that recent changes in channel geometry are

not confined to the short reach in which the former Bonner Springs gage was located. These cross sections are for locations within the reach from river mile 9.5 to river mile 31.7, but of the 11 cross sections, ten are in the reach from river mile 9.5 to 23.17.

Comparative changes in channel width which are obvious between the oldest survey at a cross section and the survey of 1977 were measured from the Corps of Engineers' cross sections as follows: A horizontal line was determined at the elevation of the first prominent break in the bank slope angle shown for the oldest survey and the horizontal distance between the profile describing the oldest survey and that of 1977 was measured along that line on both banks. Pinnacles were not considered as "slope breaks." Where prominent breaks occur on both banks, but at different elevations, the elevation of the lowest break was used. The purpose of choosing the "prominent break" in the slope as the location of measurements was to develop a uniform measurement criteria. The "prominent break" in the slope should also approximate the "active channel" level as defined by Osterkamp, but without other correlative information, this cannot be guaranteed and the method of determining the elevation of measurement quoted here is given simply as a means of making repeatable measurements. The changes in width listed below are the cumulative changes at each cross section location. Separate measurements were made of the right and left banks at each section. Widening was considered a positive value and narrowing was considered negative. The measured values of both right and left banks were then added algebraically to arrive at the sum listed. Obvious, gross changes in bank locations illustrated by the Corps of Engineers' cross sections without corresponding large increases in width, are indicative of channel migration; erosion on one bank is balanced by accretion on the other. In some instances, accretion is the result of man-made fills. At other locations, accretion is due to natural depositional processes.

Range	Range Location (River Miles)	Change in Channel Width (feet)	Elevation of Measurement (feet)	Time Period
N	9.50	0	743	1962-77
8	13.68	+160	761	1954-77
9	14.10	- 20	753	1956-77
12	16.36	- 50	753	1962-77
14	17.55	+270	752	1954-77
18	19.74	+ 40*	763	1954-77
21	21.00	+ 40	769	1956-77
23	22.04	+ 20*	774	1954-77
25	23.17	+870*	775	1954-77
26	23.70	+100	770	1962-77

*Channel migration is occurring at these sections.

The Corps of Engineers' cross sections also indicate considerable change in the elevation of the river bed. The change has been one of degradation (lowering).

The rating curve at the Bonner Springs gage for 1962 indicates that the difference in elevation between a discharge of 1,000 cfs and 2,800 cfs should be 1.3 feet. The rating curve for 1977 at DeSoto also indicates that 1.3 feet of elevation should separate discharges of 1,000 cfs and 2,800 cfs. Using an approximate value of one foot as the relative separation of these two flows in an unchanged channel, it is possible to estimate declines in water surface elevations as shown by the Corps of Engineers' cross sections.

Range	Change (decline) in Equivalent Water Surface Elevations 1962-1977
N	3 feet
9	(at least) 6 feet
12	3.5 feet
21	6 feet
26	4 feet

The effects of degradation can also be illustrated by the effect on structures within the river reach. In 1968, Earl Wikinson, "Bridge Engineer" for the Kansas Highway Department Reported, "...that the bridge near Bonner Springs on Highway K-7 has been a rather expensive project for the Highway Department. A tipping condition resulting from the washing out of certain stream materials has been arrested. A complete project to stabilize the situation has not been finished." (Research Department of the Kansas Legislative Council, 1968.) The K-7 bridge referred to is also the last location of the Bonner Springs gage at river mile 20.3. The K-7 bridge was completed in 1960. The older bridge which it replaced was demolished in 1961 (river mile 20.8).

Local residents report and Mr. Floyd Powers (Powers, 1981) of the Bonner Springs Santa Fe Station confirms that the upper portions of the foundation piles supporting the Santa Fe Railroad bridge at Bonner Springs (river mile 21.2) became visible between the pile caps and the river bottom about 1977. Santa Fe maintenance crews subsequently stabilized the bridge by filling the voids around the piles with concrete. (Floyd Powers, 1981.) The exposure of the foundation piles represented a hazard to the bridge since foundation piles are not designed to act as self-supporting columns and the piles could have been bent or broken by normal bridge usage. Piles and pile caps are routinely placed well below the depth of anticipated scour in order to avoid the problem. Exposure of the piles represented degradation greater than anticipated.

In contrast to the problems encountered by the Department of Transportation (formerly the Highway Commission) at the Bonner Springs K-7 bridge, State engineers (Corrigan 1981) report that no problems have developed at either the Turner Bridge (river mile 9.6) or the DeSoto bridge (river mile 31).

The Johnson County Water District Number 1 (JCWD No. 1) river intake is a permanent concrete structure located on the right bank of the Kansas River at river mile 15.0. The structure was completed in 1964 and is part of the JCWD No. 1 treatment facility located nearby.

The river intake is essentially a concrete tube located within the river channel itself which conducts water from the river to a concrete box structure where pumps lift the water into a pipeline leading to the JCWD No. 1 treatment facility. Water flows from the river to the pumps by gravity. The design of the intake structure includes an automatic interruption of electric power to the pumps if the river level falls below some predetermined elevation. This procedure is to prevent potential damage to the pumps and prevent the loss of energy when pumping is impossible.

The smallest volume of flow ever recorded at the Bonner Springs gage was 160 cfs, which occurred on October 11, 1956. At river mile 15.0, this corresponded to a water level surface elevation of 737.4 feet. The minimum level of pump operation was set at 735.5 feet at the JCWD No. 1 intake structure during the design of the project in 1962 and 1963.

Construction of the intake structure was completed in 1964. At the time of its first operation in the winter of that year, temporary auxiliary pumps in the river itself were necessary to provide water to the intake structure so that it could be tested. Low water at that time was due to an ice jam. Subsequent river flows were adequate to sustain operation of the intake without the use of any auxiliary pumps until May of 1966. On May 29, the river intake pumps automatically shut off due to a low water level. The

automatic cut-off elevation at the time was elevation 735.5. River discharge on May 29, 1966 was 1,230 cfs. (USGS, 1967.) In December of 1967, a minimum flow of 1,500 cfs was required to maintain the water level at 734.5. (Burns & McDonnell, 1968.) These elevations and discharges can be compared by means of the Bonner Sprirngs rating curve.

Daily Discharge (cfs)	Water Surface Elevation at Mile 15.0 (ft) 1956	May 1966	December 1967	Change (ft)
500	737.4			
1,230	738.0	735.5		2.5
1,500	738.2		734.5	3.7

At the present time, JCWD No. 1 maintains a jetty extending from the left bank near river mile 15.0 toward their intake on the right bank. The purpose of the jetty is to artificially raise the water level so that water will flow into the intake. The jetty is essential to the operation of the intake because surface elevations of equivalent flows have continued to decline since 1967.

In contrast to the JCWD No. 1 intake, the river intake structure operated by the Kansas City, Kansas Bureau of Public Utilities for their Kaw Power Station near river mile 3.4 has never experienced an automatic shutdown due to low water. (Livesly 1980.) The Kaw Power Station is in the "backwater" reach of the Missouri River where a pooling effect is evident. There is no evidence of major degradation in this lower reach of the Kansas River, but if an increase in channel capacity were to occur without a corresponding change of the Missouri channel, the effect on river levels would probably remain unnoticed. Any additional capacity developed on the Kansas River would simply be filled with backwater from the Missouri River.

The Army Corps of Engineers built a river intake for their Sunflower Ordinance Plant during World War II. The intake is located on the south bank near river mile 32.3, just above DeSoto. The river intake has not been used since 1971. Large amounts of water such as would be provided by a river intake are not currently needed at the ordinance plant because it has been on "standby" status since 1971. Plant personnel report that prior to 1971, no problems due to a lowering of the water level were apparent, but that sand bar formation and shifting of the low water channel to the north side of the main channel were troublesome until this problem was corrected by the construction of jettys along the north bank by the Corps of Engineers.

There appears to have been indefinite limits to the reach in which significant degradation was occurring in 1977. The reach is approximately defined by Range N at river mile 9.5 at its downstream end and Range 26 at river mile 23.7 at its upstream terminus. At

Range N, three feet of degradation were noted between the surveys of 1962 and 1977. At Range 26, degradation was about four feet. Between the two ranges, degradation up to eight feet was noted; the Santa Fe and K-7 bridges have required corrective maintenance; and the Johnson County Water District Number 1 intake structure has required the construction of a jetty in order to continue operations. In contrast, Turner bridge (river mile 9.6) near Range N (river mile 9.5) has not required corrective maintenance due to changes in river bed elevation (Corrigan, 1981) and the Kaw Power Station intake structure downstream of Range N has operated without difficulty since its construction in the 1950s.

Additional information concerning the reach in which degradation is occurring can be gained from consideration of the water levels indicated by the 1977 Corps of Engineers' cross sections. In the following listing, water levels were read directly from the Corps of Engineers' cross sections and are accurate only to the nearest 0.5-foot. For this reason, water surface slopes are calculated for ranges about two miles or more apart in order to average the possible errors over comparatively long distances. The information is summarized as follows:

Range		Water Level Elevation, 1977, at 1,000 cfs (feet)	Water Surface Slope to Next Downstream Cross Section (feet per mile)
DeSoto gage	(RM 31.0)	763	1.8
26	(RM 23.7)	749.5	3.0
23	(RM 22.04)	744.5	2.1
9	(RM 14.1)	727.5	1.2
N	(RM 9.5)	722*	---

*Flow was 950 cfs, rather than 1,000 cfs.

This data indicates that a steeper water surface slope occurred in 1977 between Range 26 (river mile 23.7) and Range 23 (river mile 22.04) than within any other river section in the total reach from DeSoto to Turner Bridge. The reach from Range 26 to Range 23 is within the "draw-down" reach into that area. The gradient of the river channel from Range 26 to Range 23 has been increased by lowering of the river bed at the downstream end. As a consequence of the gradient increase, the velocity of the water flowing within the reach must also increase. An increase in the velocity of flow of any stream tends to increase its ability to transport sediments and hence its erosive capability. It is the increase in velocity of flow into a depression or hole in the river bed which tends to propagate the depression in an upstream direction. The gradient on the downstream limb of a depression or hole in the river bed is flattened and, consequently, velocity of flow is slowed as the water flows out of the depression. Slowing the velocity decreases the

erosive capability of a river and, hence, holes or depressions do not tend to be propagated in a downstream direction.

The presence of the drawdown reach on the Kansas River, upstream of a river section of known degradation, indicates that the degradation will continue to be propagated even further upstream. Range 26 (river mile 23.7) which demonstrated four feet of decline in equivalent water surface elevation between 1962 and 1977 will continue to be degraded and the drawdown reach itself will be moved upstream. The process of degradation will continue to affect progressively further upstream areas until the moving zone of active erosion encounters some firm channel control.

The upstream change in velocity induced by changes in river gradients is the primary cause of erosion upstream of a degraded area. If an area of bed degradation in a river reach is unaccompanied by degradation of similar magnitude downstream or is separated from the downstream area of degradation by an undegraded river reach of normal velocity, the upstream degradation cannot be associated with that of the downstream degradation. The upstream degradation must be caused by either a local stress or by events occurring upstream, or by a combination of the two.

The Kansas River reach from Range N (river 9.5) to Range 26 (river mile 23.7) is more complex than the situation described above. It is, however, an area of upstream degradation unaccompanied by downstream degradation of similar magnitude. The average rate of stage decline for the "active channel" level at the Kansas City gage was 0.10-foot per year from 1943 to 1973. The average rate of stage decline for the same level at the Bonner Springs gage on the Kansas River from 1940 to 1958 was 0.15-foot per year and accelerated to 0.47-foot per year from 1962 to 1973. A portion of the demonstrated degradation at Bonner Springs may be due to upstream propagation of Missouri River degradation, but all of it cannot be, since it is occurring at a faster rate and is of greater magnitude than that of the Missouri River.

Eight sand dredges operate in the reach from Range N (river mile 9.5) to Range 26 (river mile 23.7). Two dredges operate below Range N, one in off-stream bays. Dredging has been practiced in the lower Kansas for a number of years. The exact length of time is unknown, but about 50 years of operation can be documented. The dredging operations are within the reach of maximum degradation, but since the acceleration of degradation is relatively recent (1962, see Figure E-17) dredging cannot be the only factor involved. For further discussion of dredging and degradation see Section II.A.4.b of this report.

Of some importance is the determination of the upstream extent of the drawdown reach since it is within that reach that degradation is actively being propagated. The Corps of Engineers' cross sections

at Range 26 (river mile 23.7), Figure E-2, indicate about five feet of elevation difference between the water level of 2,800 cfs which occurred in 1962 and the level of 1,000 cfs in 1977. Both the rating curve of the Bonner Springs gage in 1962 and that of the DeSoto gage (river mile 31.0) indicate that no more than 1.3 feet should separate the gage readings of these two flows when measured in a single year. The difference in the water surface elevations indicated on the cross section at Range 26 must then be due to changes in the channel geometry which occurred between 1962 and 1977 and caused nearly four feet of stage decline. At the river stages considered, which are low relative to the mean flow of about 6,500 cfs, the change in stage must be due primarily to degradation and hence Range 26 is not the upper limit of the drawdown reach.

Section 6 (given as river mile 31.7), Figure E-1, represents three cross sections made from field surveys in, respectively, 1956, 1962 and 1977. The sections were all made at approximately the same location. The designation for the 1977 section is a result of the latest revision in river mileage rather than a change in location. All of the sections are approximately at the present location of the DeSoto Bridge. Also of interest at this section location is Figure E-16. The stage-time relationship of the DeSoto gage shown in Figure E-16, unlike the others presented in this report, was not prepared by Osterkamp, but was prepared using his methods. The values of "active channel" and "bankfull" level flows used in preparing the diagram are those used by Osterkamp for the Bonner Springs stage-time relationship, since the USGS considers the gages to be equivalent. The gage for which the records were compiled was moved to the DeSoto Bridge in 1973 from Bonner Springs. Beginning in 1979, the USGS began using a computer-generated "shifting base" for river gages as a labor-saving device. At the DeSoto gage, discharge measurements are made every two to three weeks. The gage heights for the measured discharges, particularly at lower flows tend to vary about a mean value. Rather than prepare a new rating curve for each discharge measurement, a shifting base is used, where gage heights are shifted to the 1979 rating curve. Consequently, the values plotted on Figure E-16 for the 1979-80 and 1980-81 water year are not based upon USGS rating curves as the 1973-79 points are, but upon interpolation from the raw field data and are not adjusted to the "shifting base." The accuracy of the interpolation is a function of the density of field measurements falling near the values of discharge required (in this case, 9,500 and 20,000 cfs). The value of the gage height for 9,500 cfs shown for 1979-80 (8.4 feet) is considered fairly accurate since it is based upon four points, one of which was very near the "active channel" level (9,450 cfs and 8.38 feet on November 26, 1979). The value of gage height for the 1980-81 period is of doubtful accuracy since it was based only on two points, neither of which was near 9,500 cfs. The value of gage height for 20,000 cfs is doubtful for the period 1979-80 and fairly accurate for 1980-81. Timing of the changes in 1979-81 is arbitrary and is drawn to conform to water years.

Figure E-1 indicates that little change occurred in channel width between 1956 and 1962. The channel increased in width about 100 feet between 1962 and 1977. Figure E-16, showing the stage-time relationships at the DeSoto gage indicates that the "bankfull" level (10 percent = 20,000 cubic feet/sec) changed less than 0.5-foot between 1973 and 1979, indicating that the widening did not occur during the period of record, but prior to 1973. The DeSoto Bridge was built in 1972 and the channel was probably improved at that time. Figure E-16 indicates that widening did not continue in the period 1973-79 and probably was not active from 1979-81.

By comparing water levels shown on Figure 1 with the rating curve at the DeSoto gage for 1977, it is possible to estimate the changes in the stage-time relationships at the DeSoto Bridge location for the period 1956-77.

Discharge	Elev at Gage (1977)	Elev. by X-Section	Difference (1977)
500 cfs (1956)	762.5	763.0	-0.5'
1,100 cfs (1977)	763.2	763.2	0.0
2,800 cfs (1962)	764.4	765.5	-1.1'

These figures indicate that water levels of equivalent flows have declined when earlier water levesl are compared to the 1977 rating curve. That is, the 1977 flows occur at lower elevations than the same flows did in previous years. A comparison with other gages, however, indicates that the 1977 elevations are probably the result of general river conditions rather than local degradation. The Missouri River gage at Kansas City (Figure E-17), the Lecompton, and Topeka gages (Figure E-15) all indicate that the 1977 flows (25 percent curves) should be at lower gage heights than either the 1956 or 1962 flows. The magnitude of stage lowering between 1962 and 1977 is approximately 0.4-foot at Topeka, 0.3-foot at LeCompton and 1.3 feet at Kansas City (1973) as shown by the 25 percent curves illustrated in Figures E-15 and E-16, so the magnitudes of change of gage height estimated for the DeSoto gage are within the range of changes experienced in the Lower Kansas River and Missouri River at Kansas City due to normal riverine actions.

That the changes recorded are probably due to normal river discharge rather than induced degradation is also indicated by the fact that the DeSoto gage in the period 1973-79 (Figure E-16) shows no consistent downward trend, as does the Bonner Springs gage in the period prior to 1973 (Figure E-17). The change between the higher gage readings in 1962 at Topeka, LeCompton and Kansas City, and the lower gage readings of 1977 at those same locations occurred in the period 1968 to 1973 and could not be recorded at the DeSoto gage which was not established until 1973.

Since there is no evidence of induced channel degradation at the DeSoto gage location (river mile 31.0) as of 1977, but there is

evidence of several feet of degradation at Range 26 (river mile 23.7), the drawdown reach in question must have been located between the two points at that time. Since the intervening reach is 7.3 miles in length, the result is not very precise, but does indicate that the drawdown reach into the area of extreme degradation near Bonner Springs was not present upstream of river mile 31.0 (DeSoto gage) as of 1979 and hence cannot have influenced erosion upstream of the DeSoto gage prior to 1979.

Figures E-12a through E-12d in Appendix E are reproductions of United States Geological Survey (USGS) 7.5-minute quadrangle maps. The USGS prepares and distributes this series of maps for virtually the entire United States. They are small-scale maps which are initially prepared from field surveys and controlled aerial photographic surveys. The original date of publication is included with each map. The maps are periodically updated by new aerial surveys. It is customary to add the revisions by an overprint in indigo-colored ink rather than by a complete redrafting to include all new data. The date of any photo revisions is also included on the maps. Because changes in the width or location of river channels are generally included in the map revisions, it is possible to determine if gross changes have occurred in those parameters by comparing the original map features with the indigo-colored overprints. Because the dates of the original printing and subsequent revisions are given, it is possible to determine the time frame of any changes.

Figures E-12a to E-12c in Appendix E reproduce the USGS 7.5-minute quadrangle maps which include the reach of the Kansas River from Bonner Springs to Lawrence, Kansas. The figures are in black and white but the original indigo overprint can be recognized by its distinctive pattern; a series of fine, closely-spaced lines which appear as shaded areas.

The 7.5-minute quadrangle maps reproduced in Appendix E are listed below with their original year of printing and the years in which photo revisions were made. The figures in Appendix E do not include the 1978 revisions.

Quadrangle Name	Original Printing Date (year)	Photo Revisions (years)
Shawnee, KS	1964	1970
Edwardsville, KS	1950	1970 and 1975
Bonner Springs, KS	1950	1970 and 1975
DeSoto, KS	1951	1970 and 1978
Eudora, KS	1951	1970 and 1978
Lawrence East, KS	1950	1967 and 1978

Figure E-18 is a map reproduced from a Kansas Geological Survey Bulletin (Dufford 1958). Figure E-18 is based upon a field survey

of the U.S. Soil Conservation Service during the winter of 1951 and spring of 1952. The purpose of the survey was to determine the extent of harmful deposition and erosion, caused by the flood of 1951, so that measures could be taken to return the land to productiveness. The flood of 1951 was the greatest ever recorded on the Kansas River. The field survey by the U.S. Soil Conservation Service not only delineated areas of scour and deposition on the floodplain, but also delineated the extent of channel changes which occurred in the Lawrence-DeSoto reach as a result of the flood. USGS 7.5-minute quadrangle maps printed in 1950 and 1951 were used as base maps for Figure E-18.

With the reproductions of the USGS 7.5-minute quadrangle maps in Appendix E and the reproduction of the Kansas Geological Survey map of the 1951 flood damage, also in Appendix E, it is possible to differentiate changes in channel geometry which occurred at various times within the river reach. Unfortunately, the Kansas Survey map extends only to the Leavenworth County line near river mile 26 and does not include the river sector in which Range 26 (river mile 23.7) is located.

The sector of the river between the Leavenworth County line and DeSoto Bridge appears to be unchanged from Figure E-18 to Figure E-12b. That is, the changes shown on Figure E-12b as having occurred between 1950 and 1975 appear to have been caused by the 1951 flood, shown on Figure E-18. Insofar as the scale of Figure E-18 allows, this is confirmed by measurement from section corners to channel lines. The maps indicate changes, or lack of them, in channel width and locations at various times, but, of course, cannot illustrate changes in bed elevations nor provide information on the length or location of the drawdown reach. The drawdown reach even in 1975 must have been somewhere within the county line-DeSoto reach, but all that can be stated definitely is that it did not extend as far upstream as the DeSoto gage and therefore could not have influenced erosion in areas upstream of DeSoto.

Bank stabilization was performed by the Corps of Engineers from river miles 31.3 to 41.2 in 1969 to train the low water river channel near the Sunflower Ordinance Plant intake so that the intake could remain operative. (Turntine 1981.) The low water channel was attempting to shift to the left (north) side of the main channel, leaving the intake in the dry during periods of low water. Figure E-18 indicates that during the flood of 1951, the channel was widened through the intake reach so that low flows would later have considerably more latitude to meander than at the time the intake was built (1940s). The Sunflower Ordinance intake is located on the south bank of the river near the center of Section 20, in the DeSoto "Bottom." On Figure E-12b, the access road to the intake can be seen near the same location. Plant personnel report no problems at the intake structure attributable to degradation of the river channel (Turtine 1981). It is not known if the channel shift at the

Sunflower intake structure was accompanied by erosion of the north bank, but accretion did occur on the south bank adjacent to the Sunflower intake structure.

Photo revisions made in 1978 of the USGS 7.5-minute quadrangle map (not shown in Appendix E) indicate that no further erosion occurred between 1970 and 1978 apparently as a result of bank stabilization efforts by the Corps of Engineers in 1969 from river mile 31.3 to river mile 41.2 which includes this reach.

Still further upstream is an area of the river which was not only severely impacted by the flood of 1951, but which has continued to erode since 1951. The reach begins about two miles downstream of the Eudora Bridge in Section 33, T12S, R21E, and extends upstream to a point about two miles downstream of Bowersock Dam in Section 34, T12S, R20E, a distance of about seven river miles. Figure E-18 illustrates the changes that occurred in this reach during the 1951 flood. Beginning at the first river bend near the left-hand margin of Figure E-18, the 1951 changes can be described as follows: The channel at the first river bend was widened, primarily on the east side of the channel axis. A minor cut-off (shortening of channel length) occurred in Section 26, T12S, R20E. Channel widening and downstream migration of a small bend occurred in Section 36, T12S, R20E. From Section 36 to a point about 0.5-mile downstream of the Eudora Bridge, the channel location and configuration of the river was almost completely changed. In Sections 31 and 32 of T12S, R21E, the flood undercut the river bank so that the left bank after the flood was more than a quarter of a mile from its preflood location. This change was accompanied by intense overbank scour. Downstream of the overbank scour, the channel configuration was altered so that, while the channel before the flood had impinged upon the bluff just downstream of Eudora at an angle of nearly 90 degrees, after the flood, the angle of impingement was nearer to 30 degrees. The river channel just downstream of the impingement area to the end of the reach, under discussion, suffered minor widening.

Figure E-12a illustrates not only the changes due to the 1951 flood, but any others which occurred between 1950 and 1967. Comparison with Figure E-18 indicates that much of the reach from Lawrence to Eudora (and downstream) has undergone a number of changes after the 1951 flood.

The first bend below Lawrence moved more than 750 feet eastward from 1951 to 1967 and, though not shown on Figure E-12a, moved an additional 600 feet between 1967 and 1978. The river channel along the west side of the Eudora "Bottoms" has adjusted its channel location by straightening the course left after the 1951 flood and now flows about 300 feet east of its post-flood position. The change in the angle of impingement against the bluff just downstream of Eudora apparently produced 500 feet of bank erosion on the west

side of the Weaver "Bottom" from 1951 to 1970. An additional 300 feet occurred between 1970 and 1978.

The Lawrence-Kansas City reach is one described by Dort (1980) as historically inactive. This is not true at the present, especially in the Lawrence-Eudora reach. There, river bends are experiencing relatively rapid downstream movements and the river is consuming relatively large amounts of farmland each year. It appears that the present river activity is proceeding along trends begun in the 1951 flood, or engendered by changes due to the 1951 flood. But, the river has experienced a number of floods since 1844, and none of these apparently triggered the Lawrence-Eudora reach into action. The flood of 1951, even though it is the greatest ever recorded, is probably not the only cause of present erosion. The data seems to indicate that the Lawrence-Eudora reach was severely impacted by the 1951 flood and has not undergone the "healing" process that one would normally expect. In healing, vegetation destroyed by the flood is gradually regrown, channels and banks are restored to former grade lines by accretion, and the river gradually hides the scars produced by flooding. Apparently, these events did not immediately occur after the 1951 flood because of the drought during the 1950s and events which affected the entire river after 1962.

It should be noted that between Range 26 (river mile 23.7) and the Bowersock Dam in Lawrence (approximately river mile 51), only two Corps of Engineers' dredging permits have been issued. One of these has been abandoned for some years and the other did not commence operations until 1980. It is unlikely, particularly since the permit areas are upstream of the most severely impacted river sections in the Lawrence-Eudora reach, that these dredging operations had any significant affect on downstream erosion.

Bowersock Dam in Lawrence (approximately river mile 51.0) serves as a dividing point between the Lawrence-Kansas City reach and upstream portions of the river. Bowersock is a low-water hydroelectric dam built in 1872 and subsequently extended in length and raised in crest elevation. The present crest without flash boards is 808.0 feet. As long as the dam is in place, it serves to delimit upstream migration of velocity changes due to downstream gradient increases.

The river gage at Lecompton is the next upstream gage to be considered on the Kansas River. Osterkamp's analysis of this gage is reproduced in Figure E-21. The gage is located on a highway bridge at river mile 64.7, about 14 miles above the Bowersock Dam at Lawrence and one-half mile below the confluence with the Delaware River.

Figure E-15 indicates that the stage-time relationships of the 10 percent (18,000 cfs) and 25 percent (8,600 cfs) flow-duration rates have been relatively constant, although two trends are evident in the data after 1951. Both the 10 percent and 25 percent flows show

a general increase in stage elevation between 1951 and 1967 and a general decline thereafter. Storage was initiated at Perry Dam on the Delaware River in 1969. The changes indicated after 1967 appear to be dominated by events below the "active channel level" and are probably the result of minor channel degradation due to increased annual discharges. Changes in the stage-time relationships between 1952 and 1957 appear to be the result of the drought of the 1950s.

The gage may have been influenced by the closure of Perry Dam in 1969, but, if so, the long-term effect of that closure is represented by less than one foot of net change in either the 10 or 25 percent flow duration rates. The stage-time relationship at Lecompton appears at the present to be relatively insensitive to major historical changes on the Kansas River.

The river gage at Topeka, Kansas is presently located on the Sardou Bridge in Topeka at River Mile 83.1. From 1939 to 1961, the gage was located on the Topeka Avenue Bridge, 2.4 miles upstream of its present location. The gage had been previously located on the Sardou Bridge from 1934 to 1939. Osterkamp's analyses of the stage-time relationships of the 10 percent (14,000 cfs) and 25 percent (7,100 cfs) are reproduced in Figure E-15.

The data indicate that the stage-time relationship for both the 25 and 10 percent flows was relatively constant from 1925 to 1950 but experienced about two feet of decline from 1950 to 1978. A steeper decline has been evident since 1966 and from 1966 to 1978 about 1.4 feet of the two feet of decline mentioned above occurred.

The changes in the 10 percent stage-time relationship generally reflect those of the 25 percent relationship, indicating that most changes occurred below the "active channel" level and are probably the result of degradation rather than widening. The stage-time relationships indicate that about two feet of degradation occurred in the reaches which influenced the gage at its various locations in Topeka.

The Corps of Engineers allows four dredges to operate in the Topeka vicinity. All of these are at locations above river mile 85.5. No dredges operate in the river from Bowersock Dam (river mile 51.0) to Topeka. The stage-time relationship of the Topeka gage indicates that about two feet of degradation has occurred in the Kansas River at Topeka; however, the measured degradation cannot be the result of dredging operations in the Topeka vicinity since the gage, particularly since 1961, is inappropriately placed to measure such degradation. The present location of the gage is 2.5 miles downstream of the closest dredging operation and, as previously stated, degradation tends to be propagated in an upstream direction. A much more likely cause of degradation is the flood protection measures instituted after the flood of 1951 in Topeka, particularly

the Soldier Creek diversion channel, which enters the Kansas River 2.3 miles downstream of the present location of the Topeka gage.

The Kansas River above Topeka is identified by Dort (Dort, 1980) as "inactive" and by Osterkamp (Osterkamp, 1981) as "stable" from approximately river mile 81.0 to about river mile 100. The printing date of USGS maps representing the reach above Topeka is 1952, but whether the aerial photographs and field surveys upon which the USGS maps are based were taken prior to the flood of July 1951 is unknown. It appears likely that the original maps represent the preflood conditions and that subsequent photo revisions (1972 and 1975) represent total changes in the river channel which would include changes due to the 1951 flood. No detailed data sources describing the 1951 flood damage are available for comparison as was the case for the Lawrence-DeSoto reach and consequently, it cannot be determined if the changes indicated in the USGS maps were all caused at the same time by the flood of 1951 or have been cumulative since that time. The major change in the reach appears to be the downstream migration of a small river bend near Hickory Knob in Shawnee County, which appears to be about 500 feet from its former location.

The next upstream river gage is located at Wamego, Kansas in the reach from river mile 122 to about river mile 140. Dort (1980) describes this reach as historically "Inactive" and Osterkamp (1981) identifies it as "Stable." Osterkamp's analyses of the 25 percent and 10 percent flow duration, stage-time relationships are shown on Figure E-14.

The Wamego gage is located on the State Highway 99 bridge at Wamego, Kansas and at river mile 126.9. A small dredging operation one-half mile downstream of the gage location is the sole permitted dredge between Topeka and Manhattan.

Figure E-14 represents Osterkamp's analyses of the Wamego gage records. The graphs indicate that since the flood of 1951, the stage-time relationships of both the 10 percent (12,000 cfs) and the 25 percent (6,000 cfs) flow duration rates have been almost constant. The flood of 1951 carried away about 500 feet of the left bank of the river just downstream of the gage and the increase in channel capacity produced by that event has never "healed."

The Wamego gage is well located to measure any degradation that might be caused by the downstream dredging operation. No effect is apparent. The Wamego gage is also located 20 miles downstream of Tuttle Creek Dam and obviously no effect is discernible at the river gage of any erosional or degradational effects produced by the presence of the upstream reservoir which was closed in 1962.

In the Manhattan, Kansas area, from approximately river mile 140 to 164 is a reach classified as historically "active" and presently

"unstable." One dredge operates in this river reach. However, there is no river gage within this reach and consequently no judgement can be made on changes in stage-time relationships. Major changes on the USGS 7.5-minute quadrangle map entitled "Manhattan, Kansas" indicates major channel changes (from 1955 to 1977) only in the portion of the river downstream of the Big Blue confluence. The dredging operation is about three miles upstream of the confluence. Evidence of effects due to dredging in the Manhattan area is inadequate for any definitive statement.

Further upstream, Osterkamp (Osterkamp, 1980) examined the river gage immediately below the dam at Milford Reservoir on the Republican River (E-13). He identifies eight feet of decline in the 25 percent flow duration rate and an equal amount in the 10 percent flow duration rate. His conclusion is that the declines represent degradation without accompanying high bank erosion. This record is the only one of all the river gages on the Kansas River which documents what is common at other reservoirs in the Missouri Basin--degradation immediately downstream of a major reservoir. (Corps of Engineers, April 1981).

Degradation at this location was anticipated in the design of the outlet channel by the Corps of Engineers and is in a sense "forced degradation." The banks of the outlet were extensively protected so that any erosion which occurred would be in the channel bed. This procedure is advantageous in that it improves drainage on the floodplain.

The Ft. Riley gage on the Kansas River, eight miles downstream from the Milford Reservoir was not examined by Osterkamp, but the records are available. From December 1963 to early 1971 stages for any given discharge show a fluctuation of less than one-half foot. Since early 1971, the ratings show a drop of about one foot for all discharges up to approximately 10,000 cfs. Milford Dam was closed in 1967. One foot of change in the stage-time relationship for a given flow is not generally considered significant. A longer period of record will be needed to determine if the closure of Milford Dam is actually influencing the Ft. Riley gage.

Osterkamp (1981) summarized his data on stage-time relationships as follows: "..., the Kansas River channel, which probably was vulnerable to modification by a measurable alteration of the water or sediment discharge rates prior to regulation, remains relatively unstable and locally active. The present channel instability occurs largely in reaches that have been active historically."

"Streamflow regulation and sediment storage by reservoirs are possible causes of channel changes occurring at various Kansas River sites. An inferred deficiency of the suspended-sediment load, however, is likely to cause continuing instability of the channel. Suspended sediment in the Kansas River apparently is insufficient to

form and maintain stable alluvial banks. The inferred deficiency probably results in an increase of tractive (bed) sediment movement, general channel widening, and local braiding.

"Significant rates of channel degradation of the Kansas River presently are not occurring at most sites, but may occur in response to long-term (decades to centuries) regulation. Recent channel degradation near Bonner Springs, Kansas, may be largely the result of extraction of sand and gravel. Any natural or imposed changes that shorten the channel or further reduce the suspended-sediment discharge of the Kansas River are expected to result in additional channel instability." (Osterkamp 1981)

Temporal changes of sediment of the Kansas River have also been investigated (Osterkamp 1981). In comparison to data regarding changes in channel geometry or channel locations, the amount of data available for sediment analysis is very small. Data for extensive periods of time has been collected at only two locations: Wamego, Kansas from 1958 to the present and Bonner Springs/DeSoto from 1949 to date.

Major reservoirs introduce a number of complexities into the analyses of sediment data. The reservoirs tend to trap sediments and the downstream water releases from the reservoirs tend to be relatively sediment-free. In general, sediment-free waters tend to remove soil particles from the downstream bed and banks provided the flow can impart sufficient momentum to the size of particles available to cause movement or transport. Generally, full transport capacity is never realized. Within the Kansas River system, a number of dams have been constructed on major tributaries of the Kansas River proper within recent decades. Each of the major reservoirs has an influence on downstream sediment characteristics, but the influence of each is rarely separable.

The dates upon which the initiation of storage began at the various reservoirs and the contributing drainage area of each are as follows:

Reservoir	Initiation of Storage	Contributing Drainage Area (square miles)
Kanopolis	Feb 48	7,860
Harlan County	Nov 52	20,753
Kirwin	Oct 55	1,367
Webster	May 56	1,150
Lovewell	Oct 57	345
Tuttle Creek	Mar 62	9,628
Wilson	Dec 64	1,917
Milford	Jan 67	24,852
Glen Elder	July 68	5,076
Perry	Jan 69	1,117

It should be noted that Harlan County and Lovewell reservoirs are upstream of Milford Reservoir. Kirwin and Webster are upstream of Glen Elder.

Osterkamp (1981), in analyses of sediment data from the Smoky Hill and Kansas Rivers, summarizes his findings as follows: "Owing to differences in runoff rates preceding and following the construction of several reservoirs, the effect of regulation on suspended-sediment concentrations is difficult to assess directly. These figures and data (he lists table numbers), however, clearly show that sediment loads (unadjusted for area) after reservoir closures have been generally lower than before closures. Using Kansas River at Wamego, Kansas, as an example, suspended-sediment loads since 1967 have been roughly half those of 1957 to 1967. During that period, mean discharge at the Wamego gage, downstream sites, and presumably most upstream sites, has increased moderately from the earlier period. At the Tescott, Enterprise, and Wamego gage sites, therefore, evidence is strong that storage of fluvial sediment in upstream reservoirs is resulting in reduced suspended-sediment concentrations downstream from the reservoirs."

The period 1957-67 represents the period of time just prior to and after closure of Tuttle Creek, Wilson and Milford Lakes, which are the three closest upstream lakes to the Wamego gage. The period of time since 1967 would represent the time that the river at Wamego was under full regulation by those lakes, and the lakes constructed prior to 1957, beginning with Kanopolis in 1948.

The complexities envolved in separating the influence of the various reservoirs are further increased by the fact that sediment sampling has been done in a consistent manner on the Kansas River only since 1957 and that prior to its official closure in 1962, Tuttle Creek was closed temporarily on, at least, four occassions in the period 1957-62.

The sediment record then is lacking true historicity, in that no complete sediment record is available for periods of time prior to

the beginning of regulation in 1948 (Kanopolis), and for only two years prior to the construction of the two major dams, Tuttle Creek and Milford, since as seen below, Tuttle Creek was actually closed for a time in 1959.

Closures at Tuttle are listed below:

Dates	Date of Max Pool	Elevation at Max	Storage (AF) at Max (+)
	7-20-59	--	--
9-17-59 to 10-15-59	9-8-59	1036.5	37,000
3-26-60 to 4-20-60	4-4-60	1071.0	358,000
	10-12-61	1049.13	125,000

(Information from K.C. District, Corps of Engineers)

Since the total capacity of Tuttle Creek Lake is 3,201,500 acre feet, the amounts of water stored during the temporary closures were not great, but storage undoubtedly had some effect on the sediment content of the river. What that effect was and quantification of the effect are impossible to determine with the existing records.

Bearing the complexities of interpretation in mind, there is still a significant change in the sediment content of the Kansas River as measured at Wamego and Bonner Springs - DeSoto, between the periods of time prior to 1963 and after 1967.

Reduction of sediment concentrations after construction of Tuttle Creek, Milford and Wilson Dams is implicit in the sediment data collected at Wamego. Tuttle Creek was closed in March of 1962, Wilson Lake in December 1964, and Milford in January 1967. A comparison of equivalent flows before 1963 and after 1967 is given below.

Water Years Compared (1) and (2)		Annual Runoff (Million Acre-Feet) (1) and (2)		Annual Suspended Sediment (million tons) (1) and (2)	
1962	1969	5.7	5.7	14.6	5.8
1959	1971	3.4	3.5	12.8	4.2
Prior to Closure, for Comparison					
1958	1961	4.7	4.8	17.4	13.2

The total sediment load at Wamgeo has decreased. Gradation analyses also indicate a change in the percentage of various particle sizes, but that change does not coincide with the time of changes in the sediment supply. From 1957 to 1970, suspended sediment at Wamego was about 5 percent sand. From 1970 to the present the suspended sediment measured at Wamego has been about 10 percent sand. The bed load also appeared to coarsen slightly, but the percentage increase in coarse sand (2 percent) cannot be considered significant.

Osterkamp did not consider temporal changes in suspended sediment concentrations or annual sediment loads at the Bonner Springs/DeSoto collection point, but sediment data is available from that location, also. Reduction in annual suspended sediment loads is also implicit in the Bonner Springs data, although annual runoff values are not as closely equivalent as at Wamego. Two examples can be cited:

Water Years Compared (1) and (2)		Annual Runoff (Million Acre-Feet) (1) and (2)		Annual Suspended Sediment (million tons) (1) and (2)	
1959	1975	5.0	4.5	19.7	10.3
1960	1974	7.7	12.8	36.2	34.9
Prior to Closure, for Comparison					
1958	1961	6.8	6.7	29.3	28.7

Figure E-19 in Appendix E is a double-mass relationship of cumulative sediment at Bonner Springs plotted against cumulative sediment at Wamego. If data in a double-mass are proportional, a straight line results, the slope of which is the constant of proportionality. If the line shows one or more breaks, it is assumed that the variables are not proportional or else the constant of proportionality has been changed. In Figure E-19 the double-mass relationship is reasonably well defined for water years 1958 to 1961, which is the time of intermittent closure of Tuttle Creek Dam. The curve deflects to the left after 1961 and to the right again after 1968, indicating that the proportionality changed between those years. As was noted, Tuttle Creek was officially closed in 1962, Wilson in 1964 and Milford in 1967. Perry Lake on the Delaware River which joins the Kansas River between Wamego and Bonner Springs was closed in January of 1969. The double-mass relationship defines three periods of time, 1958 to 1961, 1962 to 1968, and 1969 to 1975. These coincide with the period before permanent lake closures (1958-1961), the period when four major reservoirs were being constructed and closed (1962-1968) and the period since construction (1969-1975). The double-mass diagram indicates major regime changes in 1962 and 1969 between Wamego and Bonner Springs.

If the annual suspended sediment passing Wamego is calculated as a percentage of that passing the Bonner Springs gage and the results are averaged over the same periods defined by the double-mass diagram shown in Figure E-19, the results are that Wamego sediment averaged 56 percent of the Bonner Springs load from 1958 to 1961, 36 percent from 1962 to 1969, and 36 percent from 1970 to 1975. The Delaware River (average annual suspended sediment: 3,250,000 tons) became noncontributing for sediment in 1969. Water discharge at Wamego for the 60-year period 1917-77 represents an average of 71 percent of the Bonner Springs discharge, but in the period 1970-75, the Wamego discharge represented only 66 percent of that at Bonner Springs, indicating that the lower portion of the Basin contributed

a larger percent of discharge and probably also of sediment than normal during the period 1970-75. Sedimentation induced by increased runoff from the lower basin apparently was trapped in Perry Lake, so that suspended sediment at Wamego continued to represent 36 percent of the suspended sediment measured at DeSoto/Bonner Springs throughout the period 1962-75, whereas the percentage of Bonner Springs water discharge represented by that measured at Wamego decreased in the period 1970-75.

If a double-mass relationship between annual suspended sediment and annual runoff as measured at Bonner Springs is made, (Figure E-20) the results are similar to the double-mass plot shown in Figure E-19 in that it indicates a definite break between 1961 and 1962 and again between 1968 and 1969. The breaks are to the right indicating a reduction in sediment weight for a given volume of water, beginning in 1962 and increasing in 1969.

From the double-mass relationship (Figure E-20), it is possible to obtain a value for the average reduction in suspended sediments on a yearly basis. The double-mass relationship indicates a slope of 4.5 tons per acre-foot for the period 1958-61, before final reservoir closure at Tuttle Creek and 2.0 tons per acre-foot for the period 1969-75, after closure at Perry. These are constants of proportionality as well as the sediment concentrations for the periods considered. These constants multiplied by the average annual runoff recorded at Bonner Springs for the two periods (1958-61 and 1969-75) would represent the average annual suspended sediment to pass Bonner Springs in the two periods considered. The average annual runoff for the two periods measured at Bonner Springs/DeSoto was 7.0 million acre-feet. Calculations indicate that the average annual suspended sediment before major regulation was 30.8 million tons and that after 1969 it was 14.0 million tons for an overall reduction of about 55 percent.

b. Dredging In Relation To Erosion

(1) Kansas River Above Bowersock Dam: The Corps of Engineers currently permits six dredging operations in the Kansas River reach from Bowersock Dam (river mile 51.0) to Manhattan (river mile 153). Of these six operations, one is at Manhattan, one is at Wamego and four are at Topeka, Kansas. Each of the dredging areas will be considered in sequence beginning upstream at Manhattan and proceeding downstream to Topeka.

A single dredge operates at Manhattan near river mile 153. The reach of the river in which the dredge is located is ungaged and the nearest gage location upstream is the Ft. Riley gage at river mile 168.9. It is unlikely that the single dredge at Manhattan has had any significant effect on the Ft. Riley gage. The river reach in which the Manhattan dredge operates is considered historically "Active" and presently "Unstable." As

pointed out by Osterkamp (1981), presently "Unstable" reaches of the Kansas River are predominantly associated with historically "Active" reaches. No evidence was found to link dredging operations to the presently "Unstable" condition of the Manhattan river reach.

A single dredge also operates at Wamego, Kansas. The Wamego gage (Figure E-14) is very well located to record any degradation or widening which might occur in the Kansas River channel which could potentially be associated with dredging activities at Wamego. However, since a major change in stage-time relationships produced by the 1951 flood, stage-time relationships at Wamego have remained virtually constant. Stage-time relationships appear to prove that local dredging has had no effect upon channel geometry near Wamego. Osterkamp (1980) notes that annual suspended sediment as measured near the Wamego gage location, since 1975, has been approximately one-half that of the pre-lake period (1958-1961).

Four dredges operate in the Kansas River within the city limits of Topeka. The Topeka river gage (Figure E-15) is inappropriately located to determine the effects of dredging operations upon degradation or other channel-geometry parameters in this locale. The Topeka gage is 2.4 miles downstream of the nearest dredging operation. Degradation as measured by the decline in stage-time relationships of the Topeka gage records (Figure E-15) must have some cause other than dredging.

This study could find no further evidence that dredging was producing significant changes in channel geometry in the Topeka vicinity. The river reach above Topeka for some 15 miles is considered historically "inactive" and presently "stable." A U.S.G.S., 7.5-minute quadrangle map originally printed in 1952 and subsequently photo revised in 1975 (Silver Lake Quadrangle) indicates some channel changes, but it is not known if these were wholely the result of the 1951 flood or are due to events since that time. No definitive statement can be made in regard to the effects of dredging on Kansas River Channel geometry in the Topeka vicinity.

In summary, there is no hard, firm evidence that dredging is causing erosion or degradation problems anywhere in the Kansas River reach from Bowersock Dam in Lawrence to Manhattan. There are erosional problems on the upper Kansas River, but dredging cannot be positively linked with those areas, whereas historical "Activity" can be. River reaches above Topeka which have been "Active" in the past are "Unstable" at the present. River reaches which were "Inactive" in the past, but presently "Unstable" (Topeka to Lawrence) are not in areas which could be influenced by dredging operations.

(2) Kansas River Below Bowersock Dam: There are twelve current permits for dredging operations in the Kansas River from Lawrence to the mouth. Two of these are for river sectors in Lawrence within two miles of Bowersock Dam. One of these permit locales has been abandoned for some years and the second operation did not begin until 1980. Because of the location and temporal frame work in which these dredging operations were conducted it is unlilkely that these operations have any effect on the general erosion that has occurred downstream of the permit locations--from Lawrence to the mouth--and the Lawrence dredging operations are accordingly excluded from the continued discussion.

From Lawrence to DeSoto considerable erosion has occurred consisting of general channel widening and accelerated downstream movement of river bends. Erosional changes in the Lawrence-DeSoto reach are discussed more fully in the previous section.

The river gage which was moved from Bonner Springs to DeSoto in 1973, however, does not indicate any major changes in stage-time relationships. This fact indicates that neither degradation (lowering) nor widening are occurring in the river reach which influences the gage readings. It also would indicate that no significant changes have been measured in the velocity of the water flowing past the DeSoto gage.

Since significant changes in channel geometry or flow velocity have not been measured at the DeSoto gage it appears that the erosion noted in the Lawrence-DeSoto reach is not associated with the river reach of significant degradation near Bonner Springs. That is, velocity increases caused by increased gradients into the Bonner Springs reach did not (as of 1979) extend upstream as far as the location of the DeSoto gage and consequently would not be available as a cause of the erosion in the reach above DeSoto, which occurred prior to 1979. The drawdown reach, the section of the river in which the velocity of flow is increased by the increase in river gradient into the degraded area near Bonner Springs, was apparently located in the reach from DeSoto (river mile 31.0) to river mile 23.7 in 1979. It is believed that the drawdown reach will continue to progress upstream and its effect will be noted at the DeSoto gage at some future date.

Ten dredges currently operate in the DeSoto-Kansas City, Kansas reach of the Kansas River. Specific locations of the Corps of Engineers' dredging permits are indicated by Figures E-12a through E-12c.

Records of the amounts of sand dredged in the Bonner Springs-Kansas City, Kansas reach are available since 1939. To illustrate changes in the amounts dredged, five-year averages are given below. The tonnage for sand is for dredging between river mile 9.5 to Bonner Springs.

Period Dec. 31 to Dec. 31)	Average Sand Removed (million tons)
1940-1945	0.51
1945-1950	0.94
1950-1955	1.42
1955-1960	1.72
1960-1965	2.11
1965-1970	1.82
1970-1975	2.38

Averages for the periods in which sediment data are available at both Wamego and Bonner Springs/DeSoto and which are designated as the pre-lake period (1958-1961); the lake construction period (1962-1968); and the post-lake period (1969 to 1975) were also calculated and are given below:

Period Jan 2. to Dec. 31)	Average Sand Removed (million tons)
1958-1961	1.79
1962-1968	1.95
1969-1975	2.37

Although sand production increased about 467 percent from 1940 to 1975 most of the increases in production (337 percent) were prior to 1955. The increase in production from the pre-lake to the post-lake period was 132 percent. The increase in production from the pre-lake period to the lake construction period was 109 percent. The latter percentage is important since it indicates that the acceleration in the decline of the stage-time relationships shown by the Bonner Springs gage did not coincide with a gross increase in sand production.

The above quoted figures can be compared directly with sediment data collected at the Bonner Springs/DeSoto locations. In the previous section it was determined that the suspended sediment concentration from 1958 to 1961 was 4.5 tons per acre-foot and from 1968 to 1975 it was 2.0 tons per acre-foot. The concentration from 1962 to 1968 was 2.2 tons per acre-foot. These are the slopes of the lines on the double-mass diagram shown in Figure E-20 for the respective periods. If these values are multiplied by the average discharge for the periods concerned a value of average-annual suspended-sediment is determined for each period.

The Corps of Engineers has estimated that before reservoir construction 15 percent of the suspended sediment entering the reach between Bonner Springs and Turner, Kansas (about river mile 9.0) was sand. The estimate for the post-construction period is 10 percent. The Corps of Engineers has also estimated that the average trap efficiency for sand in the Bonner Springs-Turner reach for all volumes of flow is approximately 78 percent.

No gradation analyses are available for the lake construction period (1962-1968). Since the estimate is 15 percent prior to the period and 10 percent afterwards it appears reasonable to use 12.5 percent, although it should be understood that 12.5 percent is merely a representative number for a true value that probably varied considerably at different times within the period.

The result of calculations using the above values are listed below. "Sand Deposited" indicates the value found by multiplying average annual discharge by the sediment concentration determined from Figure E-20. The suspended sediment discharge was then multiplied times the assumed percentage of sand in the given period and by the trap efficiency of 78 percent.

Period	Average Annual Suspended Sediment (million tons)	Average Annual Sand Deposited (million tons)	Average Annual Sand Removed (million tons)
1958-1961	31.5	3.7	1.8
1962-1968	15.4	1.5	2.0
1969-1975	14.0	1.1	2.3

If it is assumed that the percentage of sand did not change from 15 percent to 12.5 percent between the pre-reservoir period (1958 to 1961) and the reservoir construction period (1962-1968) but remained constant, then the value for "sand deposited" in 1962-1968 will change from 1.5 million tons to 1.8 million tons. Assuming that the percentage changed to 10 percent in 1962 changes the 1962 to 1968 value of sand deposited to 1.2 million tons. In any case, the value of sand removed from the Bonner Springs-Turner reach was greater than the amount replaced by riverine action in the given time period.

The listing above indicates that the amount of sand available to the Bonner Springs-Turner reach has been inadequate to replace the amounts dredged since 1962. Another estimate of the deficiency can be gained by comparing the complete period of time for which dredging records are available to the time since reservoir construction began. Values of replacement sand are calculated from the sediment concentration of 4.5 million tons

per acre-foot derived from Figure E-20 for periods prior to 1958.

Period	Average Annual Suspended Sediment (million tons)	Average Annual Sand Deposited (million tons)	Average Annual Sand Removed (million tons)
1939-1961	22.5	2.6	1.1
1969-1975	14.0	1.1	2.3

The overall reduction in sand appears to be about 42 percent based upon the above figures. This reduction is approximately the "true" amount based upon average annual discharges and sediment concentration of the two periods, however discharges were somewhat greater in the period 1969 to 1975 than that of the 60-year average for the Bonner Springs/DeSoto gage. A better estimate of the total sediment reduction can be obtained by comparing the sediment concentrations; 4.5 tons per acre-foot prior to reservoir construction and 2.0 tons per acre-foot after the period of reservoir construction. Multiplication of these values by the respective percentages of sand, 15 percent and 10 percent, which are thought to represent the same respective periods, gives "sand concentrations" of 0.68 tons per acre-foot prior to reservoir construction and 0.2 tons per acre-foot after construction. The ratio of these values is 0.34 indicating that a discharge, occurring after 1968, would contain only one-third the sand of an equal discharge which occurred prior to 1962.

Since the amounts dredged from the river since 1962 have exceeded the volume of sand brought to the Bonner Springs-Turner reach by the river, it follows that the reach must be in the process of degradation (lowering). The evidence of such degradation has been presented in previous sections.

The cause of degradation in the Bonner Springs-Turner reach appears to be due to a reduction in sediment loads by their entrapment in major, upstream lakes coupled with commercial dredging operations which since the beginning of river regulation by the reservoirs in 1962 have extracted amounts greater than it was possible for the river to replace. In essence, the reservoirs upstream and the dredgers downstream are competing for sediments and the supply is less than the demand.

But even total cessation of dredging on the lower Kansas River will not cause all degradation to cease. Both the Missouri and Kansas rivers have undergone regime changes. Since about 1943, the long-term trend of gages at Kansas City and Bonner Springs-DeSoto have been downward, in response to greater stream flows than in previous periods. In this sense, the streams are responding to the same stimulus. In addition, any degradation induced on the Missouri River will be propagated upstream along the Kansas River. Degradation at the Kansas City gage is

currently changing gage levels at the rate of 0.1-foot per year, and while not comparable to the 0.5-foot per year being experienced at Bonner Springs, the Missouri River degration is still substantial. Cessation of dredging in the Bonner Springs reach will slow but will not halt degradation.

B. CLIMATE

The Kansas River Commercial Sand and Gravel Dredging study area has a continental climate that is characterized by cold winters, warm-to-hot summers, moderate winds, abundant sunshine, low-to-moderate humidity, and a pronounced peak in rainfall late in spring and during the first half of summer. The area is in the region of prevailing westerlies, where transient low-pressure disturbances and intrusions of cold polar air are common. Both of these influences contribute to the changeable weather pattern that is characteristic of Kansas and the midwestern states.

The Gulf of Mexico is the principal source of moisture for precipitation in Kansas. Because the flow of moist air from the Gulf is more frequent over the eastern part of the study area than over the western part, the average annual precipitation in the study area decreases about 1 inch for each 17 miles of distance from east to west (Soil Conservation Service, 1975).

Approximately 75 percent of the annual precipitation occurs between April and September. The average annual precipitation for the study area (central to eastern Kansas) varies from 32 to 36 inches. Summer thunderstorms in excess of five inches of rainfall have been recorded in nearly every part of Kansas, but more frequently in the eastern part. Some of the thunderstorms are violent and produce heavy rainfall, large hailstones, and tornadoes. Damage from these storms, however, generally is local in extent and occurs in a variable and spotted pattern.

Floods in the study area are generally due to torrential and often prolonged rains. They are seldom caused by melting snow, and overflows are practically unknown during the winter season of November to February. The period of greatest flood frequency is during the spring and summer. Flash floods in smaller tributary streams of the Kansas River occur during the warmer season and are caused by intense local convective storms. Notable flood years in Kansas include 1844, 1903, 1923, 1935, 1941, 1944 and 1951.

Winter precipitation usually results from the passage of well-developed low-pressure systems and active fronts and may occur as either rain or snow or a mixture of both. Precipitation amounts in winter are, in general, considerably less than for other seasons of the year. Snowfall in the study area is light in most years. In the area of detailed investigations (Leavenworth, Wyandotte, Johnson and Douglas Counties), snowfalls average about 20 inches per year. At the western boundary of the study area at Manhattan, snowfalls average around 18.4 inches per year. Generally, February is the month of highest snowfall and usually snow remains on the ground for only a few days. Tables II-1 and II-2 summarize precipitation data for three stations within the study area.

Table II-1

PRECIPITATION DATA SUMMARY
(Mean Inches Per Month)

Month	Leavenworth and Wyandotte Counties[1]	Manhattan[2]
January	1.11	0.80
Feburary	1.31	1.12
March	2.03	1.56
April	3.05	2.73
May	4.58	4.34
June	5.08	4.76
July	3.94	4.38
August	4.07	3.87
September	3.95	3.48
October	2.57	2.30
November	2.04	1.42
December	1.34	.088
Annual	35.07	31.64

Period of Record
[1] 1897-1960
[2] 1898-1960

Source: Soil Conservation Service. 1975. Soil Survey of Riley County and Part of Geary County, Kansas.

Soil Conservation Service. 1977. Soil Survey of Leavenworth and Wyandotte Counties, Kansas.

Table II-2

SNOWFALL DATA SUMMARY
(Mean Inches Per Month)

Month	Station		
	Bonner Springs	Lawrence	Manhattan
January	5.5	4.5	4.2
February	3.2	5.2	3.5
March	3.9	4.1	3.5
April	0.7	1.0	1.5
May	Trace	0.0	Trace
June	Trace	0.0	0.0
July	0.0	0.0	0.0
August	0.0	0.0	0.0
September	Trace	0.0	0.0
October	0.0	0.3	0.2
November	0.4	0.7	0.8
December	5.4	3.4	3.0
Annual	19.1	19.3	18.4

Source:

Weather Bureau, U.S. Department of Commerce. 1959. Climates of the States--Climatic Summary of the United States.

The annual range in temperature in the study area is fairly wide because at times heat is intense in summer and occasionally arctic air surges into the area in winter. Severe winter weather is normally experienced in December, January, and February, with January having the lowest mean daily temperature. Temperatures of 10 to 25 degrees F below zero have been recorded in November through April. July and August are ordinarily the hottest summer months. Temperatures of over 100 degrees F have been recorded from April through November. Table II-3 summarizes temperature data for three stations located in the eastern, central and western parts of the study area.

Prevailing surface wind direction and mean speed normally follow a seasonal pattern. During the winter, winds from the north and west prevail over the Kansas River Basin. During the rest of the year, winds generally are from the south or southwest. Mean velocities are usually highest in March and April and average 11 to 19 miles per hour. The highest wind velocities are usually associated with storms.

C. AIR QUALITY

The entire study area has relatively clean air, due in part to a favorable geography and climate. Active air quality control programs in the commercial dredging study area have reduced visible emissions, odors and particulates from industrial operations.

Most of the lower downstream study area in Kansas City, Kansas between I-635 and the Missouri state line does not meet primary Total Suspended Particulates (TSP) Standards (Table II-4). The area from I-635 to 3 miles west of I-635 does not meet secondary standards. The sources of these particulates include industrial facilities, construction activities and dust from agricultural activities. The relative contribution of each is unknown. Antipollution programs for industrial emissions, including coal-burning power plants, are on-going. The amount of particulates from agricultural and idle lands is unknown, but could be a significant and uncontrollable portion of the area's total particulate pollution burden. Kansas Air Pollution Emission Control Regulations stipulate that "no person shall cause or permit the handling, transport, or storage of any materials, or any other use of a premise in a manner which has been demonstrated to allow sufficient quantities of particulate matter to become airborne to cause ground level particulate concentration at the property line equal to or exceeding 2.0 mg/m^3 background concentrations for any time period aggregating more than 10 minutes during any hour.

TABLE II-3

TEMPERATURE DATA SUMMARY
(Mean Degrees F Per Month)

Month	Lawrence			Manhattan			Leavenworth and Wyandotte Counties		
	Max[1]	Min[1]	Avg[4]	Max[2]	Min[2]	Avg[4]	Max[3]	Min[3]	Avg[4]
January	39.9	20.6	31.5	39.6	18.0	30.1	39.3	19.4	30.9
February	45.8	25.1	35.8	45.4	22.4	34.3	44.0	23.1	35.0
March	54.7	32.4	44.4	55.9	30.9	43.0	55.0	32.1	43.8
April	68.3	45.4	56.4	67.7	42.6	55.5	66.8	43.8	56.0
May	77.0	55.2	65.3	76.5	52.7	64.8	76.3	54.1	65.2
June	84.8	64.2	75.4	86.5	62.8	75.6	85.7	63.6	75.4
July	89.9	68.3	80.6	92.6	67.1	81.2	90.7	68.1	80.3
August	89.1	67.1	78.8	91.5	65.7	79.6	89.6	66.7	78.5
September	81.4	58.3	70.7	83.5	57.1	70.8	81.7	58.0	70.4
October	71.4	48.2	59.8	71.4	45.0	59.3	70.9	46.6	59.7
November	55.5	35.0	44.7	55.9	31.5	43.3	55.1	33.8	44.2
December	43.3	25.2	34.9	42.9	21.6	33.2	42.7	24.1	34.3
Annual	66.9	45.2	56.5	67.5	43.1	55.9	66.5	44.5	56.1

Period of Record:
[1] 1941-1970
[2] 1898-1960
[3] 1910-1960
[4] 1931-1955

Source: Soil Conservation Service. 1975. Soil Survey of Riley County and Part of Geary County, Kansas.

Soil Conservation Service. 1977. Soil Survey of Douglas County, Kansas, 1977.

National Oceanographic and Atmospheric Administration. 1974. Climate of the States Volume II. Water Information Center, Inc.

Table II-4

NATIONAL AMBIENT AIR QUALITY STANDARDS ATTAINMENT STATUS DESIGNATION
MARCH 3, 1978
KANSAS

TSP	
Wyandotte County (Kansas City Area)	
Most of the area between I-635 and the Missouri state line	Does not meet primary standards
I-635 to three miles west	Does not meet secondary standards
Shawnee County (Topeka Area)	
Area bounded by the Kansas River on the east and south, Vail Avenue on the west and Lyman Avenue on the north	Does not meet primary standards
Remainder of Study Area	Better than national standards
SO_2	
Entire Study Area	Better than national standards
O_x	
Wyandotte and Johnson Counties (Kansas City Area)	Does not meet primary standards
Douglas County (Lawrence Area)	Does not meet primary standards
Remainder of Study Area	Cannot be classified or better than national standards
CO	
Kansas City, Kansas	
Area bounded by 6th Street on the east, Washington Street on the north, 18th Street on the west, and Barnett Street on the south	Does not meet primary standards
Remainder of Study Area	Cannot be classified or better than national standards
NO_2	
Entire Study Area	Cannot be classified or better than national standards.

Source: Federal Register, March 3, 1978.

Carbon monoxide, hydrocarbons and nitrogen oxides are the major pollutants related to motor vehicles. Of these, carbon monoxide has the highest recorded levels in the Kansas City Region in comparison with National Ambient Air Quality Standards. A special report estimating future carbon monoxide levels from motor vehicle emissions has been prepared by the Mid-America Regional Council (MARC), "Supplementary Report on Analysis of Air Pollution from Motor Vehicles for the Kansas City Metropolitan Region (KCMR) in the year 2000." This report found that although there were significant carbon monoxide "hot spots" in 1974, there will be no significant carbon monoxide pollution due to motor vehicle travel in the year 2000. This finding of decreased pollution emissions despite a projected increase in traffic is a result of antipollution devices on new automobiles.

The maximum concentration of carbon monoxide from motor vehicles was found to be the same whether all planned street and highway projects in the Long-Range Street and Highway Network of the KCMR are constructed or whether no new major projects are built. Consequently, federal action on auto emission controls will have a greater impact on the area's carbon monoxide levels than action taken at the local level.

Other air quality parameters such as sulfur dioxide and ozone generally are better than national standards or cannot be classified. Higher concentrations are expected in the easternmost portion of the study area near the KCMR.

Selected air quality data for those stations within or in close proximity to the commercial sand and gravel dredging study area are found in Tables A-1 through A-7 of Appendix A. This information represents the latest data which has been validated by the Kansas Department of Health and Environment. Generally, air quality improves from east to west within the study area. The Kansas City and Topeka areas exhibit poorer air quality in comparison with other stations found along the Kansas River.

D. NOISE

There is no noise pollution data available from federal, state or local agencies for the commercial dredging study area. Noise studies are normally done for specific projects at highly specific locations. No studies are known to exist of points close enough to the study area to be pertinent.

Acknowledging increased average noise levels in urban areas, several communities in the study area have enacted ordinances to control bothersome noise sources. Presently, Kansas City, Lawrence, Topeka, and Manhattan have such ordinances. These ordinances are directed, primarily at the isolated, unusually loud kind of noise that creates a public nuisance. The main thrust in these urban noise ordinances is road traffic, construction and other amplified noise sources including radios, stereos, and musical instruments. Bonner Springs and Wamego have no noise ordinances.

Edwardsville has enacted zoning ordinances for I-1 (Light Industrial) and I-2 (Heavy Industrial) areas which stipulate noise control. All noise is to

be controlled as much as possible and is not to exceed the noise levels present during peak daily traffic flow of adjacent roadways. Noise levels may be measured with appropriate instruments from adjacent property lines.

Except for Edwardsville, no local noise standards exist for communities occurring in the commercial sand and gravel dredging study area. Under executive order, all federal operations must comply with local noise ordinances.

The major source of urban background noise in the study area is motor vehicle traffic. The Federal Highway Administration has established noise standards for new transportation facilities in developed areas. These apply to the noise level that is exceeded 10 percent of the time during peak traffic periods. Consequently, it is heavily influenced by the presence and noise emissions of trucks and motorcycles. There are no federal standards on noise; however, should noise standards be promulgated by the Environmental Protection Agency, general noise levels in the area can be anticipated to improve.

As part of the Long-Range Transportation Plan, MARC has prepared a special analysis of noise levels from projected year 2000 traffic assuming current noise emission rates ("Supplementary Report on Noise Impact Analysis for the KCMR in Year 2000," November 1976). Construction of proposed highway projects by local and state agencies will alleviate some noise by spreading traffic out to additional facilities and shifting traffic to several circumferential limited-access facilities which have wide rights-of-way. This is particularly true in Kansas City, Kansas.

The Mining Enforcement and Safety Administration (MESA) Regulation 56.5-50 limits employee exposure to occupational noise to 90 dBA daily noise dosage per 8-hour shift (U.S. Army Corps of Engineers, 1978). Regular inspections by MESA inspectors are held to verify that compliance with their safety regulations, including noise, is occurring at all commercial sand and gravel dredging sites.

Table II-5 lists typical noise levels and human response for a variety of equipment and conditions.

E. WATER QUALITY

Long-term averages of water quality data from major rivers in Kansas yields the following general characterization: turbid streams, moderately mineralized, well-buffered, with good oxygen characteristics, low organic loading, high nutrient levels, and high bacterial levels (Kansas Department of Health and Environment (KDHE), 1978). This general characterization also applies to the Kansas River main stem.

Water quality in the Kansas River, except near cities, has been primarily influenced by nonpoint pollution sources over the last two decades. Agricultural runoff consisting of sediment, organic matter and various nutrient-rich fertilizers is by far the largest contributor to surface waters in Kansas of nutrient materials, suspended solids, dissolved

Table II-5
SOUND LEVELS AND HUMAN RESPONSE

	Noise Level	Response	Hearing Effects	Conversational Relationships
	150		CONTRIBUTION TO HEARING IMPAIRMENT BEGINS	
Carrier Deck Jet Operation	140			
	130	Painfully Loud Limit Amplified		
		Speech		
Jet Takeoff (200 feet) Discotheque Auto Horn (3 feet)	120	Maximim Vocal Effort		
Riveting Machine	110			
Jet Takeoff (2,000 feet) Dredge Garbage Truck	100			Shouting in Ear
N.Y. Subway Station		Very Annoying		
Heavy Truck (50 feet) Tugboat Pneumatic Drill (50 feet)	90	Hearing Damage (8 hours)		Shouting at 2 ft.
Alarm Clock	80	Annoying		Very Loud Conversation, 2 ft.
Freight Train (50 feet)				Loud Conversation, 2 ft.
Freeway Traffic (50 feet)	70	Telephone Use Difficult		
		Intrusive		Loud Conversation, 4 ft.
Air Conditioning Unit (20 feet)	60			
Light Auto Traffic (100 feet)	50	Quiet		Normal Conversation, 12 ft.
Living Room Bedroom Library	40			
Soft Whisper (15 feet)	30	Very Quiet		
Broadcasting Studio	20			
	10	Just Audible		
	0	Threshold of Hearing		

Source: Environmental Protection Agency, Noise Pollution: Now Hear This. Washington D.C.: GPO, 1974 Reprint.

organics, and bacterial indicator groups (KDHE, 1978)). Beneficial water uses affected to varying degrees include: impairment of quality for body contact recreation, increase of municipal and industrial water treatment costs, and intermittent effects on aquatic species propagation.

Runoff from urban areas has a variable local effect on the receiving stream. Though the quality of the runoff from urban areas is known to be poor, no recurring problems of a significant nature related to urban storm water runoff have been identified (KDHE, 1978).

At present, instream water quality is determined almost entirely by flow regime. During low flow periods, the most significant quality influence is the entrance of mineral inflow from natural sources. During high flow periods, most Kansas surface waters display their poorest quality with significant increases in biochemical oxygen demand (BOD), nutrients, bacterial levels, and turbidity from nonpoint sources. Conversely, industrial and municipal source pollution have their greatest influence during low flows when less dilution occurs.

Inadequately treated municipal and industrial waste discharges into the Kansas River increased from the 1920s through the 1940s which resulted in specific river basin pollution abatement policies being adopted. With the implementation of these policies, discharges were significantly reduced by 1960. Feedlot runoff was greatest during the 1960s, but following the implementation of an active registration and permit program in 1967, this pollution source was greatly curtailed (KDHE, 1978). Point source pollution is still the major source of water quality degradation around major municipalities. As of January 1, 1978, 111 municipal, 100 industrial, and 210 agricultural point sources occurred within the Kansas River Basin (KDHE, 1978). Further, of the large river sub-basins of the Kansas River, 140 municipal, 50 industrial, and 720 agricultural point sources were listed.

According to the KDHE (1978), Kansas streams display good oxygen characteristics with dissolved oxygen generally at or above saturation levels throughout the year. Diffusion characteristics are high because of the common channel geometry of wide, shallow streams and all streams support diverse populations of photosynthetic organisms which provide additional oxygen resources. Organic loading in the Kansas River is generally low except during periods of active runoff. Table 9 of Appendix C provides dissolved oxygen levels found in the "Fishery-Dredging" study area of the lower river (Cross and DeNoyelles, 1980). As would be expected, dissolved concentrations are generally quite high in winter, early spring, and late fall. Dissolved oxygen levels can decline during the summer months when water temperatures are higher; however, concentrations in the Kansas River were always above KDHE's minimum standard level of 5.0 mg/l.

High levels of nutrient materials, particularly phosphorus, are carried by the Kansas River. Nutrient levels are elevated during periods of runoff, but even at low flows, concentrations are considerably above currently proposed national limits. The high nutrient levels; however, do not

stimulate excessive aquatic plant growth because light penetration is limited by natural turbidity levels.

Turbidity levels in the Kansas River are quite variable and appear to be related to flow. Suspended solids, particle size analysis of suspended sediments, turbidity, total dissolved solids, pH and alkalinity measurements recorded during the "Fishery-Dredging" study of the lower river are summarized in Tables 2 through 8 of Appendix C. These data indicate that the above parameters are similar in the control and other areas of the river.

No significant concentrations of heavy metals have been found in major Kansas streams, except for iron and manganese which are common. High total iron concentrations are generally found during periods of heavy clay load; however, the iron is quickly oxidized and dissolved concentrations are generally quite low. Concentrations of various heavy metals in the Kansas River at DeSoto, Kansas, are shown in Table II-6. These concentrations can be compared with metal concentrations found in the Kansas River near river mile 25.6 on selected dates in the months of August, September, and November 1979 and January, March, April, and May of 1980 during the Fishery-Dredging Study (Table 1 of Appendix C). From the parameters common to both sets of measurements, it can be seen that metal concentrations generally fall into the range delineated by maximum and minimum concentrations in Table II-6. Both data sets depict the extreme variability of metal concentrations in the river on different dates.

Sampling to determine bottom sediment concentrations of metals in the "Fishery-Dredging" study area will also be undertaken. Results of this sampling may provide additional information concerning the concentration and availability of toxic substances in Kansas River sediments and their relationship to commercial sand and gravel dredging.

Table II-6

CONCENTRATIONS OF HEAVY METALS FOUND IN KANSAS RIVER WATER[1,2]

Parameter	No. of Samples	Concentration (ug/l) Mean	Maximum	Minimum
Total Arsenic	16	8.0	65.0	2.0
Total Cadmium[3]	15	---	10.0	0.0
Total Chromium	16	8.4	60.0	0.0
Total Cobalt[3]	16	---	50.0	0.0
Total Copper	16	18.3	70.0	4.0
Total Iron	16	8,183.8	77,000.0	450.0
Total Lead[3]	16	---	100.0	5.0
Total Manganese	16	402.5	3,200.0	60.0
Total Mercury	12	0.12	0.60	0.0
Total Selenium	16	1.06	2.0	0.0
Total Zinc	16	58.8	250.0	10.0
Total Barium	4	200.0	200.0	200.0
Total Silver	4	0.25	1.0	0.0

[1] Station located at DeSoto, Kansas, river mile 31.0

[2] Derived from data found in Water Resources Data For Kansas, United States Geological Survey, Water Years 1975-1978.

[3] Eight samples recorded as a less than value: Cadmium <10, Cobalt <50, Lead <100, therefore, no means were calculated.

Significant concentrations of pesticides have not been found in Kansas streams except for a few local incidents associated with fish kills. No pesticides have been found at standard detection levels during normal surveillance, nor during special studies of irrigation return flow (KDHE, 1978). Atrazine was the only substance detected in the water column on five dates in 1976 and 1977 during sampling by the U.S. Geological Survey at DeSoto, Kansas (1977, 1978). Its average concentration was 1.7 ug/l. Bottom sediment concentrations of these substances were not detected on three sample dates during 1975 and 1977 with a detection limit of 0.10 ug/kg (USGS 1977, 78, 79). Table II-7 lists those substances tested for in the water column and bottom sediments of the Kansas River at DeSoto, Kansas.

Table II-7

PESTICIDES TESTED FOR IN THE KANSAS RIVER AT DESOTO, KANSAS

Parameter	Water[1] Column	Bottom[2] Sediment
Aldrin	X	X
Atrazine	X	X
Chlordane	X	X
DDD	X	X
DDE	X	X
DDT	X	X
Diazinon	X	X
Dieldrin	X	X
Endrin	X	X
Ethion	X	X
Heptachlor	X	X
Heptachlor epoxide	X	X
Lindane	X	X
Malathion	X	X
Methoxychlor	X	X
Methyl parathion	X	X
Methyl trithion	X	X
Parathion	X	X
PCB		X
Silvex	X	X
Simazine		X
Toxaphene	X	X
Trithion	X	X
2,4-D	X	X
2,4,5-T	X	X

[1] *Sampled on one day in November 1975, March and November 1976, February, May, August, and November 1977, and February and May of 1978. Detection limit is 0.01 ug/l.*

[2] *Sampled on one day in November 1975, May 1977, and November 1977. Detection limit is 0.10 ug/l.*

Source: United States Geological Survey. Water Resources Data For Kansas. Report Nos. KS-76-1, KS-77-1, KS-78-1.

Sediment cores are taken three times per year and analyzed for a number of parameters, including pesticides, as part of the lower Kansas River "Fishery-Dredging" study. These data are not presently available, but may provide additional information on pesticide concentrations and their availability to aquatic organisms, and the relationship of these parameters with sand and gravel dredging.

1. LOWER KANSAS RIVER QUALITY

Increased urbanization and industrialization along the lower Kansas River in Kansas City, Kansas has dramatically influenced the river over the years. During the 1960s manufacturing in this stretch was composed of food processing industries such as slaughterhouses, rendering and meat-packing plants, dairies, and canneries. Other waste sources included oil refineries and soap and paper manufacturers all of whose discharges seriously fouled the water. Feedlot or food-processing wastes accounted for all reported fish kills in 1965 (Powers and Jacobi, 1966). However, since then, such regulations as the Federal Water Pollution Control Act of 1972 and various state laws have forced area polluters to reduce their discharge load and obtain National Pollutant Discharge Elimination System (NPDES) Permits, Kansas Water Pollution Control Permits and Kansas Certifications of Compliance.

Although considerable improvement has been seen since these regulations became effective, the lower Kansas River is still in a moderately polluted condition. Approximately 25 industrial point sources occur within the lower 16 miles of the river, in addition to 11 municipal point sources from Bonner Springs to the mouth. These sources cause excessive nutrient enrichment which can significantly affect the biotic communities of the area.

The 1978 Kansas Water Quality Inventory Report (KDHE) addresses quality trends and influences in the Kansas River over the period of 1967 to 1977. During that period, the Kansas River at Kansas City, Kansas showed significant improvement in dissolved oxygen, turbidity, and ammonia content; significant deterioration in biochemical oxygen demand, temperature, total phosphate, chloride and sulfate; and no significant change in pH and fecal coliform. Table II-8 summarizes the data from 1967-1976, and also presents unpublished data collected by the KDHE in 1977 and 1978. From these data, it is difficult to make any meaningful generalizations. No trends are apparent when comparing the 10-year average to 1977 or 1978 data. Since the data presented represent only one sample per month, they should be approached with a great deal of caution. Variation within months cannot be documented and may have a substantial impact on the biotic communities in the river.

Table II-8

WATER QUALITY DATA
KANSAS RIVER AT KANSAS CITY, KANSAS[1]
(1967-1978)

Parameter	Mean	Maximum	Minimum	
Dissolved Oxygen	8.8	13.8	1.7	1967-1976
(mg/l)	7.7	13.2	3.5	1977
	9.7	14.0	2.5	1978
Biochemical Oxygen Demand	3.9	9.3	1.0	1967-1976
(mg/l)	4.5	8.4	2.1	1977
	4.1	9.3	1.8	1978
Temperature	14.0	29.0	-2.0	1967-1976
(C°)	16.0	28.0	0.0	1977
	13.3	31.0	-1.0	1978
pH	7.9	8.5	7.3	1967-1976
	8.1	8.4	7.7	1977
	7.9	8.4	7.4	1978
Turbidity	129.0	2,800.0	7.0	1967-1976
(JTU)	27.0	90.0	10.0	1977
	176.3	500.0	6.0	1978
Fecal Coliform	1,660.0	77,000	10.0	1967-1976
(per 100 ml)	1,713.0	17,000	100.0	1977
	9,178.0	54,000	140.0	1978
Ammonia (NH_3N)	0.40	1.70	0.07	1967-1976
(mg/l)	0.33	1.00	0.11	1977
	0.45	1.10	0.11	1978
Total Phosphate (PO_4)	0.92	3.00	0.32	1967-1976
(mg/l)	1.45	2.00	0.76	1977
	0.56	1.30	0.31	1978
Chloride (CL)	71.0	211.0	5.0	1967-1976
(mg/l)	109.0	211.0	20.0	1977
	53.6	112.0	18.0	1978
Sulfate (SO_4)	91.0	176.0	14.0	1967-1976
(mg/l)	126.0	191.0	47.0	1977
	75.3	140.0	36.0	1978

[1] *Source: 1978 Kansas Water Quality Inventory Report, Kansas Department of Health and Environment supplemented with 1978 data provided by the KDHE. Samples taken at river mile 0.3 at the James Street Bridge.*

According to Regulation 28-16-28, Water Quality Criteria for Interstate and Intrastate Waters of Kansas, the Kansas River is considered Class B for water-use classification. Water in this category must be protected for the following water uses:

- Secondary contact recreation such as fishing, wading, boating or other activities where ingestion of the water is not probable.
- The preservation and propagation of desirable species of fresh warm-water aquatic biota, semi-aquatic life, waterfowl, and wildlife.
- Public water supply.
- Industrial water supply.
- Agricultural purposes.

Compared to Kansas Water Quality Standards, the lower river conditions, as reported by the KDHE, (1978), (Table II-8) are as follows:

- Dissolved oxygen shows a 1978 mean (9.7 mg/l) well above the minimum standard level of 5.0 mg/l. However, the minimum 1978 value of 2.5 indicates that the river occasionally becomes lethal to fish and other aquatic animals. This level probably results from heavy loads of industrial and municipal effluents at low flow. Dissolved oxygen is necessary to degrade organic discharges into the river, otherwise anaerobic conditions prevail and strong odors result.
- The mean value for pH (7.9) is within the acceptable range of 6.5 to 8.5 set by the State of Kansas.
- Mean ammonia levels for 1978 (0.45 mg/l) are far in excess of the Kansas standard of 0.15 mg/l. In fact, they averaged three times that limit with a maximum value approximately ten times higher. Domestic and industrial sewage effluents account for most of this excess.
- Fecal coliform counts were also far in excess of the Kansas standard of 2,000 per 100 ml, both as a maximum (54,000) and a mean value (9,178). This represents a considerable increase over 1977. A breakdown in municipal sewage treatment at Bonner Springs may account for a great deal of the increase.
- Although no Kansas standard exists for phosphates, the Environmental Protection Agency has recommended 0.1 mg/l as a standard. The mean level of phosphate for 1978 was 5.6 times the proposed standard.

Kansas State Standards are not as specific for other parameters such as turbidity, chlorides, sulfates, oil and grease, toxic substances, solids, taste and odor producing substances, and color. This precludes an evaluation of these parameters.

Considering the reduced quality of the Kansas River in the lower stretches, it appears that the harsh conditions reported above would discourage the development of a balanced aquatic ecosystem. Nonetheless, future improvements in municipal and industrial sewage treatment may reverse this assessment.

Data for selected water quality parameters in the lower Kansas River at Kansas City, Kansas are shown in Table II-8. Table II-9 lists water quality data for Kansas River stations within the entire study area (river miles 0.0 to 155.4). Site specific interim water quality data for selected commercial dredging sites obtained during the Fishery-Dredging Study of the lower Kansas River, are summarized in Table 1-9 of Appendix C.

F. BIOLOGICAL ELEMENTS

The general biological communities associated with the Kansas River that occur in the commercial dredging study area vary to some degree from local area to local area. There are, however, notable similarities in the species composition and basic nature of communities in and adjacent to the river throughout the study area. The major exception is, of course, urbanized areas. In most instances, commercial sand and gravel operations occur in urbanized areas. The following descriptions are oriented toward a discussion of the biological communities occurring in and along the lower Kansas River (river miles 0.0 to 50.0), the area of greatest dredging activity, and in the entire study area of river miles 0.0 to 153.0.

1. AQUATIC ECOSYSTEM

The aquatic ecosystem within the boundaries of the Kansas River Commercial Dredging Study Area has been exposed to numerous man-made stresses.

These stresses have brought about a general degradation of what was once a balanced aquatic system regularly exposed to the natural disturbances of large flow fluctuations. The Kansas River over most of its length has been impacted by agricultural practices within the Basin. In addition to this primary stress, other reaches of the river, particularly within urban settings, have been affected by point source pollution from industrial and municipal discharges. This is especially true of the lower Kansas River where the greatest dredging activity occurs. Although some improvement appears to be occurring as a result of recent environmental controls placed on point and nonpoint source pollution, the aquatic biota of the river still suffers from marginally tolerable water quality conditions that occur from time-to-time, especially in the Kansas City Metropolitan Region.

To adequately assess the impacts that existing commercial sand and gravel dredging and its alternatives have on the biotic communities of the Kansas River, it is essential that the current conditions are well defined. The following discussions attempt to piece together the known information on the aquatic communities of the Kansas River. Much of this information is based on interim results of the "Fishery Study to Relate the Effects of the Kansas River Commercial Sand and Gravel Dredging Industry to Fish Population Dynamics in the Lower Kansas River" directed by the University of Kansas (Cross and DeNoyelles, 1980). References to this latter data throughout the remaining sections of this report refer to the study area of Kansas River miles 9.0 to 26.0.

Table II-9

WATER QUALITY DATA
KANSAS RIVER BASIN, KANSAS

Segment & Location	Data Source	Value	Dissolved Oxygen DO mg/l	Biochemical Oxygen Demand BOD_5 mg/l	Temp.	pH	Turbidity JTU	Fecal Coliform per 100 ml	Ammonia NH_3N mg/l	Total Phosphate PO_4 mg/l	Chloride Cl mg/l	Sulfate SO_4 mg/l
Kansas River	Surveillance	Min.	6.1	2.4	0	7.7	18	400	0.12	0.71	27	53
at	Network	Max.	12.8	6.3	29.0	8.4	500	8,000	0.33	4.60	154	164
Eudora, KS	1977	Avg.	8.2	4.2	17.2	8.0	GM 72	GM 2,303	0.20	2.27	98	116
Kansas River	Surveillance	Min.	6.7	0.9	0	7.6	9	10	0.05	0.50	36	53
at	Network	Max.	14.2	12.0	29	8.7	2,200	22,000	3.00	0.19	180	152
Willard, KS	1977	Avg.	10.2	4.2	15	8.1	GM 36.2	GM 157	1.50	0.11	122	115
Kansas River	Surveillance	Min.	6.2	0.9	0	7.9	10	100	0.11	0.52	48	56
at	Network	Max.	13.6	10.0	27	8.5	1,400	23,000	0.26	0.63	310	267
Manhattan, KS	1977	Avg.	9.9	3.5	13	8.1	GM 33.4	GM 7,280	0.17	0.56	190	178

Source: Kansas Department of Health and Environment, 1978.
1978 Kansas Water Quality Inventory Report.

Specific sampling locations and transects are shown in Figures F-1 and F-2 in Appendix F and in Table C-1 of Appendix C.

a. Physical Condition

The geomorphology of the Kansas River has been summarized in Section II.A of this report. The following are some of the major physical features of the Kansas River as it relates to the biological features of the commercial sand and gravel dredging study area, especially the lower 50 miles.

The Kansas River, which originates at the confluence of the Smoky Hill and Republican rivers near Fort Riley, Kansas, and flows 170 miles eastward through northeast Kansas to the Missouri River, is a large, turbid, 6th order, meandering alluvial stream. Because most of its major tributaries have been dammed, the river is under the potential influence of impoundment for most of its length. The impoundments reduce the fluctuations in yearly water levels.

The channel of the Kansas River throughout its length is shallow and braided at low flow and composed primarily of sand substrate with frequent mud bars and gravel riffles (Reimer, 1975); while the bed of its tributaries ranges from rocky, mud, hard clay, silt, gravel to sand mixtures such as sand and silt (Kansas Department of Health and Environment (KDHE, 1978). The more varied the substrate, the more diverse the fauna is expected to be. Although the banks of the Kansas River exhibit a good diversity of organisms, the shifting sands combined with sustained periods of moderately swift velocity severely limit the number of benthic species present (KDHE, 1978).

During periods of high flow, agricultural runoff and resuspension of silt and clay deposits result in high turbidity. Light penetration and subsequent photosynthetic production are therefore decreased. During these high flow-high sediment periods, benthic producer and consumer communities are scoured from shorelines and shallow water areas and are flushed downstream due to the abrasive nature of the sediment-laden current (Marzolf, 1979).

The lower Kansas River from the Turner Bridge to the mouth is different from the upper reach in that its bed contains a larger percentage of silts and clays, is influenced by backflow of the Missouri River, is heavily channelized near its mouth, and has suffered from significant industrial and municipal pollution. In this lower reach of the river, only two commercial sand and gravel operations presently exist.

Sediment is deposited in the lower river above the mouth and accumulates in muddy deposits throughout the lower several miles. These deposits are washed out during high flow periods. Little bedload reaches the lower Kansas River due to rock and gravel obstructions upstream. Since the Missouri River bed is lower than the Kansas River, as it passes through Kansas City, a significant

drop is seen in the Kansas River bed just before it enters the Missouri. This is caused from the concentration of flows and the man-made alignment of the channel at the confluence. This lower stretch of the Kansas River is considered by the Kansas Department of Health and Environment as unsuitable habitat for aquatic life due to channelization of the riverbed and its varying water quality (KDHE, 1978).

Kansas River discharge at DeSoto, Kansas (prior to October 1973 gage was at Bonner Springs) fluctuates around a mean of 6,894 cfs (United States Geological Survey, 1979). Maximum and minimum discharges are 510,000 cfs (July 13, 1951) and 160 cfs (October 11, 1956), respectively (period of record July 1917 - September 1978). The average gradient of the river in the lower stretch is 1.7 feet per mile. The average stream gradient for the entire river is 1.9 feet per mile. The average minimum depth of the channel ranges from around 20 feet near the mouth (river mile 0.5) to only 2-3 feet at river mile 9.0.

The temperature of the water fluctuates seasonally, averaging about 14 degrees C with a range of 31 degrees C to 2.0 degrees C. During the winter months when water temperatures are at or near freezing, ice forms and can occasionally freeze over the surface of the river.

Within urban areas, particularly Manhattan, Topeka, Lawrence, and Kansas City, the Kansas River is lined by numerous rip-rap and levee systems.

The principal tributaries of the mainstem Kansas River are the Big Blue River (River mile 148), Vermillion Creek (River mile 121.5), Soldier Creek (River mile 80.5), Delaware River (River mile 64.7), Wakarusa River (River mile 42.0) and Stranger Creek (River mile 35).

In the study area of detailed investigation (river miles 0-50) 15 tributaries enter the Kansas River. The biological character of these streams is discussed later in this section.

b. Plankton

Few studies of Kansas River phytoplankton, periphyton, or zooplankton communities have been conducted to date. Much of the following discussion is based on old and, at times, sketchy data. Recent changes in water quality have likely altered the planktonic community, but consequences are difficult to predict.

Macrophytes are not present in the Kansas River (Taylor, 1976). The photosynthetic producer community is composed of planktonic and benthic algae. These tiny plants are the primary producers in many aquatic ecosystems and represent the first link in the aquatic food chain. They provide food for many invertebrates and zooplankton as well as some fishes. Powers (1969) has listed 225 species for the Kansas River System, which includes all tributaries. These species

are listed in Table B-1 of Appendix B. Although the list is not exhaustive, it does provide a representative sample of the plankton that may occur in the Kansas River. Species collected during the Fishery-Dredging Study of the lower Kansas River (Cross and DeNoyelles, 1980) are noted in Tables 11 and 12 of Appendix C.

Taylor (1976) has characterized the trophic nature of the upper Kansas River. Photosynthetic production in the river near Manhattan was intermediate compared to other lotic systems. Low rates of production in the river reflected the absence of macrophytes, the mobile character of the substrate, and the relatively greater levels of turbidity. The wide range between minimum and maximum production rates is an indication of the short-term variability of photosynthetic production and respiration in the Kansas River.

Both benthic and planktonic production rates can be substantial reflecting high nutrient levels in the river yet under high flow regimes primary production is reduced.

This variability in algae production rates also occurs in the lower river. Chlorophyll a concentrations (a measure of algal biomass) were quite variable during May, 1979 through August, 1980 sampling in the Fishery-Dredging study area (Table 10 of Appendix C). This variation is attributed to a change in river conditions during the 48-hour sampling period as well as seasonal factors. The data also point out the relative importance of periphyton as an energy input to the Kansas River ecosystem. Though reservoirs, tributaries, and backwater areas are potential sources of phytoplankton in the Kansas River, the stream phytoplankton is primarily derived from the benthos. The instability of the sand substrate provides a highly dynamic environment for the establishment and growth of benthic algae; at times the photosynthesis of organic matter in the river occurs on the substrate and at times the cells break free and the synthesis takes place as they are drifting free in the current of the river. In the absence of high turbidity significant primary production occurs along some of the convex banks where the slower, shallower waters containing suitable substrates are found.

Algae communities can be good indicators of water quality. In reaches of streams that have optimum nutrient conditions, such as areas downstream from sewage outfalls, algae populations proliferate. However, if wastes discharged are toxic, a suppression of algae populations can result (Powers, 1966). Certain species of algae; notably, centric diatoms, flagellates, and blue-green algae favor highly enriched waters and exhibit huge populations in these conditions. Therefore, water which is influenced by municipal or industrial effluent and rich in organic and nutrient matter should be limited to only a few species but contain large populations of those species (Hynes, 1972). This situation has been seen in the lower Kansas River. Powers and Jacobi (1966) found the predominant phytoplankton genera during summer sampling in 1965 at 10 stations

from the Turner Bridge to the mouth to be indicative of a heavily polluted river. The predominant genera were centric diatoms, Cyclotella and Stephanodiscus; pennate diatoms, Nitzchia; one green alga, Ankistrodesmus; and an unidentified flagellate. The density of total organisms averaged 31,777 phytoplankton per milliliter.

In October, a reduction in the density of phytoplankton and a slight change in the genera collected was seen. Although Cyclotella and Stephanodiscus were still present, Nitzchia was absent from the sample. A different genus of green algae and a new flagellate, Actinastrum and Chlamydomonas, respectively, were collected. Phytoplankton density averaged 28,727 per milliliter.

The relative abundance of Cyclotella and Stephanodiscus was evidence of the high level of pollution present there. Both are considered pollution tolerant genera (Cairns, Lanza and Parker, 1972), and are not uncommon in both the Kansas and Missouri rivers.

A study in December, 1970, at five points along the lower Kansas River by Army Corps of Engineer's personnel indicated a much-reduced phytoplankton density, varying from 920 to 3,040 per milliliter. The predominant species were diatoms, with blue-green algae, green algae and flagellates also present. Genera were not described (U.S. Army Corps of Engineers, 1971).

Because of the considerable mixing of lower Kansas River water with that of the Missouri River, most species of plankton that occur in one will occur in the other.

Much of the above information was collected approximately 15 years ago. Pollution abatement policies adopted in the late 1960s and early 1970s may have resulted in some improvement in the water quality of the lower Kansas River since the mid-60s. This is borne out by plankton sampling data obtained during the lower Kansas River Fishery-Dredging Study (Cross and DeNoyelles, 1980). These data indicate that a more-diverse array of algae species presently occurs in the lower river (Table 11 of Appendix C). The structure of the phytoplankton community in the Fishery-Dredging study area is variable throughout the study reach. Reservoir discharges and seasonal factors are components of this variability. Summer dominance of the phytoplankton community by a number of green algae (Chlorophyta) occurs. Dominant genera include Ankistrodesmus, Coelastrum, Cyclotella, Dictyosphaerium, Pediastrum, Scenedesmus, Crucigenia and Actinastrum. The dinoflagellate, Dinoflagellate and diatom, Melosira also occurred as dominant species. Summer densities of phytoplankton in 1979 ranged from 2,773 to 8,565 cells per milliliter in June and August sampling. During June and August of 1980, the density ranged from 706 to 5,615 cells per milliliter. Sampling during March of 1980 yielded the highest density of 9,751 cells per milliliter.

Although no specific studies have addressed the zooplankton communities of the Kansas River, their numbers and densities are expected to be low. Powers and Jacobi (1966) reported only the presence of some bryozoans during their detailed study. Some data from the Missouri River exists (U.S. Army Corps of Engineers, 1976a), but even there only four species of unidentified rotifers and two species of crustaceans (a copepod, Senecella calanoides and a cladoceran, Bosmina longivostris) were reported.

Zooplankton sampling data collected from June of 1979 through August of 1980 during the "Lower Kansas River Fishery-Dredging Study" indicates a greater diversity of species in the river above Turner Bridge (Table 13 of Appendix C). The zooplankton community is dominated by copepods, however, cladocerans such as Daphnia and Bosmina are also relatively important.

Zooplankton require slow or still water to feed and reproduce. Tributary impoundments may be sources of zooplankton in the Kansas River; however, large river habitat generally is not suitable for zooplankton establishment. The considerable variability seen in the structure of the zooplankton community in the study area may be a result of upstream reservoir discharge.

c. Macroinvertebrates

Benthic data from 1966 (Powers and Jacobi) collected below river mile 10 on the Kansas River indicated that only 12 different kinds of macroinvertebrates were present during summer and fall sampling. The predominant organisms collected were sludgeworms (Tubificidae), which comprised 99 percent of the total benthos.

Other organisms present included: planaria (Dugesia sp.), snails (Physa sp.), caddisfly larvae (Hydropsyche sp.), damselfly nymphs (Hyponeura sp.), a bryozoan, water beetles (Stenelmis sp.), dipterans (Culicoides sp. and Chaoborus sp.), and two mayflies (Hexagenia sp. and Heptagenia sp.). Although a total of 12 species were collected, never were more than three collected at any one sampling station. The types of organisms collected point out the poor condition of the river at the time. Sludgeworms and bloodworms are considered pollution tolerant organisms. The mayflies observed belong to the Heptageniidae which are typically ubiquitious and well adapted to low-oxygen conditions.

Organism density averaged 1,035 per sq ft during the summer, increasing to over 5,000 per sq ft during the fall. Benthic populations are typically lower in summer as a result of scouring and flushing caused by spring rains. Higher sludgeworm densities were found near the mouth, where continuous buildup of organic matter occurred. Powers described the river below mile 3.6 as "grossly polluted." Indeed, the exceedingly low diversity of organisms reported indicates that habitat diversity was severly limited and water quality very poor.

The U.S. Army Corps of Engineers (1971), recorded a benthos consisting almost entirely of sludgeworms from river miles 0.1 to 7.0. Only one other organism, a dragonfly was collected. Densities of sludgeworms ranged from 1,005 to 13,768 per sq ft. The sludgeworms were reported to be abundant in the sludge banks and in areas where silt was deposited.

More recent data (1976-1979) collected by the Kansas Department of Health and Environment (KDHE) at three locations from Turner Bridge (mile 9.3) to the mouth indicate the presence of 39 types of invertebrates, many indicative of cleaner water conditions.

Before the river enters the Kansas City area, the benthic fauna is considerably improved. Sampling as recent as 1975 near Lawrence (Pearson et al., 1977) yielded a more clean-water benthos. Mayflies, stoneflies, and caddis flies which require cleaner, more oxygenated waters were common. The caddis flies Hydropsyche frisoni and H. orris accounted for approximately 55 percent of the total number collected.

The KDHE conducts a minimum amount of sampling along the Kansas River (Gilliland, personal communication, 1980). Data collected in 1975 indicated only four species present near the mouth; a mayfly (Stenonema), a water beetle (Dineutus), and two unidentified annelids. By comparison, samples taken from Bonner Springs upstream yielded a more diverse benthic fauna including stoneflies and several other species.

Sampling during the "Fishery-Dredging Study" of the lower Kansas River (river miles 24.0 to 12.0) by University of Kansas investigators indicates a healthy diversity of benthic and drift macroinvertebrates (Table 15 of Appendix C). The largest group represented was the Insecta which contained 8 orders, 24 families, and greater than 30 genera. Two species collected during this study and previously unreported for the Kansas River were Corbicula, the Asian clam and the mayfly, Homeoneuria.

Preliminary macroinvertebrate sampling data are summarized in Table 14 of Appendix C. From these data, it can be seen that there is an irregular tendency for an increase in the benthic macroinvertebrate taxa and their densities downstream from the control transects. The differences in the benthos probably reflects the differences in habitat available in this section of the river. The varying substrate types (gravel, sand, silt), depths, and current in this reach, result in an apparent increase in the diversity and density of benthic macroinvertebrates. This is in contrast to the predominate habitat type which characterizes the Kansas River throughout most of its length, a wide, shallow, sandy channel.

Whether these new data from KDHE and the Fishery-Dredging Study are indicative of a significant trend cannot be determined absolutely.

Since identifications are only to the level of genus, legitimate conclusions about the water quality conditions of the river based on the macrionvertebrates present are difficult to make. Many genera contain both pollution tolerant and pollution intolerant species. An improvement in the water quality and habitat diversity of the lower river would be expected to result in increased diversity and productivity of the macroinvertebrate fauna. This situation appears to have occurred at least above the Turner Bridge.

Regardless of water quality improvement in the river, it is known that the shifting sand substrate of the river throughout most of its length is a major limiting factor to benthic macroinvertebrate diversity and density. Benthic macroinvertebrate fauna known to be present in the Kansas River throughout its length are summarized in Table B-2 of Appendix B.

d. Fish

Although an extensive number of fish species have been reported as occuring in the Kansas River, Table B-3 of Appendix B, the existing environmental conditions of the lower eight miles of the river have effectively separated the commercial sand and gravel dredging study area into two distinct areas as far as fishery resources are concerned. The lower diversity of the fish population in the lower eight miles of the river reflects the moderate pollution load and high turbidity of the reach. Turbidity is generally higher in the lower river since most of the runoff, which courses over steeper and more erodable soils, occurs in the lower river (see Subsection II.A.3.b). At present, carp (*Cyprinus carpio*), river carpsucker (*Carpiodes carpio*), channel catfish (*Ictalurus punctatus*), white bass (*Morone chrysops*) and white crappie (*Pomoxis annularis*) occur in the lower nine miles of the river with many more species that pass through only to seek refuge up or downstream (Burns & McDonnell, 1979). The presence of those species mentioned above is indicative of considerable improvement over conditions reported earlier in the 1970s when only poor quality carp existed there. Recent sampling data collected immediately below the Turner Bridge (river mile 9.3) (Cross and DeNoyelles, 1980) also demonstrates this general improvement. Species collected in this area included a number of game fishes such as the channel catfish, bluegill (*Lepomis macrochirus*), largemouth bass (*Micropterus salmoides*), white crappie, white bass, freshwater drum (*Aplodinotus grunniens*), flathead catfish (*Pylodictis olivaris*), green sunfish (*Lepomis cyanellus*), black crappie (*Pomoxis migromaculatus*), and sauger (*Stizostedion canadense*), (Tables 16-18 of Appendix C).

The fish population of the remaining and greatest portion of the study area is (up to river mile 153) characterized by species typical of large turbid rivers. These species are of the rough-fish complex and include buffaloes (*Ictiobus* spp.), carp, carpsucker, gars (*Lepisosteus* spp.) and drum. Channel catfish and flathead catfish are common game fishes. In addition, gizzard shad (*Dorosoma*

cepedianum) and various minnows (Notropis spp., Hybopsis spp.) are abundant forage species.

Within the "Fishery-Dredging" study area (river miles 25.6-9.0) 48 species have been collected during the period May 1979 - August 1980 (Table 16 of Appendix C). Seining data resulted in a numerical dominance of three species (85.8 percent of the total), the red shiner (Notropis lutrensis), sand shiner (Notropis stramineus) and river carpsucker (Carpiodes carpio) (Table II-10). The numerical dominance of these species is expected to occur throughout the length of the Kansas River. Channel catfish were the only game fish species that made up greater than 2.0 percent of the total number collected by seining.

Conversely, the three dominant species collected by electrofishing and trammel netting were the gizzard shad, carp, and river carpsucker (Table II-11). These species accounted for 68 percent of the total number captured. Channel catfish, shortnose gar (Lepisosterus platostomus), flathead catfish, white bass, white crappie, and freshwater drum each accounted for greater than 1.0 percent of the total and collectively comprised 24.8 percent of the total number of fish captured.

Spawning and nursery areas in the Kansas River and its tributaries influence the diversity and standing crop of fishes present in the river. These areas include shallow slackwater areas and riffles both of which provide food items and cover. Cavities in the bank and hollow logs also provide nest sites especially for the catfishes. Cyprinid and catostomid fishes, adapted to large, turbid rivers generally have less specific spawning requirements. Centrarchids prefer more lentic conditions for reproduction and some species require gravel in the streambed.

Throughout most of the length of the Kansas River, cover may be limiting factor to fish density. The constantly shifting sand of the riverbed has a marked influence on habitat diversity in the river. This observation is borne out by interim results of the Fishery-Dredging Project of the lower river (Cross and DeNoyelles, 1980). Preliminary indications are that there is a general tendency toward increased fish species diversity in the downstream direction of the Fishery-Dredging Study area. This tendency is presumably linked to different habitat conditions in the areas of dredging activity as well as seasonal factors (see Tables 19 and 20 of Appendix C). Density measures, expressed as numbers or weights of fish per unit area (m^2) in the seining samples do not differ consistently among sites in the study area.

Though cover, among other things, may be a limiting factor to fish populations in the Kansas River, standing crop data (lbs/acre) compiled by the Kansas Fish and Game Commission (1979) is not excessively low with an average crop of 258.4 lbs/acre.

Table II-10

NUMBER AND PERCENTAGE OF FISH SPECIES CAPTURED BY SEINING IN THE LOWER KANSAS RIVER, FISHERY-DREDGING PROJECT, MAY 1979 - AUGUST 1980[1]

Species	Number	Percentage of Total
Shovelnose Sturgeon	1	<0.1
Shortnose Gar	19	<0.1
Longnose Gar	15	<0.1
Gizzard Shad	1,366	4.0
Goldeye	15	<0.1
Carp	23	<0.1
Golden Shiner	10	<0.1
Creek Chub	21	<0.1
Silver Chub	296	0.9
Speckled Chub	90	0.3
Sturgeon Chub	3	<0.1
Suckermouth Minnow	26	<0.1
Emerald Shiner	549	1.6
Redfin Shiner	13	<0.1
River Shiner	4	<0.1
Red Shiner	17,488	51.8
Sand Shiner	6,559	19.4
Plains Minnow	4	<0.1
Western Silvery Minnow	13	<0.1
Fathead Minnow	93	0.3
Bullhead Minnow	224	0.7
Bluntnose Minnow	218	0.6
Stoneroller Minnow	33	0.1
Bigmouth Buffalo	3	<0.1
Smallmouth Buffalo	3	<0.1
Carpsucker	4,912	14.6
Shorthead Redhorse	10	<0.1
White Sucker	2	<0.1
Black Bullhead	2	<0.1
Channel Catfish	677	2.0
Flathead Catfish	2	<0.1
Stonecat	29	<0.1
Slender Madtom	1	<0.1
White Bass	183	0.5
Largemouth Bass	46	0.1
Green Sunfish	36	0.1
Bluegill Sunfish	201	0.6
Orange-spotted Sunfish	18	<0.1
White Crappie	210	0.6
Black Crappie	10	<0.1
Sauger	7	<0.1
Walleye	1	<0.1
Orange-throated Darter	8	<0.1
Freshwater Drum	305	0.9
Longear Sunfish	1	<0.1
Skipjack Herring	2	<0.1
Total	33,752	100.0

[1] *Study area approximately river miles 25.6–9.0.*

Source: Preliminary data obtained from Cross F.B. and F.J. DeNoyelles, 1980, Principal Investigators for Fishery-Dredging Project of the lower Kansas River, prepared for U.S. Army Corps of Engineers, Kansas City District.

Table II-11

NUMBER AND PERCENTAGE OF FISH SPECIES CAPTURED BY ELECTROFISHING AND TRAMMEL NETTING IN THE LOWER KANSAS RIVER, FISHERY-DREDGING PROJECT, JULY 1979 - AUGUST 1980[1]

Species	Number	Percentage of Total
Shovelnose Sturgeon	9	0.8
Longnose Gar	10	0.9
Shortnose Gar	26	2.3
Gizzard Shad	494	43.2
Skipjack Herring	2	0.2
Goldeye	7	0.6
Carp	124	10.8
Silver Chub	2	0.2
Red Shiner	5	0.4
Sand Shiner	6	0.5
Bullhead Minnow	2	0.2
Blue Sucker	1	0.09
Bigmouth Buffalo	2	0.2
Smallmouth Buffalo	1	0.09
River Carpsucker	160	14.0
Channel Catfish	47	4.1
Flathead Catfish	22	1.9
White Bass	31	2.7
Green Sunfish	3	0.3
Bluegill	10	0.9
White Crappie	52	4.5
Black Crappie	8	0.7
Sauger	9	0.8
Freshwater Drum	106	9.3
Largemouth Bass	3	0.3
Shorthead Redhorse	1	0.09
Total	1,143	100.0

[1] *Study area approximately river miles 25.6–9.0.*

Source: Preliminary data obtained from Cross F.B. and F.J. DeNoyelles, 1980. Principal Investigators for Fishery–Dredging Project of the lower Kansas River, prepared for U.S. Army Corps of Engineers, Kansas City District.

Unique and Distinctive Species

The Kansas and Missouri rivers have the most significant populations of shovelnose sturgeon (Scaphirhynchus platorynchus) in Kansas. Specimens have been reported from the Big Blue, Republican and Arkansas rivers, but only rarely (Cross, 1967). Blue catfish (Ictalurus furcatus) are inhabitants of the Missouri River and occur occasionally in the lower Kansas River up to the low-head dam at Lawrence (river mile 51.8). Only the lower Marais des Cygnes River also harbors significant populations of this species in the state. The paddlefish (Polyodon spathula) occurs in low numbers in the Kansas River from Lawrence to Kansas City. The Missouri, Neosho, and Marais des Cygnes River also harbor populations of this species in Kansas. The sauger (Stizostedion canadense) is mainly a seasonal resident of the Kansas River during the winter months and migrates as far upstream as the dam at Lawrence. Again, significant populations in the state are relegated to the Missouri and Kansas rivers.

Changes and Trends

There is a paucity of data documenting changes and trends in the relative abundance and species composition of fishes in the Kansas River and its major tributaries. However, some general statements can be made about recent alterations in the abundance and species composition of fishes in the Basin.

Introductions of nonnative fishes in the reservoirs, lakes, and ponds of the basin in the not too distant past may result in occurrences of the striped bass (Morone saxatilis), smallmouth bass (Micropterus dolomieu), and grass carp (Ctenopharyngodon idella) in the Kansas River and its tributaries.

The blue catfish was once common in the Kansas River according to historical records, but rather rare since then. Recently, this species has been taken by fishermen below the low-head dam at Lawrence. Improved water quality in the lower river and stabilized flow regimes resulting from basin reservoir releases may now allow upstream migration of this species from the Missouri River. Until recently, only historical records of the occurrence of blue suckers in the lower Kansas River existed. Cross (1967) felt that changes in the physical character of the lower channel may have caused the decline of blue sucker numbers in the river after 1900. Specimens have since been collected in the river below Lawrence, with one individual captured to date during the "Fishery-Dredging" Study. Shortnose gar appear to be more abundant than in the past in the mainstream and young of the year sauger have been collected during 1979 below the dam at Lawrence, suggesting reproduction of this species in the river (Cross, 1980).

Significance

The commercial sand and gravel dredging study area has the potential to support a sizeable sport fishery. The Kansas River has

fair-to-good angling potential for channel catfish, freshwater drum, carp, and flathead catfish. According to Kansas Fish and Game Commission data (1977) the Kansas River is estimated to have approximately 29,909 man-days of angler use per year. Angler usage of the river is summarized in Table II-12. The figure for Wyandotte County is up from man-days estimated in earlier years.

Table II-12

ANGLER USAGE OF THE KANSAS RIVER

County	Angler Days/Year
Wyandotte	6,663
Johnson	468
Leavenworth	1,380
Douglas	2,568
Jefferson	NA*
Shawnee	11,640
Pottawatomie	1,812
Wabausunsee	1,282
Riley	1,364
Geary	732

*NA - Not Available

Source:

Kansas Fish and Game Commission. 1977.
Kansas River Basin, Kansas-Preliminary Stream Survey.

Lower Kansas River Tributaries

Due to concern about possible effects of commercial sand and gravel dredging on the tributaries of the Kansas River, those streams which empty into the lower 50 miles of the mainstream were examined. These tributaries, their location, sport fishing potential, and limiting factors are listed in Table II-13.

Agricultural runoff is the primary limiting factor to aquatic biosupport in most of these lower tributaries except for those streams which empty into the river in the lower 12 miles. This area is extensively impacted by urbanization and industry.

Fish species expected to occur in lower river tributaries include carp, green sunfish, river carpsucker, channel catfish, largemouth bass, and bullhead (*Ictalurus* spp.). A number of minnow (Cyprinidae) and sucker (Catostomidae) species may occur as well. Larger tributares of the lower Kansas River such as Stranger Creek and the Wakarusa River are expected to harbor many of the same species listed for the Kansas River at least in their lower reaches.

Table II-13

TRIBUTARIES OF THE LOWER KANSAS RIVER
RIVER MILES 0 to 50

Stream	Location of Confluence (Kansas River Mile)	Man-days Fishing/Year	Fishable Miles	Limiting Factors to Aquatic Biosupport
Turkey Creek	3.25	0	0.0	Urbanization and industry
Muncie Creek	8.5	0	0.4	Urbanization and industry
Mill Creek	11.7	0	0.0	Urbanization and industry
Little Turkey Creek	13.5	0	0.4	Agricultural runoff
Mill Creek	16.0	461	8.1	Agricultural runoff, municipal and industrial effluents
Mission Creek	18.0	0	0.4	Agricultural runoff
West Mission Creek	20.3	0	0.0	Urban runoff
Wolf Creek	21.4	25	1.1	Agricultural runoff
Little Kaw Creek	22.2	0	0.0	Agricultural runoff
Cedar Creek	26.5	54	9.2	Agricultural runoff
Kill Creek	30.6	33	8.4	Agricultural runoff
Stranger Creek	34.8	9,100	66.2	Channnel clearing[a], agricultural runoff
Captains Creek	36.9	25	11.8	Agricultural runoff
Wakarusa River	41.7	3,100	54.8	Agricultural runoff, bank erosion
Mud Creek	47.0	0	0.8	Agricultural runoff, channelization

Source: *Kansas Fish and Game Commission, 1977.*
Kansas River Basin — Preliminary Stream Survey.

[a] *Channelization is listed as a limiting factor in source document above, however, the Corps of Engineers indicates that clearing of the stream channel up to the high bank limits occurred from the mouth to mile 50 rather than channelization (straightening of the channel). (1981 Project Maps, KCD, COE, ENGCW-0-15.)*

Fishing pressure on these streams is generally light except for the two larger streams - Stranger Creek and the Wakarusa River. This may be due in part to limited public access to lower river tributaries.

2. TERRESTRIAL ECOSYSTEMS

Terrestrial ecosystems currently existing in the study area have been and continue to be greatly altered from their natural state by the activities of man. Primary disrupting activities include urbanization and agriculture. The shifting nature of the river channel and its islands and bars in addition to occasional flooding of land adjacent to the river act as a natural disrupting force on terrestrial ecosystems as well.

In general, two types of terrestrial ecosystems occur in the commercial dredging study area. These are urban-industrial and floodplain ecosystems. Floodplain ecosystems are defined as those systems encompassing cropland, riparian forest, grassland, and wetland ecological zones and their associated interfaces. While the above breakdown of ecosystems within the study area is an oversimplification, it is an accurate portrayal of conditions along the Kansas River and a valuable tool for analysis purposes.

a. Urban-Industrial Ecosystem

The cities of Manhattan, Topeka, Lawrence and Kansas City, and numerous smaller municipalities are located on or near the Kansas River in the study area. Urbanization and its effects on the terrestrial ecosystem of the Kansas River is greatest in the cities of Topeka and Kansas City.

In the study area of detailed investigation (lower 50 miles) a heavily industrial setting exists from the mouth of the Kansas River up to the Turner Bridge in Kansas City, Kansas at river mile 9.3. River mile 9.3 to Bonner Springs (river mile 21.0) is also impacted by urbanization, though less so than the lower nine miles.

Approximately five miles (river miles 50.0 to 55.0) of the river and its banks are influenced by urbanization as it passes through Lawrence. Industrial and urban areas of Topeka are found along the river from roughly river miles 76.0 to 89.0. This reach of the river is the second most urbanized setting through which the river passes. The river is also impacted by urbanization in Manhattan (river miles 147 to 150) and Fort Riley and Junction City which lie beyond the western terminus of the study area.

Flood-control levees form a partial barrier that divides portions of the study area in Kansas City, Lawrence, Topeka, and Manhattan into two basic types of terrestrial ecosystems within urban areas along the river: riverbank ecosystems which occur on the river side of the levees, and ecosystems characteristic of urban-industrial areas which occur on the land side of the flood-control levees.

Riverside ecosystems within the primary urban settings of the study area (Kansas City, Topeka, Lawrence, and Manhattan) are generally characterized by narrow bands of terrestrial vegetation on the river's edge rarely exceeding 100 feet in width. In many instances, this vegetation is confined to the bottom slope of existing levees that abut the riverbank. A surface cover of grasses and forbs characteristic of recently disturbed areas is found in areas of no streambank tree growth. Common weedy grasses found here include Canadian wild rye (Elymus canadensis), smooth brome (Bromus inermis), fall panicum (Panicum dichotomiflorum), Johnson grass (Sorghum halepense), sandbur (Cenchrus longispinus) and switchgrass (Panicum virgatum), in addition to sedges (Carex spp.). Weedy annuals such as horseweed (Conyza canadensis), yellow sweet clover (Melilotus officinalis), prickly lettuce (Lactuca serriola), mullen (Verbascum thapsus) and others also provide groundcover. Cocklebur (Xanthium pennsylvanicum) and smartweed (Polygonum sp.) are also generally abundant.

An early successional stage of small willows (Salix spp.) and cottonwood (Populus deltoides) trees, border the riverbank throughout many of these areas. However, mature trees can be found existing in narrow stands along the Kansas River in areas unsuitable for industrial development. Poison ivy (Rhus radicans), Virginia creeper (Parthenocissus guinguefolia), and riverbank grape (Vitis riparia) are common constituents of understory where understory can be discerned. Small willows, hackberry (Celtis occidentalis), and mulberry (Morus rubra) are also found as understory trees. Other trees appearing in the riparian and floodplain timber are elderberry (Sambucus canadensis), sycamore (Platanus occidentalis), and smooth sumac (Rhus glabra). In urbanized areas of the western study reach honey locust (Gleditsia tricanthos) and eastern red cedar (Juniperus virginiana) may be found.

Past and present disturbances to vegetative communities are apparent at all commercial sand and gravel dredging sites. Invading plant species comprise a large portion of the existing flora. Plant communities consist of small to medium sized cottonwoods and willows, weedy herbaceous annuals such as giant ragweed (Ambrosia trifida), sunflower (Helianthus sp.), and common broomweed (Gutierrezia dracunculoides) and a mixture of weedy grasses such as foxtails (Setaria spp.), switchgrass, sandbur, Johnson grass and fall panicum. Cocklebur and smartweed are also usually abundant. Xeric-waste areas exist on the riverbank proper and mesic zones occur on the slope of the bank. The vegetation of all these areas is characterized by a conglomeration of invading plant species with no real structural formation. This situation is also seen at two abandoned dredge sites, Lawrence Sand Co., (river mile 51.6) and Victory Sand Co. No. 2 (river mile 90.0) near Topeka with these sites characteristic of previously disturbed areas. Small sand piles and sparse ground cover are currently found at these sites.

Wildlife habitat is limited in quality and quantity in urbanized portions of the study area and is significantly influenced by the disrupting factors previously mentioned in this section. The presence of vegetative communities that provide suitable cover, food, diversity of community types, etc., necessary for the establishment and survival of many wildlife species is lacking in general from these areas as a whole, and in particular from the Kansas City and Topeka Metropolitan areas. Some wildlife species such as beaver (Castor canadensis), muskrat (Ondatra zibethicus), raccoon (Procyon lotor), striped skunk (Mephitis mephitis), and various songbird species are known to occur in these areas. Undoubtedly, various reptilian and amphibian species can be found in these areas also. The presence of the woody vegetative communities described above provides habitat for species in these portions of the study area.

The diversity and density of plant and animal species in the urban-industrial areas that border the Kansas River in the study area are quite reduced as a result of man's development of the area. Vegetation in these areas in characterized by clipped grass, scattered shrubs and ornamental trees. In more intensely developed areas, vegetation is completely lacking. Pigeons (Columba livia), English sparrows (Passer domesticus domesticus), songbirds, cottontail rabbits (Sylvilagus floridanus), Norway rats (Rattus norvegicus) and other rodents are common in such areas (U.S. Army Corps of Engineers, 1975a).

b. Floodplain Ecosystem

The remaining and greatest portion of the terrestrial ecosystem occurring along the Kansas River is found in the floodplain ecosystem existing outside of urban areas. Unlike the urban-industrial ecosystem previously described, the floodplain ecosystem of the commercial dredging study area is impacted primarily by agricultural practices. Land area occupied by natural vegetation has been greatly reduced by a number of factors. Primary among these factors is the clearing of land for agricultural usage (Saunders, 1980).

The plant communities occurring in this system along the Kansas River have been described by Kuchler (1974) as floodplain forest and savannah. This natural vegetation type is composed of medium to tall broadleaf deciduous forest often with dense undergrowth and many lianas. Kuchler also mentions that freshwater marshes with grass communities occasionally interrupt this deciduous forest growth.

There are currently three major vegetative community types in the study area. Cropland, deciduous forest, and areas dominated by grasses and forbs.

Bottomlands adjacent to the river have two generally distinct elevation levels: (1) the first bottom, next to the stream which is subject to periodic inundation, sometimes more than once a year; and (2) the higher terraces above the first bottom that are less frequently inundated. The higher terraces have been cleared of trees and are currently used for agricultural purposes (Bellah and Hulbert, 1974).

Land used for agricultural purposes in the study area is primarily used as cropland. Common crops grown include wheat, corn, milo, soybeans, truck crops and alfalfa. In many areas cultivated crops provide food for wildlife. Field margins generally support a growth of grasses and forbs characterized by such species as smooth and downy brome (Bromus inermis and Bromus tectorum), Johnson grass, giant ragweed, horseweed, nettles (Urtica sp.) and other species.

The first bottom is generally dominated by woody species. A dense growth of sandbar willows (Salix interior) typically occurs near the river's edge. Small cottonwood trees and larger peachleaf willows (Salix amygdaloides) appear as the elevation rises. Black willow (Salix nigra) is also found in the first bottom. At higher elevations in the first bottom and where the land rises to meet the upper terrace, larger trees are normally found. Cottonwoods generally are the largest trees here and usually form an open canopy. Hackberry, boxelder (Acer negundo), red mulberry, silver maple (Acer saccharinum), and green ash (Fraxinus pennsylvanica) trees are also common here. Tree species present in lesser numbers include black walnut (Juglans nigra), sycamore, honey locust, northern catalpa (Catalpa speciosa), osage orange (Maclura pomifera), basswood (Tilia americana) and others. Small trees of the above species, in addition to shrubs such as buckbrush (Symphoricarpos orbiculatus), roughleaf dogwood (Cornus drummondii), smooth sumac and woody vines such as greenbrier (Smilax sp.), Virginia creeper, wild grape (Vitis sp.), and poison ivy abound in the understory. The extent and species composition of herbaceous growth on the forest floor depends on the amount of light penetrating overhanging vegetation, the frequency of inundation, the successional stage of the plant community and other factors. Some common herbaceous plants found here include sedges, violets (Viola sp.), poison ivy, and dandelions (Taraxacum officinale). Treeless areas, dominated by grasses and forbs, on the first bottom are often restricted to small patches or areas where disturbance has occurred and the plant community is in an early successional stage. Some common grasses occurring in these areas include smooth and downy brome, sand dropseed (Sporobolus cryptandrus), and Canadian wild rye. Herbaceous plants found here include sedges, nettles, giant ragweed, horseweed, smartweed, goldenrod (Solidago spp.), catchweed bedstraw (Galium aparine) and many others.

The plant communities occurring in the study area represent a significant resource. In many cases, these communities provide the

single most important habitat in the general area for many plant and animal species. The timbered areas provide food and cover for a number of wildlife species.

Of primary significance to wildlife is the "edge" between the wooded areas lining the river and the associated croplands adjacent to the timbered areas. Such "edges" are highly productive for many wildlife species and in more intensively farmed areas provide the only suitable habitat available for wildlife. Common plant species of the study area (miles 0 to 153) are listed in Tables B-4 and B-5 of Appendix B.

Changes and Trends

Vegetative communities associated with the Kansas River and its major tributaries are generally influenced by a variety of disrupting factors. Changes in water level, flooding and inundation, bank erosion, movement of the channel and other factors all influence the plant communities associated with the river and bring about successional change.

Personnel from the U.S. Fish and Wildlife Service indicate that a major trend in the Kansas River Basin has been a reduction in the acreage of the previously discussed plant communities. They indicate that major contributors to this degradation and loss of habitat are agricultural practices and urban and industrial development. Agricultural practices appear to comprise the greatest single factor in the reduction of fish and wildlife resources. Floodplains are often farmed to the high bank of the river with extensive or total clearing of riparian areas. This often results in severe erosion problems, increased chemical pollution of streams and a significant cumulative impact on fish and wildlife resources.

A tri-agency team of biologists representing the U.S. Army Corps of Engineers, Kansas Fish and Game Commission, and the U.S. Fish and Wildlife Service have identified and evaluated the major habitat types occurring within the floodplain ecosystem of the Kansas River. Five habitat types were identified (Saunders, 1980). These are:

- Cropland - includes areas where crops are normally planted and harvested other than those naturally occurring in the area.
- Pasture - includes grasslands or pasture sites often cropped for hay or seed production.
- Riparian Woodland - includes all woody species of vegetation along river bottoms, streams, oxbows, and wetland areas.
- Wetland - includes shallow water areas such as swamps, marshes, and areas periodically inundated or saturated by water, characterized by aquatic vegetation.
- Streambank - includes the bank slope from the crest to the waters edge including vegetative cover adjacent to or extending over the bank.

Cropland is the single most abundant habitat type in the floodplains of the Kansas River (see Tables II-14 and II-15). Most of the woodlands, pasture, and wetlands and some streambank habitats have been converted to cropland. This large scale conversion has been a significant factor in the elimination or reduction of those wildlife species dependent on floodplain habitats.

Pasture, although less common as a habitat type in the floodplain, plays a significant biological role often as a transition zone between riparian woodland and cropland.

Within a mile-wide corridor centered on the Kansas River, floodplain forest accounts for approximately 15.9 percent of the total study area and 14.1 percent of the lower 56 miles of the river (Tables II-14 and II-15). These areas represent the single most important habitat type for many wildlife species (Saunders, 1980). Wildlife species associated with these riparian woodlands include white-tailed deer (*Odocoileus virginianus*, coyotes (*Canis latrans*, raccoons (*Procyon lotor*), minks (*Mustela vison*), beavers (*Castor canadensis*, muskrats (*Ondatra zibethicus*), fox squirrels (*Sciurus niger*), bobcats (*Felis rufus*), striped skunks (*Mephitis mephitis*), owls (*Bubo* spp.), hawks (*Buteo* spp.), bald eagle (*Haliaeetus leucocephalus*), kingfishers (*Megaceryle* spp.), woodpeckers (*Piciodes* spp.), and great blue herons (*Ardea herodias*).

Wetlands are relatively uncommon in the floodplains of the Kansas River (Saunders, 1980). Species associated with this habitat in the study area include amphibians (*Rana* spp., *Ambystoma* spp.), water snakes (*Natrix* spp.), herons, minks, raccoons, muskrats, red-winged blackbirds (*Agelaius phonecius*) and various species of waterfowl.

Streambank habitats support a number of furbearers including beavers, muskrats, minks, raccoons, skunks, and opossums (*Didelphis marsupialis*). Wading and shore birds such as the spotted sandpiper (*Actitis macularia*) are occasionally found on the sandbars of the Kansas River channel.

Many animal species occur in greater variety and density between the stream's riparian timber and associated croplands and grasslands. This phenomenon, called the edge effect is of primary importance to these species. Areas of mixture or ecotones where forests, fields and streams merge have the vegetative characteristics of these individual habitats, plus many additional shrubs and herbaceous species. They bring together species of forest, field, and stream areas and also attract species that require either shrub lands and/or a combination of trees, shrubs, and wetland plants.

Common vertebrates of the commercial dredging study area are listed in Tables B-6 through B-9 of Appendix B.

Table II-14

LAND USE AND VEGETATIVE COVER TYPE FOR THE KANSAS RIVER COMMERCIAL DREDGING INTENSIVE STUDY AREA[1]

	Acres	Percentage of Total Area
Agricultural Land		
Cropland	15,460.6	43.2
Farmstead	109.6	0.3
Pasture	216.8	0.6
Forest		
Deciduous	5,033.6	14.1
Shrub	0.0	0.0
Urban		
Commercial/Public	550.8	1.5
Industrial	3,167.1	8.9
Parks, Cemeteries, Open	262.6	0.7
Residential	2,216.0	6.2
Water		
Lakes	30.6	0.1
Ponds	61.2	0.2
Stream (Kansas River)	5,706.9	15.9
Other		
Erosional and Sandy Deposition Areas	532.9	1.5
Gravel/Rock Pits	357.0	1.0
Meander Scars	0.0	0.0
Parklands	0.0	0.0
River Structures (Cars, Levees, Jetties)	0.0	0.0
Nonagricultural	1,667.7	4.7
Utilities/Transportation	407.9	1.1
Total	35,781.3	100.0

[1] *Data for river miles 0.0 to 55.8.*

Source: Land Inventory and Development, Inc., 1979.

Table II-15

LAND USE AND VEGETATIVE COVER TYPE FOR THE KANSAS RIVER COMMERCIAL DREDGING STUDY AREA[1]

	Acres	Percentage of Total Area
Agricultural Land		
Cropland	52,440.7	52.2
Farmstead	374.7	0.4
Pasture	216.8	0.2
Forest		
Deciduous	16,016.5	15.9
Shrub	0.0	0.0
Urban		
Commercial/Public	1,114.4	1.1
Industrial	3,883.7	3.9
Parks, Cemeteries, Open	339.0	0.3
Residential	4,085.0	4.1
Water		
Lakes	30.6	0.03
Ponds	219.3	0.2
Stream (Kansas River)	16,373.4	16.3
Other		
Erosional and Sandy Deposition Areas	831.1	0.8
Gravel/Rock Pits	520.2	0.5
Meander Scars	0.0	0.0
Parklands	0.0	0.0
River Structures (Cars, Levees, Jetties)	0.0	0.0
Nonagricultural	3,519.0	3.5
Utilities/Transportation	512.4	0.5
Total	100,477.1	99.9

[1] *Data for river miles 0.0 to 155.4.*

Source: Land Inventory and Development, Inc., 1979.

3. THREATENED AND ENDANGERED SPECIES

There are no plant species currently listed or proposed for listing as threatened or endangered by the U.S. Department of the Interior or State of Kansas that may occur in the study area.

Animal species that are listed as endangered by the U.S. Department of the Interior and occur in the commercial sand and gravel dredging study area are the peregrine falcon (Falco peregrinus), both subspecies, and the bald eagle (Haliaeetus leucocephalus).

The peregrine falcon may occur uncommonly as a transient or winter resident usually in association with shorebird and waterfowl concentrations. The bald eagle may occur frequently as a transient or winter resident in a significant portion of the general study area (river miles 0-153). In winter, eagles fish in the streams and lakes in this area whenever possible. However, as these water bodies begin to freeze over, their diet is supplemented more by ducks, geese, and other migratory waterfowl. A number of large federal lakes which are in close proximity to the study area regularly harbor significant concentrations of wintering bald eagles. These are: Clinton Lake, Perry Lake, and Tuttle Creek Lake. In addition, significant wintering bald eagle populations can be found along a six-mile stretch of the Kansas River near LeCompton, Kansas (river mile 63) and in a stretch of the river near Belvue, Kansas (river mile 118).

In addition to the federally endangered species, the State of Kansas also has an official listing for threatened and endangered species. State endangered species which may be present in the commercial dredging study area are the pallid sturgeon (Scaphirhynchus albus), sicklefin chub (Hybopsis meeki), bald eagle, and peregrine falcon. State threatened species which may occur in the study area are the blue sucker (Cycleptus elongatus), Topeka shiner (Notropis topeki), prairie falcon (Falco mexicanus), and the northern crayfish frog (Rana areolata).

The pallid sturgeon is known to inhabit the Missouri River and the lower Mississippi River. One of only two specimens taken elsewhere came from the Kansas River at Lawrence following the 1951 flood. It is generally confined to large, muddy rivers with swift currents and is well adapted to the abrasive effect of water-borne mud and sand (Cross and Collins, 1975). "Old time" fishermen on the Missouri River indicate they rarely see this fish any more. Cross (1967) felt that pallid sturgeons may enter the lower Kansas River from the Missouri River only in years of exceptionally high water.

The sicklefin chub occupies the Missouri River and has occasionally been collected in the Kansas River around Lawrence. This species prefers the smooth, sand or gravel bottoms of deep rivers, such as the Missouri, where currents are strong (Cross and Collins, 1975). Factors affecting feeding and reproduction of this species are presently unknown. There are no Kansas records of the sicklefin chub in the last ten years.

The blue sucker also occurs in the lower Kansas River. Some specimens have been collected in the Kansas River in the last five to six years. One individual has been captured during the Fishery-Dredging Study of the lower river near river mile 25.6 (see Table 18, Appendix C). The species has larger populations in the Neosho River of southeastern Kansas. They typically reside over gravel or rubble in the strong currents of large deep rivers. At best they can be considered rare in the lower Kansas River.

The Topeka shiner may occur accidently in the Kansas River. It typically occurs in the headwater areas of small spring-fed streams, particularly in tributaries that drain limestone uplands of the Flint Hills. The Kansas River is at best a marginal and temporary habitat for this species.

The prairie falcon was formerly abundant in northwestern Kansas. Recent sightings of this species have been fairly common. The species will occur in most of the study area, except in the extreme eastern reaches.

The northern crayfish frog was once plentiful on the floodplains of Douglas County. Specimens were collected approximately 20 years ago from the Wakarusa River floodplain, but the species has not been found in this area for the last two decades. Historically, the species was more common to the Osage Cuesta and Cherokee Plains regions of southeast Kansas. The species typically resided in backwater areas such as sloughs, oxbows, and marshes.

Federal and state lists of threatened and endangered species which may occur in the study area are found in Tables B-10 and B-11 of Appendix C.

4. ADDITIONAL FACTORS WHICH INFLUENCE THE BIOTA ASSOCIATED WITH THE KANSAS RIVER

The biotic communities of the Kansas River and its banks are influenced by a variety of factors other than commercial sand and gravel dredging. Many of these factors represent stresses to the biotic communities of the river. These factors include upstream reservoir operations, Bowersock Dam at river mile 51.8, urbanization and agricultural practices (including pollution from point and nonpoint sources), and Missouri River bed degradation. Reference to the effects of some of these factors has previously been made; however, for comparative purposes these effects are summarized in the following discussions. Commercial sand and gravel dredging on the Kansas River will not be analyzed in this context. An assessment of commercial dredging and its influence on the Kansas River and its biota is addressed in Section III.A.4.

a. Upstream Reservoirs and Their Operation

Presently, 18 large federal impoundments have been constructed which directly effect the flows of the Kansas River. These impoundments are listed in Table II-16. Available information indicates that the

reservoirs of the Kansas River Basin may influence the biota of the river in several ways.

High and low flow releases influence the water quality of the Kansas River. During periods of low flow, mineral substances (total dissolved solids) are concentrated and industrial and municipal discharges exert their greatest influence (KDHE 1978). During high releases, nutrients (Heinemann et. al., 1973) and suspended sediment concentrations may increase in the Kansas River.

Table II-16

LARGE FEDERAL IMPOUNDMENTS OF THE KANSAS RIVER BASIN

Reservoir	Completion Date	Capacity (ac-ft)	Tributary Located On
Bonny	1951	170,000	Upper Republican
Cedar Bluff	1951	377,000	Smoky Hill
Clinton	1979	397,200	Wakarusa
Enders	1951	75,000	Upper Republican
Glen Elder	1969	976,000	Solomon
Harlan County	1952	840,500	Upper Republican
Harry Strunk	1949	89,000	Upper Republican
Hugh Butler	1962	87,000	Upper Republican
Kanopolis	1949	432,900	Smoky Hill
Kirwin	1955	315,000	Solomon
Lovewell	1957	92,000	Lower Republican
Milford	1967	1,160,000	Lower Republican
Norton	1965	135,000	Upper Republican
Perry	1969	770,000	Delaware
Swanson	1953	254,000	Upper Republican
Tuttle Creek	1963	2,367,000	Big Blue
Webster	1956	261,000	Solomon
Wilson	1965	776,000	Saline

Missouri Basin Inter-Agency Committee, Comprehensive Framework Study, Missouri River Basin, Appendix Volume 6, Land Resources Availability and Hydrologic Analysis and Projections, 1969.

High flows resulting from reservoir releases scour benthic algal producer communities which develop during periods of low flow and low turbidity (Marzolf, 1979).

Water level fluctuations in streams as a result of reservoir releases may affect fish spawning rhythms and feeding and breeding areas. Altered flow regimes may exert effects on other trophic levels including plankton, periphyton and macroinvertebrate communities. Fish that spawn deep enough not to be affected by water level fluctuations may spawn successfully but many species that spawn and maintain nurseries in the littoral zone (centrarchids, carp, and some forage species) will be very much

affected by water level changes and year classes may tend to be irregular. Water level fluctuations can be used to control unwanted spawning in these species. In some cases the yield and species composition of fish populations below a dam are changed (Lowe-McConnell, 1973). The reproduction of fish can be disrupted by water level changes prior to the time that eggs are deposited (Benson, 1973). Carp, river carpsucker, and smallmouth and bigmouth buffaloes are examples of fishes that require rising or constant water levels during the spawning and egg incubation periods.

River water level changes resulting from reservoir releases can have positive effects on some fish species by providing constant or rising water levels during the spawning season. Stabilized flow regimes may be a contributing factor in the reappearance of fish species previously very rare in the lower Kansas River such as the blue sucker and blue catfish. In addition, during periods of drought, reservoirs can maintain minimum flows for fish and wildlife, water quality, and water supply purposes.

The reservoirs of the Kansas River Basin may be sources of zooplankton and fish larvae in the Kansas River. The number of fish larvae in the Missouri River was directly correlated with the flushing rate from mainstream impoundments (Benson, 1973).

Reservoirs on the Kansas River tributaries may be a contributing factor in bank erosion and bed degradation in the Kansas River. Changes in channel morphology may have paralleling effects on aquatic and terrestrial ecosystems. It is not uncommon for reservoir sedimentation to cause channel degradation and bank erosion downstream (Glymph, 1973; Bondurant and Livesey, 1973). After deposition of sediment in the reservoirs, the cleaner water released through the dam will have an unsatisfied transport capacity that it will attempt to satisfy by eroding the bed and banks of the stream.

Besides altering sediment-discharge regimes, high reservoir releases may directly cause bank erosion during sustained periods of near bankfull flow (Bondurant and Livesey, 1973). High discharges can cause bank erosion downstream at least near the dam (U.S. Army Corps of Engineers, 1975b, 1976b, 1978b).

Although the above phenomena have been attributed to reservoirs, regulated stream channel relationships are not well understood. Osterkamp (1981) in his study of channel geometry of regulated streams in Kansas suggested that channel degradation and possibly channel lengthening are occurring as a result of streamflow regulation. The changes, however, appear to be occurring at rates too slow to have yet produced measurable reduction of channel gradient.

The effects of changes in channel geometry for the Kansas River on aquatic and terrestrial ecosystems are discussed in Section III.A.5 of this report.

b. Bowersock Dam

Bowersock Dam is located on the Kansas River at river mile 51.8 immediately below the Massachusetts Avenue Bridge at Lawrence, Kansas. The dam is a low-head structure approximately 787 feet in length. It was originally built in 1872 for power generation.

There are no studies or data which provide information on the effects of Bowersock Dam on the aquatic and terrestrial ecosystems of the Kansas River. Consequently, the following discussion cannot be stated with confidence, but based on available information appears reasonable.

The dam impounds approximately ten acres of water. Lentic conditions above the dam may allow phytoplankton, zooplankton and benthic invertebrate populations (which are limited in the Kansas River) to develop. Fishes which prefer lenthic and/or littoral conditions such as centrarchids may occur in greater numbers as well.

Fishes are concentrated below the dam in scour pools and the structure provides increased fishermen access. The structure blocks the upstream dispersal of many fish species during low flows.

Bowersock Dam may have a stabilizing influence on the river channel above the dam and it probably acts as a sediment trap, especially since the onset of lake regulation which discourages extremely high streamflows. These physical factors also influence the aquatic and terrestrial communities of the river.

c. Urbanization and Agricultural Practices

As discussed previously, urbanization and agricultural practices along the Kansas River have been and are the major limiting factors to aquatic and terrestrial biological communities of the Kansas River.

Urbanization along the river actively removes streambank and floodplain habitats for a variety of animal and plant species. Point source pollution occurring in urbanized and industrial areas has had severe impacts on the water quality and consequently the aquatic life of the lower Kansas River in earlier years. Water pollution regulations relating to these discharges have generally improved water quality in the lower river, but current conditions do not suggest a complete recovery, at least in the lower nine miles.

Agricultural practices constitute the greatest single limiting factor to the biotic communities of the river. Clearing of land for agricultural purposes has removed large tracts of the original

riparian and floodplain habitats along the Kansas River. Turbidity from agricultural runoff is a major limiting factor to aquatic biosupport in the Kansas River. Bank erosion has been identified as an ongoing problem along the Kansas River and has resulted in the loss of property, including croplands and wildlife habitat. Bank erosion problems are magnified by the clearing of trees and other streambank stabilizing vegetation for agricultural purposes.

d. Missouri River Bed Degradation in Rating Curve

The Missouri River at Kansas City, Missouri has been undergoing a rating curve right shift since the 1940s according to Smith (undated). It should be noted that all midwestern rivers are currently exhibiting a right shift in their rating curves (Dort, personal communication 1980, Smith undated).

Bed degradation in the Missouri River appears to be contributing at least to some degree to bed degradation in the lower Kansas River (See Section II.A.4.a). Bed degradation and its effects on the biotic communities of the Kansas River is discussed in Section III.A.5 of this report.

G. SOCIOECONOMIC CONDITIONS

1. SOCIAL AND ECONOMIC STUDY AREA

The first task in addressing the question of the social and economic impacts of commercial dredging is to define the study area. It is necessary to approach such a definition flexibly, since an area of economic impact is a nebulous concept having no precise geographic boundaries. An area of primary dependence may be considered to exist where Kansas River sand and gravel is the primary supply of aggregate material. While insufficient data is available to determine this region with certainty, it is apparent that Kansas River material is very important in the Kansas City metropolitan area, as well as broad areas surrounding Lawrence, Topeka and Manhattan. In a general sense this market area comprises a corridor with the Kansas River at its center, extending to both the north and south of the River for some 30 or 40 miles, and continuing from Manhattan in the west to Kansas City in the east.

One large Kansas City firm also sends materials outside of this corridor. Substantial tonnages of material are shipped to communities near the eastern border of Kansas and in the western quarter of Missouri, including Sedalia and Springfield. It is not known to what extent the needs of these outlying areas are supplied by Kansas River sands, but this is undoubtedly a significant economic source of supply. The considerable distances involved, for instance about 170 miles from Kansas City to Springfield, must increase the cost per ton enormously. (See Section II.G.3). This willingness to pay such high transportation costs reflects the absence of easily exploitable sources of aggregate material in southwestern Missouri.

2. CULTURAL ELEMENTS

Reviews of available cultural resource inventory data have been conducted in the archaeological, paleontological and historic - architectural resource areas along a one-mile-wide corridor of the Kansas River and its major tributaries, downstream from existing federal lakes and reservoirs. The archaeology study for the eastern portion of the study was conducted by Thomas A. Witty, Jr., along the Kansas River study corridor from the confluence with the Republican and Smoky Hill rivers to its mouth.

Northeast Kansas and the Kansas River drainage basin has been the scene of some of the earliest archaeological activities in the state and has, when investigated, been found to yield numerous and significant sites and archaeological materials ranging over a long time period (Witty, 1979). The time periods range from the Archaic (6,000 B.C. - 1 A.D.) to the historic period (A.D. 1800-1865).

a. Archaeological Resources

The archaeological study of the Kansas River floodplain conducted by Thomas A. Witty, Jr., identified 126 relevant sites. The locations of the sites indicate a fairly even cultural distribution along the river. The known sites represent the Archaic period (6000 B.C. - 1 A.D., 20 percent), Early Ceramic period (A.D. 1-1000, 49 percent), Middle Ceramic period (A.D. 1000-1500 A.D., 20 percent), Late Ceramic period (A.D. 1500-1800, less than 1 percent), and the Historic period (A.D. 1800-1865, 11 percent). Period time spans are according to Witty.

Six sites along the Kansas River are listed on the National Register of Historic Places. One site, west of Manhattan, is the early town of Pawnee on the Ft. Riley Military Reservation in Geary County. The area contains the reconstructed first Capitol of Kansas. The five other sites are in Pottawatomie County, and are located in the Vermillion Creek Archaeological District. Three other sites, one each in Jefferson, Pottawatomie, and Riley Counties, are potentially significant enough to be recommended for nomination to the Register.

The archaeological literature search by Witty, determined that the data for the remainder of the identified sites were insufficient to make an accurate evaluation of their significance.

Since much of the work in the study by Thomas Witty was done by amateurs or students, it is difficult to assess the total extent of the survey. It is possible that many sites have yet to be discovered. This must be considered should new development be planned along the floodplain proper.

b. Historic Resources

The greatest concentrations of recorded sites and structures occur in the urban areas, especially Kansas City, Lawrence and Topeka.

Bridges and cemeteries constitute the majority of known sites in the rural areas.

Of the districts and individual properties within the project corridor with are included in the National Register of Historic Places, only the following are located in the floodplain: part of the Old West Lawrence Historic District and four isolated sites in Lawrence; two sites in Topeka and one in North Topeka.

Many of the bridges and buildings recorded by the Historic American Engineering Record (HAER) are located within the floodplain of the Kansas River. However, the HAER inventory does not include any territory west of Topeka. No information pertaining to bridges between Topeka and Manhattan was located. (White, 1978).

The towns within the study corridor which have the greatest potential for historic significance include: Kansas City, DeSoto, Lawrence/North Lawrence, Topeka/North Topeka, Wamego, St. George, Wabaunsee, Manhattan, and Eudora. These towns appear to have the greatest concentrations of structures of architectural interest, and in some cases, historical significance related to the towns in general.

c. Transportation

A series of railroads follows the entire length of the Kansas River, frequently running within a one-mile-wide river corridor (see Figure IN-1). The Atchison, Topeka, and Santa Fe Railway (AT & SF) and the Union Pacific Railroad follow the banks along most of the river corridor from Kansas City, Kansas to Topeka. There they are joined by the Chicago, Rock Island and Pacific Railroad. This line, along with the Union Pacific, continues on for the length of the Kansas River.

Interstate 70 and U.S. Highway 24 follows the general course of the river for most of its length, coming within one-half mile of the river in several places. The river is crossed many times by several highways, with the greatest concentration occurring in the urban areas.

3. KANSAS RIVER COMMERCIAL DREDGING INDUSTRY ANALYSIS

Socioeconomic conditions pertaining to an industry originate with the circumstances of production. Sand and gravel production from the Kansas River in 1978 was 3,986,000 tons. According to the Kansas Geological Survey this amount was valued at $8,247,000. This was 28 percent of the 13,860,000 tons of production reported in the State of Kansas in 1978 and 37 percent of the state's sand and gravel production value that year. These figures and comparable data for 1977 are presented in Table II-17. Preliminary information for 1979 indicates that 13,150,000 tons of sand and gravel were produced in Kansas, a drop of 5.1 percent from 1978. On the Kansas River production increased 20.7 percent from 1977 to 1978.

In 1977, material sold by Kansas River dredgers was apportioned 83 percent to commercial use and 17 percent to governmental use. This material was used primarily for construction purposes, with significant amounts used as asphalt aggregate and road base fill. This distribution is detailed in Table II-18. Construction use consumes an even larger part of value produced. In construction activity, the greatest use of aggregate is in the preparation of ready-mix concrete, although there are numerous other uses. Other construction and industrial uses of sand and gravel are brick and other masonry products, filter beds, roofing, decorative glass manufacturing and miscellaneous applications.

Table II-17

KANSAS RIVER SAND AND GRAVEL PRODUCTION 1978 & 1977

	1978		1977	
	Production 1000 tons	Value 1000$	Production 1000 tons	Value 1000$
Kansas River	3,986	8,247	3,302	5,395
Total	13,860	22,200	13,000	20,000

Source: Collins, Dave. 1980. Kansas Geological Survey. Personal Communication.

Table II-18

DISTRIBUTION OF KANSAS RIVER SAND AND GRAVEL 1977

	Amount		Value	
	1000 tons	Percent	1000$	Percent
Construction	1,916	58	3,444	64
Asphalt	591	18	930	17
Road Base Fill	795	24	1,021	19

Source: Collins, Dave. 1980. Kansas Geological Survey. Personal Communication.

While Kansas River production represents a small proportion of production in the State of Kansas, its regional significance is still very great. Due to the high bulk/low value nature of sand and gravel, it becomes very expensive to transport these materials over more than a short distance. Since Kansas River aggregates are in certain cases transported over considerable distances, an important conclusion may be tentatively drawn about the importance of this industry source. Although other potential resources for aggregates exist at comparable or closer distances, Kansas River resources have been developed to such an extent as to realize important economies of scale. Consequently the Kansas River is the least costly and most plentiful source of aggregates available in the region.

On a macroeconomic level of analysis it would be advantageous to establish the relative importance of the dredging industry to the regional economy. One way to measure this importance is to estimate the industry's contribution to the total production of goods and services in the study area. Although gross output estimates are not available for the study area as such, the State of Kansas does estimate gross products for the entire state. Table II-19 displays figures covering three years for the mining industry and for the total economy. In 1977, Kansas River sand and gravel production comprised .9 percent of the total volume of mining activity and .03 percent of the gross State product. From this perspective it is clear that the Kansas River materials industry by itself comprises a relatively minor component of the Kansas economy.

Table II-19

KANSAS MINING AND GROSS STATE PRODUCT 1977, 1976 & 1975

	1977		1976		1975	
	Million$	Percent	Million$	Percent	Million$	Percent
Mining	587.3	3.1	524.8	3.0	487.8	3.1
Gross Product	19,188.0	100.0	17,317.1	100.0	15,539.8	100.0

Source: Kansas Department of Economic Development. 1979. "Development Perspective, 1978-79."

Another dimension of macroeconomic importance is the amount of employment attributable to the industry. Complete information concerning the number of persons employed is not available, however, an estimated 140 persons are employed in the entire Kansas River materials industry. In the eight county area in which the dredging operations are located, an average of 432,250 persons were employed in 1979, according to the Kansas Department of Human Resources. The contribution of the industry's employment to regional income will be addressed in the impact section.

It is evident that the major economic role of the sand and gravel industry is not as a primary economic sector in its own right, but as a source of supply of a necessary raw material for the production of many asphalts and concretes, as well as for numerous other purposes. The vast bulk of these uses lie within the construction industry. In assessing the economic significance of Kansas River dredging, it is necessary to analyze the extent of this dependence by the construction industry, which is a primary economic sector.

Before this relationship is explored, it will be useful to examine the dredging industry from a microeconomic viewpoint, in order that the operating characteristics of a dredging firm may be understood. This understanding will be important when considering the impact of various alternatives insofar as they affect these characteristics.

Information about the Kansas River dredging operations was collected through a voluntary survey. In order to avoid the disclosure of confidential proprietary information, it will not be possible to discuss individual firms. Fortunately, it is possible to describe them adequately by dealing with two distinct categories into which these firms fall. One consists of downstream dredgers; those east of DeSoto, Kansas. There are four companies operating ten dredges. These operations are generally larger, face higher costs for some factors of production and supply the massive market in the Kansas City metropolitan area. The other category consists of upstream dredgers. These operations are smaller in scope and serve smaller markets than the Kansas City area. There are seven such companies operating eight dredges.

Central to the finances of any industrial enterprise is the cost of production. There are many distinct costs involved in production, but these may be aggregated into several major categories. The following table gives averages of production cost figures provided by upstream and downstream dredgers. Five firms from the upstream sector provided this information, all four downstream operators did so.

Table II-20

KANSAS RIVER DREDGERS COST OF PRODUCTION
1979

	Upstream	Downstream
Operation and maintenance of equipment	$93,205	$428,706
Capital Depreciation	$22,724	$ 86,898
Labor Costs	$44,260	$532,607
Office and Overhead	$47,539	$506,369
General maintenance and cost not directly related	$ 5,978	N/A
Total	$180,369	$1,774,386

Source: Burns & McDonnell, 1980b. Kansas River Dredgers Survey.

Revenues of dredging operations derive from the direct sale of various aggregate products. In some firms there is also a use of aggregates for a ready-mix operation under the same ownership. This type of internal sale is not included in the following averages. Among the upstream dredgers, annual revenue in 1979 averaged $226,514. Among downstream firms, this average was $2,075,974.

These figures suggest that for the hypothetical average dredging firm in the upstream area in 1979; the differential between sales revenue and production costs (gross margin) would be 25.6 percent. For the average Kansas City area dredger, this margin was 17.0 percent. This differential, while providing an indication of rate of return, is not to

be confused with net profit, which is the earning calculated after taxes and other costs.

The amount of taxes paid by Kansas River dredging firms is unknown. These companies are subject to a State corporate income tax of 4-1/2 percent on the first $25,000 of income with a 2-1/4 percent surtax imposed on earnings above that figure. Within the range of earnings estimated above, this would suggest an average income tax liability of $2500 for the smaller firms and $20,000 for the larger firms. A royalty is also imposed on material extracted from the river. This is in the form of an excise tax of $.02 per ton on material sold. This tax produced about $80,000 in revenue from the Kansas River in 1979. These taxes may be regarded as a minor source of revenue for the State of Kansas. Dredging operators are also subject to property taxes in their respective counties. Among the eight counties in which they are found, the average rate on each $100 valuation in 1977 was $10.32. The amount paid would depend on the assessed value of the plant.

A cost which is borne by both the dredgers and their customers in varying proportions is the cost of transportation. Because of the high bulk-low value nature of aggregate materials, transportation will often comprise a large part of the final cost to users. Upstream dredgers reported costs of about $.09/ton-mile in 1979. Kansas City area dredgers averaged $.12/ton-mile.

These transportation costs are in addition to the free on board price of aggregate products. Each producer markets a variety of different specifications appropriate to different uses. Some common categories are concrete sand, asphalt sand, fill sand, and mason sand. There is not a sufficient quantity or compatibility of price information to provide averages for these different classifications. In general, prices for the more common types fell in the range of $1.80 to $2.20 per ton in 1979. While there were significant differences among the prices charged for comparable products by the various firms, no consistent differences between upstream and downstream dredgers were noted.

It should be noted that at prevailing prices a transportation distance greater than about 20 miles will cause transportation costs to exceed the basic price.

Among upstream dredgers the average number of employees is 5, with an average labor cost of $52,801. In the downstream industry, the average number of employees per firm (not one dredge) is 26, with an average labor cost of $556,801. This is equivalent to 10 workers per dredge. The labor cost outlay should not be confused with payroll, since the labor cost will usually be larger.

Having established some of the characteristics of a sand and gravel dredging operation, it is necessary to relate the activity of this industry to the general economy. Due to a lack of information, it is not possible to prepare a complete list of the consumers of Kansas River

sand and gravel. It is also not possible to trace all of the aggregate material to its eventual use more precisely than in Table II-18. However, a selective survey of sand and gravel users has provided some useful information about aggregates as an input to their production processes.

From those responses to the survey received, it appears that requirements for the purchase of sand for the production of concrete constitutes about 7-10 percent of the cost of this production. For asphalt, aggregate requirements appear to cause about 5 percent of production costs. These figures are to be understood as representing a "typical" regional firm engaged in this type of business, insofar as they are a composite of responses received, and not necessarily an average.

The tendency over time for these proportions to change is difficult to assess. It appears, however, that the price of Kansas River sand has been rising at a rate equal to and sometimes greater than the general rate of inflation. Consumers of sand and gravel reported recent price rises ranging from 5 percent to 15 percent annually. It is likely that the proportional outlays for aggregates by these producers tend to remain much the same. Asphalt producers, who must use considerable amounts of oil, have experienced a diminishing proportional outlay for aggregates as the price of petroleum products has risen sharply.

Sand and gravel has been seen to comprise a significant input in terms of value to the process of making concrete and asphalt. These materials are in turn important to the various branches of the construction industry. The quantitative magnitude of this economic relationship is not easily estimated. The size and diversity of the construction industry precludes the feasibility of a general survey to define this relationship. Fortunately, interdependencies among industries have been investigated in the process of creating input-output models. An input-output model of an economy describe the flow of goods and services between the various sectors of the economy. Each sector is assumed to require a particular and fixed set of inputs from the other sectors in order to produce its output. The output is in turn apportioned as inputs among the other sectors.

An I-O model for the Kansas economy, The Interindustry Structure of the Kansas Economy has been prepared by the Kansas Office of Economic Analysis (Emerson, 1969). Although this model is somewhat dated, it is not likely that the technical coefficients of inputs to production would change substantially, since the relevant economic sectors have remained structurally stable and have not experienced major changes in technology. The Direct and Indirect Requirements Matrix of this model indicates the requirements of a Kansas industry in order to make a $1 delivery to final demand. This includes not only direct purchases from various other industries, but takes into account the requirements of those industries in turn. Delivery to final demand is simply the sale of the industry's product.

[1] Although these coefficients are presented in six significant figures, this is not a meaningful precision over a substantial length of time.

According to this matrix, the cement and concrete industry must take .0611 of its input requirements from the nonmetallic mining industry. This corresponds fairly well to the survey results, which indicated a range of .07 to .10. The contribution of the cement and concrete sector to the construction industry can be found in this same matrix. For building construction, the coefficient is .063; for heavy construction it is .056. Since these input coefficients include cement as well as concrete, they must be treated as upper limits to the contribution of sand-based material.

Another source of this type of information which has been further disaggregated is a national I-O model. This model was created by the Bureau of Economic Analysis. The more disaggregated a model is, the more precisely it will reflect technical relationships. Aside from the modifying effect of import requirements, these relationships should apply on a regional level. The following table lists some input coefficients. The column labeled "Sum" indicates the total input requirement of aggregate-based materials for each type of construction listed.

Table II-21

INPUT REQUIREMENTS FOR CONSTRUCTION ACTIVITIES

		Concrete		Paving	
New Construction:	Block	Products	Ready-Mixed	Material	Sum
Residential Bldgs.	.00705	.00483	.02981	.00108	.04277
Nonresidential Bldgs.	.00950	.01314	.03646	.00224	.06134
Public Utilities	.00154	.01938	.01966	.00392	.04450
Highways	.00100	.03824	.03871	.02962	.10757
Other	.00246	.00875	.01793	.00341	.03255

Source: U.S. Department of Commerce. Bureau of Economic Analysis. 1974. Total Requirements for Detailed Industries, Vol. 3 of Input - Output Structure of the U.S. Economy: 1967.

The direct requirement for the products of the stone and clay mining and quarrying industry are found to be very nearly .01 for all types except highway construction, for which a coefficient of .06241 was found. This is approximately paralleled by the findings of the Kansas I-O model. In this matrix the requirement from the nonmetalic mining sector for building construction is shown as .005 and for heavy construction as .045. In both models these figures must again be regarded as upper limits for sand and gravel requirements, since they in fact include crushed stone and numerous other materials.

In the national I-O model, requirements for the stone and clay industry for concrete and asphalt production are as follows: concrete block and brick, .1089; concrete products, .05306; ready-mixed concrete, .14538; paving material, .10868. Considering the preponderant use of

ready-mixed concrete, these coefficients suggest that the input requirement of .061 in the Kansas I-O model is rather low, assuming that they correspond closely in meaning. This is probably due to the precision of disaggregation, simply reflecting the particular importance of sand in ready-mix operations. In the final analysis, based on survey results and the regional model, the 7 to 10 percent range previously estimated remains most appropriate.

Having established estimates of the requirements for sand and gravel and for concrete and asphalt in construction activity, as well as the requirements for sand and gravel in concrete and asphalt production, it is possible to combine these figures to gain an indication of the portion of construction costs in general which are attributable to sand and gravel. For most types of construction, this portion appears to be about .015, or 1-1/2 percent. For highway construction, this portion is about 7 percent of costs.

To complete the representation of the macroeconomic role of sand and gravel production, the importance of construction activity in the general economy will be briefly addressed. This is difficult to measure precisely, since there is no direct indice of this activity on a regional level. One available indicator, however, is the valuation of reported building activity. The following figures apply to major municipalities in the study area.

Table II-22

VALUE OF BUILDING PERMITS ISSUED 1979[1]

Independence, MO[2]	$ 37,098,831
Kansas City, MO[3]	$177,787,581
Kansas City, KS	$ 52,507,453
Lawrence, KS	$ 30,271,955
Leavenworth, KS	$ 8,356,504
Manhattan, KS	$ 14,468,034
Olathe, KS	$ 65,479,332
Overland Park, KS	$ 98,341,503
Prairie Village, KS	$ 6,992,848
Topeka, KS	$ 47,622,863

[1]Kansas municipalities, January to October, 1979.
[2]Public Works Department. 1980. City of Independence, MO.
[3]Public Works Department. 1980. City of Kansas City, MO.
All Kansas municipalities from: The Center for Public Affairs. University of Kansas. 1980. Kansas Statistical Abstract 1979.

Assuming that the vast bulk of construction activity occurs in urban areas, these permit values outline the economic volume of building activity in the study area. Six Kansas counties in this area are identified by the Kansas Department of Economic Development as

construction activity centers based on housing permits and employment in construction. These are Wyandotte, Johnson, Leavenworth, Douglas, Shawnee, and Riley Counties. Not surprisingly, these counties contain the Kansas municipalities listed above. Recent employment data for the core counties was obtained from the Kansas Department of Human Resources and is presented below.

Table II-23

CONSTRUCTION EMPLOYMENT NEAR THE KANSAS RIVER
1979

	Employed in Construction 1000's	Employed Civilian Labor Force 1000's	Percent
Kansas City SMSA[1] (KS)	9.8	256.6	3.8
Lawrence SMSA	1.3	33.2	3.9
Topeka SMSA	3.6	91.5	3.9
Leavenworth County	.7	18.6	3.8
Pottawattamie County	.6	9.2	6.5
Riley County	1.0	20.6	4.9
Wabaunsee County	.1	2.6	3.8
Total	17.1	432.3	4.0

[1]Standard Metropolitan Statistical Area; a Census area.
Source: Kansas Department of Human Resources. 1979. Research and Analysis Section.

Construction can be seen to provide about 4 percent of employment in the urbanized and growing counties bordering the Kansas River. The importance of construction as a regional economic sector is apparent.

Having established an outline of the microeconomic characeristics of the Kansas River dredging industry as well as its links to the macroeconomy, a basis exists for discussing the consequences of the alternatives to be considered.

H. CURRENT DREDGING OPERATIONS

All commercial sand and gravel dredging operations included in this study, except one, currently operate dredges in the channel of the Kansas River. The exception to this is the furthest downstream operation (Builders Sand Co., river mile 6.0-7.0). This latter operation dredges from "bays" which are sandpits opened immediately adjacent to the river.

Dredging operations utilize floating, hydraulic "suction" type dredges (see Figure II-4). The one feature that differs between dredges is the type of device used to loosen the sand and gravel bed, prior to its entry into the suction tube. Most dredges use a "chain-ladder" device, but several have special cutter heads. The latter allows the dredge tube to work deeper in the sand layer. One dredge uses a small water jet mounted on the suction

tube and another uses a hydraulically operated arm which moves back and forth in front of the tube. The dredged material is transported by a pipeline mounted on pontoons to a riverbank processing area where it is cleaned, sorted, sized and distributed to appropriate storage piles. Figure II-5 shows a typical on bank processing operation.

Sand is separated into the various sizes by cylindrical, nested, revolving screens through which the sand is washed by the water stream. The innermost screen of the nest allows only the finest fraction to pass and successively larger screens surround this core. The screens catch the sizes appropriate to them and dump individually onto separate conveyor systems, which convey the material to various stacking areas. Boulders, cobbles, and organic detritus are usually removed upstream of the nested screens. The organic material consists primarily of sticks and leaves. Various types of loading equipment such as front-end loaders are used to move and load the sand.

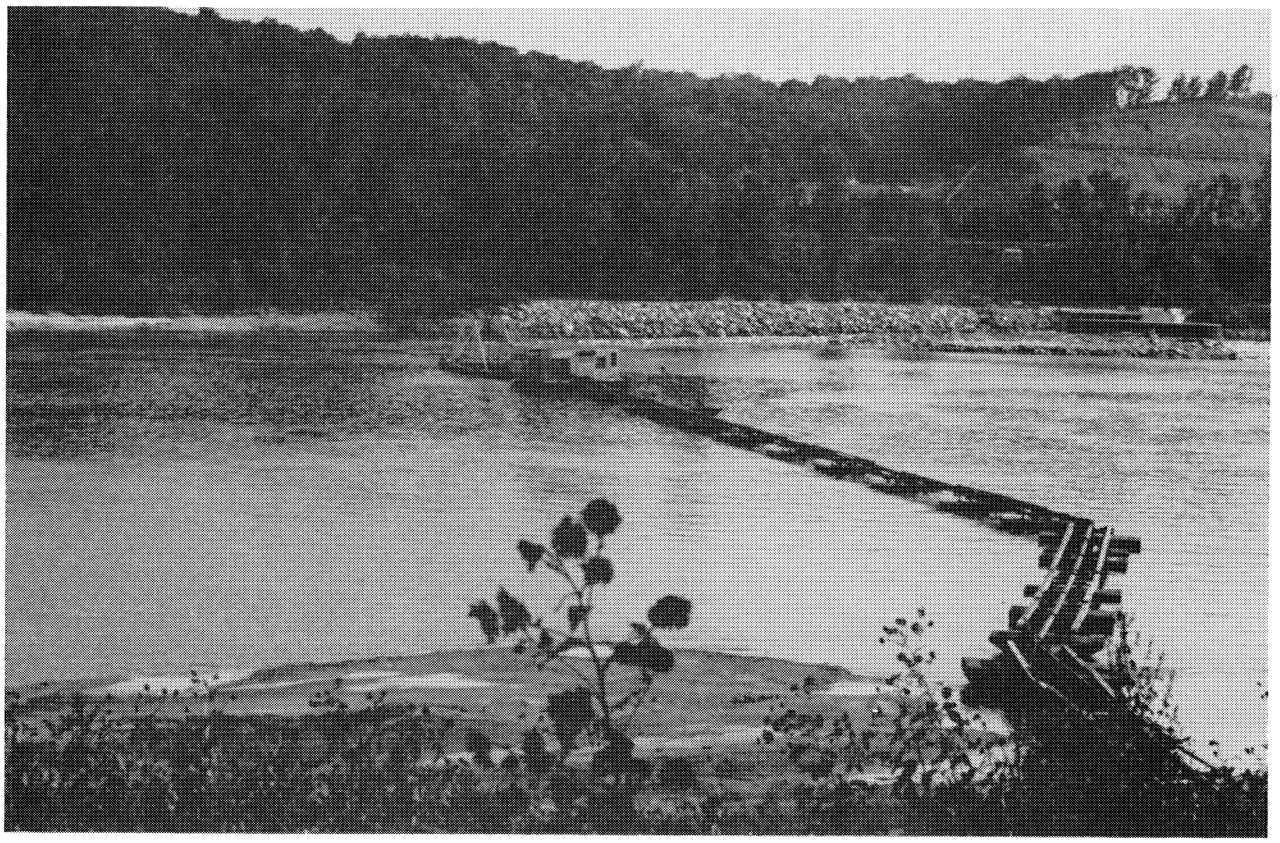
The finest fraction of the dredged material, the silt and clay, is returned to the river in the excess water stream. Effluent pipes installed to discharge from the riverbank processing area downstream of the dredges are used for this purpose.

Practically all dredges operate with electric motors. The dredging season is confined in most years to the ice-free season of March through November. A "pit" of varying depth and size is created during operation of the dredge. During high river flows these pits "trap" incoming sediments.

Also associated with the on bank processing area is a scale house. Several operations are combined with a ready-mix concrete operation which can be adjacent to or removed from the dredging site.

All of the dredging sites operate with relatively small crews considering the bulk of aggregates removed. The dredge usually requires one operator with one or two men operating the tipple. These, plus a superintendent and sometimes a mechanic comprise the basic, sand recovery crew. The number of persons employed by a sand and gravel operation is increased for larger firms and operations combined with ready-mix concrete operations.

A.



B.

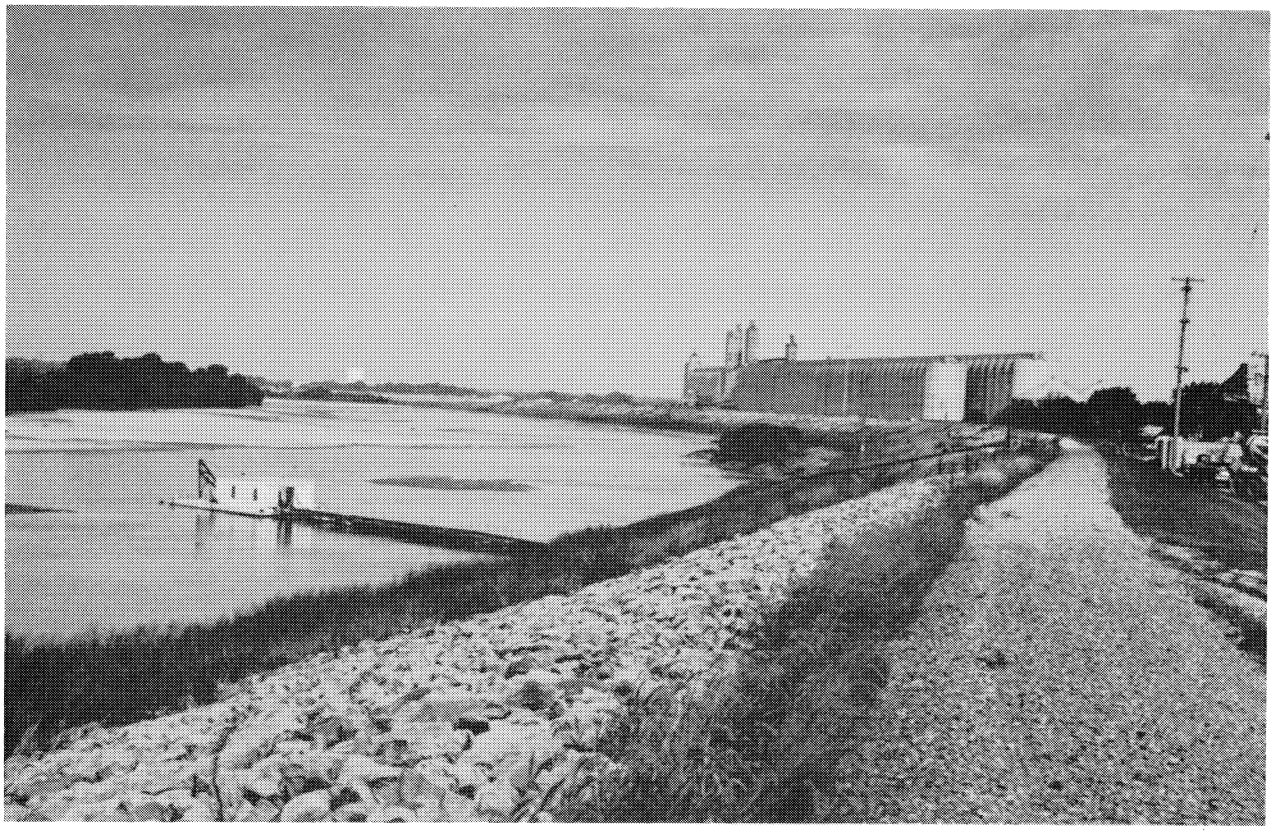


Figure II-4 Typical instream dredging operations
A. Superior Sand & Gravel, Edwardsville. River Mile 14.7 to 14.9.
B. Kansas Sand & Concrete, Inc., Topeka. River Mile 83.0 to 85.2.

Figure II-5 View of a typical on bank operation of a Kansas River dredging firm showing some sorting, processing, and handling equipment. Superior Sand and Gravel, Edwardsville. River Mile 14.7 to 14.9.

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PART III – ENVIRONMENTAL CONSEQUENCES OF EACH ALTERNATIVE

PART III
ENVIRONMENTAL CONSEQUENCES OF EACH ALTERNATIVE

A. ENVIRONMENTAL IMPACTS OF EACH ALTERNATIVE

1. PHYSICAL FEATURES IMPACTS

a. No-Action Alternative

Dredging activities which are located upstream of Bowersock Dam (river mile 51.0) and the single dredge operating immediately below Bowersock Dam cannot be linked directly with any problems of bed or bank erosion on the Kansas River. Implementation of this alternative within the reach from Bowersock Dam to Manhattan, Kansas will probably neither alleviate nor accelerate current degradation or bank erosion if dredged quantities of sand do not increase significantly. The amount of increase which could be allowed without detrimental effects is beyond the scope of this report.

Dredging activities below Bowersock Dam have removed quantities of sand from the river in excess of those replaced by the river since approximately 1962, the beginning of reservoir closures. The effect of such excess removal has been exposure of foundation elements on highway and railroad bridges near Bonner Springs, progressive lowering of water levels, malfunctioning of the Johnson County Water District No. 1 intake, and progressive widening of the river channel in the Bonner Springs-Kansas City reach. Implementation of this alternative will cause those impacts to continue and perhaps to accelerate.

b. Cessation of Dredging

The implementation of this alternative to dredging operations above Bowersock Dam and the single dredge operating immediately below Bowersock Dam will probably have no effect on river erosion.

The implementation of this alternative to dredging operations in the reach below Bowersock Dam will considerably slow but will not halt river degradation. Stage-time relationships shown by the records of the Bonner Springs gage indicate that degradation is occurring at the rate of approximately 0.5-foot per year (see Figure E-17). Stage-time relationships of the record of the Kansas City gage on the Missouri River indicate a degradation rate of 0.1-foot per year (see Figure E-17). It is inferred that cessation of dredging will reduce the degradation in the Bonner Springs reach to that occurring on the Missouri.

"Healing" of the Bonner Springs reach may not occur. That is, the river may not return to its former width and bed elevations. The river reach from Lawrence to DeSoto, for instance, has never "healed" from the 1951 flood, apparently as a result of the drought of the fifties and subsequent reduction of sediment by reservoir construction beginning in 1962. The stage-time relationship at the

Wamego gage is very stable, except for the period of the 1951 flood when it declined approximately 1.5 feet (see Figure E-14). This loss has never been recovered.

Osterkamp (1981) infers that problems of erosion on the upper Kansas River are due to a deficiency of clay sediments. If this is true, then healing cannot occur anywhere on the river.

c. Reduced Quantity of Material Extracted

The implementation of this alternative to dredging operations above Bowersock Dam or to the single dredge operating immediately below Bowersock Dam will probably have no effect on river erosion.

The implementation of this alternative to dredging operations in the Bonner Springs-Kansas City, Kansas reach may have a positive effect on bed degradation and bank erosion. If dredging were restricted to the amounts which can be replaced by the river, the Bonner Springs reach should tend toward stability. Bed degradation will not be halted, since a degradation rate of about 0.1-foot per year is occurring on the Missouri River, but that portion of the degradation which is due to removal of sand in excess of replenishment should be slowed.

Implementation of this alternative does eliminate any possibilities of "healing" of the Bonner Springs reach since no excess sediments will be available to rebuild beds and banks. Osterkamp infers that many of the problems on the upper Kansas River are due to a deficiency of clay sediments. If this is true, then healing will not take place anywhere on the river.

d. Alternative Stream Sources for Dredged Material

Implementation of this alternative, insofar as it reduces extraction from the Bonner Springs-Kansas City reach to acceptable amounts will probably have a positive effect on degradation and river widening. River erosion should be slowed.

Above Lawrence, reduced quantities of extraction will probably have no effect, either positive or negative, on river erosion.

e. Land Mining

Implementation of this alternative, insofar as it reduces extraction from the Bonner Springs-Kansas City reach of the river, should have a positive effect on river erosion, but land mining does destroy the flood plain at the location of the sand pit. Since most land mining operations are removed from the river channel and many are operated from behind levees, the sand pits have little access to sediments and restoration of the pits to former elevations and use is extremely slow. After mining operations cease, pits remain as lakes in the floodplain.

Implementation of this alternative within the reach above Bowersock dam is expected to have no effect, either positive or negative, on river erosion, but will, of course, impact the floodplain in a manner similar to land mining operations on the lower Kansas River.

2. AIR QUALITY IMPACTS

a. No-Action Alternative

Existing commercial sand and gravel dredging operations have no significant effects on the air quality of the study area. Practically all dredging rigs have been converted from diesel to electric motors which have no exhaust emissions. Since the material storage piles found at each dredging site consist mostly of sand, fugitive dust and other airborne particulates from this source are not a major problem. Access roads to each dredging site are expected to be the only significant source of particulates, since many of these roads are unpaved and periodically have heavy truck traffic. Industrial emissions, motor vehicle exhaust and dust from agricultural fields and unimproved roads, may account for the greatest degradation of air quality in the areas surrounding commercial sand and gravel dredging operations.

Most existing dredging operations are located away from population areas. The Kansas Department of Health and Environment has not received any complaints relating to air quality problems from existing commercial sand and gravel dredging operations (Buergin, personal communication, 1980).

b. Cessation of Dredging

The implementation of this alternative will decrease the particulate load of the areas surrounding commercial sand and gravel dredging operations. This will primarily result from the cessation of truck traffic on some of the gravel roads which provide access to the dredging sites. However, as mentioned previously, existing operations are not believed to significantly contribute to the air pollution load of the area. The implementation of the cessation of dredging alternative will not significantly improve the air quality of the region surrounding commercial sand and gravel dredging operations.

c. Reduced Quantity of Material Extracted

Restricting the quantities of sand and gravel that can be removed from the Kansas River will have no significant effect on the existing air quality of the study area. It is possible that by reducing the amount of material removed, access road truck traffic will decline and hence dust and other airborne particulates. However, this decrease would probably be so small as to be indetectable.

d. Alternative Stream Sources for Dredged Materials

Based on economic and geological factors the only alternative stream source for sand and gravel in the Kansas City Metropolitan Region is the Missouri River. In the western portion of the study area (upstream of Bowersock Dam) no alternative stream sources appear feasible. The Big Blue and Republican Rivers are potential sources of sand and gravel, but are impounded over much of their lengths and far removed from the Kansas City Metropolitan Region.

It is expected that a Missouri River operation will consist of bank material storage and handling facilities similar to those currently in use on the Kansas River. The Missouri River operations are also expected to be in areas not already heavily populated.

Since the Missouri River operations will be similar to existing Kansas River operations and may be located in areas already heavily influenced by industrial emissions, air quality will not be significantly affected by the implementation of this alternative, even though diesel instead of electric motors would be used to power the dredges.

e. Land Mining Alternative

Impacts to the air quality of the surrounding area from land mining of sand and gravel will depend on the mining equipment and techniques employed. To extract the floodplain sand and gravel, a certain amount of overburden must be removed. The amount of overburden removed depends on the depth at which mineable deposits are found. Most of the deposits occur at a depth of 35 to 80 feet (see Subsection III.A.6.f.). If it is assumed that 15 feet of overburden must be removed and that 40 acres per year are required to replace Kansas River production, then approximately 968,000 cubic yards of overburden would be removed annually. This is a substantial amount. During removal of the overburden increased levels of particulates will result, although this would be short term.

Once the overburden is removed, land mining is expected to employ equipment similar to that in use by existing commercial sand and gravel dredging operations. Pit mining on the floodplain at Lawrence near Interstate 70 presently utilizes a suction dredge in a flooded pit. The relatively high water table found in areas of floodplain sand and gravel deposits precludes extraction by means other than a dredge. Therefore, pit operations on the floodplain are not expected to significantly contribute to the total air pollution load of the study area.

Mining operations in areas where the sand and gravel is excavated dry would be expected to contribute to greatly increased particulate loads in the surrounding area. Some dust will result from on-site material processing and handling equipment and haul truck traffic on access roads.

3. NOISE IMPACTS

a. No Action

The major source of noise from existing commercial sand and gravel dredging operations is from loading, hauling and processing equipment. Except for several exceptions, most dredges are electrically run and contribute little to background noise levels. Dredges powered by diesel engines can be quite loud; however, due to the industrial setting in which many of the dredging operations occur, particularly those in the Topeka and Kansas City Metropolitan Regions, motor vehicle traffic and industrial operations are expected to be greater components of existing noise levels than are commercial sand and gravel operations.

The Mining Enforcement and Safety Administration (MESA) Regulation 56.5-50 limits employee exposure to occupational noise to 90 dBA daily noise dosage per eight-hour shift (U.S. Army Corps of Engineers, 1980). Regular inspections by MESA inspectors are held to verify that compliance with their safety regulations including noise is occurring at all commercial sand and gravel dredging sites. For these reasons existing commercial sand and gravel dredging operations have little effect on noise levels in the areas in which they occur.

b. Cessation of Dredging

Since existing commercial sand and gravel dredging operations on the Kansas River have little effect on background noise levels this alternative would have no real positive effect as far as noise impacts are concerned. Noise from haul truck traffic and machinery operation which currently occurs around dredging operations will cease. However, when compared to background noise from other industrial and motor vehicle traffic sources in the area the decrease in noise levels will not be noticeable.

c. Reduced Quantity of Material Extracted

For the same reasons as listed above, the implementation of this alternative will not result in any noticeable positive effect on study area noise levels. A decrease in the amount of on-site machinery operation and haul truck traffic would result, but this improvement would be masked by background noise levels which presently occur in the vicinity of commercial sand and gravel dredging operations.

d. Alternative Stream Source for Dredged Materials

The Missouri River is the only reasonable alternative stream source for sand and gravel in the metropolitan Kansas City area based on economic factors such as transportation costs. Movement of lower Kansas River (river mile 0-50) dredging operations to the Missouri River will necessitate a switch to a larger dredge capable of withstanding the swift currents of the river. One company which

presently operates on both the Kansas and Missouri Rivers utilizes a processing plant built on a barge attached to the dredge. The physical size of the Missouri River precludes the use of electrically run dredges, therefore, diesel powered dredges which generate greater noise levels will result. Also associated with this type of operation are towboats which tow the barges containing graded and washed sands to an unloading site. The towboats will also contribute to elevated noise levels around such an operation.

Noise impacts resulting from this alternative are expected to be minimal. The operations are expected to be located away from population centers and will have to comply with MESA regulations concerning employee exposure to occupational noise.

e. Land Mining

Land mining of floodplain deposits of sand and gravel is expected to be very similar to existing dredging operations in the noise levels produced. Since the water table in the floodplain of the Kansas River is relatively high, electrically run suction dredges used in flooded pits are expected to be used. The only significant contribution of noise from such an operation will be on-site machinery operation and haul truck traffic.

This type of operation will be subject to MESA regulations concerning employee occupational exposure to noise and is not expected to significantly affect noise levels. Pit mining operations will be a bothersome noise source only if they occur in close proximity to populated (residential) areas. This situation is not expected to occur.

4. WATER QUALITY IMPACTS

Much of the following discussion of the impact of commercial sand and gravel dredging operations and its alternatives on water quality is based, in large part, on interim results of the Fishery-Dredging Study of the lower Kansas River by the University of Kansas (Cross and DeNoyelles, 1980). Additional information is included where it is deemed appropriate.

a. No-Action Alternative

KDHE (1978) lists the principal pollution potential created by sand and gravel dredging as the production of suspended solids, sediment, and silt from mining in the riverbed. The disturbance of the riverbed may result in elevated suspended sediment loads downstream of the dredge. Elevated turbidity resulting from these increased suspended sediment loads interferes with photosynthesis by the river plankton and can have detrimental effects on aquatic life (Kansas Fish and Game Commission, 1978). Once this material settles out of the water column, substrates suitable for macroinvertebrate colonization as well as spawning and nursery areas for fish may be smothered.

Additional concerns have centered around increased bank erosion which elevates the river's sediment load and possible resuspension by dredging of toxic substances trapped in the riverbed sediments.

The KDHE (1978) feels that the elevated sediment loads that may result from dredging are in excess of the river's transport capacity and therefore, settle out of the water column a short distance below the dredge. Unless the river is used for some critical purpose, such as a water supply immediately downstream from dredging operations, no water quality problems are created.

Interim results of the lower Kansas River "Fishery-Dredging" study (Cross and DeNoyelles, 1980) also suggest that at present existing commercial sand and gravel dredging operations do not significantly affect water quality.

Unlike the KDHE study, the Fishery-Dredging study found no major differences between turbidity levels above and below operating dredges (Table 5 of Appendix C). This is possibly a result of the suction dredges presently in use on the river which operate in the sediment layer instead of at the sediment-water interface. Where there are major differences along the river they are the result of changing river conditions. The effluent through the outfall pipe tends to have higher turbidity values; however, this does not apparently influence downstream conditions. This is related to the very small amount of effluent discharged versus river flow. Sedimentation occurs immediately below the effluent pipe, though the area affected is so small that significant impacts are negligible.

Data for suspended solids (Table 2 of Appendix C) indicate that the values below the dredges tend to be lower than the values above the dredges. This may be related to ability of the dredge pit to "trap" incoming sediment.

Particle size analysis of suspended matter by the United States Geological Survey and "Fishery-Dredging Study" (Tables 3 and 4 of Appendix C) exhibits little real trends between control and dredged areas, although the effluent samples tend to contain a higher percentage of the suspended matter in larger size classes.

Parameters such as dissolved oxygen, total dissolved solids, pH, and alkalinity show no unusual differences above and below an operating dredge (Tables 6, 7, 8, and 9 of Appendix C). Effluent values for dissolved oxygen, pH, and alkalinity tend to be different from river channel values, but this does not seem to affect downstream conditions.

Interim results of the "Fishery-Dredging Study" indicate that there is a tendency for elevated trace metal concentrations in the reach of the river being dredged relative to the control area; however, this is not always the case (Table 1 of Appendix C). The

concentrations of metals found throughout the study area fall within the maximum and minimum range of metal concentrations sampled upstream of the study area at DeSoto, Kansas (river mile 31.0) by the USGS (Table II-6).

Besides the parameters previously mentioned, other substances are analyzed three times per year. These include the following:

Total volatile solids (TVS)	Total organic carbon (TOC)	Mirex
Chemical oxygen demand (COD)	Phenols	PCBs
Nonfilterable solids (NFS)	Oil-grease	Lindane
Immediate oxygen demand	Sulfides	Heptachlor
Total Kjeldahl nitrogen	Redox potential	Aldrin
Ammonia nitrogen	Cyanide	Heptachlor epoxide
Total phosphorus	Atrazine	Beta chlordane
Alpha chlordane	P, p-DDE	Dieldrin
Endrin	O, p-DDT	P, p-DDD
p, p-DDT		

and any others determined to be potentially present due to an upstream source. Of the two sampling periods analyzed to date, the following parameters indicated increase in the stretch of the river being dredged relative to the control area.

Month	Parameter	Control Average (mg/l)	Below Dredge Average (mg/l)
September (1979)	TVS	110.0	147.0
	TOC	5.5	27.7
	Aluminum	919.0	1218.0
	Barium	128.0	142.0
	Iron	882.0	1252.0
	Manganese	208.0	234.0
March (1980)	TVS	83.0	91.0
	NFS	59.0	76.0
	Oil-grease	0.1	0.8
	COD	2.0	12.0
	Aluminum	2490.0	2720.0
	Barium	118.0	127.0
	Iron	1,835	2037.0
	Manganese	55.0	64.0

Note: Metal concentrations are in ug/l.

All other parameters sampled in September 1979 and March 1980 were either not detectable, similar, or varied without pattern throughout the entire study area. In March, TOC showed a lower average value at the dredges than at the controls.

While it is true that some of the parameters have elevated concentrations in the dredging area versus the control area these differences are not substantial. The elevated metal concentrations are not outside the range of background concentrations.

Riverbed sediments can be "sinks" for a wide variety of chemical pollutants. Disturbance of these sediments by dredging could make these substances available to the water column and create water quality problems affecting public health or aquatic life downstream. Trapped pollutants can also be made available to the water column by the benthos and bacteria.

Future work of the "Fishery-Dredging" study will analyze riverbed sediment cores for the same parameters as mentioned above and also undertake particle size analysis. Summarization of all this data awaits further results but several observations can be made at this time.

The dredged material is composed predominantly of sand and gravel which is characteristic of and generally found in areas of high current and large bed loads. Pesticides and heavy metals become "trapped" in river bed sediments only when significant amounts of clay and organic materials can bind these substances (Morton, 1977; U.S. Army Corps of Engineers, 1976a). Due to the low clay and organic matter content of the Kansas River bed sediments, significant concentrations of these materials are not expected to occur.

The solubility of heavy metals in water appears to be controlled in large part by the levels of dissolved oxygen in the water (U.S. Army Corps of Engineers, 1978a; Ebel, 1979). A chemically reducing environment (low pH, anoxic conditions) is a major factor in the availability of heavy metals to the water column.

The good dissolved oxygen characteristics of the Kansas River and virtual absence of anoxic conditions also characterized by low pH and reducing conditions even in the deeper portions of the river also suggest that heavy metals do not exist in soluble form in the water column for any great length of time.

Though the impact of dredging operations on water quality is only being studied in the lower river, the same conclusions are presumed for upstream dredging operations. It is also noted that the continuance of the Fishery-Dredging Studies in 1981 will hopefully provide further information on water quality impacts. This work may include the examination of bioaccumulation of metals and pesticides in aquatic organisms within the study area.

b. Cessation of Dredging

It is obvious that the complete cessation of dredging on the Kansas River will benefit water quality to some degree. Implementation of this alternative will eliminate the sedimentation and turbidity problem that currently exists below the water return outfall pipe, though the area that will be benefited is relatively small. The trend toward small increases in the concentrations of certain parameters below operating dredges will be curtailed. The possibility of oil and other pollutants from spills on the plant site finding their way into the Kansas River will be eliminated.

However, based on studies of existing Kansas River dredging operations on water quality (Cross and Denoyelles, 1980; KDHE, 1978) the benefit to existing water quality from this alternative will be minimal. According to the KDHE current regulatory policies of that agency toward commercial sand and gravel dredging are believed to ensure adequate water quality. Interim results of the "Fishery-Dredging" study, suggest that no significant water quality degradation is resulting from existing operations.

c. Reduced Quantity of Material Extracted

By reducing the quantity of material extracted by existing dredging operations, the impacts to water quality discussed under III.A.5.a. will be lessened. This is due to the shorter time period in which a dredge would operate and a decrease in effluent discharges from the plant site. However, since existing operations do not appear to significantly degrade water quality, implementation of this alternative will result in minimal benefits to existing water quality.

d. Alternative Stream Sources for Dredged Materials

The only reasonable alternative stream sources for existing commercial sand and gravel dredging operations in the Kansas City Metropolitan Region is the Missouri River.

Equipment needs on the Missouri River are different from those in use on the Kansas River. Missouri River production requires a physically larger dredge capable of withstanding the swift current and hazards of the river. The processing plant is built on a barge attached to the dredge. Graded and washed sands are conveyed to barges and towed to an unloading site by towboats. Suction dredges are used to extract the sand and gravel from the river.

Since a Missouri River operation involves a greater degree of handling and processing on the river the potential for accidental discharge of the dredged material into the river exists. The suction method employed should alleviate any elevated turbidity due to an operating dredge.

Significant water quality impacts resulting from resuspension of sediment bound heavy metals and pesticides are not expected. It is

possible that these materials may be present in the riverbed sediments due to the agriculturally intensive nature of the drainage basin. Since the material to be dredged is deposited sediment (mostly sand); trapped pollutants are not present in unacceptable amounts in the dredged material (U.S. Army Corps of Engineers, 1978b).

It should be noted that the high background levels of suspended sediment in the Missouri River during high flow periods may mask any turbidity effects resulting from dredging.

This alternative will have a positive benefit by removing some of the material which may periodically choke the navigation channel.

e. Land Mining

Land mining (pit) operations on the floodplain are not expected to significantly affect ground or surface water quality. Off-river operations are required to provide sedimentation prior to discharge into the river if the discharge of the excess water stream is not back into the dredging pit (KDHE, 1978). In addition, off-river sand and gravel operations that discharge into a stream are required to have an NPDES permit limiting effluent discharges.

It is possible that spills of oil and other pollutants occurring on the material storage and handling site or directly from the dredge could enter the ground water either by leaching or runoff into the dredge pit. However, operations are required to ensure that no spills of oil or other pollutants reach any streams.

Initial removal of the overburden to create a pit in the floodplain may result in elevated turbidity levels in nearby streams during heavy runoff events. Transport of this material off-site or stabilization of the spoil material by diking, revegtating or other methods would minimize erosion of the material once it is excavated.

5. BIOLOGICAL IMPACTS

The following discussion of the impact of commercial sand and gravel dredging operations and its alternatives on aquatic biological resources is based, in large part, on interim results of the Fishery-Dredging Study of the lower Kansas River by the University of Kansas (Cross and DeNoyelles, 1980). Additional information is included where it is deemed appropriate.

a. No-Action Alternative

(1) Aquatic Communities: Interim results of the "Fishery-Dredging" study of the lower Kansas River (Cross and DeNoyelles, 1980) suggest that at present existing dredging operations have little effect on algal communities of the river. Chlorophyll a concentrations, a measure of algal biomass, show no major differences above and below each dredge (Table 10 of Appendix

C). The concentrations both increase and decrease in the study area with no significant differences between the dredged and control areas. As would be expected, the effluent tends to contain reduced chlorophyll levels; however, this is not always the case. Changing river conditions over the 48-hour sampling period being studied cause major changes in algal biomass, as do seasonal factors. Previous work on the upper Kansas River (Marzolf, 1979) has suggested that algal productivity is largely controlled by the magnitude of discharge in the river.

Though chlorophyll-a concentrations suggest no impact, initial primary productivity data, based on isotope labeling (14c), indicates a trend toward a decrease in biomass and productivity in the dredged areas relative to the control areas (see below).

	14c Counts/Minute		Algal Biomass (mg/l)
Sampling Area	June 1980	August 1980	June 1980
C2A	9308.1	5602.9	94.0
C2B	9263.6	4580.0	100.0
D1A	9508.3	4523.7	99.5
D1D	9878.4	4053.9	100.0
D2A	6234.2	3778.2	79.0
D2D	7114.4	4365.5	100.0
D3A	6297.0	4272.0	78.0
D3D	6468.2	3334.6	80.0

The structure of the phytoplankton community changes in the downstream direction beginning at the control stations. There is also variation which may be attributed to changes in season and river discharge (Table 11 of Appendix C). Some species increase in the downstream direction while others decrease (Table 12 of Appendix C).

Periphyton (benthic algae) is present in large amounts in shallow water areas having sufficient light penetration and stable substrates. These organisms are a very important trophic component of the Kansas River. Existing dredging operations may impact these communities by direct removal of productive shallow-water habitats. However, other factors such as river discharge and pollution appear to exert greater effects on river periphyton than does dredging.

The structure of the zooplankton community varies without pattern in most cases; however, there is some evidence which suggests a decline in the numbers of organisms in the downstream direction from the controls (see Table 13 of Appendix C). Considerable variation may be caused by discharge from upstream reservoirs. This phenomenon has previously been documented for ichthyoplankton on the Missouri River (Benson, 1973). At this time existing dredging operations appear to have no significant

effect on the zooplankton of the river which generally are not abundant.

Macroinvertebrate sampling in the Fishery-Dredging Study area indicates that at the present time commercial sand and gravel dredging operations have no negative effects on these organisms. Drift macroinvertebrate number and kinds do not differ consistently among sites (Table 14 of Appendix C) and benthic (bottom-dwelling) macroinvertebrates exhibit a marked tendency toward an increase in the number of taxa and their numerical densities in the downstream direction (Table 14 of Appendix C).

These results probably reflect differences in the habitats available at each sampling site. There is a strong association of benthic organisms in the lower river with favorable habitat. The higher densities occurring around the dredge sites reflect the diverse habitat conditions found there (fast, slow, and no current, armored islands and channels, varying depths, and changes in substrate particle size (gravel, sand, and silt)). This is in contrast to the control transects which sample a single monotonous habitat which characterizes the Kansas River throughout most of its length--a wide, shallow, sandy channel. It is plausible that commercial sand and gravel dredging operations may have created the diverse habitat conditions which presently exist around lower river dredge sites. Therefore, existing operations may have benefited the benthic macroinvertebrate community to this point in time. It is likely that in the immediate vicinity of the operating dredge benthic organisms are dislodged and removed (U.S. Army Corps of Engineers, 1980). However, this effect in the Kansas River may be mitigated by increased habitat diversity. Table 15 of Appendix C lists macroinvertebrate taxa collected to date in the Fishery-Dredging study area.

Fish sampling in the Fishery-Dredging study area by seining, electrofishing, and trammel netting from May 1979 through August of 1980, indicates that existing operations are having no significant negative effects on the fish population of the lower Kansas River at this time. Most of the 48 species of fish captured were found in both dredged and undredged segments of the river (Tables 16 through 18 of Appendix C). Total numbers of species recorded from the control transects vary from 17 (at C1A) to 27 (at C1B). In the dredged section of the river, 18 (at D1D) to 33 (at D3E) species have been recorded. Three species--red shiner, sand shiner, and river carpsucker predominate in seining samples from all transects. Their level of dominance declines downstream from 96 percent of all fishes taken at C1A to 68 percent at D3E, Sand shiners specifically decline from 32 percent of the total sample at C1A to 9 percent at D3E.

Species with sport or commercial fishing potential such as the channel catfish, carp, freshwater drum, white bass, white crappie, bluegill and green sunfish occur in greater numbers at the dredge sites. These changes exemplify a general tendency toward increased diversity downstream. This tendency is probably a result of increased habitat diversity at the dredge sites, though seasonal factors and gear sampling efficiency may also be involved. Tables 19 and 20 of Appendix C illustrate the increase in the number of species occurring at the dredge sites. Though diversity increases in the downstream direction, density measures, expressed as weights of fish per square meter in the seining samples do not differ consistently among sites.

As with the benthic macroinvertebrate community of the lower river, it is possible that existing sand and gravel dredging operations may have created the diverse habitat conditions which presently exist around lower river dredge sites. Existing operations may have benefited the fish population to this point in time by increasing cover and food items. It should be noted that fish may avoid the immediate vicinity of an operating dredge. This tendency is illustrated by the numbers of fish sampled in the dredge pit versus areas above and below the dredge (Tables 17 and 18 of Appendix C). Gear efficiency, however, may be a factor in the lower numbers captured in the pit.

Fish spawning in the Kansas River encompasses the general period of April through July. Therefore, direct effects (if any) of dredging operations on fish spawning will be confined mostly to this time period.

Dredging operations could possibly act in two ways to impact fish spawning: (1) through the degradation of water quality, particularly elevated turbidity and the redeposition of silt and (2) by habitat modification i.e., the removal or alteration of shallow spawning habitat.

Based on the discussion of water quality impacts discussed in Section III.4.a., degradation of water quality by existing dredging operations does not appear to be significant. Therefore, little impact on fish spawning should result when viewed from this perspective.

Fish spawning habitat occurs in practically all of the Kansas River and its tributories, but generally shallow water areas such as quiet backwaters, tributary mouths, cut banks and bank cavities, and quiet water areas along the filling banks are utilized. Current dredging operations, for the most part, are confined to the channel of the river, an area less suitable for most species as spawning habitat.

The number of young-of-year fishes collected by seining in dredged versus control areas are not radically different. In addition, existing dredging operations may be responsible for some of the diverse habitat conditions presently seen in the "Fishery-Dredging" study area.

All of the above considerations seem to indicate that dredging is having no adverse effects on fish spawning in the Kansas River.

Long-Term Effects

As discussed in Section III.A., existing dredging operations in the lower river may be contributing to changes in the river channel below DeSoto, Kansas. The bed of the river has degraded. This in turn may lead to an increase in channel depth below Bonner Springs, as replenishment will not offset the amount of aggregate extracted. The result may be extraction until the area is mined out. Future conditions may consist of a deep monotonous habitat for aquatic organisms. Degradation in the Missouri River channel below Gavins Point Dam caused a parallel lowering of the river surface, and a loss of aquatic backwater habitat for fish (Schoof, 1980). This effect would be substantial and represent a net negative impact in comparison to predredging habitat conditions characterized by a sandy, shallow channel.

It is inferred that bed degradation in the lower Kansas River will lead to a parallel downcutting of lower river tributaries. Whether downcutting will significantly alter the habitat characteristics of these streams and result in paralleling effects on aquatic organisms cannot be determined with any confidence.

Though bed degradation may be a component of bank erosion along the river below DeSoto, Kansas, the increase in suspended sediment and turbidity resulting from erosion is not believed to be significant in comparison with background conditions.

Existing dredging operations appear to have no significant direct effects on the aquatic communities of the Fishery-Dredging study area at this time. This situation is presumed to be the case at upstream dredge sites. Furthermore, current information suggests that river channel characteristics above DeSoto, Kansas are generally not affected by dredging activity. Therefore, at least into the foreseeable future, upstream dredging operations should have no significant detrimental effects on aquatic biological resources. However, long-term effects in the lower river, from habitat alteration, may be significant.

(2) Terrestrial Communities: Existing sand and gravel operations have little direct effects on the terrestrial communities currently occurring along the river. Since most operations occur within or in close proximity to urban areas pre-emption of wildlife habitat by the dredging site is not a significant problem.

Bed degradation in the lower river resulting from removal of sand above the replenishment rate may be a component of the bank erosion occurring along the Kansas River below DeSoto, Kansas. Bank erosion results in the loss of wildlife habitat occurring along the riverbank, though this habitat is primarily cropland which is not as important as other habitats (riparian timber) along the river.

Channel scour may cause dewatering of backwater areas and a decline in ground water levels (Ruttner, 1963). It is inferred that bed degradation in the lower river may also lead to a reduction in the surface water elevations of creeks and other water areas along the lower river and cause acceleration of the aging process of existing wetlands. This impact will occur over the long term. Short-term variations in river flows caused by climatic conditions may mask these changes. Wildlife affected would include amphibians, water snakes, water-oriented birds such as herons, shorebirds and waterfowl, and mammals such as the beaver, mink, raccoon, and muskrat. It should be emphasized that wetlands are relatively uncommon along the Kansas River. These areas occasionally occur as small, scattered tracts with many holding water only on an intermittent basis during flooding. In many cases, they provide, at best, only temporary habitat at widely varying times of the year.

Existing dredging operations also remove sandbars which are resting and feeding habitat and a grit source for various species of waterfowl and shorebirds. Due to the transient nature of these bars and the high frequency at which they occur in the Kansas River, this removal is not felt to have significant adverse impact.

Except for minor bank erosion in the vicinity of a dredging operation, upstream operations appear to have no significant effects on terrestrial biological resources.

(3) Threatened and Endangered Species: Of the federal and state species which may occur in the study area (Tables B-10 and B-11, the only one which definitely occurs in the study area and is potentially affected by existing commercial dredging is the blue sucker (*Cycleptus elongatus*).

Pflieger (1975) suggested that the blue sucker is tolerant to high turbidity as long as there is sufficient current to prevent

siltation. He stated that the construction of dams has decreased the current in major rivers, facilitating siltation unfavorable to the blue sucker. Cross (1967) felt that the decline of populations in the lower Kansas River resulted from a change in the physical character of the lower mainstream with a narrower, deeper channel converted to an essentially uniform, sand-choked channel, perhaps by the major flood of 1903.

The species is believed to feed on aquatic insect larvae and other benthic invertebrates (Pflieger, 1975). Based on these considerations it seems reasonable to postulate that existing sand and gravel dredging operations may have had a positive effect on blue sucker populations in the river. Increasing the diversity and abundance of food items in the lower river and temporarily eliminating sand-choked channels would benefit blue sucker populations. However, as mentioned previously, the lower river channel may change to a deep, monotonous habitat with a corresponding increase in water depth. In addition, the Missouri River backwater effect may extend further upstream than it does now in the future. Should this occur the favorable sucker habitat now existing would be lost. The area immediately below the Hub Morris plant (river mile 12.3 to 12.9) is the most favorable reach of sucker habitat in the Fishery-Dredging study area (Cross, personal communication, 1980).

The remaining species which may be affected by existing dredging operations are the pallid sturgeon, sicklefin chub, and northern crayfish frog.

Cross (1967) felt that pallid sturgeons may enter the lower Kansas River from the Missouri mainstem only in years of exceptionally high water. The sicklefin chub has not been collected in the Kansas River in recent times. The absence of any detailed life history information for both of these species precludes any conclusive analysis of dredging effects. The decline of these species in the Missouri River may have been caused by factors such as pollution, channel modification, and over-fishing (for the pallid sturgeon). In any case, the presence of these species in the Kansas River is uncertain.

The northern crayfish frog habitat requirements include floodplain sloughs, oxbows, and marshes. In the absence of water holding soils, these habitats would be expected to be affected by bed degradation in the lower Kansas River. However, as with the two other species mentioned above, the presence of this species in the study area is doubtful.

Dredging operations in the river from Lawrence west are not felt to have any effect on threatened or endangered species.

b. Cessation of Dredging

Since existing commercial sand and gravel dredging operations on the lower Kansas River appear to cause small decreases in primary productivity and zooplankton, cessation of dredging will result in a slight improvement in these parameters. A short-term decline in the density and diversity of benthic macroinvertebrates and diversity of fish species in the dredging areas may also result due to decreasing habitat diversity.

The long-term impact of this alternative on the aquatic biota will be positive. The elimination of bed degradation in the lower river will decrease bank erosion and downcutting by lower river tributaries. It should be pointed out that tributary downcutting and bank erosion are not exclusively detrimental impacts on aquatic organisms. This alternative would also prevent a possible major habitat change in the lower river resulting from mining the channel until it became a deep trench lacking in habitat diversity.

Terrestrial biological resources would gain slight benefits from this alternative. The loss of cropland habitat in the lower river due to bank erosion will occur at a lower rate. This process will not be completely curtailed since other factors are also involved in bank erosion. Bank erosion is also a natural process of alluvial stream channels and can have positive effects on the terrestrial environment associated with streambanks by encouraging successional habitat development on the filling bank of the stream.

The elimination of bed degradation will halt the accelerated aging of existing standing water areas along the lower river.

Though the on-bank processing and storage areas of individual dredgers will be free for other uses once operations cease, wildlife will not benefit since these areas are essentially xeric-waste areas with long recovery times.

The implementation of this alternative, in and by itself, will have no impact on threatened and endangered species.

The above impacts apply only to the lower Kansas River. Dredging operations west of Bowersock Dam appear to have no significant adverse impacts on the aquatic and terrestrial biota of the Kansas River and its banks.

The aquatic and terrestrial communities of the lower Kansas River, particularly its lower reach, are also stressed by fluctuating river flows, agricultural practices and runoff, industrial and domestic pollution, and other factors. Total abandonment of commercial sand and gravel dredging on the lower Kansas River would have positive long-term effects; however, due to the other stresses present, the overall quality of the river would not be significantly improved.

c. Reduced Quantity of Material Extracted

The implementation of this alternative applies only to dredging operations in the lower 50 miles of the Kansas River.

A very slight improvement in primary productivity and zooplankton abundance may result from the implementation of this alternative. The diversity and density of benthic macroinvertebrates may decline as may the diversity of fishes, due to the decline of diverse habitat. Over the long-term, however, a tendency toward channel deeping will cease.

From a terrestrial biological standpoint, the loss of cropland habitat in the lower river due to bank erosion will occur at a reduced rate. This process will not be completely curtailed since other factors are also involved in bank erosion. The curtailment of bed degradation will halt the accelerated aging of existing standing water areas along the river.

d. Alternative Stream Sources for Dredged Materials

The only feasible alternative stream source for sand and gravel is the Missouri River. Potential water quality impacts resulting from this alternative are discussed in Section III.A.4.d. Based on this analysis and the greater size and volume of water in the Missouri River significant effects on the aquatic ecosystem are not expected. Turbidity should not be a problem because of the suction method employed in dredging the sand and gravel.

Resuspension of sediment bound toxic materials such as heavy metals and pesticides may occur. It is possible that these materials may be present in elevated quantities due to the agriculturally intensive nature of the drainage basin. However, as mentioned previously, trapped, pollutant chemical substances are not believed to occur in unacceptable amounts in the riverbed sediments (U.S. Army Corps of Engineers, 1978b).

The impact of this alternative on vegetation and wildlife depends on the areas chosen for relocation. Certainly, vegetation and wildlife will be displaced by bank material storage areas and lignite processing equipment. The degree of this effect depends on the quality of habitat removed. For instance, the removal of cropland or previously disturbed habitats is less severe than the removal of riparian timber. Due to economic considerations, it is probable that the site chosen for a Missouri River dredging operation will be one which requires the least amount of clearing such as cropland or other open areas. Therefore, no significant effects on terrestrial biological resources are foreseen.

The impact of this alternative on threatened and endangered species cannot be determined in the absence of prior knowledge of the river location of individual dredging sites. However, based on the

ecological characteristics of the Missouri River near the Kansas City Metropolitan Region (U.S. Army Corps of Engineers, 1976b) and species potentially present, no adverse impacts on threatened or endangered vertebrates are expected.

e. Land Mining

The impact from this alternative on aquatic communities will be essentially nil, except in the special case of a heavy runoff event during overburden removal. Such a runoff event may result in elevated turbidity levels in nearby streams or other water bodies. Since operations are required to ensure that no spills of oil or other pollutants reach nearby streams and are subject to other environmental regulations (see II.A.4.e.) no significant impacts on aquatic biological resources are expected.

Land mining operations will adversely affect terrestrial biological resources. Clearing of a site and subsequent mining will displace vegetation and wildlife throughout the life of the operation. Assuming that 80 percent of the 1978 production of 4,000,000 tons of aggregates was extracted in the reach below Bowersock Dam, it would require approximately 42 acres of floodplain land per year to generate 3,200,000 tons (see discussion in Section III.A.6.). This land requirement is substantial when viewed over the life of a pit operation. This figure does not include land area required for associated facilities such as scales, processing equipment and material storage piles. Of course the severity of this impact depends on the quality of habitat removed. For example, the removal of cropland or other previously disturbed habitats is less severe than the removal of riparian timber.

Due to overburden removal, spoil disposal areas will also occupy floodplain areas unless the material is transported off-site. The long-term impact of land mining operations and spoil disposal could be mitigated by appropriate reclamation efforts such as grading, revegetation of exposed areas and selective plantings of trees and shrubs. Recreation and/or wildlife benefits may accrue from such an effort, although the land will never return to its original state.

Land mining operations are not expected to adversely affect threatened or endangered species.

6. SOCIOECONOMIC IMPACTS

In addressing the socioeconomic impacts of the various alternatives being considered in this study, it is important to consider the siting characteristics of the sand and gravel industry. With a clearer understanding of siting problems that may occur, mitigation plans would be more capable of minimizing potential impacts.

Naturally occurring sand and gravel deposits grow in value relative to their proximity to urban areas or to those localities where they may be needed for various purposes. In most cases, this is near populated

areas. The significance of this product is indicated by the fact that our national annual consumption of sand and gravel is about five tons per capita (Schellie, 1977). This results in industry-wide efforts to locate the sites as close to the product use as possible.

With the location of these sand and gravel operations close to urban areas, political, social and environmental confinements arise. Primary among these is the fact that producers of sand and gravel must comply with various governmental regulations and controls. Also, with the often expanding population base and resultant increase in land requirements for urban growth and development, the problem of acquiring sand and gravel lands close to their markets becomes more serious. Ironically, urban growth has often sealed-off prime sand and gravel deposits for which urban expansion is so dependent. Therefore, the sand and gravel industry is in severe competition with other interests in obtaining resource productive land; land that could be utilized for other purposes upon completion of its extractive life.

Thus, the fundamental problem of the industry is that of securing the right to continue to produce sand and gravel for the construction industry at locations that are economically feasible (Schellie, 1977).

The utilization of the Kansas River for sand and gravel extraction has minimized the above mentioned problems due to smaller land requirements than pit mining and the convenience of staying on one site for long time periods. This stability has reduced the need to preserve urban land for potential pit mining in the study area, although this possibility should not be ignored when developing lands with high sand and gravel concentrations. Also, the long-term nature of the Kansas River commercial dredging operations has virtually eliminated the need for zoning changes since the sites are predominantely located on industrial lands.

By virtue of the location of the dredge sites away from populated (residential) areas for the most part, and their relative permanence, no public complaints concerning noise, fugitive dust, traffic patterns, or unsightly conditions have been recorded by the Kansas Department of Health and Environment (Buergin, 1980). Apparently, there are no air quality designations or noise regulations placed upon the dredging industry that have caused any problems. Community acceptance of the Kansas River commercial operations has not been a problem as is often the case in the more transient surface mining sector of the aggregate industry. Should there be a movement by the Kansas River sand and gravel producers to relocate along the Kansas River or to develop surface mining pits for materials extraction, many social concerns would have to be addressed. These aspects will be discussed more fully in this section of the report as various alternatives are reviewed in detail for their possible socioeconomic impacts.

There is a substantial amount of information available regarding the siting of sand and gravel operations, the reclamation of mined-out sand

and gravel pits, and planning for the protection of nonrenewable mineral resources such as sand and gravel. Very little planning data have been located involving river dredging operations such as exist along the Kansas River. These planning aspects of the sand and gravel industry have been discussed in general in this part of the report since river mining is the major source of aggregate along the Kansas River study area. Should additional data be needed involving planning considerations for establishing pit mine operations, the reclamation of those sites, the protection of nonrenewable resources, and site selection specifics, consult the Data Source Bibliography at the end of Section III (Carriero, 1975; Godfrey, 1977; Robertson, 1975; Robertson, 1978; Stearn, 1976; Wallace, et al, 1965; Werth, 1980; Young, 1968.)

a. No Action

The no-action alternative, in which dredging operations are allowed to continue without any new restrictions, would lead to no changes in ongoing economic conditions. Changes which would occur would be consequent to conditions in the market for aggregate materials or further reductions in the replacement supply carried down the Kansas River. This deficit could have environmental consequences as noted previously in this report.

Future conditions in the case of unrestricted production can be outlined by extrapolating current trends and projecting relevant variables. Because of the general absence of time-series data, it is difficult to trace trends within or among the dredging firms. The production figures in Table III-1 apply to all Kansas producers, but are indicative of trends for the Kansas River materials industry. The main point to be drawn from reviewing these figures is the great extent to which production levels can vary because of their close link to the traditionally cyclical construction industry. Trends in the two major segments of the construction industry (building and highway) may accentuate or counteract each other in their effects on sand and gravel production.

An index which offers some measurement of pending construction activity, such as building permits issued, should serve as a good lead indicator of demand for sand and gravel. Because of the close link between construction activity and interest rates, which affect both public and private ability to finance construction, interest rate movements may also serve as accurate indicators of future demand.

Considering the broad characteristics of the economy in 1980, which include both recessionary conditions and a tendency toward high interest rates, demand for sand and gravel may be expected to diminish slightly in the 1980-81 period. This will be followed by a return to prevailing levels when a normal level of construction activity resumes.

TABLE III-1
SHIPMENTS OF SAND AND GRAVEL BY KANSAS PRODUCERS 1968-1977

Year	Quantity Shipped 1,000's of Tons	Current Dollar Value $,000's	Constant Dollar Value (1972) $,000's
1968	12,427	10,559	12,788
1969	12,029	10,061	11,602
1970	12,968	12,351	13,519
1971	11,862	11,351	11,821
1972	11,591	10,920	10,920
1973	13,261	12,663	11,969
1974	11,687	13,388	11,501
1975	10,866	13,467	10,583
1976	12,291	14,940	11,167
1977	12,100	16,580	11,730

Source: Zarley, Carol and David Collins. 1978. University of Kansas. Lawrence, Kansas. Kansas Mineral Industry Report, 1975-1977. Kansas Geological Survey.

In the long term, construction trends in the region will be related to both prevailing economic conditions and to the realization of public and private development plans. It is very speculative to attempt to predict economic conditions beyond the short term, even in the most general terms. Despite this, demographic trends and development projections can provide an indication of future construction needs, assuming that the overall trend of the economy is one of stable growth.

The Mid-America Regional Council has prepared several projections of future population and housing demand for the eight-county Kansas City metropolitan region. These projections are based on varying assumptions applied to a common methodology. The most probable of these is "Concept C," which includes assumptions of a low rate of population growth due to a low birthrate and a low rate of net migration. It is also assumed that current land use development policies and trends are continued and that the population in older central city areas will continue to decline while suburban areas grow. Employment growth is also assumed to be slower in the urban core area than in suburban centers. The following figures in Table III-2 were derived from this model.

U.S. Census estimates indicate the 1980 population of the metropolitan region to be 1,374,736 a 3.6 percent increase over the 1970 population. This suggests that the actual growth rate during the past decade has been even lower than that projected in Concept C. Because of this, it is best to regard the figures in Table III-2 as upper limits. Given these population and housing trends, it seems likely that building construction activity will continue at approximately current levels. The demand for sand and

gravel from this sector can consequently also be expected not to show sharp upward or downward trends in the next two decades.

TABLE III-2
HOUSING DEMAND AND PROJECTIONS
KANSAS CITY METROPOLITAN REGION
1960-2010

Year	Total Dwelling Units	Net Increase Dwelling Units	Population Total	Population Net Increase
1960	391,455		1,157,144	
		68,413		170,122
1970	459,868		1,327,266	
		41,788		102,454
1980	501,656		1,429,720	
		53,268		129,617
1990	554,924		1,559,337	
		42,200		94,696
2000	597,124		1,654,033	
		38,040		79,965
2010	635,164		1,733,998	

Source: Mid-America Regional Council. 1974 Population & Employment Forecast to 2025 Concept C.

The amount of highway and road construction to expect during this period is very difficult to assess. Changing funding priorities due to both financial and energy considerations have made future levels of heavy construction activity very uncertain. The Mid-America Regional Council's Long Range Street and Highway Plan, which serves to coordinate the planning considerations of the numerous governmental bodies in the metropolitan region, proposes that by the year 2000 nearly 300 miles of streets and highways will be built, with the widening of an additional 300 miles of existing roadway. In MARC's own current view, however, this scale of construction is not likely to be realized. In general, highway funding has recently tended to be proportioned more towards maintenance and less toward new construction. According to projections made by MARC of the cost of road construction, including an eight percent inflation factor, and the possible sources of revenue for this activity, there will be a $1.8 billion shortfall (in 1977 dollars) with regard to building the proposed road network. The gap between costs and revenues is expected to increase through time, such that in the late 1980's the cost of maintenance and projects which do not increase capacity will begin to exceed revenue. This means that capacity projects will be undertaken only at the expense of deferring maintenance of the existing system. Since the long range plan for major capacity construction is based in part on population projections, it will

remain to be seen whether budgetary shortfalls of the expected severity will result.

While any predictions are obviously speculative, there does not seem to be any reason to expect a sharp increase or decrease in the volume of road and highway construction and resurfacing activity. The demand for material aggregates from this sector is correspondingly not likely to vary greatly.

The available data suggests that the present volume of sand and gravel production is likely to be continued in the foreseeable future; allowing for a broad range of variability and a long term trend of limited growth. An economic variable likely to show change is the product price, which has tended to rise at a rate equal to or greater than the general rate of inflation. This trend is expected to continue in the near future. The cost of transportation of aggregates is equally subject to inflationary price increases. The trend of this increase appears to be about $0.01 per ton-mile per year. Other socioeconomic variables such as employment will not change substantially in the "no-action" alternative.

b. Cessation of Dredging

A complete cessation of dredging would have severe economic consequences and would necessitate the establishment of an alternative source for the material no longer being produced. To trace out these effects, first a microeconomic and then a macro view will be taken.

The consequences for the Kansas River dredging firms would be severe. Whether or not an individual firm would stay in business would depend upon its particular conditions. Certainly a small upstream dredging firm, should its source of production be removed, would no longer have any basis for operation. In the case of three of these firms, however, they are also the owners of ready-mixed concrete operations. These entrepreneurs would not necessarily be deprived of livelihoods, if they could find a replacement source of aggregates at a comparable cost. The ability of these firms to invest in the alternatives to be discussed is very problematic, depending largely on the availability of substantial financing, since sufficient internal funds almost certainly do not exist. The larger downstream dredgers may be in a better position to obtain the financing necessary to undertake a new type of operation, but this again will depend on numerous shifting economic contingencies. To create a worst case scenario, it is quite possible that these firms would be forced out of existence.

With the elimination of output, approximately four million tons of aggregate per year, there would be a loss of jobs which currently support this production. This would imply the direct loss of about 140 positions, as stated earlier in Section II.G.3.

Other macroeconomic variables, such as product price and haul distance, are difficult to address outside the context of potential alternatives. The major existing sources of aggregate material in the study area other than the Kansas River dredgers are floodplain pit operations in Kansas City, Kansas, Lawrence, Topeka, and several sites on or near the Missouri River. Three firms dredge sand and gravel on the Missouri River within the study area, while another company operates from a pit near the river. It is not known what exact share of the regional aggregate market these sources currently supply, but it is certainly less than the aggregate materials supplied by the Kansas River dredging firms. These other aggregate sources could not supply the needs of the regional construction industry by themselves, but if faced with a sudden sharp increase in demand the firms would almost certainly raise their prices considerably. It is impossible to apply a quantitative value to this increase, but given the nature of this market, with a relatively elastic supply (variable with price) and an inelastic (invariant) demand, the price increase is likely to be considerable.

Assuming that it became necessary to replace the majority of the lost production by purchasing material from existing producers, it would be necessary to transport this material over considerable distances. If material were purchased in the Jefferson City area, for instance, it would have to be carried roughly 120 miles, not considering local hauling. At prevailing rail rates, this would cost about $6 per ton. From the St. Louis area this cost would be about $12.50 per ton. It is highly speculative to predict what actual sources might be available which could provide the needed materials. In any case there are considerable practical difficulties involved in supplying the continuing operations of concrete plants and other users with nonlocal sources of aggregate.

The cost consequences of the elimination of a local source of aggregates can be seen to be considerable, an increase of several hundred percent appearing likely. This increase would apply both to nonregional materials, due to transportation costs; and to regional materials, due to a drastic alteration of market conditions. For example, aggregate handling facilities, materials transfer depots and additional use of transportation systems will add considerably to the transportation costs. There is also a possibility that practical difficulties with stockpiling, transport availability and other matters would create insurmountable barriers to relying on nonregional sources of supply.

Shifting to a macroeconomic perspective, the elimination of Kansas River dredging production would induce some impact on the regional economy. The effect realized when an existing industry changes its level of production is due in part to the need for other industries which supply inputs directly to the initial impact industry to alter their own production correspondingly. These industries in turn will modify their levels of inputs, some of which are produced by still

other regional industries. Additionally, industries experiencing major changes in production may change payments to the labor factor of production, altering household incomes. Variations in household income in turn affect consumption of retail and service sector goods and services, which could influence employment in those areas of the economy. This complicated chain of cause and effect may be quantified by tracing the original change through the relationships defined in an input-output model. The result of summing these multiple relationships is called, sensibly, a multiplier.

In the situation being studied, this type of impact is not nearly so significant as that which stems from the change in the supply of the product of the industry being initially modified. This type of supply induced change is sometimes called a forward linkage, as opposed to the backward linkage just described. In this case, the major impact lies in the loss of a necessary input to the construction sector. This forward linkage affects the macroeconomy through the same mechanisms as a backward linkage, after supply changes have impacted the production of the processing industry. The multipliers developed from I-O models are not applicable to estimating a forward linkage impact, unless the output change of the initially impacted processing industry is quantitatively known.

In this case the forward linkage is double, since price increases and other supply considerations will affect the output and price of concrete, asphalt and other aggregate-based materials. This in turn will affect the cost and initiation of construction activity. These effects are realized through the individual decisions of numerous entrepreneurs. Each of these decision makers in some way assesses changes in the average and marginal cost of production and the resulting profitability of price and production levels. Due to the complexity of this relationship, it is not possible to predict a change in construction activity levels based on uncertain changes in the cost of aggregates. This uncertainty precludes the generation of macroeconomic impact estimates derived from applying multipliers to construction activity.

This should not be considered a critical absence of information, since the input requirements of aggregate for construction activity have been shown to be fairly low (Section II.G.3.). In view of this, even sharp changes in the prices of aggregates are not likely to significantly affect the level of construction activity or the level of employment in that sector. A far more important macroeconomic impact will be a possible increase in the cost of construction. If the scenario previously drawn, in which aggregates would need to be purchased and transported from producers outside of the study region, were to become a reality, the effective price could rise from 400-700 percent depending on the distance of the source. Based on input requirements, this would raise total building construction costs 6-9 percent. This would comprise a very sharp increase above and beyond existing inflation. The effect on

highway and road construction, which is heavily dependent on aggregates, could raise costs 30-40 percent.

Cost increases of this magnitude would have far reaching effects on the construction industry. Costs would be passed on to local governments, businesses and home buyers, giving a sharp impetus to the inflationary spiral. The financial difficulties facing road construction and maintenance, described in the MARC report already mentioned, would be increased considerably. Deterioration of the transportation system would become more likely.

This series of consequences is delineated mainly to satisfy the requirement to predict the results of cessating dredging, independently of considering possible regional alternatives. In fact these do exist, and as cheaper sources of aggregate than extraregional producers become available, they would be exploited in the face of the continuing economic demand for sand and gravel. The probable consequences of relying on these alternatives is discussed in following sections. In summary, the conditions just described would contribute considerably to both inflationary and recessionary tendencies in the regional economy. If unimpeded, market demand can be expected to be met by an entrepreneurial initiative to exploit alternative existing resources within the region.

In assessing the economic benefits and losses associated with these alternatives, it will be useful to understand what impact to the economy can be directly associated with the ending of the Kansas River production and its input requirements as shown in the backward linkage previously described. Multipliers based on the Bureau of Economic Analysis national input-output model have been developed for 173 regions of the United States. The region centered around Kansas City includes northeastern Kansas and northwestern Missouri and covers the entire study area.

Using the derived multiplier for nonmetallic mineral industries and applying it to an annual value of production within a probable range, say $9,000,000, a value of $22,086,000 results. This figure is an indicator of the total loss of gross output per year from the regional economy which would result from the loss of the Kansas River dredging industry and the demand represented by its input requirements.

A further calculation based on the multiplier yields an earnings impact multiplier. Using the hypothetical production value of $9,000,000, this multiplier predicts a total arrival loss in regional income of $6,382,854. On the basis of the ratio of employment to earnings projected to prevail in this economic region, a loss of gross output of this magnitude may be expected to cost the region a total of about 560 jobs. From a macroeconomic viewpoint, these are relatively minor impacts, although of course they would not appear minor to the individuals and businesses affected.

An additional consequence of ending aggregate production on the Kansas River would be to eliminate virtually the only regional source of industrial sand. Industrial or silica sand is an important input to the manufacture of glass and ceramics, as well as for other purposes such as refractory material. One Kansas City firm produced approximately a quarter of a million tons of this material in 1979. Industrial sand is produced in large quantities from formations in eastern Missouri, but not currently from other alluvial sources. It is not known whether this material is commercially producible from the Missouri River.

It should be noted that the consequences of ending dredging have been assessed with the tacit assumption that some alternative source of aggregates must be found. This is because aggregates are a necessary material for most construction activities. To not adequately supply the demand for aggregates would cause a severe curtailment of construction in the region. This is an unimaginable alternative, since it would precipitate high levels of massive unemployment and other severely recessionary characteristics for the regional economy.

c. Reduced Quantity of Material Extracted

The alternative of reducing the quantity of material extracted addresses the fact that it is the removal of material in excess of the natural replacement rate, rather than dredging activity as such, which appears to be linked to the more serious environmental problems which are being investigated. The dredging firms on the Kansas River are being faced with a reduction in the annual replacement of the nonrenewable resource of sand and gravel. Reducing the level of dredging activity to the replacement rate would attempt to mitigate these environmental concerns while causing a less severe socioeconomic impact than in the cessation alternative.

About 4 million tons of sand was extracted from the Kansas River in 1980 according to a survey of dredge operators. Of this amount, it is estimated that 80 percent, or about 3.2 million tons is extracted below DeSoto, and about 0.8 million tons from the river upstream. The replenishment rate of sand below DeSoto is approximately 1 million tons per year (see Section II of this report). The replacement rate of sand for the upstream sector must be at least 0.8 million tons since that amount is extracted without obvious direct impacts on the river.

Since the replacement rate appears to be about 1.8 million tons, the current rate of about 4 million tons per year would necessitate a 55 percent reduction in material extraction along the entire river.

The manner of apportioning such a reduction is a regulatory and legal question, but two basic options seem apparent. One would be to impose a production limit on all dredging operators, an approach

which at least superficially appears most equitable. The other would be to severely restrict or ban extraction of material downstream of the Bowersock Dam in Lawrence, Kansas. This alternative would have the advantage of applying itself directly to the area where environmental degradation has been most concentrated. Our estimate, based on incomplete information received from the Kansas River dredging firms, indicates that about 80 percent of the production from the Kansas River takes place downstream of DeSoto. This option would lessen impact on the upstream dredgers, but would, of course, severely impact downstream dredgers. In the event of the first option, a reduction of total extraction from the river to the replacement level would necessitate that upstream dredgers reduce their production levels about 55 percent, while the larger downstream dredgers would be required to reduce production by about 60 percent assuming sands not dredged upstream would be available downstream. Under these conditions it would probably be impossible for any of these firms to remain in business, since revenues would drop far below costs, which are largely fixed. For this reason the consequences of this alternative are practically equivalent to those of the total cessation scenario.

Under the conditions of the second alternative, the supply of aggregates would remain adequate in the upstream area (Wamego, Manhattan, Topeka) but would not be so in metropolitan Kansas City. This would necessitate the location of a major alternative source. Banning production along a specified stretch of the river would of course create an incentive for the larger firms to move their operations upstream, a cost which could probably be absorbed by the firms in question. Estimates for the cost of such a move range from $150,000 to $250,000. The noncapital moving costs include dismantling, transporting, and reassembling the equipment, the lost production time during the changeover, and other administrative costs involved in such a move, However, doing this would raise the cost of transportation substantially. An increase in transportation distance of 40 miles would add about $3.60 to the cost of a ton of aggregates. Since this cost is usually born in part by the dredgers, this would be a discouraging factor for such a move. This added cost would also tend to make Kansas River materials less competitive in the face of potential alternative sources nearer the metropolitan customers. Decisions about whether or not to continue dredging from the Kansas River would depend on the relative cost projections particular to each firm.

Aside from these considerations, there does not appear to be technical or institutional socioeconomic barriers to increasing production at upstream locations. Any number of sites may be available for purchase or lease, considering the amount of agricultural and vacant land along the riverbank and depending upon land use restrictions which could hinder the siting process. The following table details land use along the Kansas River from its source to the area of the Bowersock Dam. The corridor studied

varies with the configuration of the river ranging from one to two miles in width with the Kansas River at its center.

TABLE III-3
LAND USE ALONG THE KANSAS RIVER, 1978
RIVER MILES 56 TO 170

	Acres	Percentage
Agriculture - Cropland	41,039.8	53.8
- Farmstead	305.9	0.4
- Pasture	0.0	0.0
River Bank Erosion	392.6	0.5
Gravel/Rock Pits	170.9	0.2
Forest - Deciduous	14,333.6	18.8
- Shrub	0.0	0.0
Meander Scars	0.0	0.0
Nonagricultural Lands	3,156.9	4.1
Park Lands	0.0	0.0
River Structures	0.0	0.0
Utilities, Transportation	104.5	0.1
Urban - Commercial/Public	1,887.0	2.5
- Industrial	1,568.4	2.1
- Parks, Cemetaries, Open	76.4	0.1
- Residential	2,037.3	2.7
Water - Lake	0.0	0.0
- Pond	229.5	0.3
- Stream	11,632.1	15.2
Total	76,298.6	100.8[1]

[1] Due to rounding.

Adapted from: Land Inventory & Development, Inc. 1979. "Land Use Compilation Data for the Kansas River and Tributaries." Laramie, Wyoming. Prepared for the Army Corps of Engineers. Kansas City District.

It is evident that urban development along the Kansas River is still confined to several relatively small stretches. Aside from obtaining an appropriate site, initiation of a new dredging operation would require permits from both the State of Kansas and the Corps of Engineers. The issue of these permits, which might normally be routine, might in this case hinge on broader considerations than the appropriateness of a particular site. Local zoning and licensing requirements would also have to be met. In Shawnee County, which includes Topeka, this type of operation requires a special permit. Consideration for such a permit requires the submittal of a plan detailing aspects of the operation which might affect adjacent land users. Aside from unacceptable site conditions, which have not been a problem with existing sites, there are few, if any, additional barriers to the issuing of such a

permit. In rural areas, permitting requirements tend to be minimal or nonexistent.

From a planning perspective, the alternative of a reduced quantity of material extracted appears to be fundamentally undesirable. By severely limiting sand and gravel extraction below the Bowersock Dam, affected firms would likely be induced to move their operation to an upstream location. This would only move the problem upstream, delay environmental impacts, and probably spread the effects over a wider area. The ease of relocating an operation would largely depend upon the availability of industrial sites, the rezoning of lands for extractive purposes, and public acceptance of the utilization of available land for sand and gravel production. Since it may appear to be an economically attractive alternative to some firms, it will remain for the Corps of Engineers to restrict such operations for environmental reasons as is deemed necessary.

d. Alternative Sources for Dredged Materials

In the event of either the elimination or reduction of production from the Kansas River, two substantial and plausible alternatives seem evident. One is to increase production on the Missouri River. The other is to mine materials from open pits where concentrations of sand and gravel are found. Either possibility raises numerous microeconomic and planning questions about the plausibility of applying existing labor and capital to new resources and the costs of such a transformation. These questions are difficult to address, both because of a lack of information and because of the inherent uncertainty of entrepreneurial initiatives in a complex market economy. The best that can be done is to outline the problems involved and the various situations which may result.

If existing producers of sand and gravel were to abandon their present operations and attempt to initiate either alternative, a very substantial capital investment would be necessary. Shut down costs are likely to be relatively small, since there would be no reason to dismantle and transport much equipment. This is because either alternative would require new production capital and support equipment. Labor requirements for the new capital plant would also be entirely different, in most cases requiring a greater number of workers.

The magnitude of these capital costs is highly uncertain, but to establish a dredge on the Missouri River with a level of production comparable to a large Kansas operation, it would probably be necessary to invest in excess of $3,000,000. Initiation of a pit operation would probably require $500,000. The ability of existing firms to generate this type of investment would depend entirely on the financial resources available to them.

It is certain that no dredging firm has access to sufficient internal funds to carry out either alternative. Lending

institutions would provide the necessary loans, if it could be demonstrated to their satisfaction that the potential for a substantially profitable operation exists. This will necessarily depend in part on the credit history and past performance of a given firm. A primary determinent, however, would be the existing resources of a firm, both financial and managerial. Smaller firms, in the event of a complete cessation of production on the Kansas River, might have difficulty finding financial support for converting to alternatives, since such operations would clearly require a much greater capital investment than the original. If this were so, these firms would effectively be forced out of business. The legal ramifications of this consequence would have to be addressed by an authority in that field.

Some dredging operators exist as divisions of larger firms. These dredgers may have access to sufficient internal funds or to the financing capability of the parent firm in order to facilitate a move. This possibility will derive from the costs and revenue potential perceived by the parent company, as well as its investment plans and capacities.

Larger firms typical of the metropolitan Kansas City area would be more likely to have access to financing. Decisions about whether to move into alternative resources and how to do so would be based on numerous factors. The high level of interest rates which have been a persistent economic factor will certainly serve to discourage expansive ventures. It is not likely that operations of this size would simply go out of business, however, without attempting to move to other locations. A relevant fact is that two of the metropolitan area dredgers on the Kansas River also dredge from the Missouri. These firms would be in a position to expand existing facilities, and would incur somewhat lower costs than starting with nothing. The continuing and certain existence of a demand for aggregates, deriving from the functions of the construction industry, will guarantee a market for material produced, at roughly known prices. This high probability of a certain volume of revenue would be encouraging both for entrepreneurial initiatives and for the financing to make them possible.

The continuing demand for aggregates as an aspect of public and private construction activity in itself assures that some alternative resource will be exploited in lieu of Kansas River supplies. It is generally true of a commodity market that a restriction of supply causes prices to rise in the face of a constant demand. This rise will be a signal to potential investors that a substantial return can be realized by producing for this market. It is possible then that new production can originate with entrepreneurs not previously involved in this particular industry. The users of sand and gravel themselves may consider it necessary to guarantee their supply by entering the aggregate business. This could occur either through the initiative of a single large user or

through the cooperation of users in recognition of their common interest. While it is impossible to say what actual mechanism will come into existence, the eventual development of new sources would be inevitable if Kansas River production is seriously restricted.

The assertion that Missouri River dredging and pit mining are viable alternatives to present practices warrants some analysis of their feasibility.

e. Alternative Stream Sources for Dredged Materials

Dredging from the Missouri requires a significantly different procedure than dredging from the Kansas River. Since the Missouri is a larger river, with swifter and stronger currents, a larger dredge is required. Processing and sorting is carried out on a barge also on the river. Graded and washed sands are loaded on barges and towed to unloading sites, to be stockpiled. Due to the high proportion of fine sands and silt, relatively less of the material dredged is useable. It is also necessary for some purposes to remove lignite from the material recovered, since this is very prevalent and is considered a deleterious material in concrete production.

The more extensive equipment and additional processing involved, and the larger labor force required for operations, explain the large capital investment needed to produce aggregates from the Missouri River. This larger capital cost is equivalent to a higher unit cost of production. This in turn will require a higher unit price for Missouri sand and gravel in order to provide a rate of return comparable to that currently realized by Kansas River dredgers. Prevailing prices for common specifications for sand from the Missouri are in the range of $2.20-$2.30 per ton. It is very likely that competition from Kansas River products have necessitated similar prices. In order to obtain a more typical rate of return, prices in the area of $2.60 per ton would probably have been necessary at 1979 cost levels. Considering recent inflationary trends, as well as the cost of investment funds expressed as a rate of interest, this hypothetical average price would be expected to exceed $3.00 per ton by 1982. This may be considered indicative of the prices to be expected for the products of an aggregate industry predominately based on the Missouri. Inflation levels previously discussed should be presumed to continue in the near future, excepting any major changes in national economic trends.

The physical requirement of siting and establishing new dredges along river reaches does not appear to present serious obstacles. The task of finding appropriate locations is not trivial, since there are a number of constraints. Large stretches of the Missouri River in the outlying parts of the metropolitan Kansas City area are not accessible by major roads. It is necessary of course to be able to transport dredged materials as cheaply as possible to consumers. Some river bank stretches near urban concentrations are already in

use for various industrial purposes. Others are park lands or recreational areas. Other considerations would include finding areas of the river with substantial deposits and an absence of hazards, as well as not interfering with flood control measures. A cursory survey of Corps of Engineers hydrographic maps and regional maps seemed to indicate numerous potential sites along various parts of the Missouri River which may satisfy the necessary siting conditions. It would be appropriate for a more detailed survey to be undertaken by someone knowledgeable of industry-related siting requirements.

Having located a successful site, it would of course be necessary to purchase or lease it for industrial use. The amount of land required for river operations is not very great, possibly 15-20 acres. Most land immediately adjacent to the Missouri River in the metropolitan area is vacant if it is not already in industrial or commercial use, according to the maps consulted. While the availability of any particular site must remain in question, this is not likely to be a problem. Land zoning along the Missouri is largely industrial, according to the planning and zoning offices of Kansas City, Missouri (City Development, 1980), Kansas City, Kansas (Speise, 1980) and Sugar Creek, Missouri (Lovelace, 1980). Each municipality imposes its own licensing and permitting requirements, which normally require an assessment of possible consequences and impacts and several levels of review. The current existence of several active sites in these municipalities indicates that there is no serious problem in this regard.

As noted earlier, the start-up of a new dredge site along a river bank entails more than the purchase of the required land and preparation of the site. Commercial dredging operations must contend with public attitudes and their potential impacts on local land owners. If adequate planning is not undertaken prior to setting up a new operation, nearby property owners are more likely to become annoyed and disturbed by a new facility. By carefully considering such items as appearance, proper fencing, minimum noise, dust, traffic interference, and taking necessary safety precautions, potential resentment of a new facility could be minimized. Additionally, a post-closure plan allowing for site rehabilitation would help to alleviate the concerns of nearby land owners and actually result in an increase in property values.

Since most dredge sites are located in industrial areas and require a relatively small labor force, minimal impacts upon local schools or neighborhoods are expected.

f. Land Mining

The initiation of pit mining requires the location of a suitable sand and gravel deposit, purchasing the land above it and establishing the necessary capital plant to produce the material. The geology of locating such deposits is outside the scope off this

economic analysis, but some generalizations may be made about potential resources. One source of such information is the Construction Materials Inventory series prepared by the Kansas State Highway Commission. These inventories survey resources for construction aggregate. Such studies have been done for Johnson, Shawnee, Douglas and Jefferson Counties within the study area. There appear to be three types of sand and gravel deposits found in these counties. Glacial drift deposits are widely scattered and vary greatly in depth. They are not usually economically mineable. Terrace deposits of various ages are found in stream valleys. These deposits are overlain by silt and clay and have not been exploited in the past. Rising prices could make it economical to mine these deposits. Quaternary alluvium is material deposited relatively recently by the Kansas River. This appears to be the most feasible resource for pit mining, both physically and financially. This type of deposit is virtually identical with material found in the River itself.

The depth of these alluvial deposits varies, but is usually between 35 and 80 feet. If a depth of 35 feet is assumed, with 15 feet of overburden which must be removed, it is possible to estimate the surface area associated with a specific volume of sand and gravel. This relationship was quantified by the project geologist. Under these assumptions, the removal of 200,000 tons of sand and gravel would require the complete mining of 6 acres of land. A million tons of production would consume 13 acres. An effort to meet the total annual market demand for Kansas River material in the study area, by producing for instance 5 million tons of aggregates, would require the complete mining of 44 acres. Each individual pit site would also require some land for scales, roads, stockpiling, etc., probably something like 10 acres. It may be approximated from this data, a scenario in which pit mining were to entirely replace river dredging, that 40 to 50 acres per year would be consumed in mining activity. This type of land use may be considered to remove the land area from any other productive potential, although various types of rehabilitation are possible in the long run.

While this rate of production might be sustainable for some time, it would be a very considerable collective cost for dredgers to continue to obtain land at this rate. This cost would also be very likely to increase over time. Another and possibly more important consideration is the environmental cost. Land which has been pit mined is essentially destroyed, and while it is possible to fill a pit in various ways, the land will never be entirely returned to its original state. In this case, since the land in question is in the river floodplain, most or all of it would be prime farmland. Almost all of the land not currently in agricultural use is either forested or is urbanized. Consequently, zoning and land use restrictions may prove critical. In 1978, about 540 acres, or .5 percent of the land near the Kansas River was used for extraction purposes (Land Inventory and Development, Inc., op.cit.). How much of an expansion

of this activity would prove acceptable to the public or to governmental authorities is difficult to predict. In the face of competing land uses, it seems that the total replacement of Kansas River production by pit mining in the floodplain is not likely.

Largely the same considerations would apply to pit mining in the Missouri River floodplain. While a detailed land-use inventory for the Missouri River banks is not available, an agricultural resources map for the Kansas City Metropolitan region seems to indicate that the land along the Missouri River is a roughly equal mixture of cropland, woodland and open land (Van Doren-Hazard-Stallings, 1975). A soil grouping map indicates that the bottomland is almost entirely in the Leta-Onawa-Flaynie Association, which is considered prime farmland by the Soil Conservation Service.

Despite potential barriers, it is unquestionably possible for pit mining to be expanded as an industry and to supplement other alternative sources of aggregates, especially in the near future.

The microeconomics of pit mining is unclear since little information is available. According to one operator, the cost of obtaining the necessary equipment to initiate production would currently fall into a range of $200,-500,000, depending on how much new equipment it would be necessary to purchase. Real estate costs would depend of course on the size and location of the site. A 20-acre site on high-quality farmland might require $20,-40,000 at current market values. Labor requirements would not differ greatly from a river operation. Adminstrative costs might be slightly lower, due to a lightened regulatory burden. Financing a move from a river site to a pit site would involve the same considerations already discussed with regard to Missouri River dredging, except that the total expense would probably be less. Interest rates, expected rates of return and other factors would weigh in each firm's decisions regarding this alternative.

Most sand and gravel mines are situated in or near urban areas. Although pit mining is not common along the Kansas River, the circumstances surrounding the pit mining alternative should be considered from a planning viewpoint.

The economic justifications used to mine sand and gravel in urban areas are facing more restrictions than ever before. There has been increased concern of late, involving adequate mineral aggregate supply. The environmental impact of mining is now a major consideration, and the allocation of land for mineral extraction is also an important concern (Thomson, 1980).

Thomson also identifies "social conflicts" which arise as a result of pit mining in urban and rural surroundings. Major conflicts involve landscape impacts, dust, noise, ground vibrations, and vehicle traffic. These conflicts may translate to added expenses

for the operator, which could in turn strain their operations profit margin. Studies have indicated that to landowners adjacent to existing pit mines, the conflicts range from a slight annoyance to specific safety hazards. There also seems to be a relationship between the number of complaints received and the proximity of a site to other urban land use activities, notes Thomson.

Conflicts are unavoidable when mining facilities are sited, especially in an urban area. There is a growing demand for construction materials and for the land where they are mined. This often results in additional constrictions placed on potential operators. Alternative development of mineable lands are often the result of the added pressures of urban growth.

Additional zoning requirements and permit applications also add to the costs of a sand and gravel operation. These and other costs are usually absorbed by the producers as opposed to the higher transportation costs caused by locating mine sites further away from the urban center.

Should the sand and gravel dredgers along the Kansas River be required to limit or cease their operations for any reason, pit mining would be a likely alternative for them. Some operators have indicated in interviews that they have already purchased land for future mining activity should this alternative be necessary.

It is imperative that the owners of potential pit mining operations consider more than simply the capital investment of purchasing their new site and the preparation of their facility. When making this critical business decision, the owner must plan to absorb the costs of mitigating some unfavorable impacts that may be caused by his operation. The owner must try to reasonably mitigate adverse noise and dust, possible water drainage problems, traffic congestion and highway deterioration, as well as unpleasant site conditions. The sand and gravel operator should also anticipate zoning problems if his proposed site is located near potential or existing recreation lands, near historic or archaeological resources, on or near prime or unique farmland, or on any land that is not zoned industrial.

The Soil Conservation Service (SCS) has noted that land mining could have serious effects on prime and unique farmland, as well as soil and water conservation practices that may now exist on the land. It is recommended that the local county conservation districts and the SCS offices serving those counties be consulted for assistance in the identification of prime farmlands and in the modification or restoration of conservation practices that may be affected by the establishment of a pit mine.

The environmental restrictions noted above, and urban encroachment have caused a loss in available sand and gravel reserves. Zoning ordinances and building codes have often been used to prohibit a

land use which is not in the public interest (Thomson, 1980). This results in zoning regulations that discourage mining. One zoning technique to alleviate this problem according to Thomson, would be the establishment of mineral resource extraction districts. The mineral zone would be established to prevent land uses from encroaching upon mineral lands prior to extraction. Additionally, the end use of the mineral lands would be systematically planned prior to mining. Some areas of the country have proposed mineral resource zones and a few have been implemented in Colorado and Wisconsin.

The creation of mineral resource zones by local governments may be a means for reducing future conflicts that result from mining in an urban environment and provide the greatest potential for preserving sites for extraction of mineral aggregates. The mineral aggregate producer, and indirectly the public, can cooperate to solve the problems of supplying mineral aggregates of usable quality and sufficient quantity at reasonable prices and at acceptable environmental costs.

If proper planning procedures are followed in establishing a new site, the impacts on local neighborhoods, schools and communities should be minimal.

Existing and potential recreation sites are identified in Section III.E of this report. In assessing new sites for dredging and/or land mining, operators must coordinate their efforts with the Kansas Park and Resources Authority and local park officials to determine possible recreation impacts in the earliest stages of planning. This should help to minimize any adverse recreation impacts and allow sand and gravel operators to incorporate features that will enhance recreation opportunities.

B. ANY ADVERSE ENVIRONMENTAL EFFECTS WHICH CANNOT BE AVOIDED SHOULD THE ALTERNATIVE BE IMPLEMENTED

Potential effects of each alternative were discussed in detail in previous sections of this report. The following discussions summarize effects of each alternative which are considered unavoidable.

1. NO ACTION

Existing dredging operations will continue to have minor effects on the air quality and noise levels of the study area. Turbidity and sedimentation immediately below the effluent outfall pipe will continue to have a small local impact on the water quality and aquatic communities of the Kansas River. Certain parameters, principally the metals aluminum, barium, iron, and manganese, may continue to exhibit elevated levels below operating dredges, though these levels are not outside those expected to occur naturally. Future work of the "Fishery-Dredging" study of the lower Kansas River will provide further information on the effects of commercial sand and gravel dredging on the water quality of the Kansas River.

Lower river sand and gravel extraction will continue to be a component of bed degradation and its concomitant effects on river channel morphology and ecology. The impacts of bed degradation will be an increase in width (bank erosion) above the dredging area, and a long-term trend toward an increase in depth in the dredging area below Bonner Springs. Ground water, backwaters, and standing water areas adjacent to the river channel may exhibit long-term declines in water surface elevations. This will have localized effects on the aquatic and terrestrial biological communities of the lower river. Bridges, water intakes, and boat ramps in the lower river may be adversely effected by continued dredging due to lower water elevations. The stability of Bowersock Dam at Lawrence may be adversely effected though this cannot be determined without further study. Water intakes and other structures above the dam may be impacted if the dam is breached.

2. CESSATION OF DREDGING

The complete cessation of dredging would cause unavoidable negative economic impacts until a suitable alternative for high quality aggregate is found. The jobs of those directly employed in Kansas River commercial sand and gravel dredging would be lost. The indirect consequences of this alternative to other sectors of the economy would likewise reduce employment as well as increase the costs of new facilities, including residential property, commercial and industrial structures, and roads and highways.

It is doubtful that the streambank land currently utilized for material processing and storage will be available for other uses. This is due to the cost of site reclamation, the more readily available sites elsewhere, and the more floodprone nature of most sites. This precludes residential, commercial, or industrial use except behind levees. The usefulness for wildlife habitat or agriculture is limited for some time due to the xeric-waste areas which characterize abandoned dredge sites. It is possible that some recreation need such as river access could be provided or the abandoned sites could be revegetated and reclaimed.

3. REDUCED QUANTITY OF MATERIAL EXTRACTED

Based on the economic analysis presented in Section III.A.6 of this report the reduced quantity alternative is essentially identical to the cessation alternative in terms of its economic consequences to the study area. This is assuming that the amount of sand and gravel which can be mined is restricted to the replenishment rate. Of course reducing the quantity of aggregate extracted to some level below current production but above the replenishment rate would decelerate river bed degradation in the lower Kansas River, though the feasibility of this requires further study.

In any case, restricting production to the replenishment rate would result in the loss of jobs in the dredging industry as well as unemployment in industries which depend on sand and gravel, i.e. the construction trades. This is until a suitable alternative for aggregates is found. Should individual dredging concerns switch to

another alternative (land mining or alternate stream sources) or industries which use sand and gravel obtain this material from sources outside the study area, costs for residential property, commercial and industrial structures, and roads and highways will increase.

As with the elimination of the dredging alternative, abandoned on-bank processing areas are not suitable for any other uses with the possible exception of recreation and agriculture if the land is reclaimed.

4. ALTERNATIVE STREAM SOURCES FOR DREDGED MATERIALS

The Missouri River appears to be the only feasible alternative stream source for aggregates in reasonable proximity to the study area. The implementation of this alternative will increase the cost of sand and gravel and consequently the costs of those sectors of the economy which depend on sand and gravel. Increased costs will result from the capital investment involved in a transfer to the Missouri River. Due to the poorer quality of Missouri River sand as an aggregate material and the presence of relatively high amounts of lignite, processing costs will increase. Labor costs will also rise due to the increased number of individuals required to operate a Missouri River sand and gravel operation.

Depending on the location of a Missouri River dredging site, land will be preempted from agricultural or wildlife habitat uses.

Insufficient information is available to accurately predict the effects of Missouri River sand and gravel dredging on river hydrology and ecology. However, due to the relatively high discharge of the Missouri River, environmental stresses presently acting on the river's ecosystem, and interim results of the "Fishery-Dredging" study of the lower Kansas River, no significant adverse impacts on the Missouri River ecosystem are foreseen.

There will be minor increases in the particulate load of the surrounding area and in background noise levels. However, these effects are felt to be insignificant.

5. LAND MINING

Air quality, in regards to the particulate load of the area, will deteriorate to a limited extent during overburden removal on the floodplain. Once dredging in pits proceeds, dust will originate from on-site material processing and handling and haul truck traffic on access roads. These effects should not be significant.

Background noise levels will increase during the implementation and operation of a pit mine. This will primarily result from on-site equipment operation and haul truck traffic on adjacent access roads. These effects are also felt to be insignificant.

Surface water and ground water quality could be adversely affected during a heavy runoff event while overburden is being removed. This

also applies to unstabilized spoil piles if such spoil is not transported off-site. However, owing to the flat topography of the floodplain, significant runoff of silt and other pollutants to adjacent waterways is not expected.

The major adverse impact of a land mining operation for sand and gravel is the preemption of floodplain lands which are, for the most part, committed to agricultural uses. Depending on the siting of such operations, land mining on the floodplains of the Kansas and Missouri River may potentially remove prime farmlands. It would be very expensive and difficult, if not impossible, to restore these lands to their original condition. Adverse impacts on vegetation and wildlife are also expected during the life of a pit operation. The degree of this impact depends on the quality of the habitat removed. From a biological standpoint, the removal of cropland and other previously disturbed habitats is not as severe as the removal of shrub and riparian timber communities.

Due to the investment costs involved in obtaining and developing a mining site, and costs associated with transporting sand and gravel, the cost of aggregate materials will increase. This effect will be transmitted through the industries which utilize sand and gravel and ultimately borne by the public.

C. THE RELATIONSHIP BETWEEN SHORT-TERM USES OF MAN'S ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The following discussions examine the extent to which existing dredging operations and its alternatives involve short-term commitments of resources and long-term maintenance of productivity and environmental values. Also identified is the reduction of long-term opportunities which would result from short-term uses.

1. NO ACTION

The continued operation of existing sand and gravel operations enhances the long-term economic potential of the study area. By supplying high quality aggregates at a lower cost relative to other sources, indirect long-term benefits accrue to the construction industry in the study area.

The short-term use of finite river bed sand and gravel deposits will lead to an eventual decline in these deposits in the river since they will not be replenished in place from outside sources.

While certain sectors of man's environment gain long-term benefits from existing dredging operations, other sectors, will experience declines in productivity, which is a consequence of bed degradation. Bank erosion decreases lands available for agricultural and wildlife productivity. Bed degradation decreases the long-term productivity of existing wetlands and tributaries by causing a parallel lowering of surface water elevation in these areas. Existing operations to this point in time may be enhancing the aquatic productivity of the lower river by creating

greater habitat diversity. However, long-term aquatic productivity in the lower river may decline due to a substantial deepening of the channel and lack of habitat diversity.

It is evident that existing dredging operations present a trade-off in terms of long-term benefits to man's environment. Existing dredging operations supply high quality aggregates, at a lower relative cost, and therefore directly benefit the construction of new facilities (residences, commercial buildings, roads, etc.). This in turn results in economic expansion and the creation of jobs and an improvement in the standard of living of people in the adjoining area.

While the long-term productivity of man's environment, in an economic sense, is enhanced by existing dredging operations, losses of other environmental values may occur. These values include agricultural production and aquatic and terrestrial biological habitats. The useful life of structures such as bridges and water intakes may be curtailed by bed degradation and the parallel lowering of water surface elevations.

The extent and importance of the loss of agricultural productivity and biological habitats along the lower Kansas River when viewed in the context of other environmental stresses is difficult to predict. However, these losses may be important and certainly difficult to reverse.

2. CESSATION OF DREDGING

Cessation of all existing dredging operations on the Kansas River, in and by itself, would result in immediate and severe economic consequences in the study area. This is particularly true of the construction industry. The long-term economic productivity of the study area would be expected to decline until a suitable substitute or alternative source for quality aggregates is found.

Agricultural productivity may decrease more slowly due to decreased bank erosion, though to what degree cannot be determined with any confidence since other factors also contribute to bank erosion.

The long-term productivity of aquatic and terrestrial habitats in and along the river and its tributaries will increase due to the halting of bed degration. The increase in productivity is uncertain because of other stresses which currently impact fish and wildlife resources in the study area.

Clearly, the implementation of this alternative involves the decrease of long-term productivity from an economic standpoint, while the long-term productivity of agricultural lands and fish and wildlife habitat may be improved.

3. REDUCED QUANTITY OF MATERIAL EXTRACTED

This alternative would increase the long-term productivity of the study area in regards to the supply of sand and gravel in the Kansas River

channel. The reserves of mineral resources would not be depleted at the existing rate. Based on economic considerations discussed elsewhere in this report, this alternative is essentially identical to the cessation of dredging alternative if current production is reduced to the "replenishment rate." For all practical purposes this reduction may make existing dredging operations economically infeasible.

The long-term productivity of man's environment would be greatly curtailed if alternate supplies of aggregates were not found. Agricultural productivity may decrease at a slower rate due to decreased bank erosion, especially in the lower river. The degree of this decrease is difficult if not impossible to determine since other factors also appear to be responsible for bank erosion along the Kansas River.

The long-term productivity of existing wetlands along the lower river would be enhanced by reducing the acceleration of their aging process. Wetlands, however, are relatively uncommon along the Kansas River. The long-term productivity of streambank habitats would be increased. A potential decrease in long-term aquatic productivity may be curtailed due to decreasing the rate of channel deepening.

The useful life of existing and future structures such as bridges and water intakes may be prolonged due to the deceleration of bed degradation.

4. ALTERNATIVE STREAM SOURCES FOR DREDGED MATERIALS

The short-term use of an alternative stream source for aggregates, in this case the Missouri River, will provide an ingredient for construction of new facilities (residences, commercial buildings, roads, etc.) and hence possible local economic expansion. More jobs would result near the Missouri River operations and the standard of living of many people in the adjoining area will be improved, although fewer jobs will be available along the Kansas River. However, due to the poorer quality of the aggregate material in relation to Kansas River deposits, and the type of equipment required to extract and process the aggregate, this material will be produced at an increased cost.

Agricultural and wildlife productivity are environmental values which may decline from this alternative. However, due to the size of the Missouri River and the amount of land required for processing and storage of sand and gravel, the losses of the above values should not be significant. The relationship of this alternative to long-term aquatic productivity cannot be determined with absolute certainty but is also believed to be of minor significance.

The short-term use of Missouri River sand and gravel deposits represents the use of a finite resource with the consequential long-term decline in reserves.

5. LAND MINING

Implementation of a land mining alternative for obtaining aggregate materials represents the short-term use of finite sand and gravel resources. Long-term productivity of man's environment in regard to employment and economic well-being may be enhanced. Construction of buildings, roads, and other projects which depend on high quality aggregates will be an integral part of man's long-term productivity, although it is not altogether possible to predict man's requirements into the distant future.

Land mining will undoubtedly decrease long-term agricultural productivity. The floodplain land surface will be changed, never to return to its original condition. Reclamation of these lands may provide long-term benefits to recreation and wildlife.

Clearly, land mining of sand and gravel would involve increased productivity in one aspect of man's environment, that of supplying aggregate materials for construction and other purposes; however, the long-term productivity of agricultural lands will suffer.

D. ANY IRREVERSIBLE OR IRRETRIEVABLE COMMITMENTS OF RESOURCES WHICH WOULD BE INVOLVED IN THE ALTERNATIVE SHOULD IT BE IMPLEMENTED

1. NO ACTION

Due to the presence of dams on upstream tributaries, the sand and other aggregate material mined from the Kansas River will not be replenished in the lower 50 miles of the river at current extraction rates, although some sand may be replenished in incidental quantities from bank erosion. Replenishment in this context is the transfer of mineral resource from one point to another. Of course, since this resource is finite, the extraction of one ton decreases the resource reserve by one ton, irregardless of where the geological source is located. The removal of such material is an irreversible and irretrievable commitment of nonrenewable resources.

The continued operation of dredges on the Kansas River will also entail an irreversible and irretrievable commitment of fuel (electricity and petroleum) and manpower for equipment operation.

2. CESSATION OF DREDGING

The total abandonment of commercial sand and gravel dredging on the Kansas River, in and of itself, will not result in any irreversible or irretrievable commitment of resources.

3. REDUCED QUANTITY OF MATERIAL EXTRACTED

In comparison with existing dredging operations, reducing the quantity of sand and gravel dredged in the Kansas River will decrease the rate at which the mineral resource is being diminished. Commitments of energy (electricity, petroleum), money, and manpower for equipment operation will also decrease. The alternative will still remove a finite

resource, but prolong its availability in comparison with existing dredging operations.

4. ALTERNATIVE STREAM SOURCES FOR DREDGED MATERIALS

The sand and gravel removed from the Missouri River or any other stream source represents an irreversible and irretrievable commitment of mineral resources. Depletion of useable aggregate deposits in the Missouri River near the Kansas City Metropolitan Region is also an important consideration. The annual suspended sediment load in the Missouri River at St. Joseph, Missouri has decreased since the closure of main stem reservoirs in 1952 (U.S. Army Corps of Engineers, 1976b). It is inferred that the supply of coarser materials such as sand into this reach has also decreased due to main stem reservoirs. However, larger deposits of lower quality sands may prolong the usefulness of the Missouri River as an aggregate source in comparison to the Kansas River.

The operation of dredges on an alternate stream source such as the Missouri River will entail an irreversible and irretrievable commitment of energy (electricity, petroleum), money, and manpower at a rate greater than that presently resulting from Kansas River operations. This is a result of the greater investment in equipment and labor costs, poorer quality aggregate, and lower percentage of coarse sands found in the Missouri River.

5. LAND MINING

Sand and gravel removed from a floodplain deposit represents an irreversible and irretrievable commitment of nonrenewable resources. The transfer of these nonrenewable resources from another area generally will not occur due to the presence of flood control reservoirs in the Kansas River Basin which eliminate all but the most severe flood events.

Land mining operations represent an irreversible and irretrievable commitment of energy (electricity, petroleum), money, and manpower. This commitment of resources would be greater than that currently committed by existing dredging operations.

Land mining operations also represent an irreversible and irretrievable commitment of floodplain lands (probably cropland) which are unlikely to be restored to their original condition.

E. RELATIONSHIP OF ALTERNATIVES TO FUTURE PUBLIC PLANS, POLICIES AND DEVELOPMENTS

Since much of the state of Kansas' population is located along the Kansas River and its major tributaries, industrial, commercial, and residential growth, as well as the expansion of opportunities would be expected to continue. Most, if not all future development would occur outside of the floodplain, while a considerable amount of the flood control levees and floodplain areas would be developed close to urban areas for recreational use.

There will be an increasing demand and subsequent need for recreation facilities through the year 2000 along the river corridor. This indicates increased pressure upon state and local planners to provide added recreational facilities, especially with access to the Kansas River area (Kansas Park and Resources Authority and Oblinger-Smith Corporation, Outdoor Recreation Plan for Kansas, 1975).

The Heritage Conservation and Recreation Service (HCRS) has conducted a potential recreation site investigation along the Kansas River and tributaries in conjunction with the total Kansas River Bank Stabilization Study (HCRS, 1979). Thirty-two sites were selected by a grading criteria based on access, water attraction, vegetative cover, soils, land use, slope, user availability, and costs for acquisition and development. Fourteen of these sites are located along the Kansas River from Manhattan to its confluence with the Missouri River.

From this HCRS study, it has been determined that the greatest potential for recreation is found on numerous stretches of the lower Kansas River. These particular segments meet the criteria for Recreational River designation under the Wild and Scenic Rivers Act and should be viewed with this in mind. Future phased planning efforts should take this into serious consideration. The Kansas Park and Resources Authority, HCRS, and numerous private individuals believe this designation should occur. This recreation concept should be kept in mind, should any dredging firms consider relocation along the Kansas River.

The HCRS has identified only one recreation area along the 153-mile reach of the Kansas River corridor (within 1,000 feet of mid-channel) that is associated with their specific programs. This is the DeSoto City Park in Johnson County which was acquired, in part, and developed with matching assistance from the Land and Water Conservation Fund. The HCRS does not expect the dredging operations to have much, if any, effect on DeSoto Park since it is not immediately adjacent to the river.

Following is a summary of the present and future recreation plans of the counties and communities along the Kansas River from Manhattan to Kansas City, Kansas as identified in the HCRS report "Kansas River (Kaw) Potential Recreation Site Investigation," and updated by comments from the Kansas City District Corps of Engineers and other public officials.

Only minimal recreation planning is occurring at the county level. Shawnee and Johnson Counties, however, have indicated considerable interest in the Kansas River recreation potential. The other counties have indicated no present or future plans. Of the municipalities that were contacted, only a few have accomplished, or are considering, some recreation planning along the Kansas River.

Kansas City, Kansas developed a riverfront park concept in 1975 that included recreation development of two sites along the Kansas River. These areas are identified as Argentine and Kaw Point. The Argentine site proposes the development of a boat ramp and dock, parking, picnic area, and

a motorcycle scramble area. Kaw Point development would include a marina, boat ramp, parking, an overlook, picnic area, and a restaurant. The lack of funds has delayed construction on these sites for the present.

Although Bonner Springs has not developed a recreation plan along the river, it is very interested in the Bank Stabilization Plan.

The city of Lawrence does have a flood protection levee system and is working with the Corps of Engineers in development of a 994-acre riverfront park. In addition, the city is presently developing a 25-acre park along the south side of the river. An extensive hiking and bicycling trail system is proposed on the rest of the levees.

Topeka has not developed any recreation plans along the river, but is working in cooperation with the Kansas Fish and Game Commission for fisherman-access sites. The city has considered a 6- to 8-mile-long nature and bike trail system near the river. Presently, this proposal has been removed from consideration due to the expense of the project. There is also an undeveloped 20-acre site presently being leased as a cycle area north of the Phillip Billard Airport. This cycle area would be eliminated should the trail system be constructed.

The city of Manhattan has not developed any recreation plans of its own, but is working closely with the Kansas Fish and Game Commission on a boat ramp and small recreation site located along the Big Blue River.

The Corps of Engineers' Kansas City Urban Study (Van Doren-Hazard-Stallings, 1975) has identified two potential recreation sites of approximately 350 acres. They are located along the Kansas River in Johnson County. The smaller of the two areas is located between Spring and West Mission Creek on the south side of the Kansas River. The larger acreage is located at the confluence of Cedar Creek.

There are no existing or potential wildlife refuge areas located along the Kansas River corridor. The state forester is currently cooperating with the U.S. Fish and Wildlife Service in a new program of identifying potential areas of unique or nationally significant ecosystems. This effort should be closely monitored since there could be sites of this category on the tributary streams.

None of the alternatives being considered in this study would be expected to have any adverse impacts relative to future public plans, policies and developments in the study area. However, should the quantity of sand and gravel extracted from the lower Kansas River be reduced or eliminated in the future, this may have some effect on the level of bank erosion currently experienced. This could possibly reduce the amount of structural and nonstructural improvements that may be proposed when the Kansas River Bank Stabilization Study is completed.

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APPENDIX A – AIR QUALITY DATA

Table A-1
SAMPLE AIR QUALITY DATA
SUSPENDED PARTICULATE MATTER ($\mu g/m^3$)

Site Location	Year	Number of Observations	24-Hour High	24-Hour Second High	Annual Geometric Mean
Kansas City, Kansas					
Sixth and Ann Avenues	1978	60	346	192*	74
Miami and Baltimore Avenues	1975	52	248	245*	110
Turner High School	1978	56	211	147	66
420 Kansas Avenue	1978	54	539	474**	150
Lawrence, Kansas					
710 Massachusetts	1977	59	162	127	50
Topeka, Kansas					
1941 N.E. 39th	1978	54	97	91	46
215 E. 7th Street	1978	58	193	148	64
1615 W. 8th	1978	51	155	131	65
1231 Eugene	1978	15	198	193*	58
Rossville, Kansas					
Marion and Navarre St.	1978	60	194	147	58
Manhattan, Kansas					
1150 Poyntz	1977	43	109	102	57

***Indicates Exceedance of Primary Standard*
**Indicates Exceedance of Secondary Standard*

Source: Kansas Department of Health and Environment. 1979. Division of Environment, Bureau of Air Quality and Occupational Health. Topeka, Kansas.

Table A-2

SAMPLE AIR QUALITY DATA
SULFUR DIOXIDE[1] ($\mu g/m^3$)

Site Location	Year	Number of Observations	24-Hour Maximum	24-Hour Second High	Annual Arithmetic Mean
Kansas City, Kansas					
6th and Ann Avenue	1977	59	12	10	4
Miami St. and Baltimore Ave.	1975	44	34	22	5
420 Kansas Avenue	1977	51	86	75	15
Lawrence, Kansas					
710 Massachusetts	1977	60	24	18	4
Topeka, Kansas					
1941 N.E. 39th	1977	60	27	26	4
215 E. 7th Street	1977	55	14	13	4
1615 W. 8th	1977	59	24	23	5
1231 Eugene	1977	60	30	25	5
Rossville, Kansas					
Marion and Navarre St.	1977	58	18	12	3
Manhattan, Kansas					
1150 Poyntz	1977	45	12	6	2

[1] *Bubbler Method.*

Source: Kansas Department of Health and Environment. 1979. Division of Environment, Bureau of Air Quality and Occupational Health. Topeka, Kansas.

Table A-3
SAMPLE AIR QUALITY DATA
SULFUR DIOXIDE[1] ($\mu g/m^3$)

Site Location	Year	Number of Observations	24-Hour Second High	3-Hour Second High	Annual Arithmetic Mean
Kansas City, Kansas					
6th and Ann Avenues	1977	7,927	190	407	32
	1978	7,871	118	550	NA
3105 Fairfax Road	1978	1,923	98	310	NA
Lawrence, Kansas					
750 Kentucky	1977	5,055	35	NA	NA
Topeka, Kansas					
535 Kansas Avenue	1977	5,632	5	NA	NA
Manhattan, Kansas					
3rd and Poyntz	1973	3,493	14	19	13

[1] *Continuous Method*

NA–Data Not Available

Source: Kansas Department of Health and Environment. 1979. Division of Environment, Bureau of Air Quality and Occupational Health. Topeka, Kansas.

Table A-4
SAMPLE AIR QUALITY DATA
NITROGEN DIOXIDE[1] ($\mu g/m^3$)

Site Location	Year	Number of Observations	24-Hour Maximum	24-Hour Second High	Annual Arithmetic Mean
Kansas City, Kansas					
6th and Ann Avenue	1977	55	86	NA	47
Miami St. and Baltimore Ave.	1975	45	60	NA	33
420 Kansas Avenue	1977	58	110	NA	54
Lawrence, Kansas					
710 Massachusetts	1977	55	76	NA	28
Topeka, Kansas					
1941 N.E. 39th	1977	58	35	NA	11
215 E. 7th Street	1977	55	56	NA	31
1615 W. 8th	1977	60	73	NA	28
1231 Eugene	1977	59	71	NA	30
Rossville, Kansas					
Marion and Navarre St.	1977	57	32	NA	13
Manhattan, Kansas					
1150 Poyntz	1977	43	58	NA	14

[1] *Bubbler Method.*

NA–Data Not Available

Source: Kansas Department of Health and Environment. 1979. Division of Environment, Bureau of Air Quality and Occupational Health. Topeka, Kansas.

Table A-5

SAMPLE AIR QUALITY DATA
NITROGEN DIOXIDE[1] ($\mu g/m^3$)

Site Location	Year	Number of Observations	1-Hour Maximum	24-Hour Maximum	Annual Arithmetic Mean
Kansas City, Kansas					
6th and Ann Avenues	1975	8,328	451	114	30
	1978	6,138	250	NA	NA
Lawrence, Kansas					
750 Kentucky	1977	3,366	140	NA	NA
Topeka, Kansas					
535 Kansas Avenue	1974	2,122	75	23	10
Manhattan, Kansas					
3rd and Poyntz	1973	2,468	120	67	25

[1] *Continuous Method*

NA–Data Not Available

Source: Kansas Department of Health and Environment. 1979. Division of Environment, Bureau of Air Quality and Occupational Health. Topeka, Kansas.

Table A-6
SAMPLE AIR QUALITY DATA
CARBON MONOXIDE ($\mu g/m^3$)

Site Location	Year	Number of Observations	1-Hour Maximum	1-Hour Second High	8-Hour Maximum	8-Hour Second High
Kansas City, Kansas						
6th and Ann Avenue	1978	8,298	16	15	10.4	9.6
3105 Fairfax Road	1977	4,465	21	17	10.0	9.3
Lawrence, Kansas						
750 Kentucky	1977	5,335	20	19	11.4	11.1**
Topeka, Kansas						
535 Kansas Avenue	1977	5,174	20	20	11.5	11.5**
Manhattan, Kansas						
3rd and Poyntz	1973	5,151	28	19	9.1	9.0

***Indicates Exceedance of Primary Standard*

Source: Kansas Department of Health and Environment. 1979. Division of Environment, Bureau of Air Quality and Occupational Health. Topeka, Kansas.

Table A-7
SAMPLE AIR QUALITY DATA
OZONE ($\mu g/m^3$)

Site Location	Year	Number of Observations	1-Hour Maximum Per Day	1-Hour Second High Per Day	Annual Arithmetic Mean
Kansas City, Kansas					
6th and Ann Avenues	1978	6,635	130	130	23
3105 Fairfax Road	1977	3,647	260	250**	NA
Lawrence, Kansas					
750 Kentucky	1977	4,921	300	260**	NA
Topeka, Kansas					
535 Kansas Avenue	1977	4,950	160	150	NA
Manhattan, Kansas					
3rd and Poyntz	1973	682	115	115	33

***Indicates Exceedance of Primary Standard*
NA–Data Not Available

Source: Kansas Department of Health and Environment. 1979. Division of Environment, Bureau of Air Quality and Occupational Health. Topeka, Kansas.

APPENDIX B – BIOLOGICAL DATA

Table B-1

PHYTOPLANKTON FOUND IN
THE KANSAS RIVER SYSTEM

Centric Diatoms
- *Cyclotella nana*
- *C. atomus*
- *C. meneghiniana*
- *C. pseudostelligera*
- *C. glomerata*
- *C. kutzingiana*
- *C. stelligeroides*
- *Stephanodiscus hantzschii*
- *S. invisitatus*
- *S. asterea v. minutula*
- *S. alpinus*
- *Melosira distans*
- *M. distans v. alpigena*
- *M. granulata*
- *M. granulata v. angustissima*
- *Biddulphia leavis*

Pennate Diatoms
- *Achnanthes minutissima*
- *A. lanceolata*
- *Amphiprora alata*
- *A. ornata*
- *Asterionella formosa*
- *Amphora montanum*
- *A. submontanum*
- *Cymbella sp.*
- *Cymbella ventricosa*
- *Gomphonema affine*
- *G. angustatum*
- *G. angustatum v. intermedia*
- *G. angustatum v. obesa*
- *G. gracile v. naviculoides*
- *G. subclavatum*
- *G. clevei*
- *G. olivaceum*
- *G. parvulum*
- *Diploneis sp.*
- *Diatoma vulgare*
- *Gyrosigma fasciola*
- *G. scalproides*
- *Pleurosigma sp.*
- *Pinnularia braunii*
- *P. microstauron*
- *Synedra ulna*
- *Surirella palmerii*

Table B-1 (continued)

Surirella angustata
S. ovata v. salina
S. striatula v. l.
Cymatopleura sp.
Cocconeis sp.
Caloneis sp.
C. amphisbaena
C. bacillum
Meridion circulare
Fragilaria intermedia
F. vaucheriae
Navicula mutica v. chonii
N. pelliculosa
N. pupsula Fo. minutula
N. syommetrica
N. tantula
N. vancheriae v. densistriata
N. viridula v. argunensis
N. viridula v. linearis
N. v. viridula v. rostruta
N. accomoda
N. aszellus
N. caduca
N. cryptocephala
N. cryptocephala v. exilis
N. crytocephala v. veneta
N. gracilis v. schizonemoides
N. menisculus
N. menisculus v. obtusa
N. canalis
N. cuspidata v. ambigua
N. tripunctata v. schizonemodies
N. vaucheriae
N. phgmaea
N. hungarica
N. lanceotala
N. pupula
N. mutica
Nitzschia acicularis
N. closterium
N. frustulum
N. holsatica
N. palea
N. filiformis
N. hungarica
N. amphibia
N. fasciculata
N. apiculata
N. paradoxa
N. tryblionella

Table B-1 (continued)

- Nitzchia gracilis
- N. linearis
- N. sigma
- N. capitellata
- N. clausii
- N. romana
- N. stagnorum
- N. subcapitellata
- N. tarda
- N. umblicata
- N. valdestriata
- N. dissipata
- N. frustulum
- N. invicta v. lanceolata
- N. palea
- N. palea v. kutzingiana
- N. pseudoamphioxys

Green Coccoids

- Actinastrum sp.
- Ankistrodesmus sp.
- A. falcatus
- Chlorella sp.
- Closteriopsis sp.
- Closterium dianae
- Coelastrum sp.
- Crucigenia sp.
- C. tetrapedia
- C. irregularis
- Dictyosphaerium sp.
- Golenkinia sp.
- Kirschneriella sp.
- Micractinium sp.
- Netrium sp.
- Oocystis sp.
- Pediastrum sp.
- Scenedsmus sp.
- S. opoliensis
- S. quadnicauda
- S. acuatus
- S. dimorphus
- S. acuminatus
- Schroderia sp.
- Selenastrum sp.
- Staurastrum gracile
- Tetraedron sp.
- Tetrastrum sp.

Green Filamentons

- Cladophora sp.
- Gomontia codiolifera
- Microspora sp.

Table B-1 (continued)

- Ophiocytium sp.
- Palmogloea protuberans
- Spirogyra sp.
- Stigeoclonium sp.

Blue-Green Coccoids
- Agmenellum sp.
- Anacystis sp.
- Coelosphaerium sp.

Blue-Green Filamentons
- Anabaena sp.
- A. circinalis
- Anabaenopsis sp.
- Lyngbia sp.
- Oscillatoria sp.
- O. subtilissma
- Phormidium tenue
- Rhaphidiopsis sp.
- Spirulina sp.

Green Flagellates
- Chlamydomonas - Carteria sp.
- Chlamydomonas globosa
- C. incerte
- C. paradoxa
- C. reinhardii
- Chlorogonium sp.
- Collodictzon sparsevacuolatum
- Endorina elegans
- Gonium pectorale
- Lobomonas ampla
- L. bernardinensis
- Phacotus sp.
- P. lenticularis
- Pteronomas cruciata
- Pandorina morum
- Mesostigms viride
- Euglena acus
- E. anabaena
- E. chadefaudii
- E. clavata
- E. ehrenbergii
- E. intermedia
- E. oxyuris
- E. pisciformis
- E. polymorpha
- E. sociabilis
- E. tripteris
- E. viridis
- Anisonema strenum
- Heteronemu abruptum
- H. sacculus

Table B-1 (continued)

Notosolenus obliquus
Peranema pleururium
Lepocinclis pocinclis
L. ovum
L. texta
Phacus longicanda v. attennata
P. pleuronectes
P. pyrum
P. tortus
P. triqueter
Trachelomonas abrupta
T. bulla
T. crebea
T. hisipda v. crenulatocollis
T. hispida
T. lacustris
T. oblonga
T. scabra
T. stokesiana
T. superba
T. varians
T. verrucosa v. granulosa
T. volvocina
T. volvocinopsis
T. zorensis
T. verrucosa

Brown Flagellates
Ceratium sp.
Cryptomonas erosa
C. marssonii
C. tetrapyrenoidosa
Cyathomonas truncata
C. hyalina
Gymnodinium sp.
Peridinium sp.
Mallomonas sp.
Urceolus alenizini
Monas sp.
Rhodomonas sp.

Source: Powers, R. E.. 1969. Phytoplankton Found in the Kansas River System. Federal Water Pollution Control Administration, Kansas City, MO.. NTIS PB-260159.

Table B-2

BENTHIC INVERTEBRATE TAXA KNOWN
TO INHABIT THE KANSAS RIVER

	COLLECTION LOCATION		
	Bonner Springs to Mouth	Lawrence to Bonner Springs	Manhattan to Lawrence
INSECTA			
Diptera (Flies)			
Tanypus			X
Psychoda			X
Chaoborus*	X	X	
Chironomus*	X	X	X
Cricotopus	X	X	X
Dicrotendipes	X	X	
Glyptotendipes	X	X	
Tribelos	X	X	
Polypedilum	X	X	X
Paracladopelma	X	X	
Goeldichironomus	X		
Tabanus			X
Palpomyia			X
Pentaneura		X	
Psectrocladius		X	
Simulium*	X	X	
Culicoides	X		X
Stenochironomus		X	
Parachironomus			X
Rheotanytarsus		X	X
Cryptochironomus		X	X
Stichochironomus			X
Procladius			X
Coelotanypus			X
Diamesa			X
Ablabesmyia		X	X
Hemerodromia*	X		
Chironomids	X	X	X
Simuliids	X	X	
Tendipedids	X	X	X
Ceratopogonids*	X	X	
Psychodids	X		
Tipulid*	X		
Trichoptera (Caddis flies)			
Oxyethira		X	
Cheumatopsyche	X	X	X
Hydropsyche*	X	X	X
Potamyia*		X	X
Nectopsyche		X	X

Table B-2 (continued)

	COLLECTION LOCATION		
	Bonner Springs to Mouth	Lawrence to Bonner Springs	Manhattan to Lawrence
Triaenodes			X
Mayatrichia		X	
Ochrotrichia	X		
Leptocerid*	X		
Plecoptera (Stoneflies)			
Perlesta*	X	X	X
Acroneuria	X	X	X
Neoperla	X	X	X
Taemiopteryx	X		X
Claassenia			X
Isogenus			X
Attaneuria	X	X	X
Hydroperla		X	X
Isoperla*	X	X	X
Paragnetina	X	X	X
Perlid			X
Taeniopterygid			X
Chrloroperlid		X	
Ephemeroptera (Mayflies)			
Stenonema*	X	X	X
Baetis*	X	X	X
Hexagenia*	X	X	X
Pentagenia	X	X	X
Caenis*	X	X	X
Tortopus			X
Potamanthus*	X		X
Centroptilum			X
Paraleptophlebia		X	
Isonychia*	X	X	X
Stenacron		X	X
Heptagenia*	X	X	X
Homoeoneuria*	X		
Blasturus			X
Tricorythodes*	X	X	X
Ephoron		X	X
Ameletus		X	X
Leptophlebid*	X	X	
Odonata (Dragonflies and Damselflies)			
Gomphoides			X
Argia*	X	X	X
Dromogomphus	X	X	X
Hetaerina	X	X	X
Gomphus*	X	X	X
Macromia			X
Neurocordulia	X		X
Nasiaeschna	X		

Table B-2 (continued)

	COLLECTION LOCATION		
	Bonner Springs to Mouth	Lawrence to Bonner Springs	Manhattan to Lawrence
Calopteryx			X
Enallagma			X
Hyponeura	X	X	X
Progomphus			X
Anisopteran	X		
Gomphid	X	X	X
Megaloptera (Alderflies, Dobsonflies)			
*Corydalus**	X	X	X
Hemiptera (Bugs)			
Metrobates		X	X
Rhagovelia	X	X	X
Ranatra sp.		X	
Belostoma	X	X	
Pentacora			X
Gerris			X
Notonecta			X
Hemiptera			
*Tricoryxa**	X		
Tenegobia			X
Trepobates			X
Corixid	X	X	X
Saldid			X
Orthoptera			X
Coleoptera (Beetles)			
*Dubiraphia**	X		
Berosus			X
Dineutus	X	X	X
Neoelmis		X	
*Stenelmis**	X	X	X
*Macronychus**			X
Hydrovatus			X
Helichus	X	X	
Laccophilus			X
Copelatus		X	
Gyretes			X
Gyrinus	X	X	
Peltodytes	X		X
Cleptelmis	X		
Hydeoporus		X	X
Haliplus	X	X	
Tropisternus	X		
Hydrophilid			X
Elmid	X		X
OLIGOCHAETA			
Branchiura			X
Tubificid	X	X	X

Table B-2 (continued)

	COLLECTION LOCATION		
	Bonner Springs to Mouth	Lawrence to Bonner Springs	Manhattan to Lawrence
Oligochaete	X		
HIRUDINEA			
Erpobdella		X	X
CRUSTACEA			
Hyalella		X	
Astacid	X	X	X
Orconectes			X
GASTROPODA			
Lymnaea			X
Physa sp*	X	X	X
Ferrissia		X	
Physid	X		X
PELECYPODA			
*Corbicula**	X		
Sphaerium	X	X	X
Sphaerid		X	
Pelecypod*	X		
TURBELLARIA			
Dugesia sp.	X		X
Planarian			X
COLLEMBOLA			
Isotomurus		X	X
NEMATOMORPHA			
Gordius			X
BRYOZOA	X		X
Bryozoan			
COPEPODA			
*Argulus**	X		

Table B-2 (continued)

Source: Kansas Department of Health and Environment, unpublished data collected from 1975-1979, provided by D. Gilliland.

Powers, R. E. and G. Z. Jacobi. 1966. Biological Survey of the Kansas River Basin. Federal Water Pollution Control Administration. NTIS PB-228-206.

Pearson, J. G., E. S. Bender, D. J. Taormina, V. J. Kelmeckis, P. F. Robinson, and A. E. Asaki. 1977. Results of Aquatic Ecological Surveys at Sunflower Army Ammunition Plant, Lawrence, Kansas, Part J. Macroinvertebrates and Water Quality. EO-TR-76119.

Cross, F. B. and F. J. DeNoyelles, Principal Investigators. 1980. "Fishery-Dredging Study." (in progress). University of Kansas. Prepared for U. S. Army Engineer District, Kansas City, Missouri

* Collected during "Fishery - Dredging" Study of lower Kansas River.

Table B-3

FISHES OF THE KANSAS RIVER AND TRIBUTARIES

Common Name	Scientific Name
Chestnut Lamprey	*Ichthyomyzon castaneus*
Shovelnose Sturgeon*	*Scaphirhynchus platorynchus*
Plains Killifish	*Fundulus kansae*
Paddlefish	*Polyodon spathula*
Short-nosed Gar*	*Lepisosteus platostomus*
Long-nosed Gar*	*Lepisosteus osseus*
American Eel	*Anguilla rostrata*
Gizzard Shad*	*Dorosoma cepedianum*
Goldeye*	*Hiodon alosoides*
Northern Pike	*Esox lucius*
Carp*	*Cyprinus carpio*
Goldfish	*Carassius auratus*
Golden Shiner*	*Notemigonus crysoleucas*
Creek Chub*	*Semotilus atromaculatus*
Flat-headed Chub	*Hybopsis gracilis*
Silver Chub*	*Hybopsis storeriana*
Speckled Chub*	*Hybopsis aestivalis*
Sturgeon Chub*	*Hybopsis gelida*
Sucker-mouthed Minnow*	*Phenacobius mirabilis*
Emerald Shiner*	*Notropis atherinoides*
Red-finned Shiner*	*Notropis umbratilis*
Northern Common Shiner	*Notropis cornutus*
River Shiner*	*Notropis blennius*
Red Shiner*	*Notropis lutrensis*
Sand Shiner*	*Notropis stramineus*
Plains Minnow*	*Hybognathus placitus*
Fathead Minnow*	*Pimephales promelas*
Bull-headed Minnow*	*Pimephales vigilax*
Blunt-nosed Minnow*	*Pimephales notatus*
Big-mouthed Buffalo*	*Ictiobus cyprinellus*
Black Buffalo	*Ictiobus niger*
Small-mouthed Buffalo*	*Ictiobus bubalus*
River Carpsucker*	*Carpiodes carpio*
Northern Redhorse*	*Moxostoma macrolepidotum*
White Sucker*	*Catostomus commersoni*
Black Bullhead*	*Ictalurus melas*
Yellow Bullhead	*Ictalurus natalis*
Channel Catfish*	*Ictalurus punctatus*
Blue Catfish	*Ictalurus furcatus*
Flathead Catfish*	*Pylodictis olivaris*
Stonecat*	*Noturus flavus*
White Bass*	*Morone chrysops*
Largemouth Bass*	*Micropterus salmoides*
Green Sunfish*	*Lepomis cyanellus*
Bluegill*	*Lepomis macrochirus*

Table B-3 (continued)

Orange-spotted Sunfish*	*Lepomis humilis*
White Crappie*	*Pomoxis annularis*
Walleye*	*Stizostedion vitreum*
Sauger*	*Stizostedion canadense*
Logperch	*Percina caprodes*
Orange-throated Darter*	*Etheostoma spectabile*
Freshwater Drum*	*Aplodinotus grunniens*
Black Crappie*	*Pomoxis nigromaculatus*
Quillback*	*Carpiodes cyprinus*
Stoneroller*	*Campostoma anomalum*

* - Collected during "Fishery - Dredging" Study of lower Kansas River.

Source: Cross. F.B.. 1967. *Handbook of Fishes of Kansas*. Univ. of Kansas, Museum of Natural History. Miscellaneous Publication No. 45, 357 pp.

Division of Fishes. 1979. *Kansas River Fishes (Lawrence to Kansas City)*. Univ. of Kansas, Museum of Natural History.

Kansas Fish and Game Commission. 1980. *Kansas River Basin, Kansas Stream Survey*. D-J Project F-15-R-14.

Table B-4

COMMON HERBACEOUS PLANTS
OF THE KANSAS RIVER BASIN

Common Name	Scientific Name
Broomweed	Gutierrezia dracunculoides
Lambsquarter	Chenopodium album
Canada fleabane	Conyza canadensis
Pokeweed	Phytolacca americana
Canada goldenrod	Solidago canadensis
Canada wild rye	Elymus canadensis
Canada woodnettle	Laportea canadensis
Carolina lovegrass	Eragrostis penctinacea
Common ragweed	Ambrosia artemisiifolia
Jimsonweed	Datura stramonium
Common sunflower	Helianthus annuus
Drummond aster	Aster drummondii
Elm-leaf goldenrod	Solidago ulmifolia
Fall panicum	Panicum dichotomiflorum
Johnson grass	Sorghum halapense
Slender flatsedge	Cyperus ferruginescens
Slender wild rye	Elymus villosus
Smartweed	Polygonum bicorne
Smooth brome	Bromus inermis
Downy brome	Bromus tectorum
Stinging nettle	Urtica dioica
Switchgrass	Panicum virgatum
Marestail	Erigeron canadensis
Tall thistle	Circium altissimum
Virginia Rye	Elymus virginicus
Waveyleaf thistle	Cirsium undalatum
Western ragweed	Ambrosia psilostachya
Dandelion	Taraxacum officinale
White aster	Aster ericoides
Palmer's pigweed	Amaranthus palmeri
Panicled aster	Aster simplex
Poison hemlock	Conium maculatum
Marijuana	Cannabis sativa
Prairie ground cherry	Physalis pumila
Prickly lettuce	Lactuca serriola
Purple lovegrass	Eragrostis spectabilis
Red sprangletop	Leptochloa filiformis
Rice cutgrass	Leersia oryzoides
Woodland phlox	Phlox divaricata
Catchweed bedstraw	Galium aparine
Yellow sweet clover	Melilotus officinalis
Barnyard grass var. microstachva	Echinochloa muricata
Bog hemp	Boehmeria cylindrica

Table B-4 (continued)

Flatsedge	Cyperus aristatus
Florida lettuce	Lactuca floridana
Giant ragweed	Ambrosia trifida
Violets	Viola sp.
Green foxtail	Setaria viridis
Rock muhly	Muhlenbergiaa sobolifera
Rough pigweed	Amaranthus retroflexus
Russian thistle	Salsola iberica
Sand dropseed	Sporobolus cryptandrus
Dock	Rumex sp.
Sand lovegrass	Eragrostis trichodes
Indianagrass	Sorghastrum avenaceum
Jerusalem artichoke	Helianthus tuberosus
Little bluestem	Andropogon scoparius
Marsh muhly	Muhlenbergia racemosa
Mullen	Verbascum thapsus
Nodding beggarstick	Bidens cernua
Hoary vervain	Verbena stricta
Cocklebur	Xanthium pennsylvanicum
Kochia	Kochia scoparia
Ivyleaf morningglory	Ipomoea hederacea
Knotweed	Polygonum aviculare
Carpetweed	Mollugo verticillata
Puncture vine	Tribulus terrestris
Milkweed	Asclepias spp.
Bur cucumber	Sicyas angulata
Field bindweed	Convolvulus arvensis
Crabgrass	Digitaria spp.
Sandbur	Cenchrus longispinus
Plantain	Plantago spp.
Sedge	Carex spp.

Source: Tom Saunders, Area Manager, U.S. Fish and Wildlife Service

Burns & McDonnell Engineering Company. 1980. Report on the Social and Environmental Inventory for the Kansas River Bank Stabilization Study. Prepared for U. S. Army Corps of Engineers, Kansas City District.

Table B-5

COMMON TREES AND SHRUBS OF THE
KANSAS RIVER AND TRIBUTARIES

Common Name	Scientific Name
Black walnut	*Juglans nigra*
Ohio buckeye	*Aesculus glabra*
Eastern redcedar	*Juniperus virginiana*
Eastern cottonwood	*Populus deltoides*
Pecan	*Carya illinoensis*
Bur oak	*Quercus macrocarpa*
Chinkapin oak	*Quercus muehlenbergii*
Pin oak	*Quercus palustris*
Slippery elm	*Ulmus rubra*
American elm	*Ulmus americana*
Hackberry	*Celtis occidentallis*
Red mulberry	*Morus rubra*
Osage-orange	*Maclura pomifera*
American sycamore	*Platanus occidentallis*
Eastern redbud	*Cercis canadensis*
Kentucky coffeetree	*Gymnociadus dioicus*
Honeylocust	*Gleditsia triacanthos*
Black locust	*Robinia pseudoacacia*
Silver maple	*Acer saccharinum*
Boxelder	*Acer negundo*
Sandbar willow	*Salix interior*
Peach-leaved willow	*Salix amygdaloides*
Black willow	*Salix nigra*
Common persimmon	*Diospyrus virginiana*
Green ash	*Fraxinus pennsylvanica*
Northern catalpa	*Catalpa speciosa*
American plum	*Prunus americana*
Fragrant sumac	*Rhus aromatica*
Smooth sumac	*Rhus glabra*
Roughleaf dogwood	*Cornus drummondii*
Buckbrush	*Symphoricarpos orbiculatus*
Currant	*Ribes odoratum*
Gooseberry	*Ribes missouriense*
Poison ivy	*Rhus radicans*
Virginia creeper	*Parthenocissus quinquefolia*
Moonseed	*Menispermum canadense*
Wild grape	*Vitis riparia*
Prairie rose	*Rosa suffulta*

Table B-5 (continued)

Greenbriar	*Smilax hispida*
Elderberry	*Sambucus canadensis*
Bittersweet	*Celatstrus scandens*

Source: Tom A. Saunders, Area Manager, U.S. Fish & Wildlife Service.

Burns & McDonnell Engineering Company. 1980. *Report on the Social and Environmental Inventory for the Kansas River Bank Stabilization Study*. Prepared for the U. S. Army Corps of Engineers, Kansas City District.

Table B-6

COMMON MAMMALS OF THE KANSAS RIVER AND TRIBUTARIES

Common Name	Scientific Name
Opossum	*Didelphis virginiana*
Short-tailed Shrew	*Blarina brevicauda*
Least Shrew	*Cryptotis parva*
Eastern Mole	*Scalopus aquaticus*
Little Brown Myotis	*Myotis lucifugus*
Big Brown Bat	*Eptesicus fuscus*
Eastern Cottontail	*Sylvilagus floridanus*
Fox Squirrel	*Sciurus niger*
13-lined Ground Squirrel	*Spermophilus tridecemlineatus*
Beaver	*Castor canadensis*
Plains Harvest Mouse	*Reithrodontomys montanus*
Deer Mouse	*Peromyscus maniculatus*
White-footed Mouse	*Peromyscus leucopus*
Hispid Cotton Rat	*Sigmodon hispidus*
Eastern Wood Rat	*Neotoma floridana*
Muskrat	*Ondatra zibethicus*
Prairie Vole	*Microtus ochrogaster*
Woodland Vole	*Microtus pinetorum*
Norway Rat	*Rattus norvegicus*
House Mouse	*Mus musculus*
Coyote	*Canis latrans*
Raccoon	*Procyon lotor*
Mink	*Mustela vison*
Long-tailed Weasel	*Mustela frenata*
Badger	*Taxidea taxus*
Striped Skunk	*Mephitis mephitis*
Bobcat	*Felis rufus*
White-tailed Deer	*Odocoileus virginianus*

Source: Tom Saunders, Area Manager, U.S. Fish and Wildlife Service,

Cockrum, E.L. 1952. Mammals of Kansas. *University of Kansas Publications, Museum of Natural History*. 7(1):1-303.

Table B-7

COMMON BREEDING BIRDS OF THE KANSAS RIVER AND TRIBUTARIES

Common Name	Scientific Name
Great Blue Heron	*Ardea herodias*
Green Heron	*Butorides virescens*
Belted Kingfisher	*Megaceryle alcyon*
Spotted Sandpiper	*Actitis macularia*
Bank Swallow	*Riparia riparia*
Red-winged Blackbird	*Agelaius phoeniceus*
Yellow-headed Blackbird	*Xanthocephalus xanthocephalus*
Killdeer	*Charadrius vociferus*
American Coot	*Fulica americana*
Turkey Vulture	*Cathartes aura*
Red-tailed Hawk	*Buteo jamaicensis*
Swainson's Hawk	*Buteo swainsoni*
Marsh Hawk	*Circus cyaneus*
American Kestrel	*Falco sparverius*
Ring-necked Pheasant	*Phasianus colchicus*
Bobwhite	*Colinus virginianus*
Mourning Dove	*Zenaida macroura*
Rock Dove	*Columba livia*
Barn Owl	*Tyto alba*
Screech Owl	*Otus asio*
Great Horned Owl	*Bubo virginianus*
Common Nighthawk	*Chordeiles minor*
Chimney Swift	*Chaetura pelagica*
Yellow-billed Cuckoo	*Coccyzus americanus*
Ruby-throated Hummingbird	*Archilochus colubris*
Common Flicker	*Colaptes auratus*
Red-headed Woodpecker	*Melanerpes erythrocephalus*
Downy Woodpecker	*Picoides pubescens*
Hairy Woodpecker	*Picoides villosus*
Eastern Kingbird	*Tyrannus tyrannus*
Western Kingbird	*Tyrannus verticalis*
Great Crested Flycatcher	*Myiarchus crinitus*
Horned Lark	*Eremophila alpestris*
Rough-winged Swallow	*Stelgidopteryx ruficollis*
Cliff Swallow	*Petrochelidon pyrrhonota*
Barn Swallow	*Hirundo rustica*
Purple Martin	*Progne subis*
Blue Jay	*Cyanocitta cristata*
Eastern Phoebe	*Sayornis phoebe*
Common Crow	*Corvus brachyrhynchos*
White-breasted Nuthatch	*Sitta carolinensis*
Brown Thrasher	*Toxostoma rufum*
Mockingbird	*Mimus polyglottos*
American Robin	*Turdus migratorius*
Gray Catbird	*Dumetella carolinensis*

Table B-7 (continued)

Eastern Bluebird	*Sialia sialis*
Loggerhead Shrike	*Lanius ludovicianus*
Starling	*Sturnus vulgaris*
House Sparrow	*Passer domesticus*
Eastern Wood Pewee	*Contopus virens*
Tufted Titmouse	*Parus bicolor*
House Wren	*Troglodytes aedon*
Bell's Vireo	*Vireo belii*
Red-eyed Vireo	*Vireo olivaceus*
Eastern Meadowlark	*Sturnella magna*
Western Meadowlark	*Sturnella neglecta*
Yellow Warbler	*Dendroica petechia*
Orchard Oriole	*Icterus spurius*
Northern Oriole	*Icterus galbula*
Yellow-breasted Chat	*Icteria virens*
Common Grackle	*Quiscalus quiscula*
Brown-headed Cowbird	*Molothrus ater*
Cardinal	*Cardinalis cardinalis*
American Goldfinch	*Spinus tristis*
Field Sparrow	*Spizella pusilla*

Source: Tom Saunders, Area Manager, U.S. Fish and Wildlife Service,

Johnston, R.F. 1964. The breeding birds of Kansas. *University of Kansas, Museum of Natural History Publications*. 12(14):575-655.

Common and scientific names taken from: Bull J. and J. Farrand Jr.. 1977. *The Audubon Society Field Guide to North American Birds Eastern Region*. Alfred A. Knopf Inc. New York.

Table B-8

COMMON REPTILES OF THE KANSAS RIVER AND TRIBUTARIES

Common Name	Scientific Name
Northern Snapping Turtle	*Chelydra serpentina*
Eastern Ornate Box Turtle	*Terrapene ornata*
False Map Turtle	*Graptemys pseudogeographica*
Western Painted Turtle	*Chrysemys picta*
Red-eared Turtle	*Chrysemys scripta*
Midland Smooth Softshell	*Trionyx muticus*
Western Spiny Softshell	*Trionyx spiniferus*
Eastern Collared Lizard	*Crotaphytus collaris*
Eastern Fence Lizard	*Sceloperus undulatus*
Ground Skink	*Leiolopisma laterale*
Five-lined Skink	*Eumeces fasciatus*
Great Plains Skink	*Eumeces obsoletus*
Prairie Skink	*Eumeces septentrionalis*
Prairie Lined Racerunner	*Cnemidophorus sexlineatus*
Western Slender Glass Lizard	*Ophisaurus attenuatus*
Prairie Ringneck Snake	*Diadophis punctatus*
Eastern Hognose Snake	*Heterodon platyrhinos*
Eastern Yellow-bellied Racer	*Coluber constrictor*
Great Plains Rat Snake	*Elaphe guttata*
Black Rat Snake	*Elaphe obsoleta*
Bullsnake	*Pituophis melanoleucus*
Prairie Kingsnake	*Lampropeltis calligaster*
Speckled Kingsnake	*Lampropeltis getulus*
Milk Snake	*Lampropeltis triangulum*
Western Ribbon Snake	*Thamnophis proximus*
Western Plains Garter Snake	*Thamnophis radix*
Red-sided Garter Snake	*Thamnophis sirtalis*
Lined Snake	*Tropidoclonion lineatum*
Texas Brown Snake	*Storeria dekayi*
Graham's Crayfish Snake	*Regina grahami*
Blotched Water Snake	*Natrix erythrogaster*
Northern Water Snake	*Natrix sipedon*
Copperhead	*Agkistrodon contortrix*
Western Massasauga	*Sistrurus catenatus*

Source: Collins. J.T.. 1974. *Amphibians and Reptiles in Kansas*. Univ. of Kansas, Museum of Natural History, Public Education Series No. 1.

Table B-9

COMMON AMPHIBIANS OF THE KANSAS RIVER AND TRIBUTARIES

Common Name	Scientific Name
Small-mouthed Salamander	*Ambystoma texanum*
Tiger Salamander	*Ambystoma tigrinum*
Mudpuppy (Waterdog)	*Necturus maculosus*
Plains Spadefoot Toad	*Scaphiopus bombifrons*
American Toad	*Bufo americanus*
Great Plains Toad	*Bufo cognatus*
Rocky Mountain Toad	*Bufo woodhousei*
Blanchard's Cricket Frog	*Acris crepitans*
Western Chorus Frog	*Pseudacris triseriata*
Cope's Gray Treefrog	*Hyla chrysoscelis*
Bullfrog	*Rana catesbeiana*
Plains Leopard Frog	*Rana pipiens*
Plains Narrow-mouthed Frog	*Gastrophryne olivacea*

Source: Collins, J.T.. 1974. *Amphibians and Reptiles in Kansas*, Museum of Natural History, University of Kansas, Public Education Series No. 1.

Table B-10

FEDERALLY LISTED THREATENED OR ENDANGERED
SPECIES THAT MAY OCCUR IN THE STUDY AREA

Common Name	Scientific Name
Peregrine Falcon	*Falco peregrinus*
Bald Eagle	*Haliaeetus leucocephalus*

Table B-11

STATE LISTED THREATENED OR ENDANGERED SPECIES THAT MAY OCCUR IN THE STUDY AREA[1,2]

Common Name	Scientific Name
Northern Crayfish Frog	*Rana areolata circulosa**
Pallid Sturgeon	*Scaphirhynchus albus*
Sicklefin Chub	*Hybopsis meeki*
Blue Sucker	*Cycleptus elongatus**
Topeka Shiner	*Notropis topeka**
Prairie Falcon	*Falco mexicanus**

[1] Selected from official state list authorized by K.S.A. 72-501-510.

[2] All species included in the U.S. Fish and Wildlife Service list (Table B-10) are also listed by the State of Kansas and are not repeated here.

* threatened

APPENDIX C – INTERIM RESULTS OF FISHERY-DREDGING STUDY

APPENDIX C

INTERIM RESULTS OF THE FISHERY-DREDGING STUDY OF THE LOWER KANSAS RIVER

F.B. Cross and F.J. DeNoyelles

Principal Investigators

January 1981

University of Kansas

Prepared for the U.S. Army

Corps of Engineers, Kansas

City District

Table C-1

WATER QUALITY AND BIOLOGICAL SAMPLING TRANSECTS OF THE "FISHERY-DREDGING" STUDY OF THE LOWER KANSAS RIVER

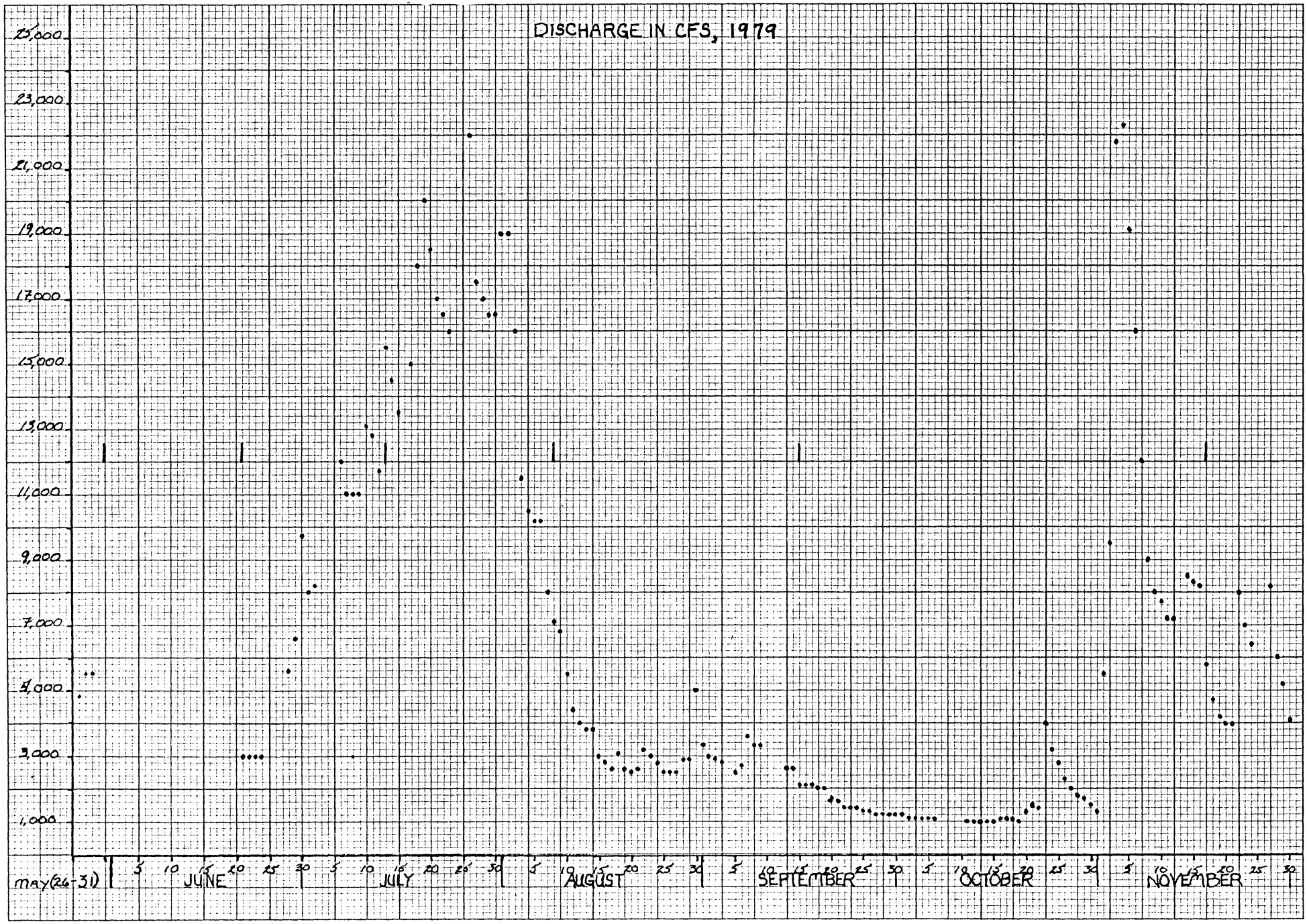
Transect	Location (River Miles)	Remarks
C1A	25.6	
C1B	25.6	
C2A	24.0	
C2B	24.0	
D1A	21.3–22.3	200 yds. above dredge
D1B		Upstream boundary of dredge pit
D1C		Downstream boundary of dredge pit
D1EFF		Discharge from onbank processing area
D1D		200 yds. below dredge
D1E		400 yds. below dredge
D2A	15.2–16.4	200 yds. above dredge
D2B		Upstream boundary of dredge pit
D2C		Downstream boundary of dredge pit
D2EFF		Discharge from onbank processing area
D2D		200 yds. below dredge
D2E		400 yds. below dredge
D3A	12.3–12.9	200 yds. above dredge
D3B		Upstream boundary of dredge pit
D3C		Downstream boundary of dredge pit
D3EFF		Discharge from onbank processing area
D3D		200 yds. below dredge
D3E		400 yds. below dredge
Partial Study Site	8.0–9.3	Below Turner Bridge

Note: Though the spatial relationship between all transects at a sampling site always remain the same, the transects may be moved on individual sampling dates to account for movement of the dredge.

K+E 10 X 10 TO ½ INCH 46 1320
7 X 10 INCHES MADE IN U.S.A.
KEUFFEL & ESSER CO.

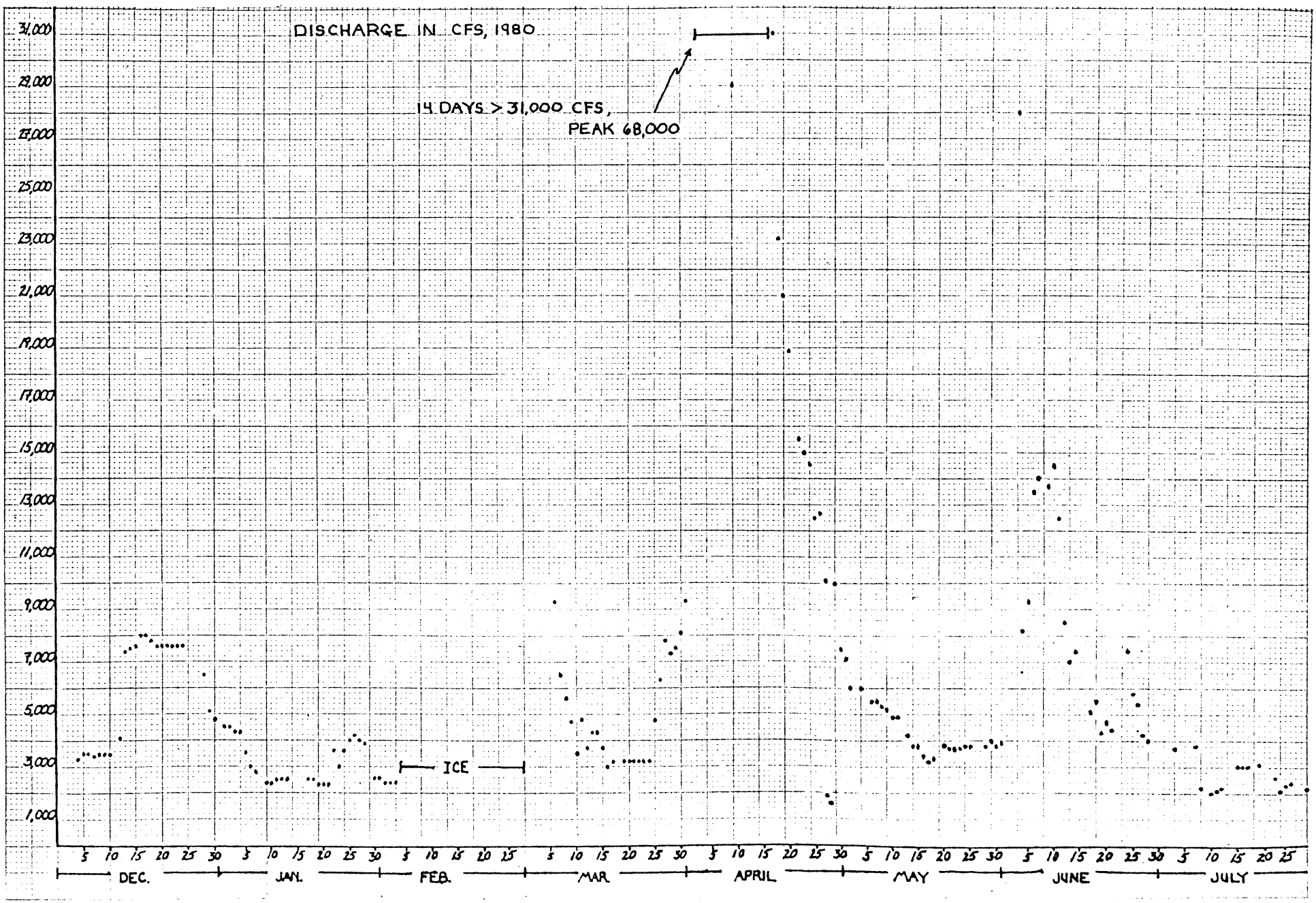
STATION: DESOTO

Figure 1a. River stages, as discharge in cfs, May-Nov. 1979.



STATION: DESOTO

Figure 1b. River stages, as discharge in cfs, Dec. 1979-July 1980.



Sampling schedule for lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980.

1979	Seining	Elec-fish	Water Quality	EPA-Trace Metals	EPA-Cores/Water	USGS-Susp. Solids	Aquatic Biology	Primary Productivity	24 Hour Pit Sample
30-31 May, 4 June	X		X						
12-15 June							X		
20-21 June	X		X						
12-13 July	X		X						
19-20 July		X							
6-7 Aug.						X			
8-9 Aug.	X		X						
20-21 Aug.				X			X		
22-23 Aug.									
31 Aug.	X	X							
8-9 Sept						X			
15-16 Sept	X		X	X					
20-21 Sept					X				
5 Oct.		X							
11-12 Nov.							X		
17-18 Nov.	X		X	X					
8-9 Dec.		X				X			
1980 18-19 Jan.	X		X	X					
7-8 Mar.		X				X			
10-11 Mar.	X		X	X	X				
22-23 Mar.							X		
11-12 Apr.		X				X			
2-3 May	X		X	X					
19-20 May		X				X			
21-22 May	X		X	X					
19 June								X	
23-24 June		X	X	X					
26-27 June	X					X			
17-18 July	X					X			
31 July, 1 Aug.							X		
5-6 Aug.		X	X	X					
11 Aug.		X							
13-14 Aug.	X					X			
19-20 Aug.		X			X				
23 Aug.									X
29 Au[illegible]									

Table 1. Trace metal concentrations from composite samples in the lower Kansas River Fishing Dredging Project, August 1979 through May 1980. * Level undetectable using present methods.

AUGUST 1979

	C1B	C2B	D1A	D1EFF	D1E	D2A	D2EFF	D2E	D3A	D3EFF	D3E
Silver ug/l	*	*	*	*	*	*	*	*	*	*	*
Aluminum ug/l	1000	1100	1310	3570	1220	1890	10100	1000	2180	5670	1510
Arsenic ug/l	*	*	*	*	*	*	*	*	*	*	*
Barium ug/l	129	136	143	189	141	145	717	143	154	520	145
Beryllium ug/l	*	*	*	*	*	*	*	*	*	*	*
Cadmium ug/l	4	*	*	*	7	*	3	*	*	* *	*
Chromium ug/l	6	*	*	*	6	*	17	*	*	11	*
Copper ug/l	30	27	18	48	35	12	32	32	20	21	10
Iron ug/l	893	951	1130	5220	1090	1810	9380	909	2100	15400	1430
Manganese ug/l	141	144	154	277	158	168	211	159	180	1860	160
Nickel ug/l	*	*	*	*	*	*	*	*	*	*	*
Lead ug/l	*	*	*	*	*	*	*	*	*	*	*
Antimony ug/l	*	*	*	*	*	*	*	*	*	*	*
Selenium ug/l	*	*	*	*	*	*	*	*	*	*	*
Thallium ug/l	*	*	*	*	*	*	*	*	*	*	*
Zinc ug/l	42	49	24	46	74	*	72	39	21	45	*
Calcium mg/l	50	55	56	59	56	55	68	58	56	94	56
Magnesium mg/l	14	15	15	16	16	15	12	16	15	16	15
Sodium mg/l	71	76	77	74	81	71	71	88	70	30	76
Mercury ug/l	0.4	0.2	*	*	*	*	0.3	*	*	*	0.2

Table 1. Continued.

SEPTEMBER
1979

	C1B	C2B	D1A	D1EFF	D1E	D2A	D2EFF	D2E	D3A	D3EFF	D3E
Silver ug/l	*	*	*		*	*	*	*	*	*	*
Aluminum ug/l	1550	1450	2490		1540	1790	1180	1620	2110	6600	2280
Arsenic ug/l	*	*	*		*	*	*	*	*	*	*
Barium ug/l	125	144	156		145	143	247	139	154	594	154
Beryllium ug/l	*	*	*		*	*	*	*	*	*	*
Cadmium ug/l	*	3	*		*	*	*	4	*	*	*
Chromium ug/l	6	7	11		*	9	9	10	44	15	8
Copper ug/l	18	52	34		31	34	32	48	2770	26	28
Iron ug/l	1360	1410	2290		1480	2100	1550	1690	235	22900	2660
Manganese ug/l	193	236	266		224	216	52	219	*	2100	237
Nickel ug/l	*	*	*		*	*	*	*	*	*	*
Lead ug/l	29	*	*		*	*	*	*	*	*	*
Antimony ug/l	*	*	*		*	*	*	*	*	*	*
Selenium ug/l	*	*	*		*	*	*	*	*	*	*
Thallium ug/l	*	*	*		*	*	*	*	48	*	*
Zinc ug/l	*	36	33		29	31	23	35	56	55	35
Calcium mg/l	52	58	59		57	54	141	55	16	115	57
Magnesium mg/l	13	16	17		16	16	13	16	74	18	16
Sodium mg/l	80	82	82		83	74	51	71	*	33	75
Mercury ug/l	*	*	*		*	*	*	*		*	*

Table 1. Continued.

NOVEMBER
1979

	C1B	C2B	D1A	D1EFF	D1E	D2A	D2EFF	D2E	D3A	D3EFF	D3E
Silver ug/l	3	3	*		*	*		*	*	*	3
Aluminum ug/l	4490	4390	4840		5210	5360		5180	5560	15600	5760
Arsenic ug/l	*	*	*		*	*		*	*	*	*
Barium ug/l	177	174	171		180	166		163	163	699	166
Beryllium ug/l	*	*	*		*	*		*	*	*	*
Cadmium ug/l	*	*	*		*	*		*	*	6	*
Chromium ug/l	*	8	8		*	*		6	7	20	11
Copper ug/l	8	9	14		5	8		4	5	16	7
Iron ug/l	3700	3580	3600		3840	4030		3900	4220	27800	4440
Manganese ug/l	106	110	111		109	121		123	119	2360	128
Nickel ug/l	*	19	*		*	*		18	*	27	*
Lead ug/l	37	*	33		*	*		*	*	*	*
Antimony ug/l	*	*	*		*	*		*	*	*	*
Selenium ug/l	*	*	*		*	*		*	*	*	*
Thallium ug/l	*	*	*		*	*		*	*	*	*
Zinc ug/l	*	*	*		*	*		*	*	59	*
Calcium mg/l	66	66	64		66	61		60	59	123	60
Magnesium mg/l	14	15	14		15	14		13	13	20	13
Sodium mg/l	46	44	44		47	35		33	32	36	31
Mercury ug/l	0.7	0.6	1.7		0.7	0.5		0.8	0.6	0.9	0.7

Table 1. Continued.

JANUARY
1980

	C1B	C2B	D1A	D1EFF	D1E	D2A	D2EFF	D2E	D3A	D3EFF	D3E
Silver ug/l	*	*	*		*	*		*	*		*
Aluminum ug/l	1630	1590	1560		1400	1650		1660	2190		2500
Arsenic ug/l	*	*	*		*	*		*	*		*
Barium ug/l	157	155	159		156	155		150	150		155
Beryllium ug/l	*	*	*		*	*		*	*		*
Cadmium ug/l	*	*	*		*	*		*	*		*
Chromium ug/l	*	*	*		*	*		*	7		*
Copper ug/l	*	*	*		*	*		*	17		*
Iron ug/l	1120	1100	1100		1040	1170		1240	1510		1750
Manganese ug/l	46	45	48		43	65		60	77		94
Nickel ug/l	*	*	*		*	*		*	*		*
Lead ug/l	*	*	*		*	*		*	*		*
Antimony ug/l	*	*	*		*	*		*	*		*
Selenium ug/l	*	*	*		*	*		*	*		*
Thallium ug/l	*	*	*		*	*		*	*		*
Zinc ug/l	40	*	*		*	*		*	*		*
Calcium mg/l	99	101	104		98	98		95	92		95
Magnesium mg/l	22	23	24		22	22		22	20		21
Sodium mg/l	105	107	110		105	100		98	93		96
Mercury ug/l	0.4	0.6	0.5		0.4	0.4		0.4	0.3		0.3

Table 1. Continued.

MARCH
1980

	C1B	C2B	D1A	D1EFF	D1E	D2A	D2EFF	D2E	D3A	D3EFF	D3E
Silver ug/l	*	*	*		*	*		*	*		*
Aluminum ug/l	2880	2120	2460		2940	2760		2540	2980		2700
Arsenic ug/l	*	*	*		*	*		*	*		*
Barium ug/l	130	131	135		138	131		130	134		133
Beryllium ug/l	*	*	*		*	*		*	*		*
Cadmium ug/l	*	*	*		*	*		*	*		*
Chromium ug/l	4	3	3		2	3		4	3		2
Copper ug/l	19	28	25		10	17		22	18		11
Iron ug/l	2140	1920	2220		2220	2060		6300	2260		2120
Manganese ug/l	61	62	70		66	65		79	74		69
Nickel ug/l	*	*	11		*	8		12	10		6
Lead ug/l	*	*	*		*	*		*	*		*
Antimony ug/l	*	*	*		*	*		*	*		*
Selenium ug/l	*	*	*		*	*		*	*		*
Thallium ug/l	*	*	*		*	*		*	*		*
Zinc ug/l	13	12	12		10	11		165	12		12
Calcium mg/l	71	71	72		74	71		71	72		75
Magnesium mg/l	17	18	18		19	17		18	18		19
Sodium mg/l	37	37	37		39	37		38	37		38
Mercury ug/l	0.2	*	0.2		0.3	0.3		0.4	0.3		*

Table 1. Continued.

APRIL
1980

	C1B	C2B	D1A	D1EFF	D1E	D2A	D2EFF	D2E	D3A	D3EFF	D3E
Silver ug/l	*	*	*	*	*	*	*	*	*		*
Aluminum ug/l	4920	5120	4660	9729	5520	5480	108000	5480	5940		5800
Arsenic ug/l	*	*	*	*	*	*	79	*	*		*
Barium ug/l	161	164	158	234	169	167	1910	170	179		173
Beryllium ug/l	*	*	*	*	*	*	6	*	*		*
Cadmium ug/l	*	*	*	2	*	*	50	*	*		*
Chromium ug/l	*	2	2	7	3	2	105	2	2		2
Copper ug/l	7	6	18	9	5	7	153	6	6		4
Iron ug/l	3620	3700	3600	8680	4000	3940	158200	4120	4360		4220
Manganese ug/l	130	130	127	244	139	136	2640	147	152		146
Nickel ug/l	*	*	9	9	*	*	134	*	*		*
Lead ug/l	*	*	*	*	*	*	35	10	7		*
Antimony ug/l	*	*	*	*	*	*	*	*	*		*
Selenium ug/l	*	*	*	*	*	*	33	*	*		*
Thallium ug/l	*	*	*	*	*	*	*	*	*		*
Zinc ug/l	17	14	18	33	13	15	462	15	17		15
Calcium mg/l	81	83	79	88	81	82	194	82	92		86
Magnesium mg/l	15	16	15	17	16	15	35	16	18		17
Sodium mg/l	49	50	48	50	48	50	54	51	63		61
Mercury ug/l	1.0	1.1	0.9	1.0	1.0	0.9	0.6	1.1	1.0		1.3

Table 1. Continued.

MAY
1980

	C1B	C2B	D1A	D1EFF	D1E	D2A	D2EFF	D2E	D3A	D3EFF	D3E
Silver ug/l	*	*	*	*	*	*	*	*	*	*	*
Aluminum ug/l	2760	2800	3080	13980	2880	1830	56800	1078	1272	2060	1366
Arsenic ug/l	*	*	*	*	*	*	*	*	*	*	*
Barium ug/l	157	162	167	310	163	135	1852	121	122	516	124
Beryllium ug/l	*	*	*	*	*	*	3	*	*	*	*
Cadmium ug/l	*	*	*	5	*	*	30	*	*	3	*
Chromium ug/l	3	2	3	17	3	2	61	*	*	3	2
Copper ug/l	8	9	11	22	10	9	112	6	8	5	6
Iron ug/l	2060	2020	2220	17500	2040	1384	98800	930	1086	12800	1182
Manganese ug/l	123	126	132	580	127	104	1064	78	88	1738	90
Nickel ug/l	*	7	*	23	*	*	81	*	*	*	*
Lead ug/l	18	10	7	18	21	13	113	16	9	26	12
Antimony ug/l	*	*	*	*	*	*	*	*	*	*	*
Selenium ug/l	*	*	*	*	*	*	*	*	*	*	*
Thallium ug/l	*	*	*	*	*	*	*	*	*	*	*
Zinc ug/l	10	11	13	50	10	7	294	5	6	10	6
Calcium mg/l	66	68	68	87	66	58	178	52	54	103	53
Magnesium mg/l	19	20	20	21	21	18	28	18	18	16	18
Sodium mg/l	63	65	64	65	64	66	67	65	66	36	65
Mercury ug/l	*	*	*	*	*	*	*	*	*	*	*

Table 2. USGS suspended solids concentration from sampling sites in lower Kansas River, Fishery-Dredging Project, August 1979 through March 1980. Two days required for each monthly sampling series.

mg/1

	C1A	C1B	C2A	C2B	D1A	D1B	D1C	D1EFF	D1D	D1E	D2A	D2EFF	D2B	D2C	D2D	D2E	D3A	D3B	D3C	D3EFF	D3D	D3E
August 1979	208.3	197.7	212.5	209.3	299.3	203.7	193.0	ONS	221.3	210.3	272.3	ONS	195.7	203.0	204.0	221.0	220.7	219.0	216.3	N.O.	205.0	243.0
Sept. 1979	157.6	169.9	178.3	159.8	383.8			NO		437.6	692.3	NO				663.3	605.0			230.0		520.0
Dec. 1979			59.4	84.7	217.9				68.8		89.7					80.7	155.3			958.0		106.7
March 1979		138.3	134.3		204.7			NO		203	95.7	NO				98.0	88.0			N.O.		89.3

Table 3. USGS particle size analysis from sampling sites in the lower Kansas River, Fishery-Dredging Project, Aug. 1979 through March 1980. The numbers in the table represent the percent of the total suspended solids with a fall diameter less than 0.062mm and 0.125mm. N.O.- dredge not operating. Two days required for each monthly sampling series.

		C1B	C2B	D1A	D1B	D1C	D1EFF	D1D	D1E	D2A	D2EFF	D2B	D2C	D2D	D2E	D3A	D3B	D3C	D3EFF	D3D	D3E
August 1979	0.062mm	94	93	73	88	95		86	86	97		98	92	98	97	98	98	99		99	93
	0.125mm	100	100	84	100	100		100	100	100		100	100	100	100	100	100	100		100	100
Sept. 1979		93	95	95			N.O.		89	100	N.O.				100	100			58		98
		100	100	100			N.O.		100	100	N.O.				100	100			80		100
Dec. 1979		91	96	68			N.O.		91	99	N.O.				100	99			92		97
		100	100	100			N.O.		100	100	N.O.				100	100			100		100
March 1980		87	89	81			N.O.		65	98	N.O.				97	97			N.O.		96
		100	100	100			N.O.		100	100	N.O.				100	100			N.O.		100

Table 4. Coulter Counter particle size analysis from selected stations in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. N.O.- dredge not operating

	C1A	C2A	D1A	D1EFF	D1E	D2A	D2EFF	D2E	D3A	D3EFF	D3E
May 1979											
-8u	39182	37711	41749		37834	28842		30470	31152		28742
-13u	41307	41653	40649		42333	42703		40067	42499		42853
13-16u	8152	9444	7513		9704	9537		9630	9847		11265
16-25u	1085	1164	1047		1404	2723		2400	2482		3047
5-32u	401	433	412		511	841		790	814		1023
32-40u	159	146	144		135	200		156	179		241
40-51u	40	43	43		38	58		56	67		72
1-64u	12	17	11		11	15		12	23		22
June 1979											
	18490	13524	17079	N.O.	16927	19789	7716	19169	21895	46024	20787
	17623	17240	17807		19368	16949	39333	16689	16356	12550	17105
	7833	8263	8361		9076	6887	37127	7095	6443	1911	5629
	4964	5372	5743		5815	3814	11960	4125	3450	542	2504
	2088	2438	2690		2770	1686	3089	1893	1485	302	1198
	457	540	644		658	427	565	495	485	133	875
	97	135	169		161	114	92	135	119	55	93
	26	38	46		46	27	12	44	35	9	24
July 1979											
	14601	17897	17398	4564	6349	11718	6369	17715	14348	7695	21334
	28515	32959	29856	12764	17315	26456	27977	40346	33600	25064	40472
	13512	16303	14320	13512	13540	16714	27885	18269	18788	5274	19477
	3963	3051	3891	4532	5057	4624	12652	6142	5244	1294	4642
	1772	1175	1770	1473	1788	1829	4180	2677	2231	567	1722
	733	469	737	525	707	703	896	1151	905	241	651
	213	141	236	140	209	253	127	362	332	93	183
	34	62	42	32	35	61	15	69	80	31	41
August 1979											
	41047	38952	36130	36760	40502	32464	24861	34925	37835	30884	33337
	24887	22041	23913	29627	27480	29272	43992	30115	27345	37515	25867
	4313	3852	3473	5469	3909	5070	35320	5223	3996	8862	4101
	870	821	861	1418	806	1130	10968	999	809	1743	908
	341	313	376	644	336	443	4509	387	322	659	332
	125	108	157	268	133	162	1357	134	106	204	128
	42	50	57	94	42	51	313	41	27	57	40
	9	7	10	24	9	11	62	10	5	15	8

Table 4. continued.

	C1A	C2A	D1A	D1EFF	D1E	D2A	D2EFF	D2E	D3A	D3EFF	D3E
June 1980											
5-8u	30892	33167	29537	N.O.	27022	12569		28143	16060	N.O.	21548
8-13u	36112	35503	36934		37216	40403		44275	36333		46895
13-16u	9693	8602	10975		10540	30132		18969	25200		26480
16-25u	1987	1778	2350		2374	5192		2919	4089		4135
25-32u	827	736	954		960	1302		684	962		1079
32-40u	309	278	374		350	295		248	255		280
40-51u	102	116	136		115	111		65	76		65
51-64u	37	46	37		38	23		6	24		17
August 1980											
	31918	34769	37545	22904	34548	9157	too	15843	20681	N.O.	20440
	30450	33309	33165	41347	33966	33924	turbid	37904	42237		41091
	7675	7478	7208	23161	7727	24277		24343	21524		20709
	1809	1517	1286	6165	1479	8025		6323	19267		4480
	679	491	476	2413	554	3769		2253	1390		1517
	309	191	172	978	221	1043		732	416		437
	145	70	72	409	80	311		175	93		119
	50	16	24	122	32	80		36	21		31

Table 5. Turbidity measurements from sampling sites in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. N.O.- dredge not operating. Two days required for each monthly sampling series.

TURBIDITY ntu

	C1A	C1B	C2A	C2B	D1A	D1B	D1C	D1EFF	D1D	D1E	D2A	D2EFF	D2B	D2C	D2D	D2E	D3A	D3B	D3C	D3EFF	D3D	D3E
MAY 1979	110.0	111.7	110.0	106.7	110.0				126.7		78.3		75.0	75.0	85.7	79.5	86.7	87.0	88.0		89.3	87.0
JUNE	36.3	40.5	37.0	39.7	39.3	43.5	40.5	N.O.	39.7	42.0	33.7	220.0	39.0	45.0	29.3	34.0	33.7	30.5	33.0	73.0	220.	29.0
JULY	160.0	163.3	165.0	167.5	168.3	167.5	167.5	165.0	166.7	168.3	200.0	220.0	202.5	200.0	200.0	200.0	210.0	202.5	210.0	65.0	205.0	206.7
AUG.	56.0	54.3	53.7	56.3	58.0	58.0	61.0	75.0	59.0	57.7	60.0	210.0	54.5	52.5	58.7	56.7	54.0	56.5	57.0	98.0	55.0	55.0
SEPT.	21.7	21.3	22.3	20.7	17.7	19.0	20.0	N.O.	18.7	18.3	26.7	17.0	23.5	24.5	23.3	22.3	29.0	28.0	26.0	100.0	25.0	27.0
NOV.	79.7	75.3	78.0	77.0	75.3	80.5	79.0	N.O.	84.3	82.7	171.5	N.O.	93.5	84.0	91.7	89.3	96.3	93.0	106.0	370.0	824.5	105.7

	C1A	C1B	C2A	C2B	D1A	D1B	D1C	D1EFF	D1D	D1E	D2A	D2EFF	D2B	D2C	D2D	D2 E	D3A	D3EFF	D3B	D3C	D3D	D3E
JAN. 1980	22.67	22.7	22.3		22.2	22.5	22.0	N.O.	22.8	22.2	58.67	N.O.	22.6	22.5	26.4	28.9	116.3	N.O.	31.0	29.0	31.8	34.8
MAR.	59.0	59.0	60.3	58.3	58.7	59.0	59.0	N.O.	58.3	58.7	24.7	N.O.	29.0	31.0	25.7	26.3	29.3	N.O.	28.0	30.0	30.0	30.0
APRIL	97.7	96.3	96.3	95.7	98.3	101.0	98.0	280.0	101.0	100.7	104.0	3000.0	102.0	100.0	108.0	104.0	118.7	N.O.	124.0	120.0	121.3	118.7
MAY	77.7	65.3	64.3	65.3	65.0	68.0	64.5	208.0	63.0	65.7	37.0	684.0	29.0	28.5	26.7	21.3	33.0	196.0	26.0	26.0	34.0	37.3
JUNE	56.3	53.3	53.3	52.3	53.7	63.0	72.0	N.O.	73.7	130.3	808.0	1568.0	376.0	724.0	688.0	493.3	640.0	N.O.	640.0	688.0	542.0	736.0
AUG.	29.0	29.7	34.3	31.0	32.0	36.0	34.0	272.0	37.6	35.7	613.3	664.0	604.0	544.0	514.7	578.7	525.3	N.O.	556.0	508.0	533.3	525.3

Table 6. Total dissolved solids measurements from sampling sites in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. N.O.- dredge not operating. Two days required for each monthly sampling series.

TOTAL DISSOLVED SOLIDS ppm

	C1A	C1B	C2A	C2B	D1A	D1B	D1C	D1EFF	D1D	D1E	D2A	D2EFF	D2B	D2C	D2D	D2E	D3A	D3B	D3C	D3EFF	D3D	D3E
MAY 1979	233	233	230	230	228				228		252		250	255	251	254	252	250	255		250	253
JUNE	280	283	280	278	280	280	280	N.O.	278	278	290	290	290	290	290	290	290	293	285	250	290	290
JULY	141	141	142	144	143	142	145	145	145	145	150	150	150	150	149	149	147	147	145	224	145	144
AUG.	183	185	185	185	185	185	185	185	185	185	193	360	190	190	192	193	190	190	193	190	192	193
SEPT.	258	257	258	258	255	258	258	N.O.	255	255	280	N.O.	273	280	277	280	272	270	275	275	270	273
NOV.	210	210	210	210	210	210	205	N.O.	210	210	180		183	183	182	180	177	180	180	255	180	178

	C1A	C1B	C2A	C2B	D1A	D1B	D1C	D1EFF	D1D	D1E	D2A	D2EFF	D2B	D2C	D2D	D2E	D3A	D3EFF	D3B	D3C	D3D	D3E
JAN. 1980	333	334	333		333	330	330	N.O.	330	333	316	N.O.	325	324	325	320	314	N.O.	321	321	321	320
MAR.	210	210	212	210	215	215	215	N.O.	215	215	218	N.O.	217	217	217	216	216	N.O.	216	216	215	216
APRIL	215	215	215	215	215	215	215	215	215	215	215	215	215	215	213	215	238	N.O.	240	240	240	240
MAY	230	232	232	230	230	230	230	230	230	230	224	225	230	230	230	228	185	230	228	230	230	230
JUNE	233	235	237	237	230	230	230	N.O.	230	230	190	190	200	185	182	180	140	N.O.	182	185	182	187
AUG.	257	270	270	260	263	270	265	240	257	253	141	140	140	143	142	138		N.O.	142	143	142	141

Table 7. pH measurements from sampling sites in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. N.O.- dredge not operating. Two days required for each monthly sampling series.

pH	C1A	C1B	C2A	C2B	D1A	D1B	D1C	D1EFF	D1D	D1E	D2A	D2EFF	D2B	D2C	D2D	D2E	D3A	D3B	D3C	D3EFF	D3D	D3E
MAY 1979	8.2	8.2	8.2	8.2	8.2				8.2		8.7		8.7	8.6	8.6	8.7	8.7	8.8	8.8		8.7	8.7
JUNE	8.5	8.4	8.4	8.4	8.4	8.5	8.4	N.O.	8.4	8.4	8.2	7.9	8.2	8.2	8.1	8.3	8.3	8.3	8.4	7.3	8.3	8.4
JULY	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0	7.9	8.0	7.9	7.9	7.9	7.9	7.9	7.9	7.9	8.0	7.9	7.5	7.9	7.9
AUG.	8.4	8.4	8.3	8.4	8.4	8.4	8.4	8.5	8.5	8.5	8.5	8.2	8.5	8.6	8.6	8.6	8.4	8.4	8.5	8.4	8.5	8.5
SEPT.	8.7	8.7	8.7	8.7	8.5	8.5	8.6	N.O.	8.5	8.6	8.6	8.1	8.6	8.6	8.6	8.6	8.5	8.5	8.5	7.1	8.5	8.4
NOV.	8.3	8.3	8.3	8.3	8.3	8.3	8.3	N.O.	8.3	8.3	8.2	N.O.	8.3	8.2	8.3	8.3	8.3	8.3	8.2	7.3	8.2	8.2

	C1A	C1B	C2A	C2B	D1A	D1B	D1C	D1EFF	D1D	D1E	D2A	D2EFF	D2B	D2C	D2D	D2E	D3A	D3EFF	D3B	D3C	D3D	D3E
JAN. 1980	8.3	8.3	8.3		8.4	8.4	8.4	N.O.	8.3	8.3	8.2	N.O.	8.2	8.2	8.3	8.2	8.1	N.O.	8.2	8.2	8.3	8.2
MAR.	8.2	8.2	8.1	8.1	8.1	8.1	8.1	N.O.	8.1	8.1	8.3	N.O.	8.2	8.2	8.2	8.3	8.2	N.O.	8.3	8.3	8.2	8.2
APRIL	8.5	8.5	8.6	8.5	8.6	8.6	8.5	8.5	8.6	8.6	8.6	8.2	8.7	8.7	8.6	8.6	8.4	8.4	8.4	N.O.	8.4	8.4
MAY	8.3	8.4	8.5	8.5	8.5	8.5	8.5	8.2	8.5	8.5	8.3	7.7	8.0	8.0	8.0	8.0	8.1	7.1	8.2	8.2	8.2	8.2
JUNE	8.5	8.6	8.6	8.6	8.6	8.6	8.6	N.O.	8.7	8.7	7.6	7.7	7.5	7.7	7.4	7.6	7.7	N.O.	7.5	7.5	7.6	7.7
AUG.	7.7	7.7	7.6	8.0	8.2	8.4	8.5	7.8	8.4	8.4	7.6	7.7	7.7	7.6	7.7	7.7	7.6	N.O.	7.6	7.6	7.6	7.6

Table 8. Total and phenolphthalein alkalinity measurements from sampling sites in the lower Kansas River, Fishery-Dredging Project, May 1979 through January 1980. total/phenolphthalein; N.O.- dredge not operating. Two days required for each monthly sampling series.

ALKALINITY mg/l

	C1A	C1B	C2A	C2B	D1A	D1B	D1C	D1EFF	D1D	D1E	D2A	D2EFF	D2B	D2C	D2D	D2E	D3A	D3B	D3C	D3EFF	D3D	D3E
MAY 1979	173/0	178/0	171/0	170/0	178/0	—	—	—	176/0	—	192/14	—	191/17	192/12	190/14	188/16	190/16	188/14	188/14	—	191/15	187/14
JUNE	136/2	141/2	131/1	127/0	124/1	123/2	122/1	N.O.	121/1	122/0	130/0	214/0	124/0	128/3	131/0	129/0	129/0	132/0	129/4	341/0	128/0	133/4
JULY	155/0	155/0	153/0	153/0	153/0	164/0	146/0	154/0	153/0	153/0	157/0	170/0	165/0	153/0	158/0	155/0	148/0	151/0	151/0	282/0	147/0	148/0
AUG.	163/10	162/12	163/9	162/10	161/11	162/10	166/12	164/10	163/11	162/12	161/11	TOO TURB	160/9	161/10	163/14	152/11	158/8	159/5	161/10	167/6	157/7	159/7
SEPT.	147/10	144/13	143/11	144/11	145/7	150/4	148/10	N.O.	146/7	147/9	143/13	98/2	142/10	143/12	142/11	143/13	144/8	144/9	144/12	340/2	142/10	143/9
NOV.	177/4	179/4	179/4	178/4	179/4	179/4	180/4	N.O.	178/4	179/4	176/4	N.O.	169/4	167/4	169/4	171/4	171/4	169/4	168/2	326/0	177/1	170/2

	C1A	C1B	C2A	C2B	D1A	D1B	D1C	D1EFF	D1D	D1E	D2A	D2EFF	D2B	D2C	D2D	D2E	D3A	D3EFF	D3B	D3C	D3D	D3E
JAN. 1980	219/10	218/11	217/12	—	223/9	214/12	215/14	N.O.	221/10	223/11	210/10	N.O.	218/9	213/9	214/8	212/9	207/8	N.O.	217/11	209/10	211/7	209/8
MAR.																						
APRIL																						
MAY																						
JUNE																						
AUG.																						

Table 9. Oxygen concentrations from sampling sites in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. N.O.- dredge not operating. Two days required for each monthly sampling series.

OXYGEN CONCENTRATION mg/l	C1A	C1B	C2A	C2B	D1A	D1B	D1C	D1EFF	D1D	D1E	D2A	D2EFF	D2B	D2C	D2D	D2E	D3A	D3B	D3C	D3EFF	D3D	D3E
MAY 1979	7.9	7.8	7.8	7.9	7.8				7.8		9.4		9.0	9.5	9.5	10.2	9.0	9.4	8.9		9.1	8.6
JUNE	12.5	11.1	12.7	12.9	12.9	12.0	12.2	N.O.	12.1	11.8	9.1	5.7	9.1	9.5	9.1	9.0	9.7	9.8	9.9	7.45	9.9	9.9
JULY	6.8	6.9	6.8	6.8	6.8	6.6	6.9	6.6	6.7	6.6	6.5	0.0	6.5	6.4	6.6	6.5	6.7	6.5	6.5	7.6	6.6	6.6
AUG.	7.7	7.7	7.4	7.8	8.1	8.2	8.2	7.4	8.0	8.3	9.1	5.8	9.4	9.4	9.3	9.5	7.6	7.4	7.5	7.5	7.3	7.4
SEPT.	11.6	12.3	12.4	12.4	9.6	9.4	9.4	N.O.	9.8	10.0	11.2	8.2	10.8	11.4	11.7	11.5	8.4	8.7	8.9	6.2	9.0	8.8
NOV.	10.5	10.4	10.4	10.4	10.4	10.3	10.4	N.O.	10.1	10.4	10.4	N.O.	10.7	10.7	10.6	10.3	10.5	10.6	10.6	10.8	10.3	10.4

	C1A	C1B	C2A	C2B	D1A	D1B	D1C	D1EFF	D1D	D1E	D2A	D2EFF	D2B	D2C	D2D	D2E	D3A	D3EFF	D3B	D3C	D3D	D3E
JAN. 1980	12.1	12.6	12.6		12.2	11.9	12.3	N.O.	12.5	12.2	11.8	N.O.	11.8	11.8	12.0	11.8	11.7	N.O.	12.0	12.0	11.9	12.1
MAR.	12.0	11.8	12.2	11.7	11.6	11.5	11.5	N.O.	11.7	11.8	11.6	N.O.	11.7	11.4	11.6	11.5	11.7	N.O.	12.0	11.6	11.7	11.7
APRIL	9.7	9.8	10.0	10.0	10.6	10.6	10.5	9.2	9.8	10.9	11.2	TOO TURB	10.9	11.0	11.4	11.3	9.3	N.O.	9.3	9.3	9.4	9.2
MAY	12.2	12.8	13.4	13.6	12.9	13.6	13.1	TOO TURB	13.4	13.4	9.8	TOO TURB	10.1	10.3	10.3	10.0	9.9	6.0	10.4	10.3	10.3	10.4
JUNE	9.7	10.4	10.9	11.2	12.3	12.1	12.7	N.O.	12.8	12.7	7.2	6.9	6.5	7.2	6.6	7.2	7.2	N.O.	6.5	7.0	6.5	6.4
AUG.	6.6	6.7	7.2	7.7	9.1	9.1	9.5	6.4	8.0	9.1	5.5	2.4	5.6	5.1	5.7	5.0	5.3	N.O.	5.6	5.5	5.8	5.1

Table 10. Chlorophyll a concentrations as a measure of algal biomass from sampling sites in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. N.O.- dredge not operating. Two days required for each monthly sampling series.

CHLOROPHYLL a ug/l

	C1A	C1B	C2A	C2B	D1A	D1B	D1C	D1EFF	D1D	D1E	D2A	D2EFF	D2B	D2C	D2D	D2E	D3A	D3B	D3C	D3EFF	D3D	D3E
MAY 1979	16.5	16.8	16.3	16.5	16.3				15.7		53.7		53.5	54.0	55.1	56.6	57.5	60.0	61.0		59.0	59.5
JUNE	55.3	55.3	54.3	56.7	55.3	62.0	60.0	N.O.	60.3	62.3	43.5	11.5	47.0	50.3	38.8	42.2	37.0	37.5	39.0	42.0	34.3	34.7
JULY	7.3	7.2	7.3	7.1	7.3	7.3	7.4	7.4	7.4	7.4	7.6	7.1	7.7	7.8	7.6	7.7	7.8	7.8	7.9	3.1	7.7	7.4
AUG.	16.9	16.5	17.9	19.8	21.3	22.4	25.1	22.6	24.9	26.0	29.1	8.8	31.2	30.8	30.2	30.9	21.6	21.0	21.2	18.6	21.1	21.0
SEPT.	78.7	79.3	79.0	77.0	74.3	73.5	74.5	N.O.	74.4	75.0	79.3	6.5	78.0	79.0	78.0	79.0	78.7	79.0	77.0	7.4	76.3	70.7
NOV.	5.9	5.9	5.8	5.9	6.0	6.1	6.2	N.O.	6.3	6.3	6.5	N.O.	5.8	5.7	5.8	5.8	5.7	5.8	5.9	5.3	6.2	6.0

	C1A	C1B	C2A	C2B	D1A	D1B	D1C	D1EFF	D1D	D1E	D2A	D2EFF	D2B	D2C	D2D	D2E	D3A	D3EFF	D3B	D3C	D3D	D3E
JAN. 1980	10.4	11.4	11.3		11.38	12.2	12.5	N.O.	12.0	12.1	10.3	N.O.	10.3	10.4	10.2	10.3	13.8	N.O.	10.7	10.7	10.8	11.0
MAR.	7.4	7.7	7.8	7.6	8.0	8.0	8.0	N.O.	8.1	8.0	8.0	N.O.	8.3	8.4	8.3	8.4	8.8	N.O.	8.8	8.8	8.8	8.6
APRIL	41.3	42.3	43.0	43.7	49.0	50.0	51.0	41.0	53.0	54.3	44.0	8.0	44.5	44.0	43.3	45.3	31.7	N.O.	33.0	32.0	32.3	32.3
MAY	114.3	103.0	99.3	99.7	95.0	95.0	97.0	89.0	94.0	95.0	66.7	20.0	56.0	52.0	52.0	42.7	52.7	4.3	50.0	50.0	50.7	49.0
JUNE	88.3	87.7	86.0	84.3	72.3	89.0	90.0	N.O.	86.7	84.0	38.0	36.0	49.5	40.0	17.7	16.8	40.3	N.O.	43.0	37.0	40.0	34.3
AUG.	45.7	49.0	51.7	51.7	53.3	54.0	54.5	30.0	56.7	53.0	17.0	0.05	16.9	17.8			14.3	N.O.	15.6	15.5	15.5	16.4

Table 11. Phytoplankton species list from sampling sites in the lower Kansas River, Fishery-Dredging Project, June 1979 through August 1980.

* species present; *+ species present and dominant.

	June 1979	August	November	March 1980	June	August	Benthic August	Bloom August
Actinastrum	*+	*+			*	*	*	
Anabaena	*	*					*	
Ankistrodesmus	*+	*+		*		*		
Aphanocapsa	*	*						
Asterionella				*				
Biddulphia				*				
Chlamydomonas				*+				
Closteriopsis		*						
Coelastrum cambricum	*+	*+			*+	*+	*	
Cosmarium							*	
Crucigenia	*+					*		
Cryptomonas	*	*		*	*	*		*
Cyclotella	*+	*+	*		*+	*+	*	
Dictyosphaerium	*	*+	*			*+		
Dinoflagellata		*				*+		
Eudorina					*			
Euglena		*		*	*	*	*	*
Gonium	*				*			*
Kirchneriella	*	*		*				
Lyngbya		*						
Melosira		*	*	*+		*	*	
Merismopedia	*	*						
Navicula							*	
Nitzschia	*	*		*	*	*	*	*
Oedogonium							*	
Oocystis	*	*			*	*		
Oscillatoria	*	*				*	*	*
Pandorina						*		*
Pediastrum	*	*			*	*+	*	*
Pleurosigma		*					*	
Scenedesmus acuminatus	*+	*+		*	*+	*+	*	
Surirella		*		*	*			
Trachelomonas						*		*

Table 12. Enumeration of dominant phytoplankton species by station and month, lower Kansas River, Fishery-Dredging Project, June 1979 through August 1980. (count x 9.8 = #/ml)

	C2A	D1A	D1E	D2A	D2E	D3A	D3E
June 1979							
Actinastrum	12	46	30	81	38	14	27
Ankistrodesmus	36	68	49	65	38	8	26
Coelastrum cambricum	44	64	124	76	92	76	96
Crucigenia	80	82	58	40	29	12	28
Cyclotella	229	118	213	165	140	151	136
Scenedesmus	38	80	82	124	58	22	84
August 1979							
Actinastrum	139	173	153	100	239	39	270
Ankistrodesmus	91	34	73	47	61	30	51
C. cambricum	135	160	142	182	94	154	92
Cyclotella	56	49	80	58	66	47	55
Dictyosphaerium	142	202	103	108	165	22	78
Scenedesmus	84	134	96	151	76	98	94
S. acuminatus	108	122	152	119	98	107	134
November 1979	All species in low concentration.						
March 1980							
Chlamydomonas	185	132	200	221	150	186	189
Melosira	810	638	444	468	357	401	398
June 1980							
Coelastrum	0	36	8	16	32	28	88
Cyclotella	62	57	71	79	80	78	115
Scenedesmus	2	0	4	16	0	26	24
S. acuminatus	8	12	16	24	4	21	37
August 1980							
Coelastrum	128	100	24	134	59	84	34
Cyclotella	88	91	100	109	94	117	109
Dictyosphaerium	96	130	14	68	24	76	4
Dinoflagellata	5	5	9	10	3	4	2
Pediastrum	48	16	64	55	0	0	16
Scenedesmus	114	116	52	58	66	72	40
S. acuminatus	94	80	22	54	44	40	40

Table 13. Enumeration of the zooplankton by station and by month, lower Kansas River, Fishery-Dredging Project, June 1979 through August 1980. (Number per 628.3 liters)

	C2A	D1A	D1E	D2A	D2E	D3A	D3E
June 1979							
Cyclopoid copepod	64	64	74	56	71	63	74
Calanoid copepod	2	3	0	4	4	5	2
Nauplii	38	35	28	4	3	27	55
Simocephalus	0	0	0	0	1	1	1
Bosmina	0	3	0	0	0	0	1
Diaphanosoma	0	0	1	0	0	0	0
Daphnia	1	0	0	0	0	0	0
Ostracoda	1	6	1	1	0	0	4
August 1979							
Cyclopoid copepod	16	26	14	17	6	13	4
Calanoid copepod	1	2	3	0	0	0	0
Nauplii	7	3	2	6	0	0	5
Simocephalus	0	0	0	0	0	1	0
Diaphanosoma	0	0	0	0	1	0	0
Ceriodaphnia	0	1	0	0	0	0	0
Ostracoda	0	0	0	0	0	1	0
November 1979							
Cyclopoid copepod	169	71	34	126	77	58	44
Calanoid copepod	28	46	3	28	21	10	18
Nauplii	20	9	2	10	8	8	4
Simocephalus	1	1	0	1	0	0	0
Bosmina	7	7	1	5	3	1	3
Daphnia	38	26	11	28	20	11	11
Ceriodaphnia	1	1	2	0	3	1	2
Ostracoda	0	4	0	0	1	0	0
March 1980							
Cyclopoid copepod	327	322	131	206	198	223	255
Calanoid copepod	22	23	5	19	32	22	11
Nauplii	6520	246	124	246	326	572	855
Simocephalus	0	1	0	0	0	0	0
Bosmina	26	20	8	16	17	34	28
Diaphanosoma	0	0	0	0	0	1	0
Daphnia	5	4	0	0	0	1	2

Table 13. continued.

	C2A	D1A	D1E	D2A	D2E	D3A	D3E
June 1980							
Cyclopoid copepod	158	186	*	215	242	97	93
Calanoid copepod	55	72	*	112	111	59	69
Nauplii	31	204	*	244	337	163	142
Simocephalus	5	1	*	3	1	0	1
Bosmina	11	4	*	6	12	3	3
Daphnia	94	65	*	145	123	32	38
Ceriodaphnia	2	2	*	0	1	0	0
Chydorus	0	0	*	1	0	0	0
Ostracoda	1	1	*	0	0	0	0
August 1980							
Cyclopoid copepod	9	5	0	8	21	7	8
Nauplii	3	0	0	0	2	0	0
Diaphanosoma	3	1	0	6	52	16	24
Ostracoda	1	0	0	1	0	0	0

* this transect not sampled.

Table 14. Diversity and abundance of benthic and drift organisms, by transect, in the lower Kansas River. Based on preliminary analysis of samples taken in March, June, and August 1980. "Number Taxa" refers to Families listed in Table 15. Total volume was recorded as 0.1 cc even if less.

		C2A		D1A		D1E		D2A		D2E		D3A		D3E	
		Pibb	Drift	Pibb	Drift	Pibb	Drift	Pibb	Drift	Pibb	Drift	Pibb	Drift	Pibb	Drift
March 1980	Number Taxa	3	3	11	2	13	3	9	2	12	1	7	7	15	0
3 Pibb	Number Organisms	9	9	118	7	123	4	76	3	190	1	40	18	144	0
1 Drift	Total Volume	.1	.1	.8	-	1.1	-	1.1	-	1.9	-	.5	.6	1.5	0
June 1980	Number Taxa	2	5	11	3	10	8	7	11	9	4	8	7	16[1]	4[1]
3 Pibb	Number Organisms	3	24	97	16	91	20	25	69	58	12	33	15	354	11
2 Drift	Total Volume	.1	1.3	1.0	.2	.6	.2	.3	.5	.6	.7	1.0	.2	4.2	.1
August 1980	Number Taxa	4	5	9	5	10	6	8	1	10	2	8	4	13	7
3 Pibb	Number Organisms	22	14	408	18	1024	35	538	55	433	48	203	14	468	80
2 Drift	Total Volume	.2	.1	2.7	.4	12.3	.6	4.5	.3	3.4	.3	2.9	.1	4.2	.3

[1] June samples at D3E consisted of 2 Pibbs and 1 Drift set, due to excessive depths and current in center channel.

[2] Pibb samples one square foot.

Table 15. Groups of invertebrates represented in benthos and drift samples from seven transects: March, June, and August 1980.

Annelida		
Oligochaeta (aquatic earthworms)	C2A, D1E, D2A, D2E, D3A, D3E	
Crustacea		
Copepoda (copepods)	D3E	
Argulus sp.		
Insecta		
Plecoptera (stoneflies)		
Perlidae	D1A, D1E, D2A, D3E	*Perlesta placida*
Perlodidae	D1E, D3A, D3E	*Isoperla* sp.
Ephemeroptera (mayflies)		
Baetidae	all	*Baetis* spp.
Caenidae	C2A, D1A, D1E, D2A, D3A, D3E	*Caenis* spp.
Ephemeridae	D1E, D2A, D2E, D3A, D3E	*Hexagenia* sp.
Heptageniidae	D1A, D1E, D2A, D2E, D3E	*Heptagenia*, *Stenonema*
Leptophlebiidae	D1A, D3A, D3E	
Oligoneuridae	C2A, D1A, D1E, D3E	*Homeoneuria*, *Isonychia*
Potamanthidae	D3E	*Potamanthus* sp.
Tricorythidae	D1A, D1E, D2A, D3E	*Tricorythodes*
Odonata (damselflies and dragonflies)		
Coenagriidae	D1E, D3E	*Argia apicalis*
Gomphidae	D1A, D2A, D2E, D3A, D3E	*Gomphus intricadus*
Hemiptera (true bugs)		
Corixidae	all	*Tricoryxa* sp.
Megaloptera (alderflies and dobsonflies)		
Corydalidae	D1E	*Corydalis cornutus*
Trichoptera (caddisflies)		
Hydropsychidae	all	*Hydropsyche*, *Potamyia*
Leptoceridae	all	
Polycentropodidae	D2A	*Neureclipsis* sp.
Coleoptera (beetles)		
Elmidae	all	*Dubiraphia*, *Macronychus*, *Stenelmis*
Diptera (true flies)		
Ceratopogonidae	all	
Chaoboridae	D1A	*Chaoborus* spp.
Chironomidae	all	
Empididae	D1A, D2A, D3E	*Hemerodromia*
Simuliidae	D1A, D1E, D3A, D3E	*Simulium*
Tipulidae	D3E	
Mollusca		
Gastropoda (snails)		
Physidae	D1E, D2A	*Physa hauni*
Planorbidae	D1E	*Helisoma trivolvis*
Pelecypoda		*Corbicula*
Corbiculidae		

Table 16. Summary of fishes collected using seining methods in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. For each transect, the total number of fish caught is tabulated by species for the entire sampling period. The transect total of all species is summarized at the bottom of the appropriate column. The cumulative total of each species for all transects is along the right-hand margin.

SITE:	C1A	C1B	C2A	C2B	D1A	D1D	D1E	D2A	D2D	D2E	D3A	D3D	D3E	Part.	Total
SPECIES:															
Shovelnose Sturgeon	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Shortnose Gar	0	1	1	1	0	0	5	2	1	0	4	3	1	0	19
Longnose Gar	0	0	0	3	1	1	1	2	0	1	0	5	1	0	15
Gizzard Shad	0	16	8	79	22	73	2	589	84	106	207	106	70	4	1366
Goldeye	0	0	1	1	0	0	0	5	3	0	0	1	4	0	15
Carp	1	1	1	7	1	0	2	1	0	0	1	4	4	0	23
Golden Shiner	0	2	0	1	0	0	5	0	0	0	0	1	1	0	10
Creek Chub	1	0	2	3	4	3	0	0	2	0	1	4	1	0	21
Silver Chub	0	0	1	11	6	8	16	13	18	193	18	1	11	0	296
Speckled Chub	10	0	3	2	6	4	9	1	0	2	5	0	44	4	90
Sturgeon Chub	0	0	0	0	0	0	0	0	0	0	0	1	2	0	3
Suckermouth Minnow	3	1	2	0	9	0	2	2	1	3	0	0	3	0	26
Emerald Shiner	0	15	25	5	7	1	22	7	5	14	169	73	179	27	549
Redfin Shiner	0	1	0	0	4	1	3	1	0	1	1	1	0	0	13
River Shiner	0	1	0	0	0	0	0	0	0	0	0	1	1	1	4
Red Shiner	686	1782	530	3084	1958	801	1963	946	1092	1276	439	1936	952	43	17488
Sand Shiner	701	738	487	1548	626	258	362	200	427	414	226	403	167	2	6559
Plains Minnow	0	0	0	0	0	0	0	0	0	0	2	1	0	1	4
W. Silvery Minnow	0	0	0	0	0	0	1	0	0	0	1	3	4	4	13
Fathead Minnow	6	4	9	11	5	3	2	19	1	11	2	16	4	0	93
Bullhead Minnow	2	22	3	35	16	1	10	17	6	17	59	14	11	11	224
Bluntnose Minnow	1	13	24	23	13	10	20	3	5	88	3	9	6	0	218
Stoneroller Minnow	1	1	4	0	22	0	2	0	1	0	0	1	0	1	33
Bigmouth Buffalo	0	0	0	0	0	0	0	0	0	0	1	0	2	0	3
Smallmouth Buffalo	0	1	0	1	0	0	0	0	0	0	0	0	1	0	3
Carpsucker	727	511	843	680	345	395	122	261	183	292	223	119	208	3	4912
Shorthead Redhorse	0	4	0	3	0	0	2	0	0	0	1	0	0	0	10
White Sucker	2	0	0	0	0	0	0	0	0	0	0	0	0	0	2
Black Bullhead	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2
Channel Catfish	48	29	11	17	29	18	25	32	136	96	44	39	114	39	677
Flathead Catfish	0	0	0	0	0	0	0	0	0	1	0	0	1	0	2
Stonecat	0	0	0	0	8	0	1	0	0	0	0	20	0	0	29
Slender Madtom	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
White Bass	4	7	17	14	10	1	1	26	10	54	22	6	11	0	183
Largemouth Bass	1	7	0	1	6	1	4	7	2	0	10	4	2	1	46
Green Sunfish	0	1	1	4	0	2	1	2	2	7	4	2	10	0	36
Bluegill Sunfish	0	1	5	3	7	0	42	27	4	19	22	17	52	2	201
Orange-spotted Sunfish	0	1	0	0	0	0	5	1	0	1	0	6	4	0	18
White Crappie	2	13	15	38	2	0	7	10	22	10	18	22	49	2	210
Black Crappie	0	0	0	0	0	0	9	0	0	0	0	1	0	0	10
Sauger	0	2	3	0	0	0	0	0	1	0	0	1	0	0	7
Walleye	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Orange-throated Darter	0	0	0	0	1	0	0	0	0	0	0	0	7	0	8
Freshwater Drum	0	9	6	11	2	8	26	42	11	82	67	10	22	9	305
TOTAL:	2197	3185	2002	5586	3111	1589	2678	2216	2017	2688	1550	2832	1951	154	33750

1 Longear Sunfish

2 Skipjack Herring

2833

Summary of fishes collected using seining methods in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. For each transect, the total number of fish caught by species is tabulated on a monthly basis. The monthly total of all species is summarized at the bottom of the appropriate column. The cumulative total of each species for all months is presented along the right-hand margin.

SITE: C1A

SPECIES:	May 1979	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. '80	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
Shovelnose Sturgeon		1															1
Shortnose Gar																	
Longnose Gar																	
Gizzard Shad																	
Goldeye																	
Carp											1						1
Golden Shiner																	
Creek Chub		1															1
Silver Chub																	
Speckled Chub							10										10
Sturgeon Chub																	
Suckermouth Minnow															3		3
Emerald Shiner																	
Redfin Shiner																	
River Shiner																	
Red Shiner	82	166		15	82		16						144	19	162		686
Bigmouth Shiner																	
Sand Shiner	19	144			40		141		1		6		80	43	227		701
Plains Minnow																	
W. Silvery Minnow																	
Fathead Minnow					6												6
Bullhead Minnow													2				2
Bluntnose Minnow				1													1
Stoneroller Minnow		1															1
Bigmouth Buffalo																	
Smallmouth Buffalo																	
Carpsucker		6		1	1		9						27	26	657		727
Shorthead Redhorse																	
Black Bullhead																	
Channel Catfish	29						8								11		48
Flathead Catfish																	
Stonecat																	
White Bass				3									1				4
Largemouth Bass		1															1
Green Sunfish																	
Bluegill Sunfish																	
Orange-spotted Sunfish																	
White Crappie	1				1												2
Black Crappie																	
Sauger																	
Orange-throated Darter																	
Freshwater Drum																	
White Sucker		2															2
TOTAL:	131	320		20	130		184		1		7		254	88	1060		2197

Summary of fishes collected using seining methods in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. For each transect, the total number of fish caught by species is tabulated on a monthly basis. The monthly total of all species is summarized at the bottom of the appropriate column. The cumulative total of each species for all months is presented along the right-hand margin.

SITE: C1B

SPECIES:	May 1979	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. '80	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
Shovelnose Sturgeon																	
Shortnose Gar			1														1
Longnose Gar																	
Gizzard Shad				4								8			2	2	16
Goldeye																	
Carp				1													1
Golden Shiner													2				2
Creek Chub																	
Silver Chub																	
Speckled Chub																	
Sturgeon Chub																	
Suckermouth Minnow														1			1
Emerald Shiner													1		14		15
Redfin Shiner															1		1
River Shiner													1				1
Red Shiner	216	432	88	57	18		27		264		1	24	139	91	127	298	1782
Bigmouth Shiner																	
Sand Shiner	101	124	116	60			76		71		52	18	17	15	73	15	738
Plains Minnow																	
W. Silvery Minnow																	
Fathead Minnow				2									1	1			4
Bullhead Minnow															16	6	22
Bluntnose Minnow		1		2					2				1		7		13
Stoneroller Minnow				1													1
Bigmouth Buffalo																	
Smallmouth Buffalo		1															1
Carpsucker	3	64	1	4			2				1	2	38	8	374	14	511
Shorthead Redhorse		1												3			4
Black Bullhead																	
Channel Catfish	8		4										17				29
Flathead Catfish																	
Stonecat																	
White Bass				1									5		1		7
Largemouth Bass		7															7
Green Sunfish	1																1
Bluegill Sunfish															1		1
Orange-spotted Sunfish		1															1
White Crappie		3										4	6				13
Black Crappie																	
Sauger	2																2
Orange-throated Darter																	
Freshwater Drum	6	3															9
Walleye		1															1
TOTAL:	337	637	210	132	18		105		337		54	56	228	119	616	335	3184

Summary of fishes collected using seining methods in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. For each transect, the total number of fish caught by species is tabulated on a monthly basis. The monthly total of all species is summarized at the bottom of the appropriate column. The cumulative total of each species for all months is presented along the right-hand margin.

SITE: C2A

SPECIES:	May 1979	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.'80	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
Shovelnose Sturgeon																	
Shortnose Gar														1			1
Longnose Gar																	
Gizzard Shad			1		1							3				3	8
Goldeye		1															1
Carp		1															1
Golden Shiner																	
Creek Chub			1												1		2
Silver Chub		1															1
Speckled Chub									2					1			3
Sturgeon Chub																	
Suckermouth Minnow			1											1			2
Emerald Shiner													2		23		25
Redfin Shiner																	
River Shiner																	
Red Shiner	53	16	44	17	44		13				6	64	94	61	70	48	530
Bigmouth Shiner																	
Sand Shiner	13	12	194	13	18		23		1		34	13	28	44	38	56	487
Plains Minnow																	
W. Silvery Minnow																	
Fathead Minnow	1		3												5		9
Bullhead Minnow																3	3
Bluntnose Minnow			16		2										4	2	24
Stoneroller Minnow		1	3														4
Bigmouth Buffalo																	
Smallmouth Buffalo																	
Carpsucker		3	315	1	40		38				5	9		12	234	186	843
Shorthead Redhorse																	
Black Bullhead																	
Channel Catfish	1		4		1		4					1					11
Flathead Catfish																	
Stonecat																	
White Bass		1	14	1											1		17
Largemouth Bass																	
Green Sunfish		1															1
Bluegill Sunfish			1		2											2	5
Orange-spotted Sunfish																	
White Crappie	2	2	4	1	6												15
Black Crappie																	
Sauger	3																3
Orange-throated Darter																	
Freshwater Drum	2		3		1												6
TOTAL:	75	39	604	33	115		78		3		45	90	124	120	376	300	2002

Summary of fishes collected using seining methods in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. For each transect, the total number of fish caught by species is tabulated on a monthly basis. The monthly total of all species is summarized at the bottom of the appropriate column. The cumulative total of each species for all months is presented along the right-hand margin.

SITE: C2B

SPECIES:	May 1979	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. '80	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
Shovelnose Sturgeon																	
Shortnose Gar	1																1
Longnose Gar														3			3
Gizzard Shad							1						4	61		13	79
Goldeye															1		1
Carp														7			7
Golden Shiner													1				1
Creek Chub		1					1							1			3
Silver Chub													4	7			11
Speckled Chub												1			1		2
Sturgeon Chub																	
Suckermouth Minnow																	
Emerald Shiner		1					3								1		5
Redfin Shiner																	
River Shiner																	
Red Shiner	250	117	114	16	59		1825				76	339	125	85	46	32	3084
Bigmouth Shiner																	
Sand Shiner	15	10	252				991				129	63	23	47	9	9	1548
Plains Minnow																	
W. Silvery Minnow																	
Fathead Minnow	1											1	2	6	1		11
Bullhead Minnow							3					13	8	3	7	1	35
Bluntnose Minnow			2	1			7					8	1	3	1		23
Stoneroller Minnow																	
Bigmouth Buffalo																	
Smallmouth Buffalo															1		1
Carpsucker	12	4	159				7				2	1	284	162	41	8	680
Shorthead Redhorse														3			3
Black Bullhead																	
Channel Catfish	11		3		1							1			1		17
Flathead Catfish																	
Stonecat																	
White Bass													1	10	3		14
Largemouth Bass																1	1
Green Sunfish							4										4
Bluegill Sunfish							2									1	3
Orange-spotted Sunfish																	
White Crappie					1		1					2	25	8	1		38
Black Crappie																	
Sauger																	
Orange-throated Darter																	
Freshwater Drum	1		1										6		3		11
TOTAL:	291	133	531	17	61		2845				207	429	484	406	117	65	5586

Summary of fishes collected using seining methods in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. For each transect, the total number of fish caught by species is tabulated on a monthly basis. The monthly total of all species is summarized at the bottom of the appropriate column. The cumulative total of each species for all months is presented along the right-hand margin.

SITE: D1A

SPECIES:	May 1979	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.'80	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
Shovelnose Sturgeon																	
Shortnose Gar																	1
Longnose Gar		1										3		2		17	22
Gizzard Shad																	
Goldeye																	
Carp			1														1
Golden Shiner																	
Creek Chub		3	1														4
Silver Chub			6														6
Speckled Chub			1				2		2							1	6
Sturgeon Chub																	
Suckermouth Minnow			8											1			9
Emerald Shiner															6	1	7
Redfin Shiner															4		4
River Shiner																	
Red Shiner	210	317	732	43	13		2		3		4	51	42	53	39	449	1958
Bigmouth Shiner																	
Sand Shiner	88	44	193	3			8		25		24	33	48	35	67	58	626
Plains Minnow																	
W. Silvery Minnow																	
Fathead Minnow			3												2		5
Bullhead Minnow	1											1			1	13	16
Bluntnose Minnow			4										2		1	6	13
Stoneroller Minnow			22														22
Bigmouth Buffalo																	
Smallmouth Buffalo																	
Carpsucker	2	47	15		3				6		3	2	9	14	177	70	345
Shorthead Redhorse																	
Black Bullhead																	
Channel Catfish			16				2					9	1			1	29
Flathead Catfish																	
Stonecat	2				6												8
White Bass												2	1	1	6		10
Largemouth Bass		1	3											1		1	6
Green Sunfish																	
Bluegill Sunfish									5							2	7
Orange-spotted Sunfish																	
White Crappie												1	1				2
Black Crappie																	
Sauger																	
Orange-throated Darter															1		1
Freshwater Drum			2														2
Slender Madtom					1												1
TOTAL:	303	413	1007	46	19		14		41		31	103	104	107	304	619	3111

Summary of fishes collected using seining methods in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. For each transect, the total number of fish caught by species is tabulated on a monthly basis. The monthly total of all species is summarized at the bottom of the appropriate column. The cumulative total of each species for all months is presented along the right-hand margin.

SITE: D1D

SPECIES:	May 1979	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. '80	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
Shovelnose Sturgeon																	
Shortnose Gar																	
Longnose Gar		1															1
Gizzard Shad															1	72	73
Goldeye																	
Carp																	
Golden Shiner																	
Creek Chub		3															3
Silver Chub																8	8
Speckled Chub			1								1				1	1	4
Sturgeon Chub																	
Suckermouth Minnow																	
Emerald Shiner													1				1
Redfin Shiner															1		1
River Shiner																	
Red Shiner	67	198	9	29	21		91		4		3	53	178	21	15	112	801
Bigmouth Shiner																	
Sand Shiner	18	12	1	4			37		5		13	11	99	9	2	47	258
Plains Minnow																	
W. Silvery Minnow																	
Fathead Minnow				3													3
Bullhead Minnow																1	1
Bluntnose Minnow				6	2								2				10
Stoneroller Minnow																	
Bigmouth Buffalo																	
Smallmouth Buffalo																	
Carpsucker	6			5			5				2	1	122	4		250	395
Shorthead Redhorse																	
Black Bullhead																	
Channel Catfish			14				2						1			1	18
Flathead Catfish																	
Stonecat																	
White Bass																1	1
Largemouth Bass																1	1
Green Sunfish														2			2
Bluegill Sunfish																	
Orange-spotted Sunfish																	
White Crappie																	
Black Crappie																	
Sauger																	
Orange-throated Darter																	
Freshwater Drum				7												1	8
TOTAL:	91	214	25	54	23		135		9		19	65	403	36	20	495	1589

Summary of fishes collected using seining methods in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. For each transect, the total number of fish caught by species is tabulated on a monthly basis. The monthly total of all species is summarized at the bottom of the appropriate column. The cumulative total of each species for all months is presented along the right-hand margin.

SITE: D1E

SPECIES:	May 1979	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.'80	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
Shovelnose Sturgeon																	
Shortnose Gar			5														5
Longnose Gar			1														1
Gizzard Shad				1								1					2
Goldeye																	
Carp	1	1															2
Golden Shiner												5					5
Creek Chub																	
Silver Chub		2	6												8		16
Speckled Chub					1				3		3			2			9
Sturgeon Chub																	
Suckermouth Minnow														1		1	2
Emerald Shiner		1													21		22
Redfin Shiner												2	1				3
River Shiner																	
Red Shiner	442	67	249		30				1		25	660	276	34	92	87	1963
Bigmouth Shiner																	
Sand Shiner	1	19	7		1						38	140	23	43	64	26	362
Plains Minnow																	
W. Silvery Minnow															1		1
Fathead Minnow															2		2
Bullhead Minnow												2	2	1	1	4	10
Bluntnose Minnow		1	3									10	4		2		20
Stoneroller Minnow			1											1			2
Bigmouth Buffalo																	
Smallmouth Buffalo																	
Carpsucker		3	2	2								1	2	14	61	37	122
Shorthead Redhorse			2														2
Black Bullhead																	
Channel Catfish	6		10	1										1	5	2	25
Flathead Catfish																	
Stonecat																1	1
White Bass													1				1
Largemouth Bass		1	2												1		4
Green Sunfish														1			1
Bluegill Sunfish			17									25					42
Orange-spotted Sunfish												5					5
White Crappie			3	1								3					7
Black Crappie				2								7					9
Sauger																	
Orange-throated Darter																	
Freshwater Drum			18									8					26
Longear Sunfish			1														1
TOTAL:	450	95	327	7	32				4		66	869	309	98	258	158	2673

Summary of fishes collected using seining methods in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. For each transect, the total number of fish caught by species is tabulated on a monthly basis. The monthly total of all species is summarized at the bottom of the appropriate column. The cumulative total of each species for all months is presented along the right-hand margin.

SITE: D2A

SPECIES:	May 1979	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.'80	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
Shovelnose Sturgeon																	2
Shortnose Gar	2														1		2
Longnose Gar		1												1	496	80	589
Gizzard Shad				11			1										
Goldeye		4	1														5
Carp		1															1
Golden Shiner																	
Creek Chub																	
Silver Chub		5	1											7			13
Speckled Chub			1														1
Sturgeon Chub																	
Suckermouth Minnow														2			2
Emerald Shiner					2							2			3		7
Redfin Shiner															1		1
River Shiner																	
Red Shiner	144	254	36	2	60				4		9	217	84	5	20	111	946
Bigmouth Shiner																	
Sand Shiner	15	15	17	7			1				18	82	14	6	8	17	200
Plains Minnow																	
W. Silvery Minnow																	
Fathead Minnow		18									1						19
Bullhead Minnow	1	1												3	5	7	17
Bluntnose Minnow															3		3
Stoneroller Minnow																	
Bigmouth Buffalo																	
Smallmouth Buffalo																	
Carpsucker	3	6		6	1		2		41		14	12	1	3	87	85	261
Shorthead Redhorse																	
Black Bullhead																	
Channel Catfish			25	1			2							2		2	32
Flathead Catfish																	
Stonecat																	
White Bass		11		1									1	10	2	1	26
Largemouth Bass		7															7
Green Sunfish		1													1		2
Bluegill Sunfish					1										13	13	27
Orange-spotted Sunfish																1	1
White Crappie	1													3	6		10
Black Crappie																	
Sauger																	
Orange-throated Darter																	
Freshwater Drum			1				2							39			42
TOTAL:	166	324	82	28	64		8		45		42	313	100	81	646	317	2216

Summary of fishes collected using seining methods in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. For each transect, the total number of fish caught by species is tabulated on a monthly basis. The monthly total of all species is summarized at the bottom of the appropriate column. The cumulative total of each species for all months is presented along the right-hand margin.

SITE: D2D SPECIES:	May 1979	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.'80	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
Shovelnose Sturgeon																	
Shortnose Gar	1																1
Longnose Gar																	
Gizzard Shad												2			68	14	84
Goldeye		1	2														3
Carp																	
Golden Shiner																	
Creek Chub		2															2
Silver Chub	1	13	2											1	1		18
Speckled Chub																	
Sturgeon Chub																	
Suckermouth Minnow														1			1
Emerald Shiner	1														2	2	5
Redfin Shiner																	
River Shiner																	
Red Shiner	195	111	22	9	72		25		1		24	491	14	4	60	64	1092
Bigmouth Shiner																	
Sand Shiner	101	9	46	5	4		21		19		26	134		2	56	4	427
Plains Minnow																	
W. Silvery Minnow																	
Fathead Minnow			1														1
Bullhead Minnow		1												1	3	1	6
Bluntnose Minnow															5		5
Stoneroller Minnow		1															1
Bigmouth Buffalo																	
Smallmouth Buffalo																	
Carpsucker	1	22	12	1	3		1					78			63	2	183
Shorthead Redhorse																	
Black Bullhead																	
Channel Catfish	6		128												2		136
Flathead Catfish																	
Stonecat																	
White Bass	1	2			1							1		4	1		10
Largemouth Bass		2															2
Green Sunfish																2	2
Bluegill Sunfish																4	4
Orange-spotted Sunfish																	
White Crappie	3	4										14		1	1		22
Black Crappie																	
Sauger	1																1
Orange-throated Darter																	
Freshwater Drum	1	1	1				1							6			11
TOTAL:	312	169	214	15	80		48		20		50	720	14	20	262	93	2017

Summary of fishes collected using seining methods in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. For each transect, the total number of fish caught by species is tabulated on a monthly basis. The monthly total of all species is summarized at the bottom of the appropriate column. The cumulative total of each species for all months is presented along the right-hand margin.

SITE: D2E SPECIES:	May 1979	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.'80	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
Shovelnose Sturgeon																	
Shortnose Gar																	
Longnose Gar															1		1
Gizzard Shad					1									3	79	23	106
Goldeye																	
Carp																	
Golden Shiner																	
Creek Chub																	
Silver Chub		1	24		1									163	4		193
Speckled Chub														2			2
Sturgeon Chub																	
Suckermouth Minnow														2	1		3
Emerald Shiner					1										12	1	14
Redfin Shiner													1				1
River Shiner																	
Red Shiner	39	46	39	1	151		9		436		222	143	58	14	104	14	1276
Bigmouth Shiner																	
Sand Shiner	36	9	35	3	7		2[illegible]		78		49	127	29	9	15	15	414
Plains Minnow																	
W. Silvery Minnow																	
Fathead Minnow							1		5		4	1					11
Bullhead Minnow														4	8	5	17
Bluntnose Minnow			13									1		1	73		88
Stoneroller Minnow																	
Bigmouth Buffalo																	
Smallmouth Buffalo																	
Carpsucker	1	1	34		61				1		2	47	2	6	29	108	292
Shorthead Redhorse																	
Black Bullhead																	
Channel Catfish	3		68		12		11					1		1			96
Flathead Catfish			1														1
Stonecat																	
White Bass		2	1		3								1	44	3		54
Largemouth Bass																	
Green Sunfish			1				1								4	1	7
Bluegill Sunfish			1		2		1									15	19
Orange-spotted Sunfish														1			1
White Crappie		1			3							1		2	1	2	10
Black Crappie																	
Sauger																	
Orange-throated Darter																	
Freshwater Drum	1		8		8		1							64			82
TOTAL:	80	60	225	4	250		26		520		277	321	91	316	334	184	2688

Summary of fishes collected using seining methods in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. For each transect, the total number of fish caught by species is tabulated on a monthly basis. The monthly total of all species is summarized at the bottom of the appropriate column. The cumulative total of each species for all months is presented along the right-hand margin.

SITE: D3A

SPECIES:	May 1979	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. '80	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
Shovelnose Sturgeon																	
Shortnose Gar	3	1															4
Longnose Gar																	
Gizzard Shad		1		50	8		5		5					1	57	80	207
Goldeye																	
Carp														1			1
Golden Shiner																	
Creek Chub														1			1
Silver Chub		1	8											5	4		18
Speckled Chub							2							3			5
Sturgeon Chub																	
Suckermouth Minnow																	
Emerald Shiner	1	10			7		71		9		4	9			19	39	169
Redfin Shiner														1			1
River Shiner																	
Red Shiner	15	34	145	1	1		66				13	79	7	12	11	55	439
Bigmouth Shiner																	
Sand Shiner	12	4	37	1			69				6	65	7	5	2	18	226
Plains Minnow							1									1	2
W. Silvery Minnow							1										1
Fathead Minnow			2														2
Bullhead Minnow							3		6			35	1	3	9	2	59
Bluntnose Minnow							1					1	1				3
Stoneroller Minnow																	
Bigmouth Buffalo			1														1
Smallmouth Buffalo																	
Carpsucker	1	8	122	3	2		2		1			1			14	69	223
Shorthead Redhorse		1															1
Black Bullhead																	
Channel Catfish			23						2						19		44
Flathead Catfish																	
Stonecat																	
White Bass			9	7										4	2		22
Largemouth Bass			10														10
Green Sunfish							2					1				1	4
Bluegill Sunfish			1						1							20	22
Orange-spotted Sunfish																	
White Crappie			1	2								4		5	2	4	18
Black Crappie																	
Sauger																	
Orange-throated Darter																	
Freshwater Drum			32	4	2							1		25	3		67
TOTAL:	32	60	391	68	20		223		24		23	196	16	66	142	289	1550

Summary of fishes collected using seining methods in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. For each transect, the total number of fish caught by species is tabulated on a monthly basis. The monthly total of all species is summarized at the bottom of the appropriate column. The cumulative total of each species for all months is presented along the right-hand margin.

SITE: D3D

SPECIES:	May 1979	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. '80	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
Shovelnose Sturgeon													2	1			3
Shortnose Gar		1												1	3		5
Longnose Gar				3	3								3		51	46	106
Gizzard Shad																	
Goldeye		1															1
Carp		2												2			4
Golden Shiner		1															1
Creek Chub		4															4
Silver Chub														1			1
Speckled Chub																	
Sturgeon Chub				1													1
Suckermouth Minnow																	
Emerald Shiner	1	2		2	10		2				12	5			3	36	73
Redfin Shiner		1															1
River Shiner															1		1
Red Shiner	359	519	8	34	66		11		20		40	550	46	52	133	98	1936
Bigmouth Shiner																	
Sand Shiner	41	63		2	5		3		11		28	115	3	13	26	93	403
Plains Minnow															1		1
W. Silvery Minnow												1			2		3
Fathead Minnow		14					1								1		16
Bullhead Minnow	1											1			2	10	14
Bluntnose Minnow					1							2			4	2	9
Stoneroller Minnow		1															1
Bigmouth Buffalo																	
Smallmouth Buffalo																	
Carpsucker	6	11		2	2							18		8	17	55	119
Shorthead Redhorse																	
Black Bullhead																	
Channel Catfish	10	1	14	2	6		1							4	1		39
Flathead Catfish																	
Stonecat	2	2		11	5												20
White Bass	1	2													3		6
Largemouth Bass		2													2		4
Green Sunfish																2	2
Bluegill Sunfish					1										3	13	17
Orange-spotted Sunfish																6	6
White Crappie		3			9							1	1		1	7	22
Black Crappie																1	1
Sauger	1																1
Orange-throated Darter																	
Freshwater Drum	1				2								1	5	1		10
Skipjack Herring	2																2
TOTAL:	425	630	22	57	110		18		31		80	693	56	87	255	369	2833

Summary of fishes collected using seining methods in the lower Kansas River, Fishery-Dredging Project, May 1979 through August 1980. For each transect, the total number of fish caught by species is tabulated on a monthly basis. The monthly total of all species is summarized at the bottom of the appropriate column. The cumulative total of each species for all months is presented along the right-hand margin.

SITE: D3E

SPECIES:	May 1979	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan.'80	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
Shovelnose Sturgeon												1					1
Shortnose Gar												1					1
Longnose Gar							6					32			25	7	70
Gizzard Shad																	
Goldeye		1	3														4
Carp			1											2		1	4
Golden Shiner												1					1
Creek Chub														1			1
Silver Chub	5		2	1										3			11
Speckled Chub	28			14	1										1		44
Sturgeon Chub	1			1													2
Suckermouth Minnow														3			3
Emerald Shiner		1		1	2		11				7	151	3			3	179
Redfin Shiner																	
River Shiner											1						1
Red Shiner	89	37	46	6	16		20		123		326	175	10	19	9	76	952
Bigmouth Shiner																	
Sand Shiner	1	2	7	5	5		10		3		56	24	7	23	18	6	167
Plains Minnow																	
W. Silvery Minnow											1				3		4
Fathead Minnow			1						1		2						4
Bullhead Minnow			1								2	1			7		11
Bluntnose Minnow											1	1		3		1	6
Stoneroller Minnow																	
Bigmouth Buffalo														2			2
Smallmouth Buffalo														1			1
Carpsucker		1										78	17	71	26	15	208
Shorthead Redhorse																	
Black Bullhead																2	2
Channel Catfish	6		95				1								6	6	114
Flathead Catfish			1														1
Stonecat																	
White Bass				1								2		6		2	11
Largemouth Bass														2			2
Green Sunfish																10	10
Bluegill Sunfish		1														51	52
Orange-spotted Sunfish																4	4
White Crappie												27		11	1	10	49
Black Crappie																	
Sauger																	
Orange-throated Darter														4	3		7
Freshwater Drum			5									1	2	14			22
TOTAL:	130	43	162	29	24		48		127		396	495	39	165	99	194	1951

SITE: Partial

SPECIES:	May 1979	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Jan. '80	Feb.	Mar.	Apr.	May	June	July	Aug.	TOTAL
Shovelnose Sturgeon																	
Shortnose Gar																	
Longnose Gar																	
Gizzard Shad																4	4
Goldeye																	
Carp																	
Golden Shiner																	
Creek Chub																	
Silver Chub																	
Speckled Chub				4													4
Sturgeon Chub																	
Suckermouth Minnow																	
Emerald Shiner																27	27
Redfin Shiner																	
River Shiner																1	1
Red Shiner				6												37	43
Bigmouth Shiner																	
Sand Shiner				2													2
Plains Minnow																1	1
W. Silvery Minnow																4	4
Fathead Minnow																	
Bullhead Minnow																11	11
Bluntnose Minnow																	
Stoneroller Minnow				1													1
Bigmouth Buffalo																	
Smallmouth Buffalo																	
Carpsucker																3	3
Shorthead Redhorse																	
Black Bullhead																	
Channel Catfish				39													39
Flathead Catfish																	
Stonecat																	
White Bass																	
Largemouth Bass																1	1
Green Sunfish																	
Bluegill Sunfish				1												1	2
Orange-spotted Sunfish																	
White Crappie				2													2
Black Crappie																	
Sauger																	
Orange-throated Darter																	
Freshwater Drum				9													9
TOTAL:				64												90	154

Table 17. Summary of fishes collected using an electro-fisher and trammel nets in the lower Kansas River, Fishery Dredging Project, July 1979 through February 1980. Values given in the following table indicate number captured at each site. Each of two control sites combine two transects; at dredge sites, "above" = 1 transect; "pit" = 1 transect; "below" = 1 transect. "Effort" = the lineal length of shoreline covered by electro-fishing at each site. For dredge pits, time values indicate total operation time of trammel nets for each site.

	CONTROL		DREDGE 1			DREDGE 2			DREDGE 3			PARTIAL STUDY SITE
	C1	C2	Above	Pit	Below	Above	Pit	Below	Above	Pit	Below	
Shovelnose Sturgeon												
Longnose Gar					1				1			
Shortnose Gar					1				1	3		1
Gizzard Shad							17			1	19	
Skipjack Herring											1	
Goldeye							1				1	
Carp					2			1		8	5	5
Silver Chub												
Red Shiner												
Sand Shiner												
Bullhead Minnow												
Blue Sucker												
Bigmouth Buffalo												
Smallmouth Buffalo												
River Carpsucker					4	2		2		5	1	7
Channel Catfish						2			1			
Flathead Catfish											1	
White Bass												2
Green Sunfish												
Bluegill Sunfish												
White Crappie								1				
Black Crappie												
Sauger										1	1	
Freshwater Drum					4	2			6	3		6
E-F Effort(meters)				300	200	200	330	200	100	420	800	1100
Tram. Net Time(hrs)				1' 30"			2'			4' 30"		
Total no. Fish				0	12	6	18	4	9	21	29	21

Sampling dates:

19-20 July 1979
31 August 1979
5 October 1979
8-9 December 1979

Table 18. Summary of fishes collected using an electro-fisher and trammel net in the lower Kansas River, Fishery Dredging Project, March 1980 through August 1980. Values given in the following table indicate number captured at each site. Each of two control sites combine two transects; at dredge sites, "above" = 1 transect; "pit" = 1 transect; "below" = 1 transect. "Effort" = the lineal length of shoreline covered by electro-fishing at each site. For dredge pits, time values indicate total operation time of trammel nets for each site.

	CONTROL		DREDGE 1			DREDGE 2			DREDGE 3			PARTIAL STUDY SITE *
	C1	C2	Above	Pit	Below	Above	Pit	Below	Above	Pit	Below	
Shovelnose Sturgeon							1			8		
Longnose Gar	1	1			2	2			1	1		
Shortnose Gar	2	4				2	1		3	2	5	1
Gizzard Shad	13	47	3		3	182		24	74	2	28	81
Skipjack Herring												1
Goldeye					1				1		1	2
Carp	13	19	6	5	16	3	4	2	6		10	19
Silver Chub					1							1
Red Shiner	4		1									
Sand Shiner			5								1	
Bullhead Minnow			1						1			
Blue Sucker	1											
Bigmouth Buffalo							2					
Smallmouth Buffalo											1	
River Carpsucker	18	29	7		7	10	8	2	20	5	20	13
Channel Catfish	10	2			4	5	8		1	3	4	7
Flathead Catfish	4	3	2		2							10
White Bass	3	3			3	4			6		2	8
Green Sunfish						1		1				1
Bluegill Sunfish					6			2	1			1
White Crappie	2	1			11	11	2		15	1	4	4
Black Crappie								1	1	1		5
Sauger											3	4
Freshwater Drum	9	6	6	3	4		1	1	24	1	19	11
E-F Effort(meters)	1400	1535	760	50	900	1100	100	1600	1050	100	1310	1075
Tram. Net Time(hrs)							9' 35"			10' 15"		
Total no. Fish	80	115	31	8	62	219	25	32	154	26	98	173

Sampling dates:
7-8 March 1980
11-12 April 1980
19-20 May 1980
23-24 June 1980
5-6 August 1980
11 August 1980

* Largemouth Bass - 3
Shorthead Redhorse - 1

Table 19. Average areas sampled, numbers of species found, and densities of fishes in monthly samples obtained by seining at transects, May through December, 1979. Area in square meters, weight in grams. See Table 16 for species represented.

SITE:	C1A*	C1B	C2A	C2B	D1A	D1D	D1E*	D2A	D2D	D2E*	D3A	D3D	D3E
Total Area	357	218	303	228	111	118	179	231	360	183	408	174	164
No. Species	4.6	5.8	8.2	5.7	5.7	4.7	6.8	6.5	6.8	6.0	7.8	9.0	6.2
No. Fish	120	240	157	646	327	92	181	112	140	79	133	210	73
Total Weight	228	330	286	482	212	96	557	246	233	120	410	317	136
No. Fish/m^2	0.52	1.16	0.54	6.09	3.50	0.57	1.49	0.62	0.33	0.38	0.35	1.24	0.40
Wt. Fish/m^2	0.95	0.73	1.23	2.75	2.36	0.72	5.07	1.25	0.54	0.62	1.05	1.70	0.78

* No data for C1A July 1979

* No data for D1E Nov. 1979

* No data for D2E Sept. 1979

Table 20. Average areas sampled, numbers of species found, and densities of fishes in monthly samples obtained by seining at transects, January through August, 1980. Area in square meters, weight in grams. See Table 16 for species represented.

SITE:	C1A	C1B	C2A	C2B	D1A	D1D	D1E	D2A	D2D	D2E	D3A	D3D	D3E
Total Area	441	292	285	409	306	275	127	301	100	193	237	348	264
No. species	3.2	6.6	4.7	9.8	7.3	5.0	6.7	7.2	6.0	8.7	8.7	9.2	9.6
No. fish	282	303	151	285	187	150	232	251	82	319	122	247	221
Total weight	620	184	140	477	208	289	173	243	55	207	522	749	804
No. fish/m^2	0.57	1.60	0.65	1.11	0.67	0.51	2.15	1.68	1.06	2.04	0.50	1.56	1.35
Wt. fish/m^2	0.91	0.68	0.61	1.38	0.77	0.60	1.71	0.95	0.85	1.04	2.09	2.20	2.99

APPENDIX D – EXPLANATION OF TERMS

APPENDIX D

EXPLANATION OF TERMS

Active-Channel Reference Level: A geomorphic term which Osterkamp (1981) defines in two ways. (1) As a short-term feature of the river channel itself. The elevation at which a break occurs in the relatively steep bank slope of the active channel to a more gently sloping surface beyond. The break normally coincides with the lower limit of permanent vegetation. (2) As the stage of the discharge which just fills the river channel to the elevation of the slope break mentioned above. The stage of the "active-channel level" generally approximates the mean discharge for most streams in Kansas.

Accretion: The gradual addition of new land to old by the deposition of sediment carried by the water of a stream.

Bankful Level: (1) Elevation of the top of the slope of a river channel occurring above the active-channel level. (2) The stage of river discharge required to fill the channel to the "bankful level." Bankful stage of most streams roughly coincides with the stage of a flood event with a two-year recurrence interval.

Concentration: As used in this study, the suspended sediment in a stream in tons per acre-foot of stream discharge per year. The weight of sediment per unit volume of water per year.

Degradation: The general lowering of the elevation of a river bed.

Gage: Any device for measuring the elevation of the water surface at a given location on the course of a stream. When gage data is combined with a knowledge of the cross-sectional area of the channel at the gage location and the velocity of flow, the volume of water passing the gage in a given time can be calculated.

Meander: One of the series of somewhat regular and looplike bends in the course of a stream.

Meander Scars: Crescentic cuts in the upland bordering a stream, representing cut-and-fill action by river bends in the process of meander sweep.

Meander Sweep: A river bend slowly erodes the banks on the downstream sides of its loop and at the same time fills, adjacent to the banks, on the upstream sides of its loop, so that the river bend, without appreciably changing its shape, progressively changes its location in a downstream direction. River bends in a given river reach tend to move downstream at nearly the same velocity. This combined movement of meanders is known as "sweep."

Rating Curve: The graph which relates gage height to discharge rates at a given gage location and a given time.

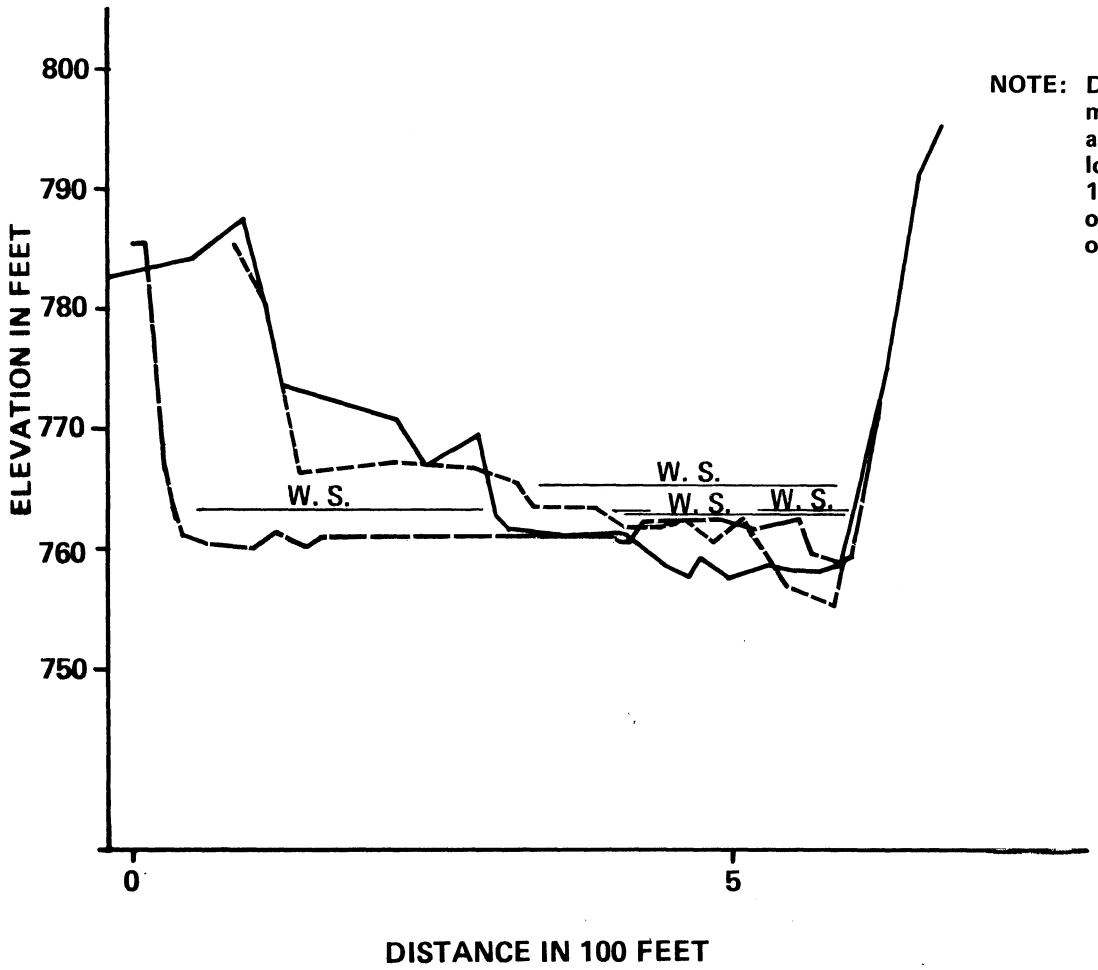
Stage: The elevation of a water surface above any chosen datum plane; gage height.

Stage-Time Relationship: The change in stage (gage height) exhibited by a given discharge at a gage location over a definite time period; usually found by comparing rating curves compiled for the gage in question during its period of record.

Yield: The weight of sediment in a stream per unit volume of water in the stream per area of the stream drainage basin per unit of time. As used in this study it is in the units of tons per acre-foot per square mile per year.

* * * * *

APPENDIX E – KANSAS RIVER GEOMETRY AND SEDIMENTATION DATA



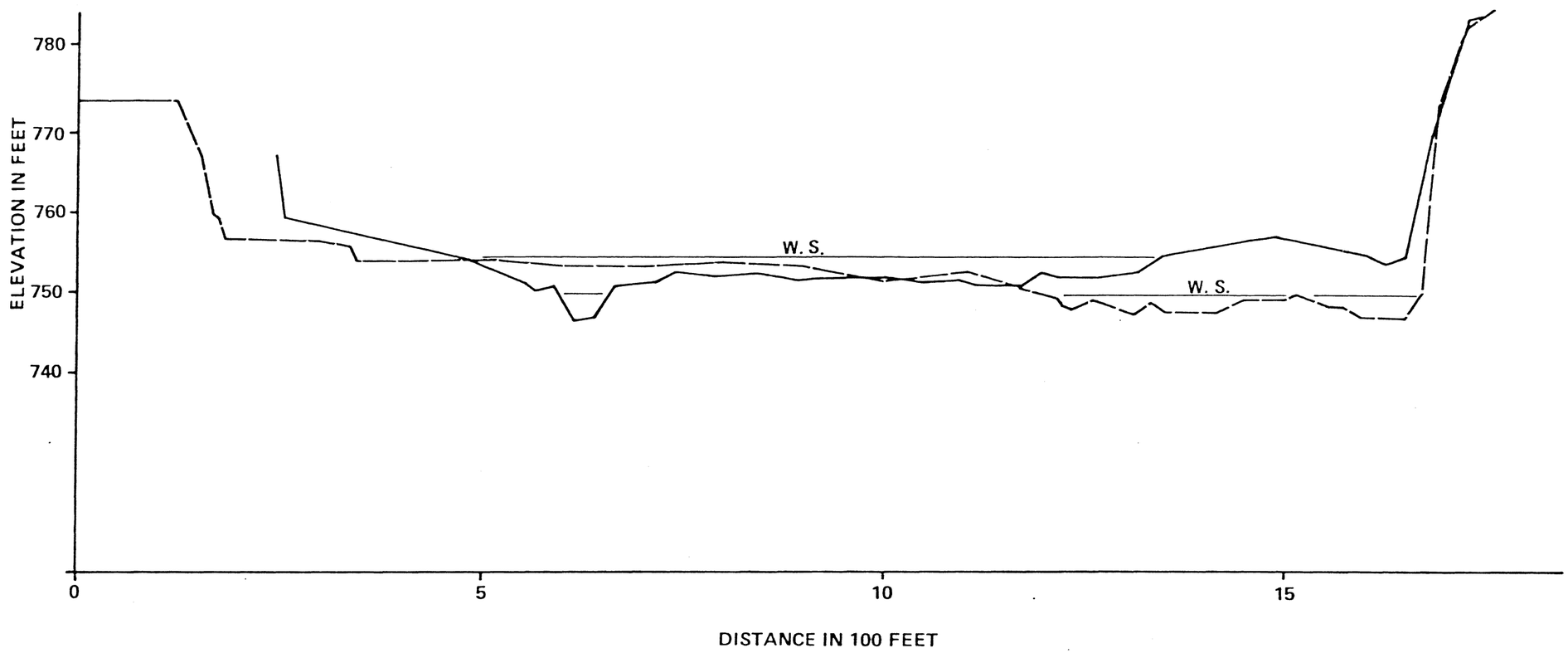
NOTE: Despite the difference in river mileage, all sections shown here are at approximately the same location. The change shown for the 1977 section is due to a revision of river distances by the Corps of Engineers.

Source: Corps of Engineers

——— NOV 56 - 500 CFS
- - - - 28 NOV 62 - 2800 CFS
— — 7 APR 77 (Mile 31.04) - 1100 CFS

KANSAS RIVER
X-SEC 6
MILE 31.7
LOOKING DOWNSTREAM

Figure E-1

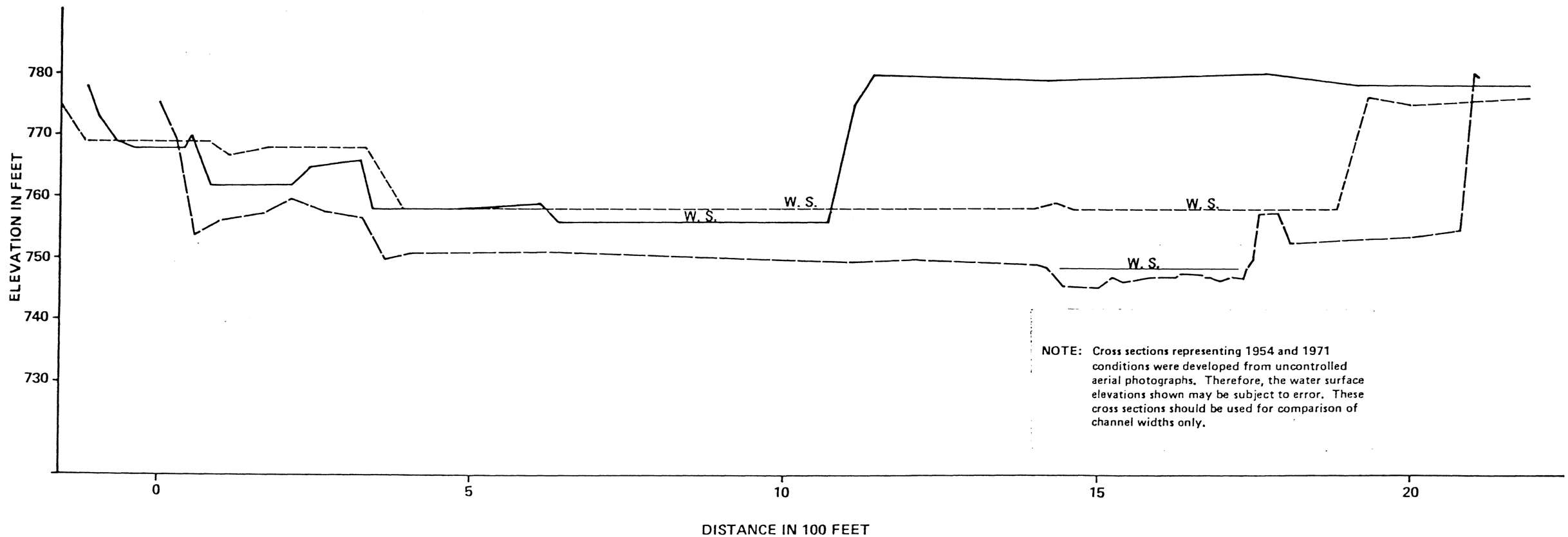


Source: Corps of Engineers

——— 28 NOV 62 - 2800 CFS
— — 31 MAR 77 - 1200 CFS

KANSAS RIVER
X-SEC RANGE 26
MILE 23.70
LOOKING DOWNSTREAM

Figure E-2



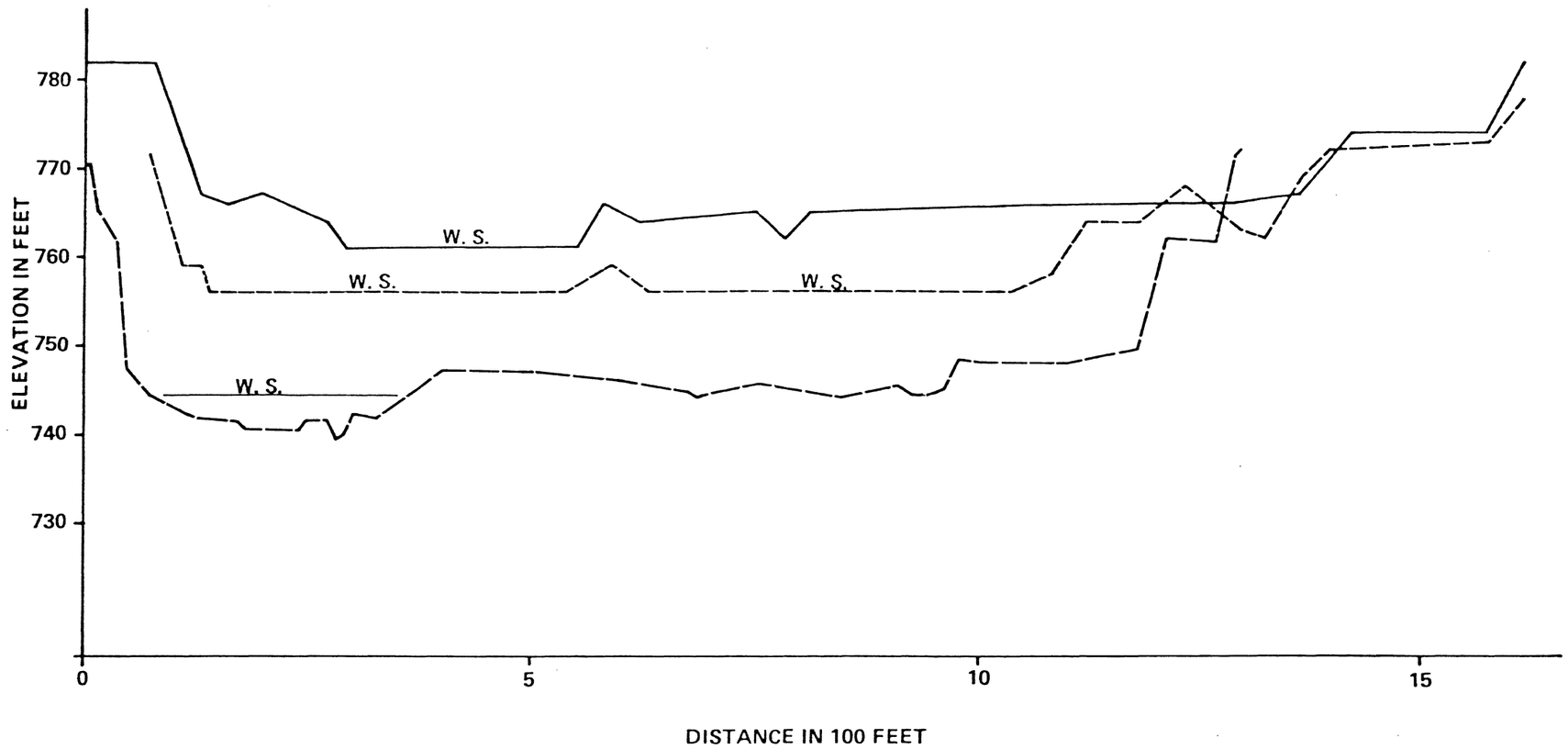
NOTE: Cross sections representing 1954 and 1971 conditions were developed from uncontrolled aerial photographs. Therefore, the water surface elevations shown may be subject to error. These cross sections should be used for comparison of channel widths only.

Source: Corps of Engineers

——— 20 NOV 54 - 750 CFS
– – – – 24 JAN 71 - 1500 CFS
— — 31 MAR 77 - 1200 CFS

KANSAS RIVER
X-SEC RANGE 25
MILE 23.17
LOOKING DOWNSTREAM

Figure E- 3

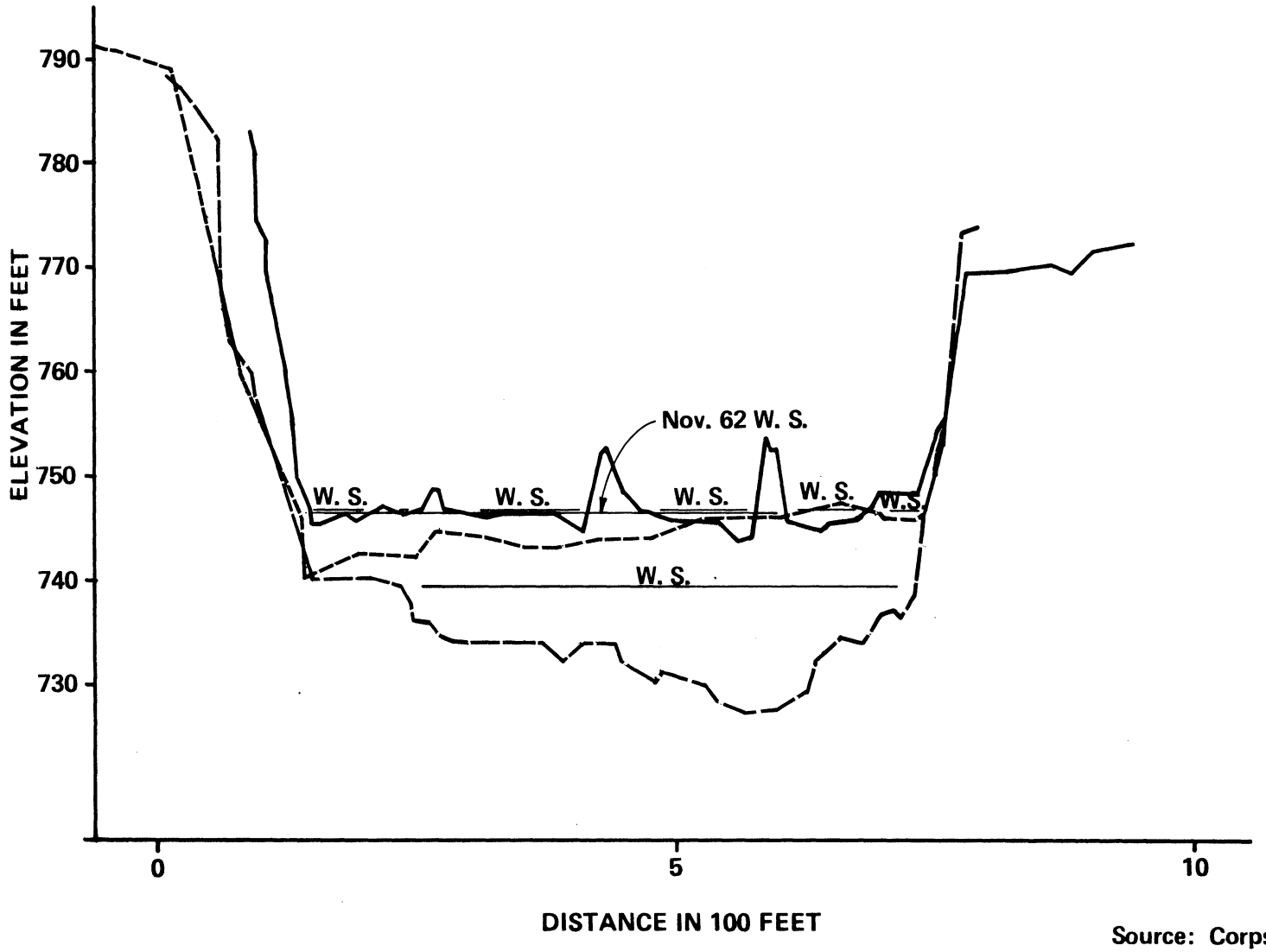


——— 20 NOV 54 - 750 CFS
– – – – 24 JAN 71 - 1500 CFS
— — 29 MAR 77 - 1000 CFS

KANSAS RIVER
X-SEC RANGE 23
MILE 22.04
LOOKING DOWNSTREAM

Source: Corps of Engineers

Figure E-4

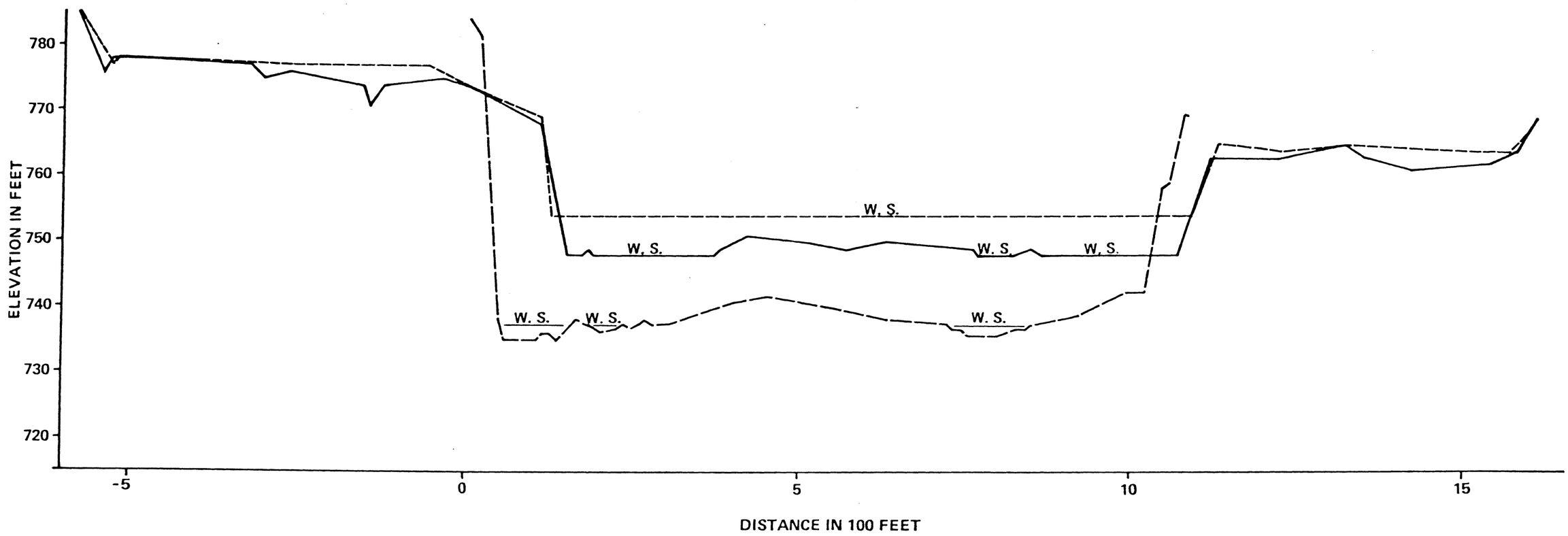


Source: Corps of Engineers

NOV 56 - 500 CFS
28 NOV 62 - 2800 CFS
29 MAR 77 - 1000 CFS

KANSAS RIVER
X-SEC RANGE 21
MILE 21.00
LOOKING DOWNSTREAM

Figure E-5

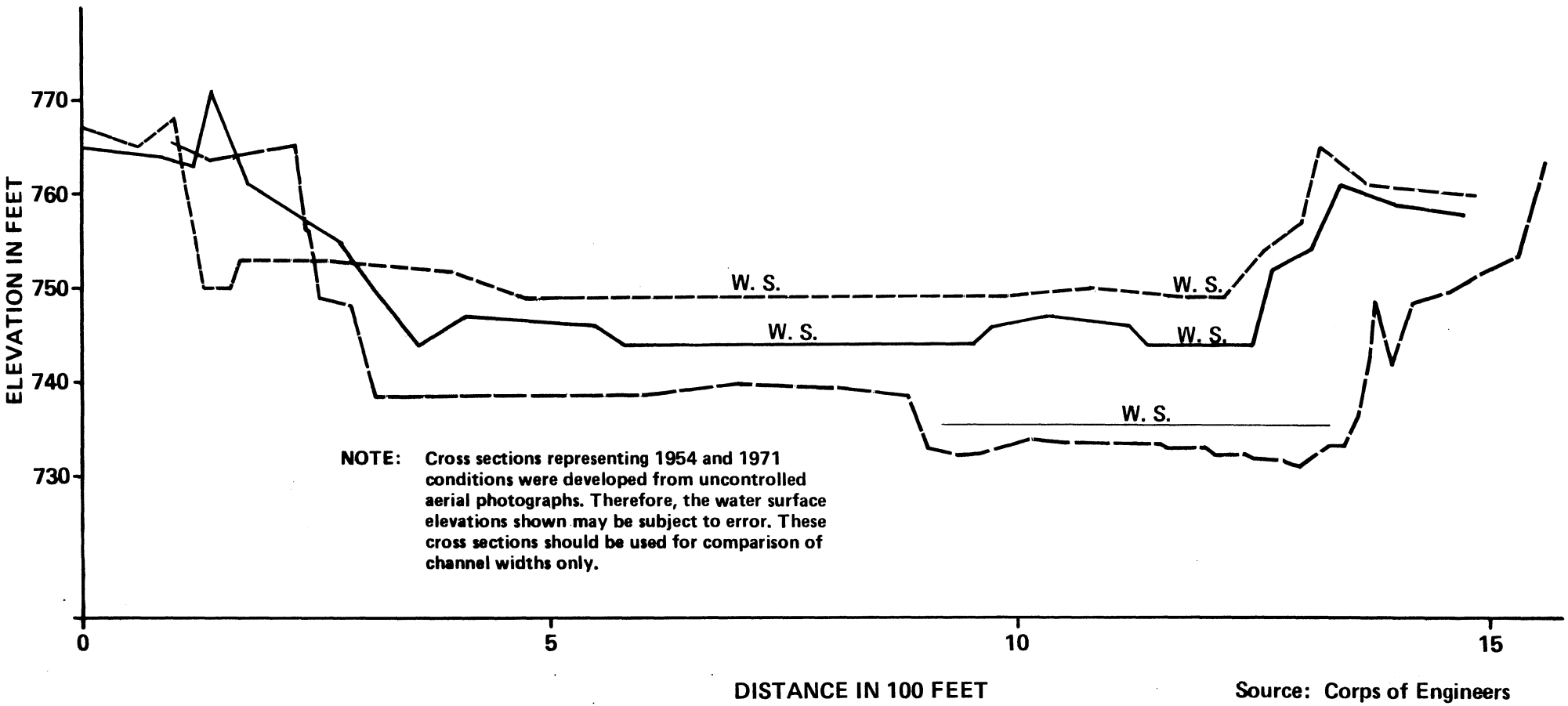


Source: Corps of Engineers

——— 20 NOV 54 - 750 CFS
- - - - - 24 JAN 71 - 1500 CFS
— — 23 MAR 77 - 1000 CFS

KANSAS RIVER
X-SEC RANGE 18
MILE 19.74
LOOKING DOWNSTREAM

Figure E-6

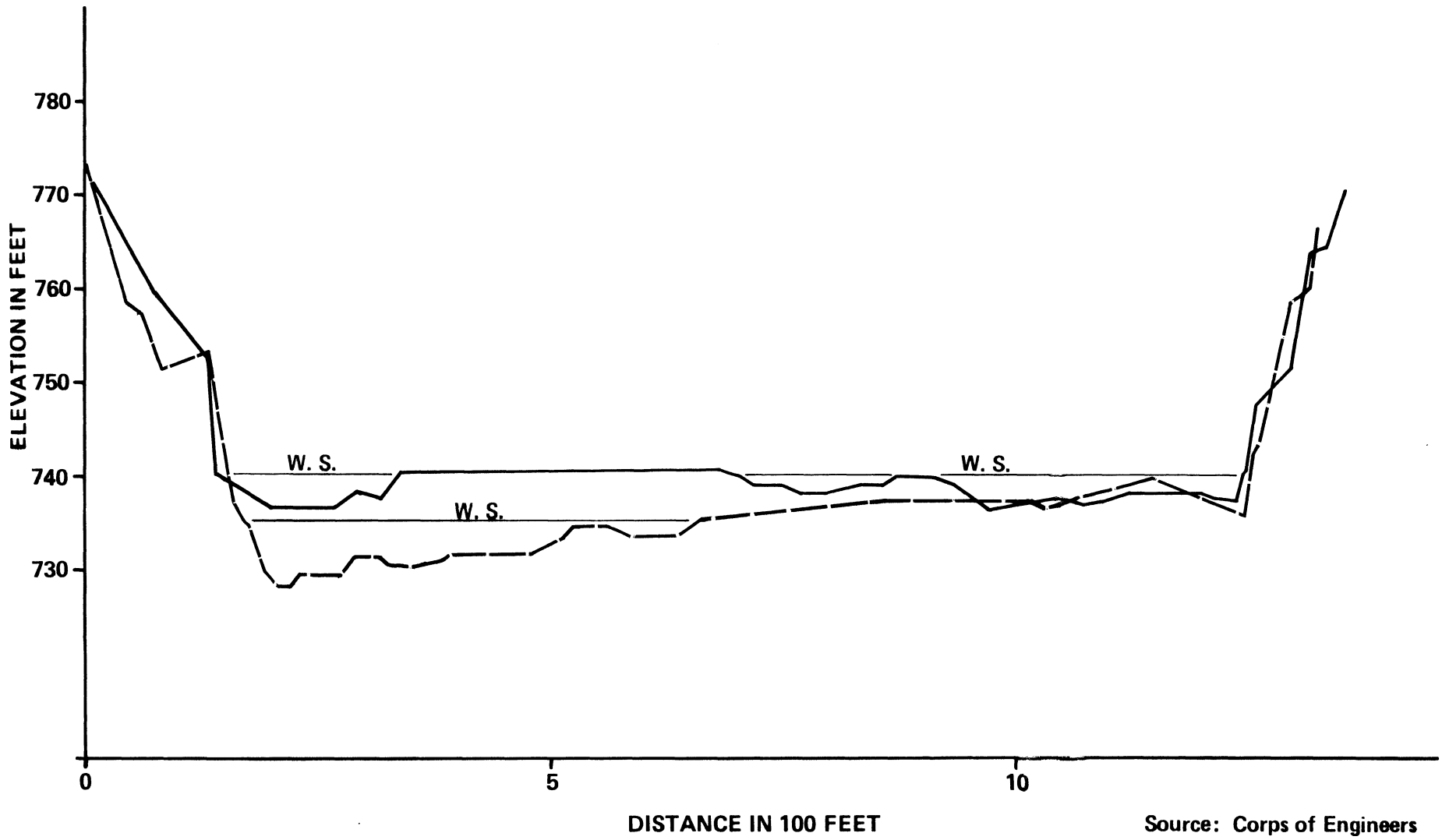


Source: Corps of Engineers

20 NOV 54 - 750 CFS
24 JAN 71 - 1500 CFS
22 MAR 77 - 1000 CFS

KANSAS RIVER
X-SEC RANGE 14
MILE 17.55
LOOKING DOWNSTREAM

Figure E-7

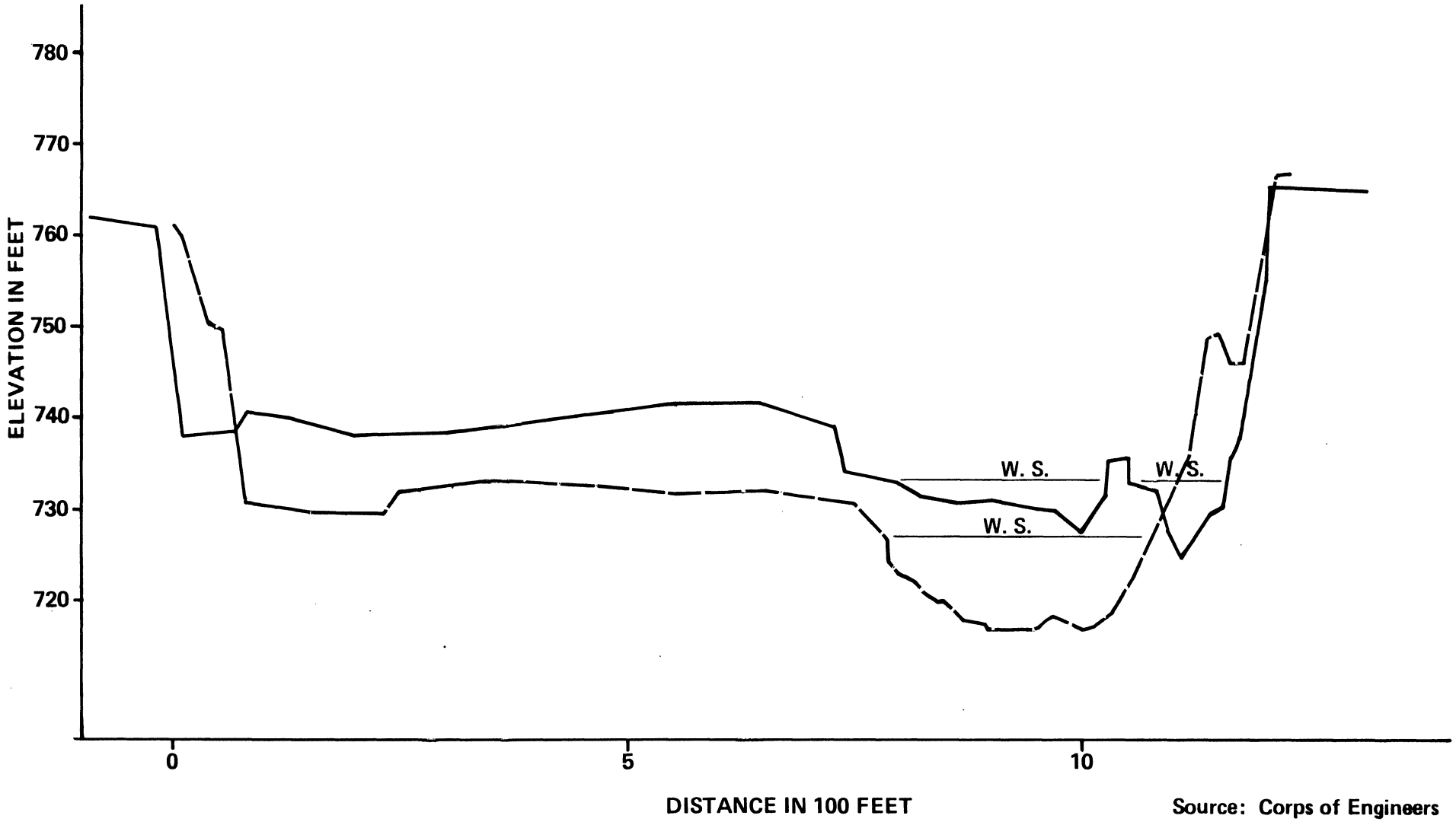


Source: Corps of Engineers

29 NOV 62 - 3000 CFS
22 MAR 77 - 1000 CFS

KANSAS RIVER
X-SEC RANGE 12
MILE 16.36
LOOKING DOWNSTREAM

Figure E-8

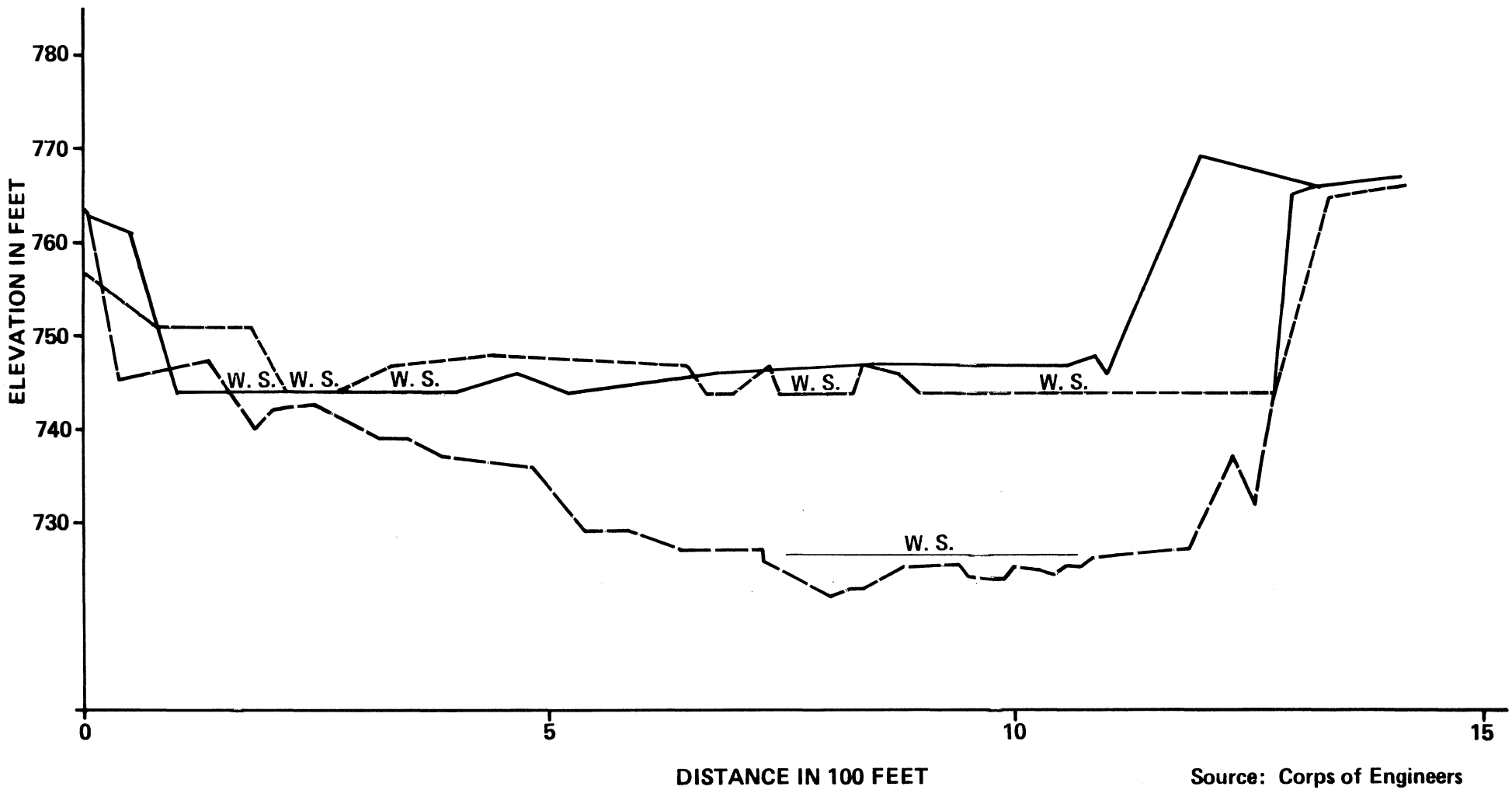


Source: Corps of Engineers

NOV 56 - 500 CFS
16 MAR 77 - 1000 CFS

KANSAS RIVER
X-SEC RANGE 9
MILE 14.10
LOOKING DOWNSTREAM

Figure E-9

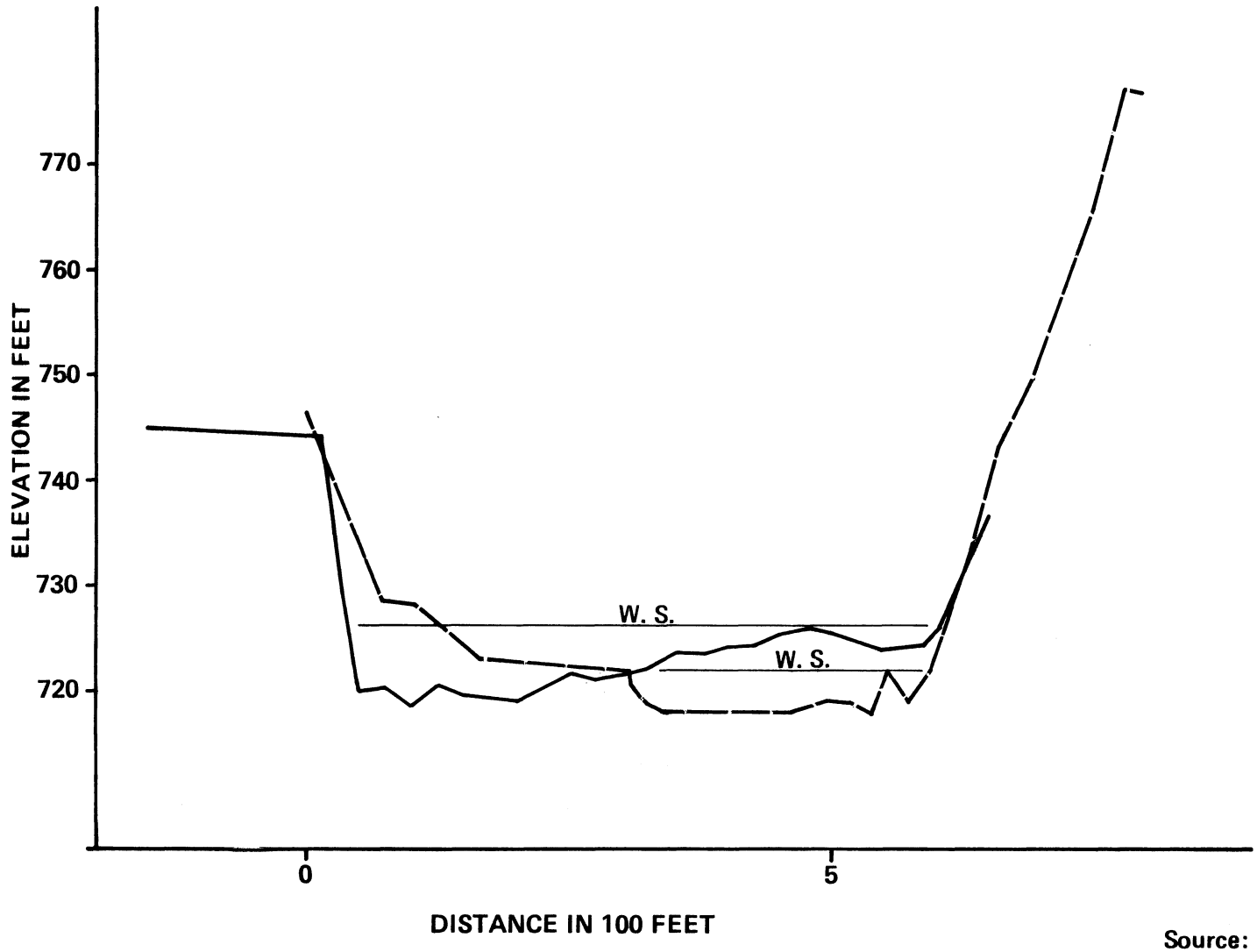


Source: Corps of Engineers

20 NOV 54 - 750 CFS
24 DEC 70 - 2000 CFS
16 MAR 77 - 1000 CFS

KANSAS RIVER
X-SEC RANGE 8
MILE 13.68
LOOKING DOWNSTREAM

Figure E-10

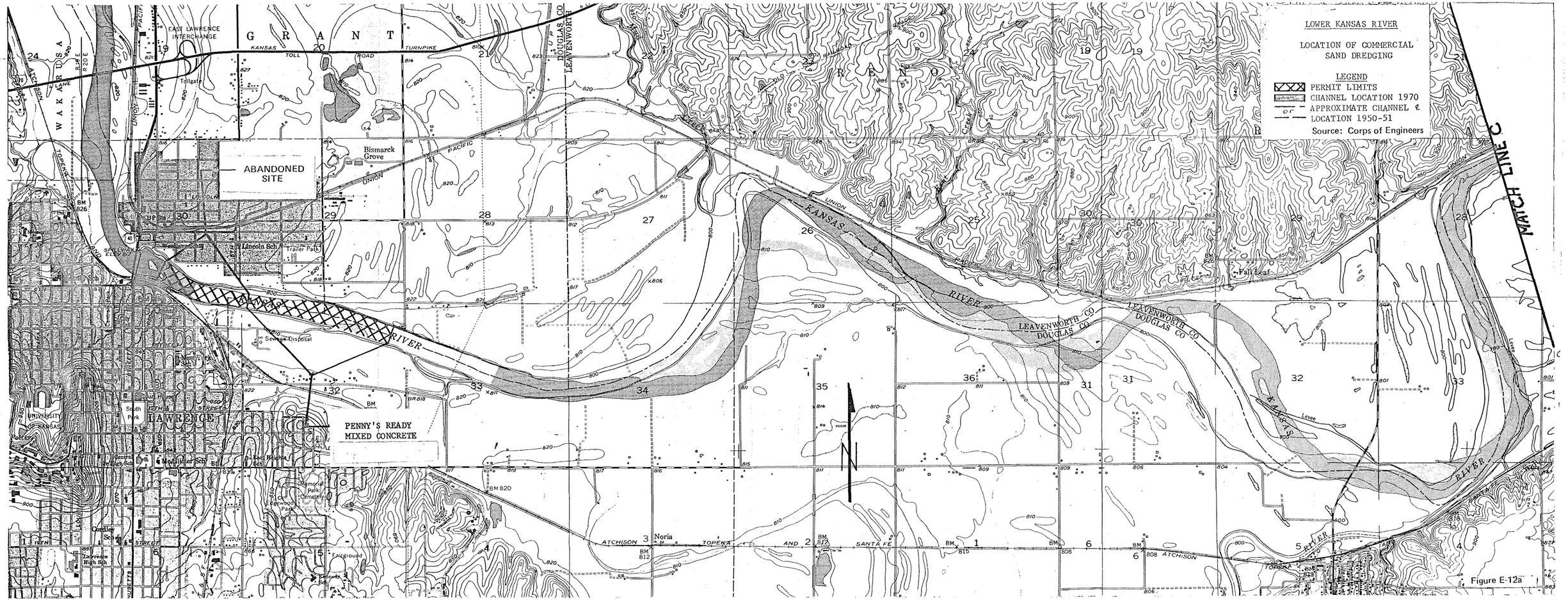


Source: Corps of Engineers

28 NOV 62 - 2800 CFS
8 MAR 77 - 950 CFS

KANSAS RIVER
X-SEC RANGE N
MILE 9.50
LOOKING DOWNSTREAM

Figure E-11


LOWER KANSAS RIVER
LOCATION OF COMMERCIAL SAND DREDGING
LEGEND
PERMIT LIMITS
CHANNEL LOCATION 1970
APPROXIMATE CHANNEL ℄ LOCATION 1950-51
Source: Corps of Engineers
ABANDONED SITE
PENNY'S READY MIXED CONCRETE
KANSAS RIVER
MISSOURI RIVER
MATCH LINE C
GRANT
RENO
WAKARUSA
EAST LAWRENCE INTERCHANGE
KANSAS TOLL ROAD TURNPIKE
Tollgate
Bismarck Grove
UNION PACIFIC
Lincoln Sch
Trailer Park
Sewage Disposal
LAWRENCE
South Park
Memorial Park Cemetery
Oliver Sch
Lawrence High Sch
Fairground
Noria
ATCHISON TOPEKA AND SANTA FE
LEAVENWORTH CO
DOUGLAS CO
Fall Leaf
Levee
Figure E-12a

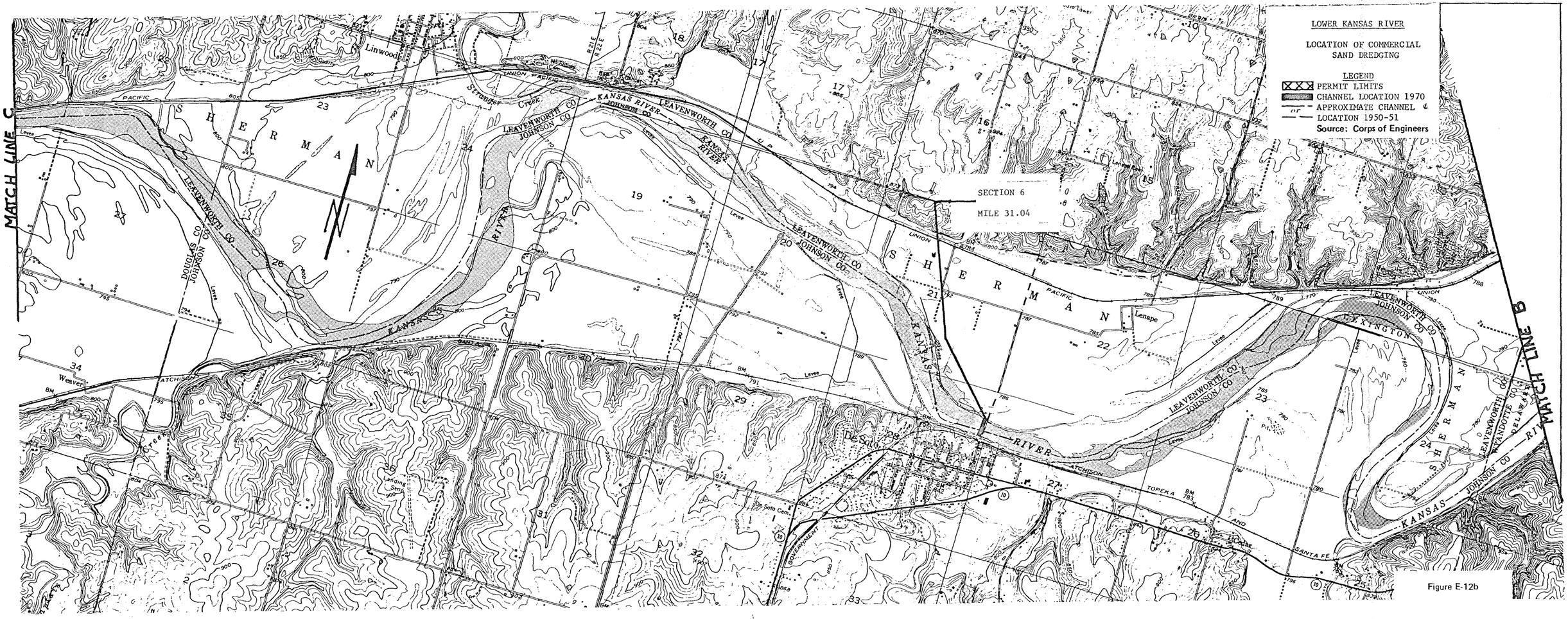

LOWER KANSAS RIVER
LOCATION OF COMMERCIAL SAND DREDGING
LEGEND
PERMIT LIMITS
CHANNEL LOCATION 1970
APPROXIMATE CHANNEL LOCATION 1950-51
Source: Corps of Engineers
SECTION 6
MILE 31.04
MATCH LINE C
MATCH LINE B
SHERMAN
KANSAS RIVER
LEAVENWORTH CO
JOHNSON CO
DOUGLAS CO
Linwood
Stranger Creek
Lenape
Weaver
De Soto
Lexington
Cedar
UNION PACIFIC
ATCHISON TOPEKA AND SANTA FE
GOVERNMENT
Levee

Figure E-12b

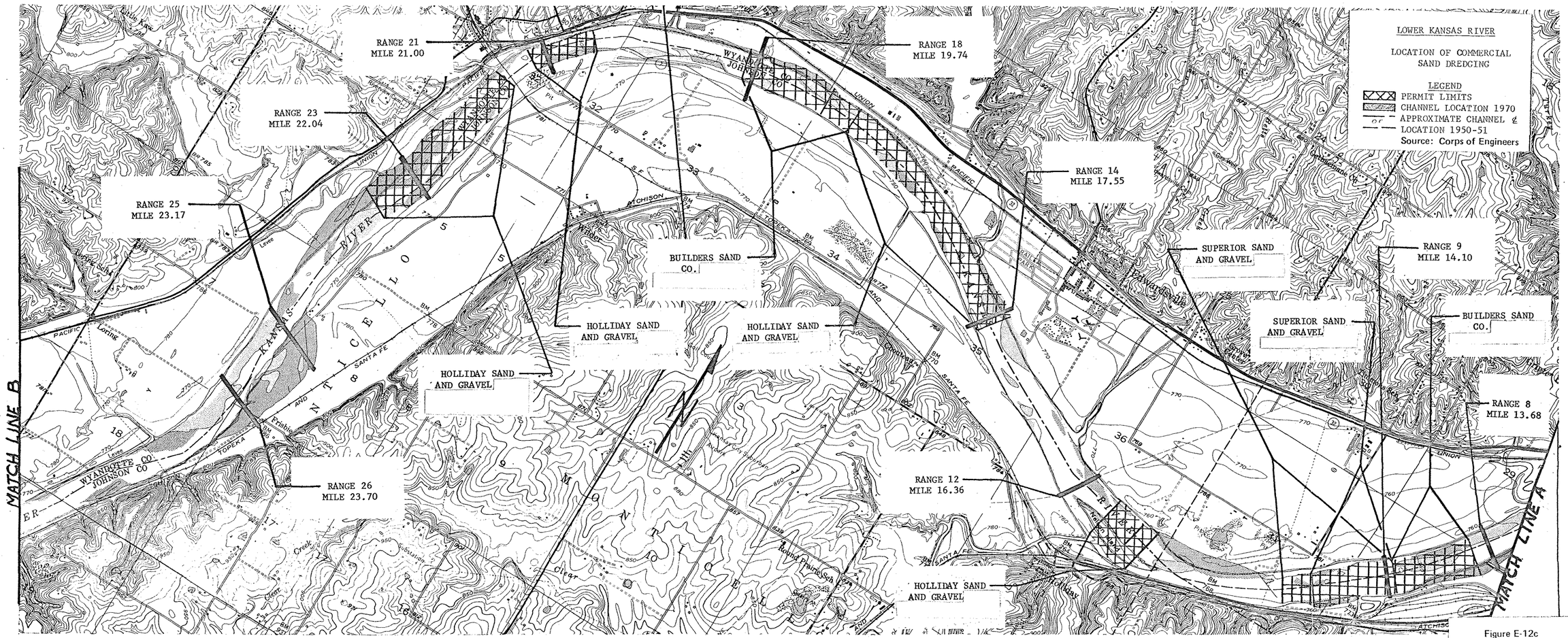
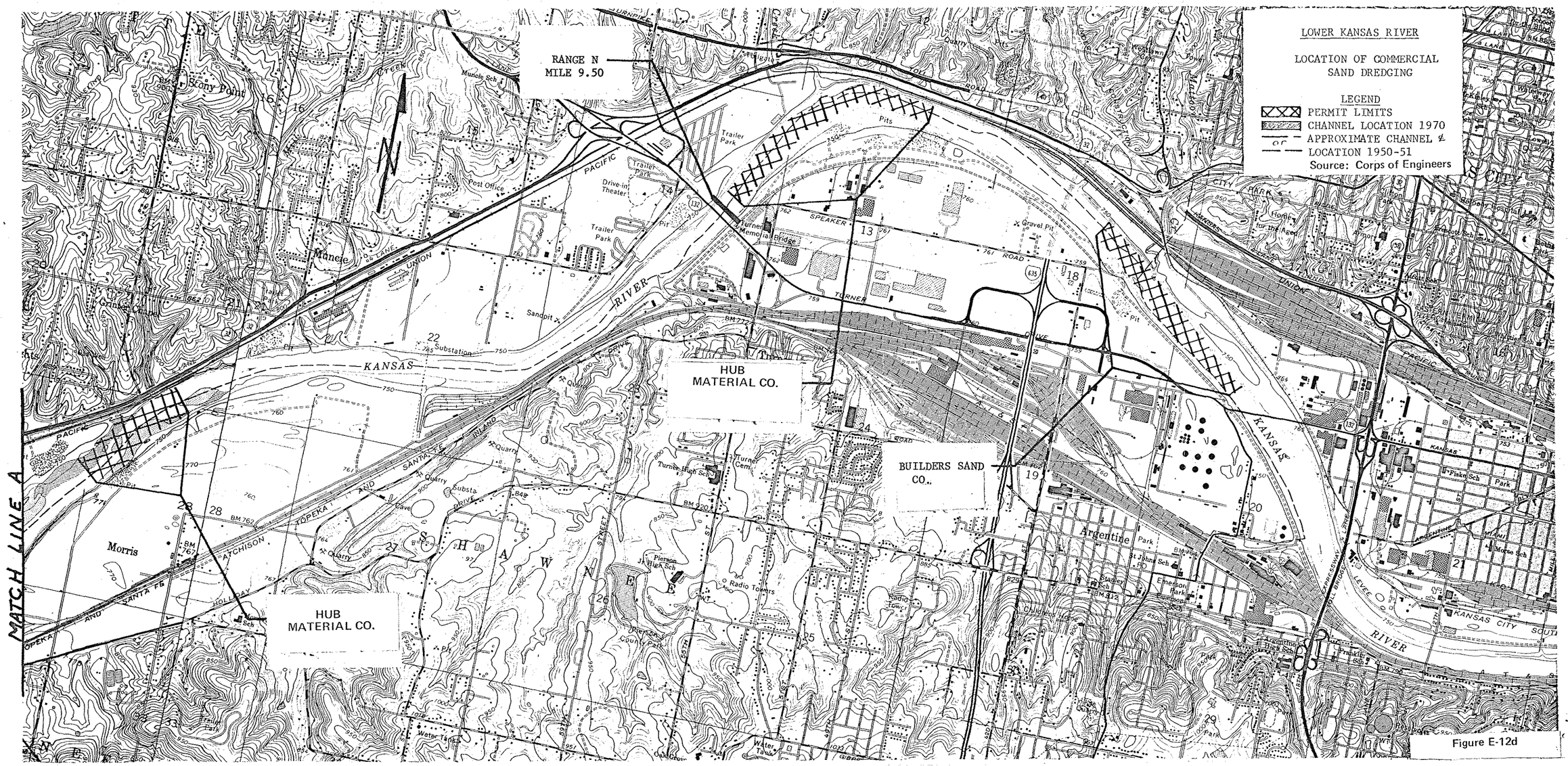
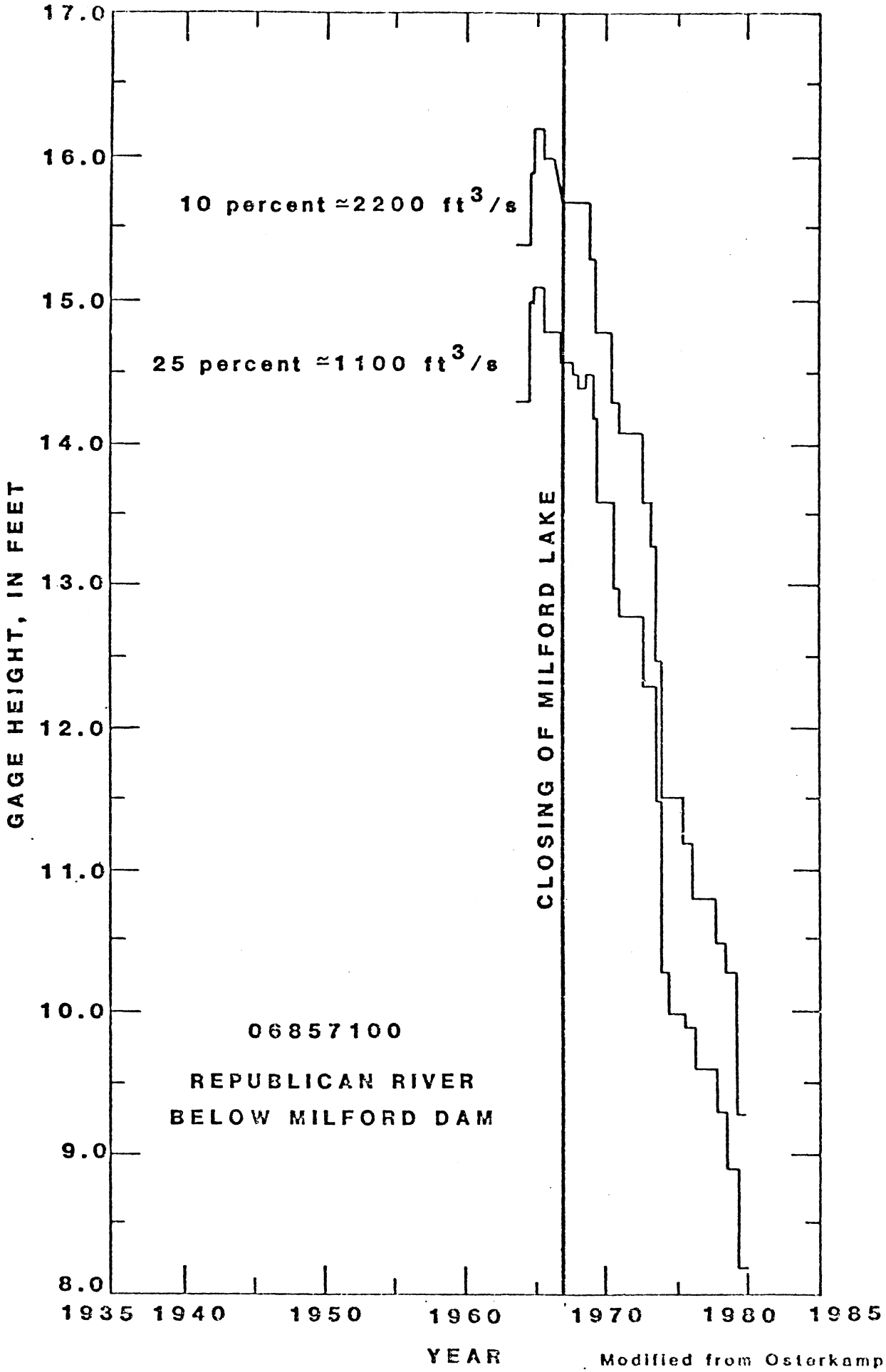

LOWER KANSAS RIVER
LOCATION OF COMMERCIAL SAND DREDGING
LEGEND
PERMIT LIMITS
CHANNEL LOCATION 1970
APPROXIMATE CHANNEL ℄ LOCATION 1950-51
Source: Corps of Engineers
RANGE 21 MILE 21.00
RANGE 23 MILE 22.04
RANGE 25 MILE 23.17
RANGE 26 MILE 23.70
RANGE 18 MILE 19.74
RANGE 14 MILE 17.55
RANGE 12 MILE 16.36
RANGE 9 MILE 14.10
RANGE 8 MILE 13.68
BUILDERS SAND CO.
HOLLIDAY SAND AND GRAVEL
HOLLIDAY SAND AND GRAVEL
HOLLIDAY SAND AND GRAVEL
HOLLIDAY SAND AND GRAVEL
SUPERIOR SAND AND GRAVEL
SUPERIOR SAND AND GRAVEL
BUILDERS SAND CO.
MATCH LINE B
MATCH LINE A
WYANDOTTE CO
JOHNSON CO
KANSAS RIVER
MONTICELLO
Kansas City
Edwardsville
Holliday
Rapid Prairie Sch
UNION PACIFIC
ATCHISON TOPEKA AND SANTA FE

Figure E-12c


LOWER KANSAS RIVER
LOCATION OF COMMERCIAL SAND DREDGING
LEGEND
PERMIT LIMITS
CHANNEL LOCATION 1970
APPROXIMATE CHANNEL ℄ LOCATION 1950-51
Source: Corps of Engineers
RANGE N MILE 9.50
HUB MATERIAL CO.
BUILDERS SAND CO.,
HUB MATERIAL CO.
MATCH LINE A
KANSAS RIVER
Argentine
Morris
Manoa
Turner Memorial Bridge
Pits
Gravel Pit
Trailer Park
Drive-in Theater
Post Office
Sandpit
Substation
Quarry
Turner High Sch
Pierson Jr High Sch
Radio Towers
Water Tower
Kansas City South
Figure E-12d



Modified from Osterkamp and Hedman, b, in review

Figure E-13.- -Stage-time relations corresponding to 25-percent and 10-percent flow-duration rates for gage site Republican River below Milford Dam, Kans

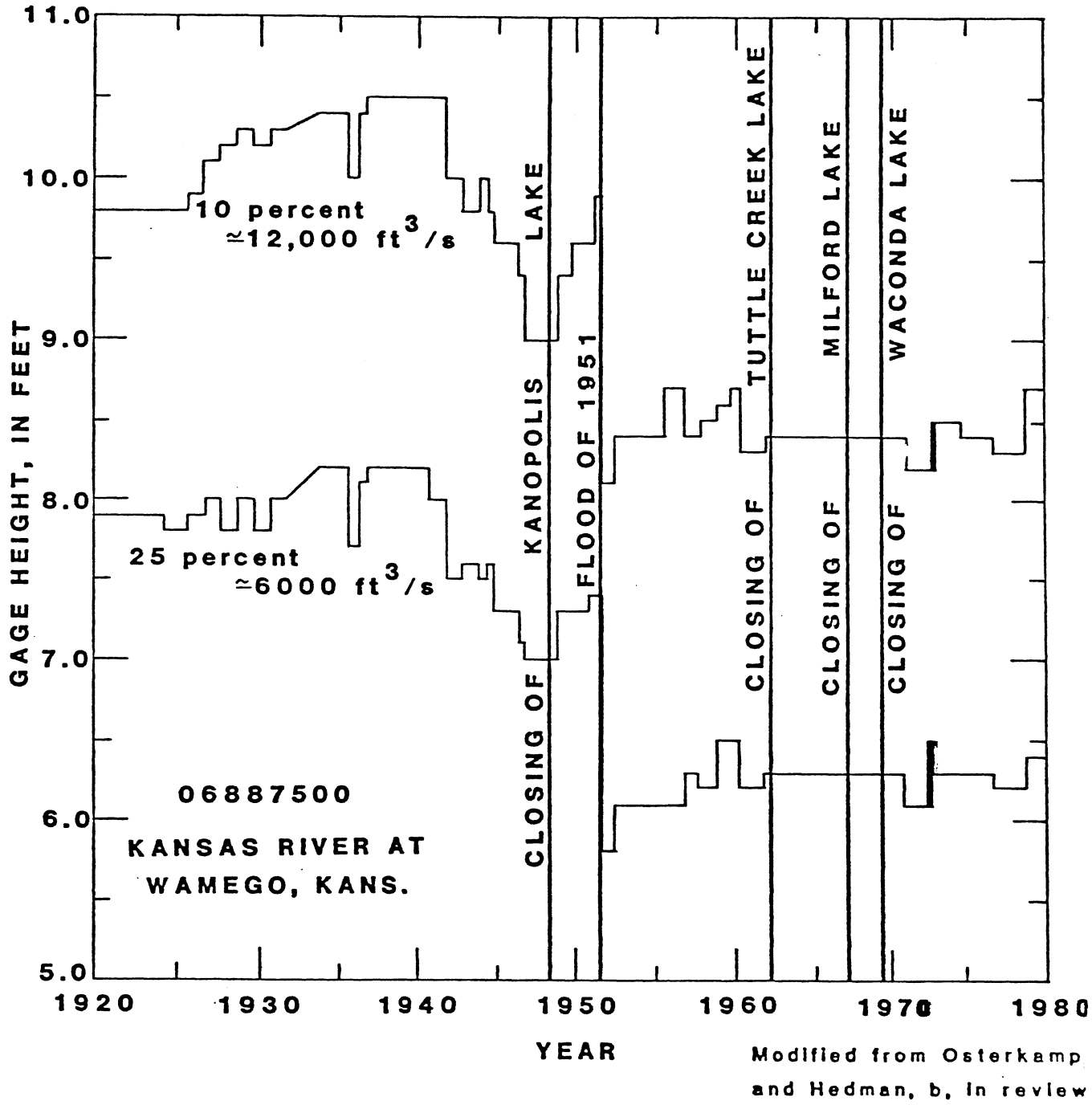


Figure E-14.- -Stage-time relations corresponding to 25-percent and 10-percent flow-duration rates for gage site Kansas River at Wamego, Kans.

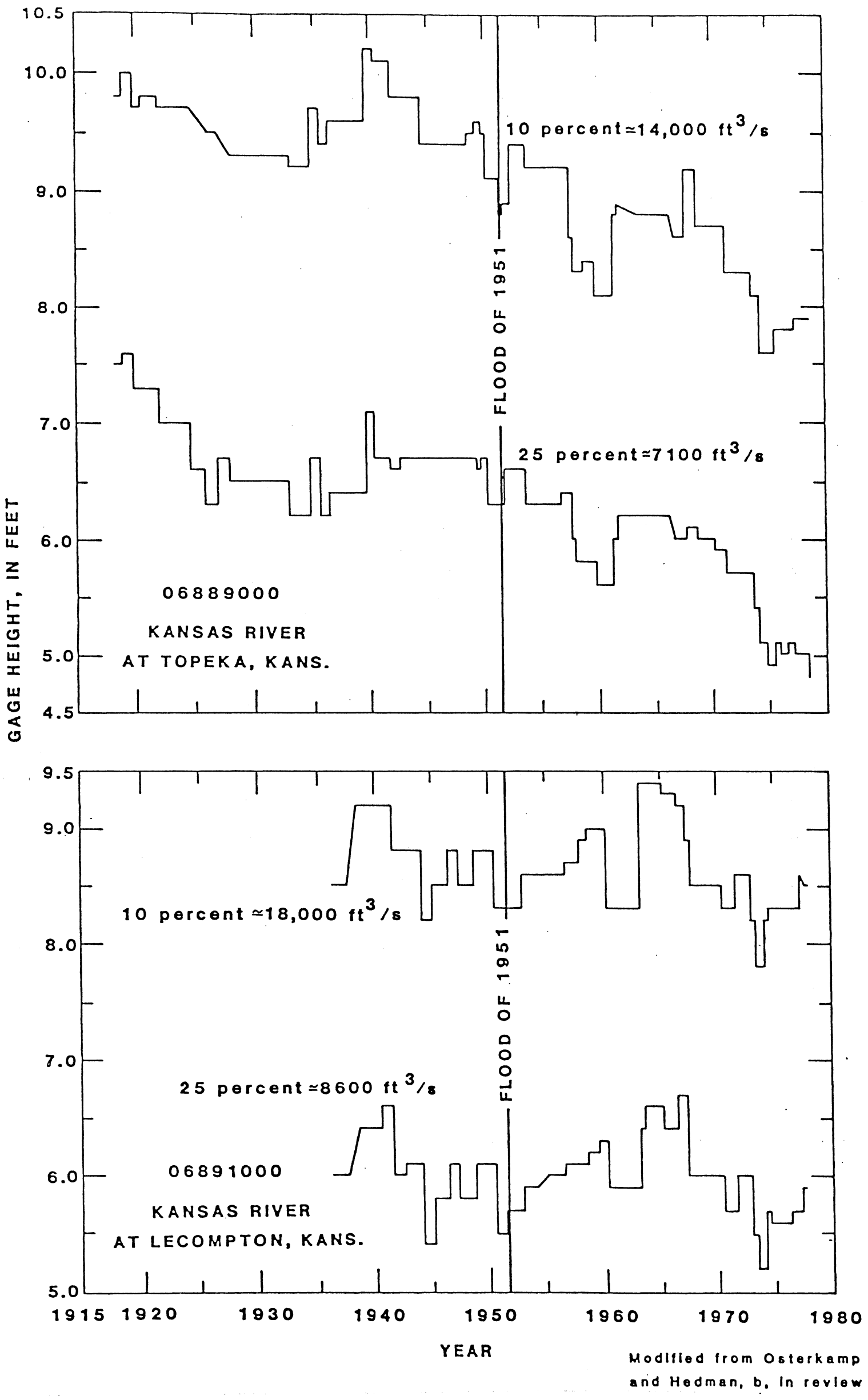


Figure E-15.- -Stage-time relations corresponding to 25-percent and 10-percent flow-duration rates for gage site Kansas River at Topeka, Kans., and Kansas River at Lecompton, Kans.

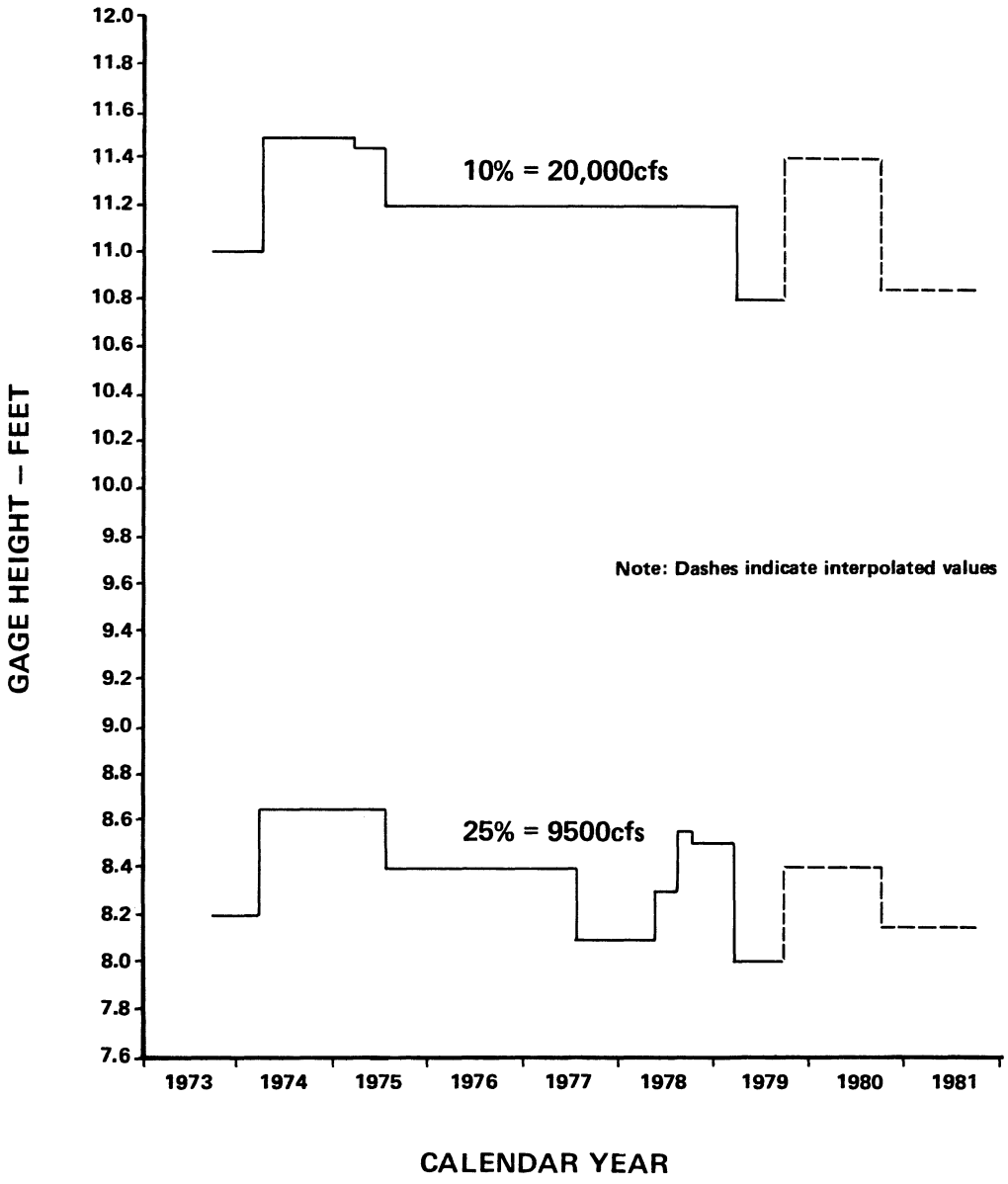


Figure E-16 — Stage-time relations corresponding to 25-percent and 10-percent flow-duration rates for gage site Kansas River at De Soto, Kansas (Data source — USGS)

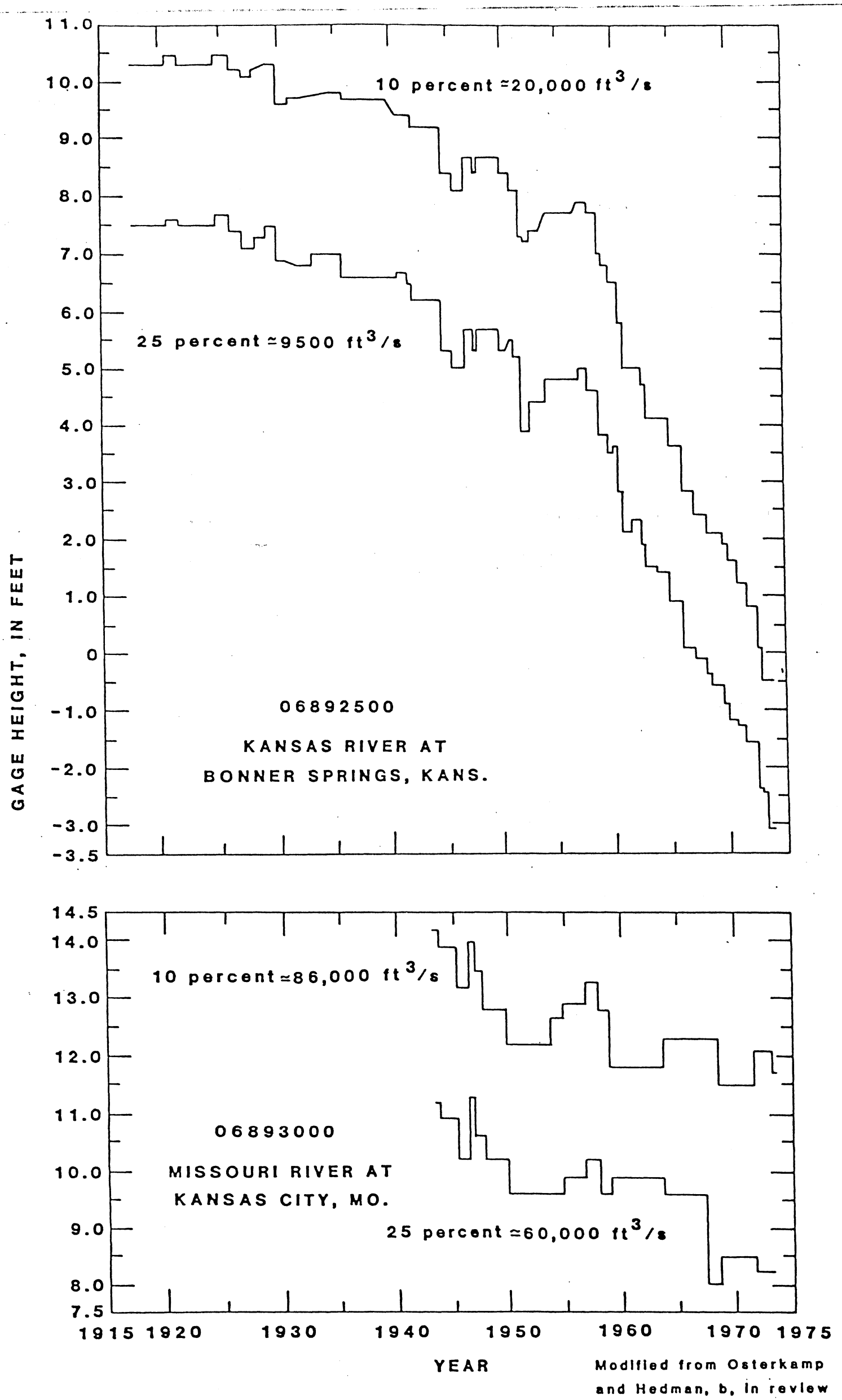
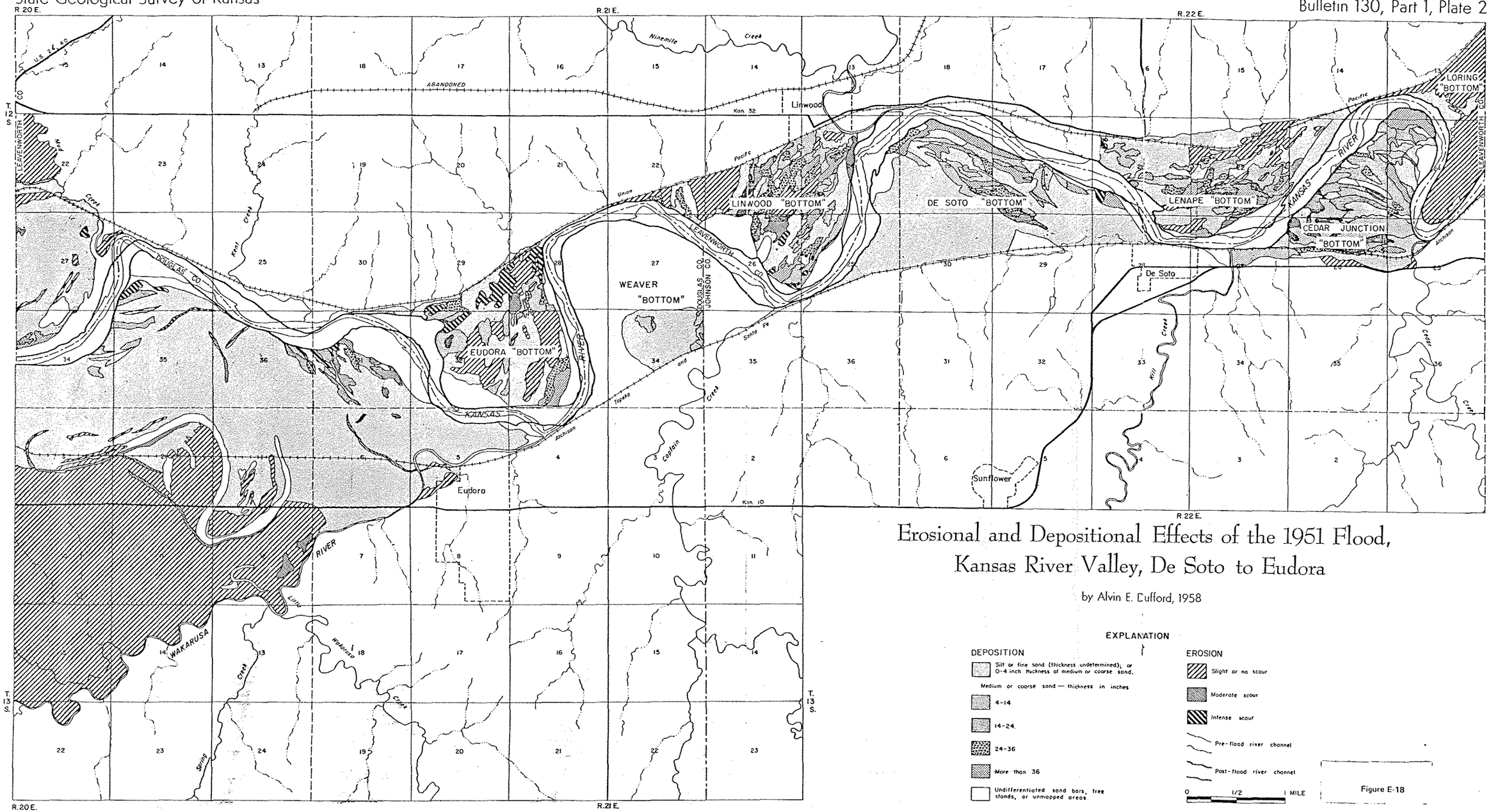


Figure E-17.- -Stage-time relations corresponding to 25-percent and 10-percent flow-duration rates for gage site Kansas River at Bonner Springs, Kans., and Missouri River at Kansas City, Mo.



Erosional and Depositional Effects of the 1951 Flood, Kansas River Valley, De Soto to Eudora

by Alvin E. Cufford, 1958

EXPLANATION

DEPOSITION

- Silt or fine sand (thickness undetermined); or 0-4 inch thickness of medium or coarse sand.
- Medium or coarse sand — thickness in inches
  - 4-14
  - 14-24
  - 24-36
  - More than 36
- Undifferentiated sand bars, tree stands, or unmapped areas.

EROSION

- Slight or no scour
- Moderate scour
- Intense scour
- Pre-flood river channel
- Post-flood river channel

0 1/2 1 MILE

Figure E-18

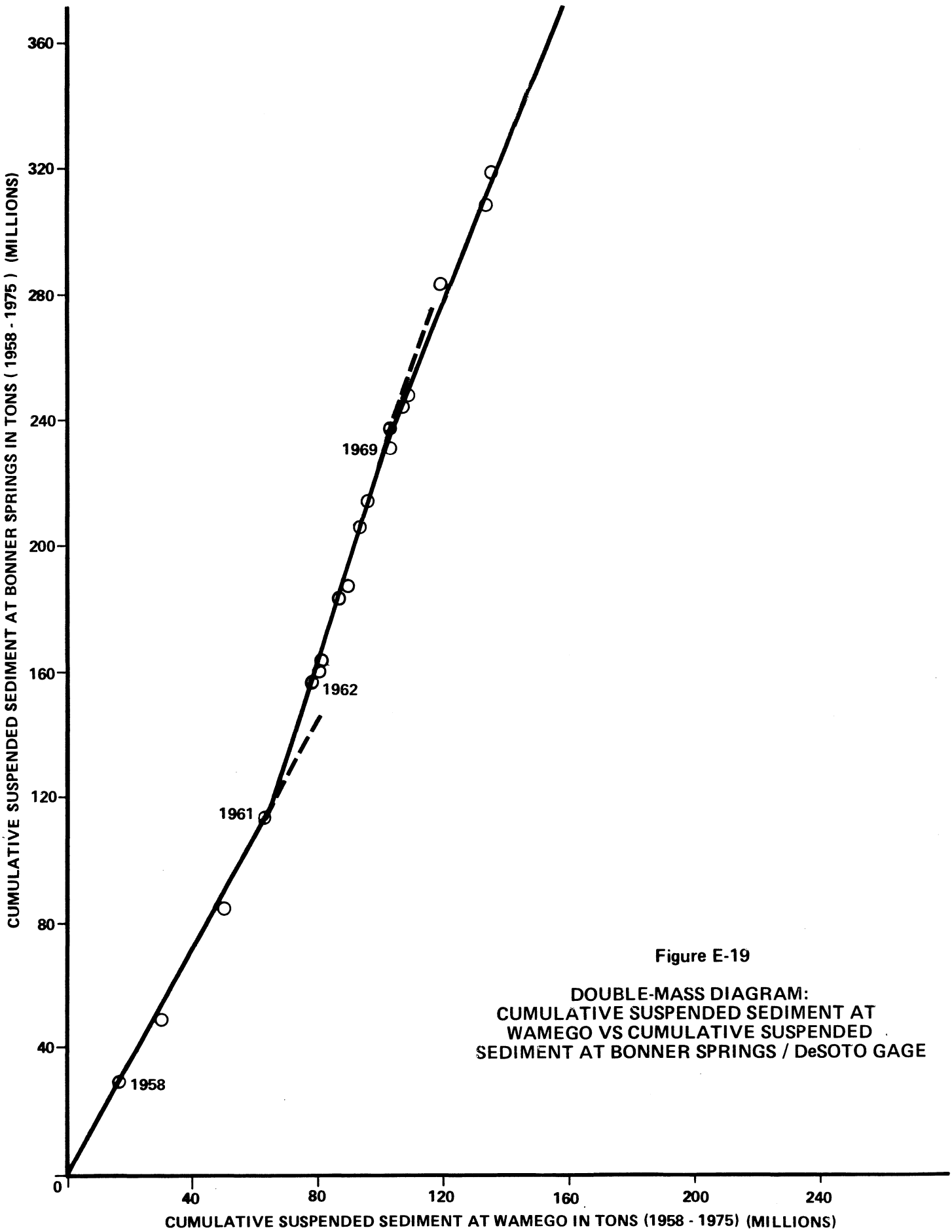


Figure E-19

DOUBLE-MASS DIAGRAM:
CUMULATIVE SUSPENDED SEDIMENT AT
WAMEGO VS CUMULATIVE SUSPENDED
SEDIMENT AT BONNER SPRINGS / DeSOTO GAGE

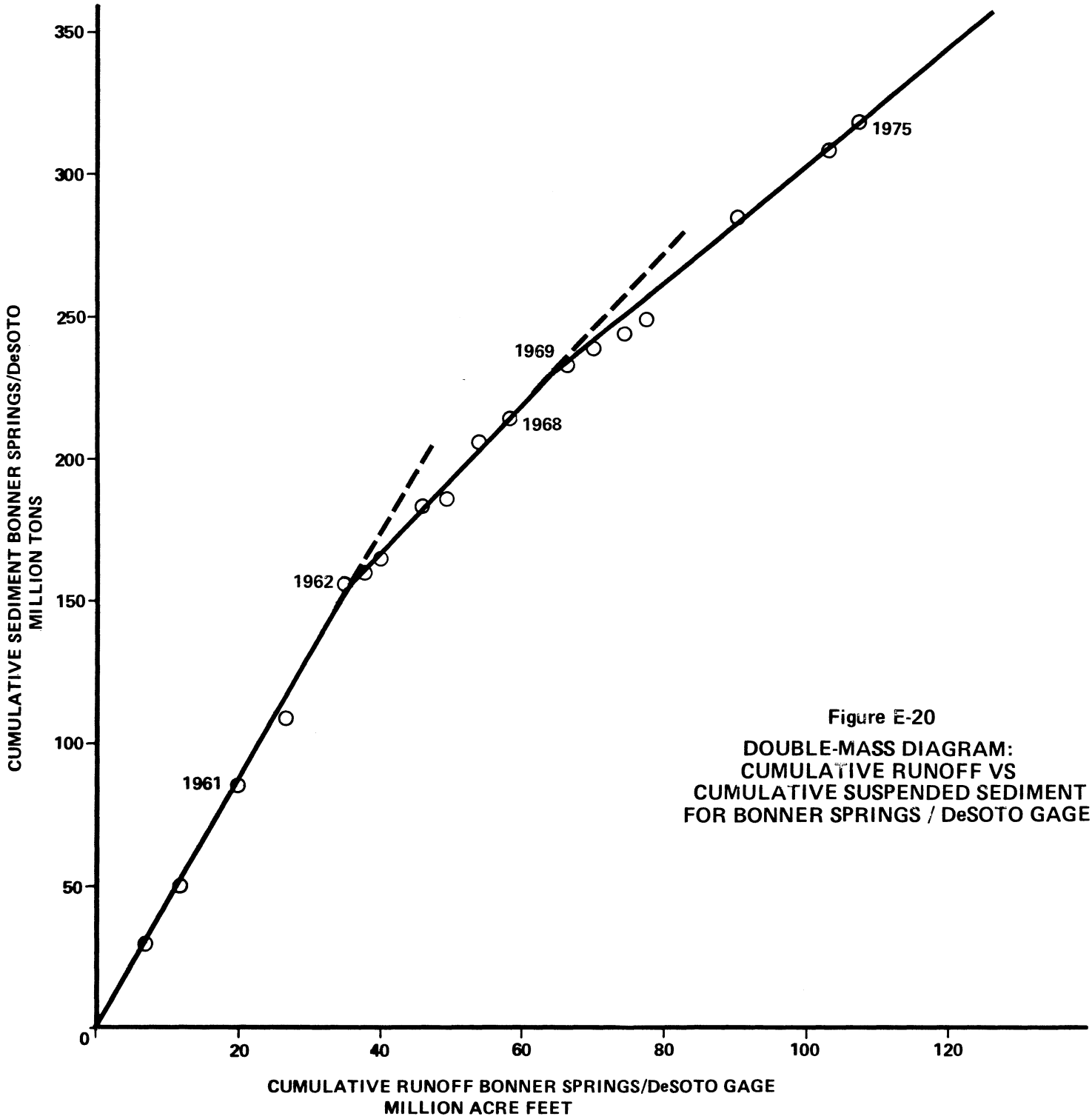
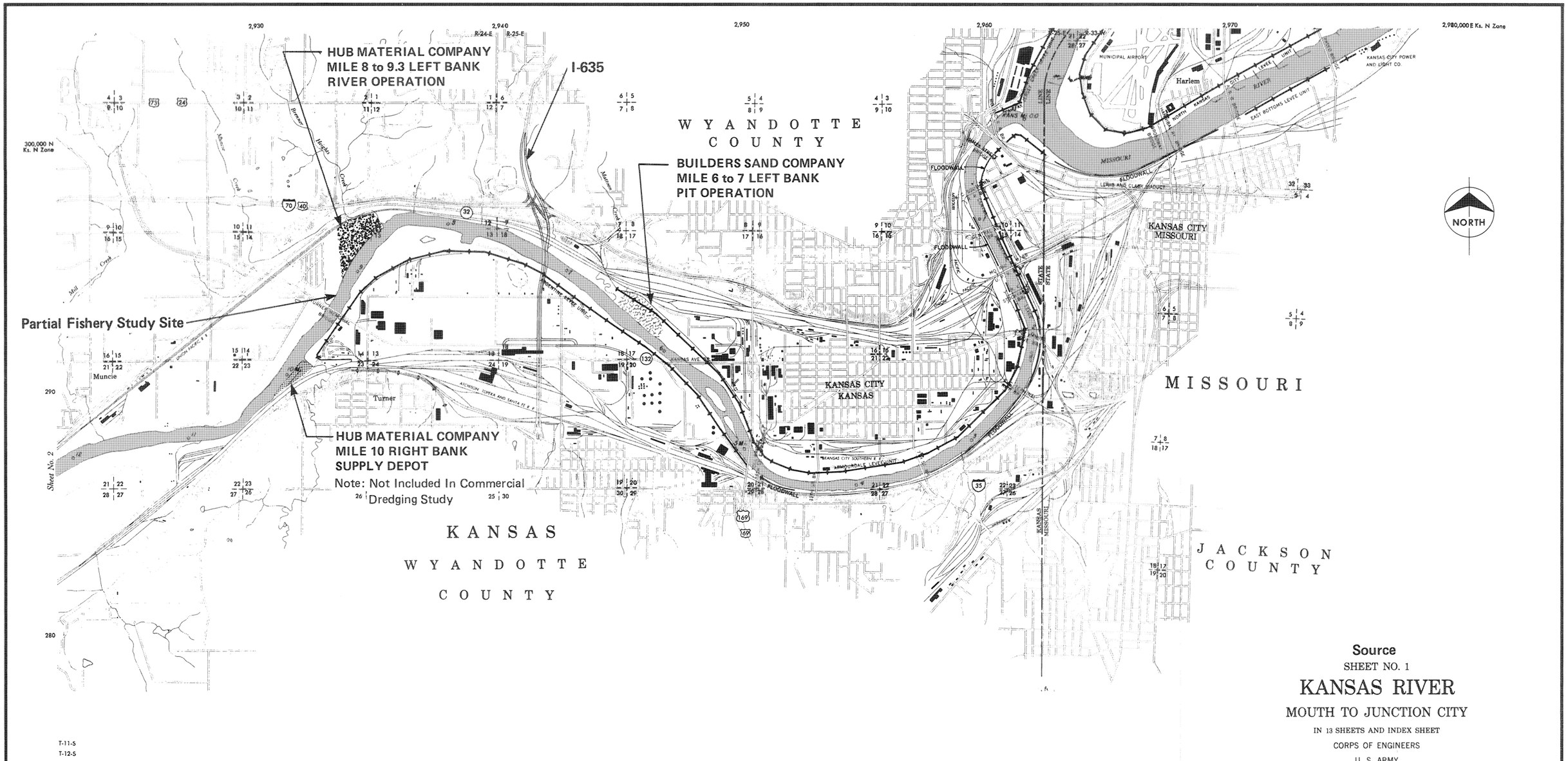


Figure E-20

DOUBLE-MASS DIAGRAM:
CUMULATIVE RUNOFF VS
CUMULATIVE SUSPENDED SEDIMENT
FOR BONNER SPRINGS / DeSOTO GAGE

APPENDIX F – KANSAS RIVER COMMERCIAL DREDGING STUDY AREA IN 11 SEGMENTS



LEGEND

- Sand and Gravel Dredge Operation
- Sand and Gravel Pit Operation
- Supply Depot

LEGEND

Miles Above Mouth of the Kansas River (1956 Adjusted) ... 150 0
Road
Trail
Overhead Power Line
Pipeline
Kansas River Levee System
Farm Levee
Dike
Railroad

2000 0 2000 4000 6000
SCALE IN FEET

Source

SHEET NO. 1

KANSAS RIVER

MOUTH TO JUNCTION CITY

IN 13 SHEETS AND INDEX SHEET

CORPS OF ENGINEERS

U. S. ARMY

NOTES

Topography by Corps of Engineers standard photogrammetric process from aerial photographs taken in 1971.

From the mouth to Junction City the Kansas state plane coodinate system (Lambert) is indicated at 10,000 feet intervals by tick marks at the limit of each map sheet.

River distances, indicated in miles above the Mouth refer to thalweg as established in 1956.

Burns & McDonnell
ENGINEERS - ARCHITECTS - CONSULTANTS

Figure F-1

KANSAS RIVER COMMERCIAL DREDGING STUDY AREA — RIVER MILE 0 -12.2

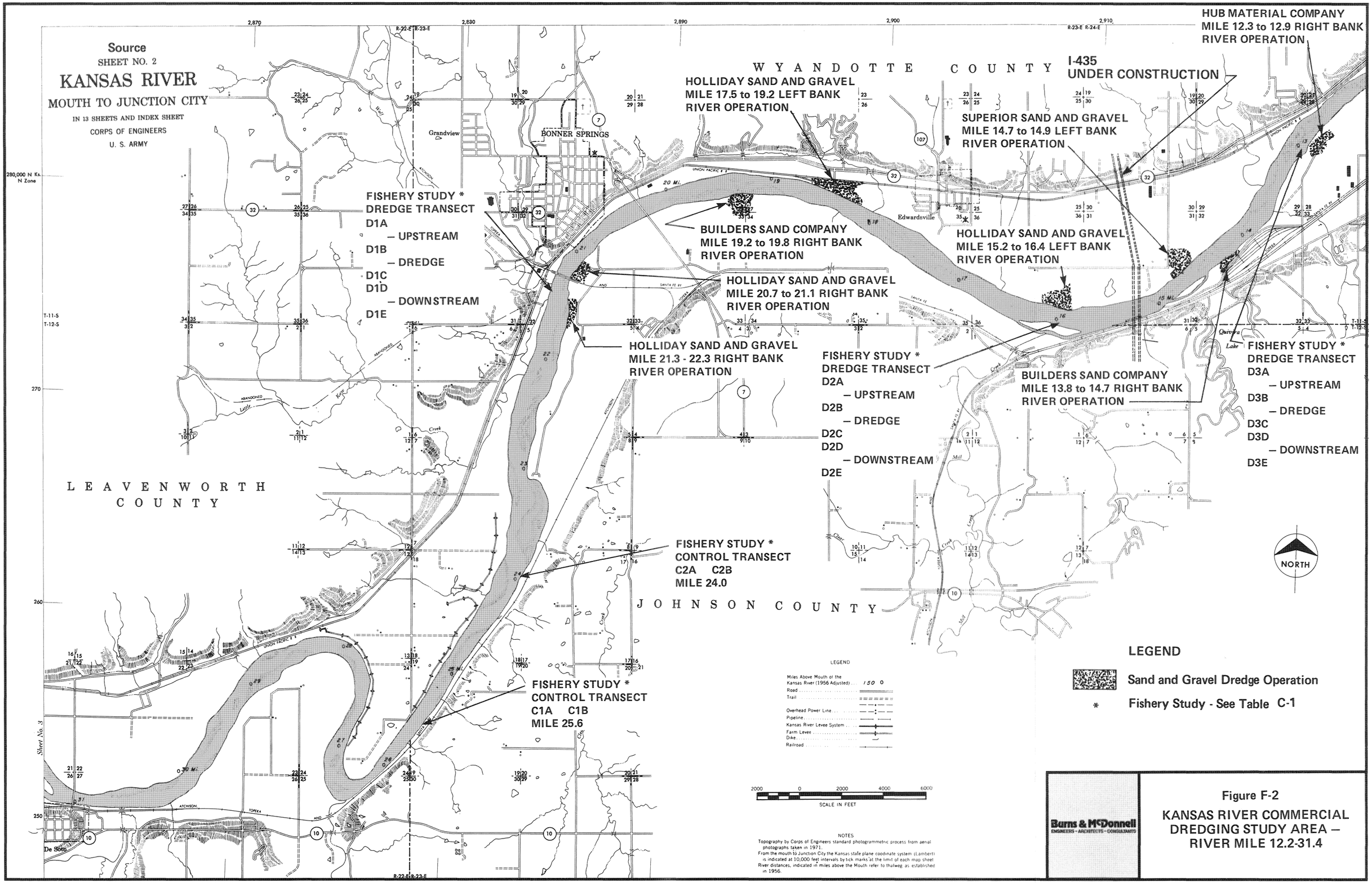
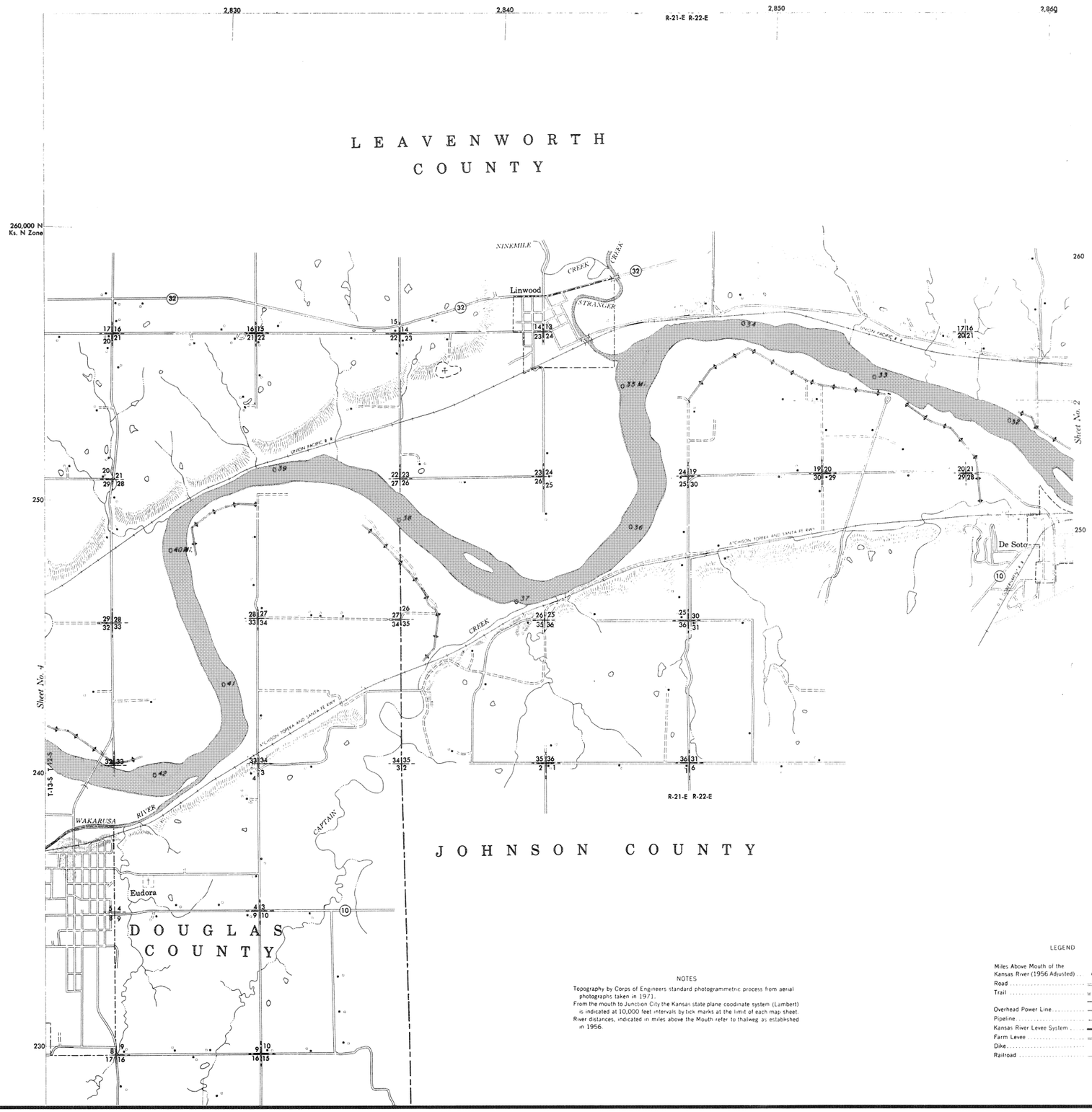


Figure F-2
KANSAS RIVER COMMERCIAL DREDGING STUDY AREA – RIVER MILE 12.2-31.4



Source

SHEET NO. 3

KANSAS RIVER

MOUTH TO JUNCTION CITY

IN 13 SHEETS AND INDEX SHEET

CORPS OF ENGINEERS

U. S. ARMY

Note: No Dredge Site In This River Segment

N

2000 0 2000 4000 6000

SCALE IN FEET

NOTES

Topography by Corps of Engineers standard photogrammetric process from aerial photographs taken in 1971.

From the mouth to Junction City the Kansas state plane coodinate system (Lambert) is indicated at 10,000 feet intervals by tick marks at the limit of each map sheet. River distances, indicated in miles above the Mouth refer to thalweg as established in 1956.

LEGEND

Miles Above Mouth of the Kansas River (1956 Adjusted) . . . 150 0

Road . . . . . .

Trail . . . . . .

Overhead Power Line . . . . . .

Pipeline . . . . . .

Kansas River Levee System . . . . . .

Farm Levee . . . . . .

Dike . . . . . .

Railroad . . . . . .

Burns & McDonnell
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Figure F-3

KANSAS RIVER COMMERCIAL DREDGING STUDY AREA — RIVER MILE 31.4- 42.8

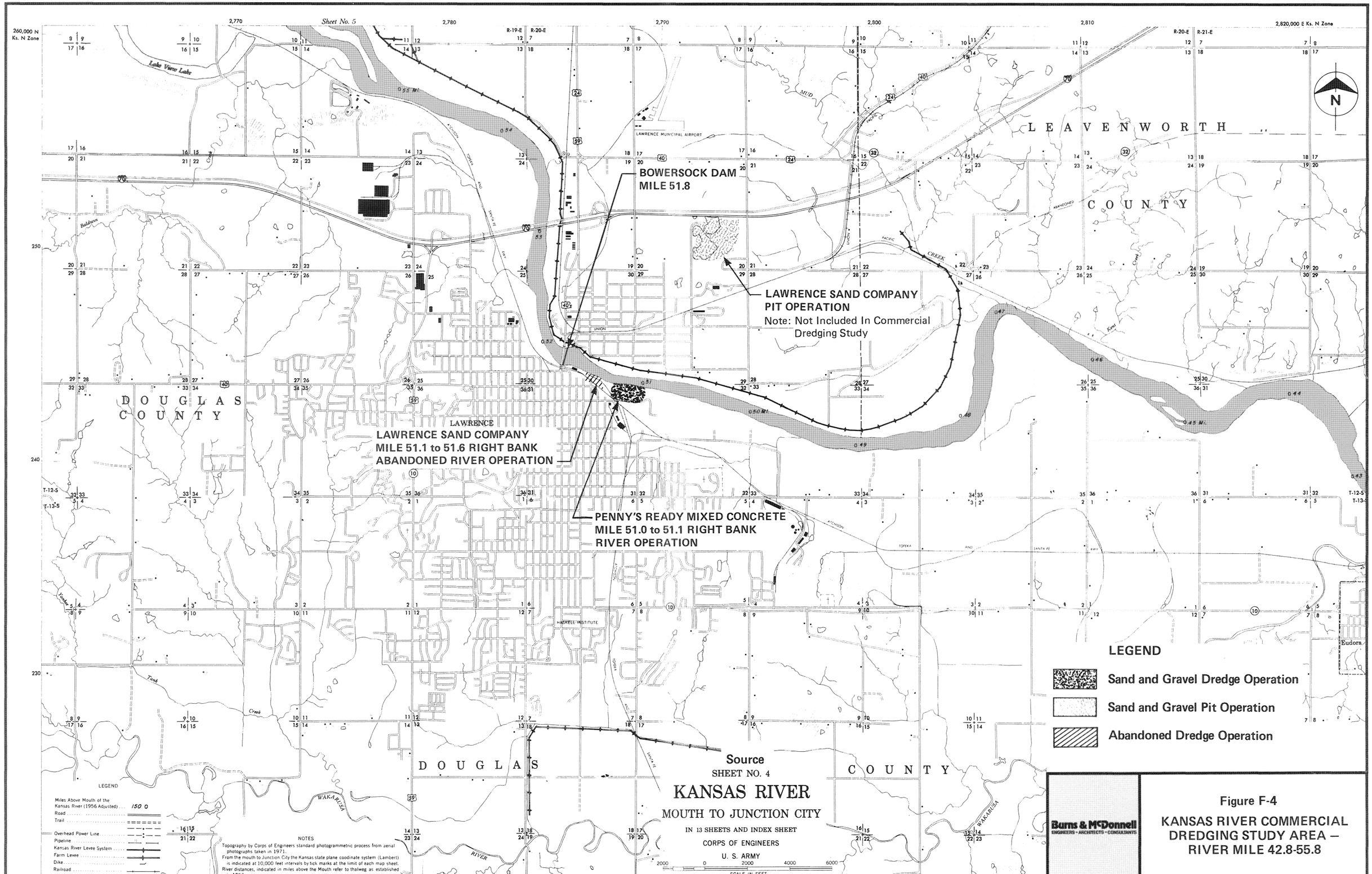
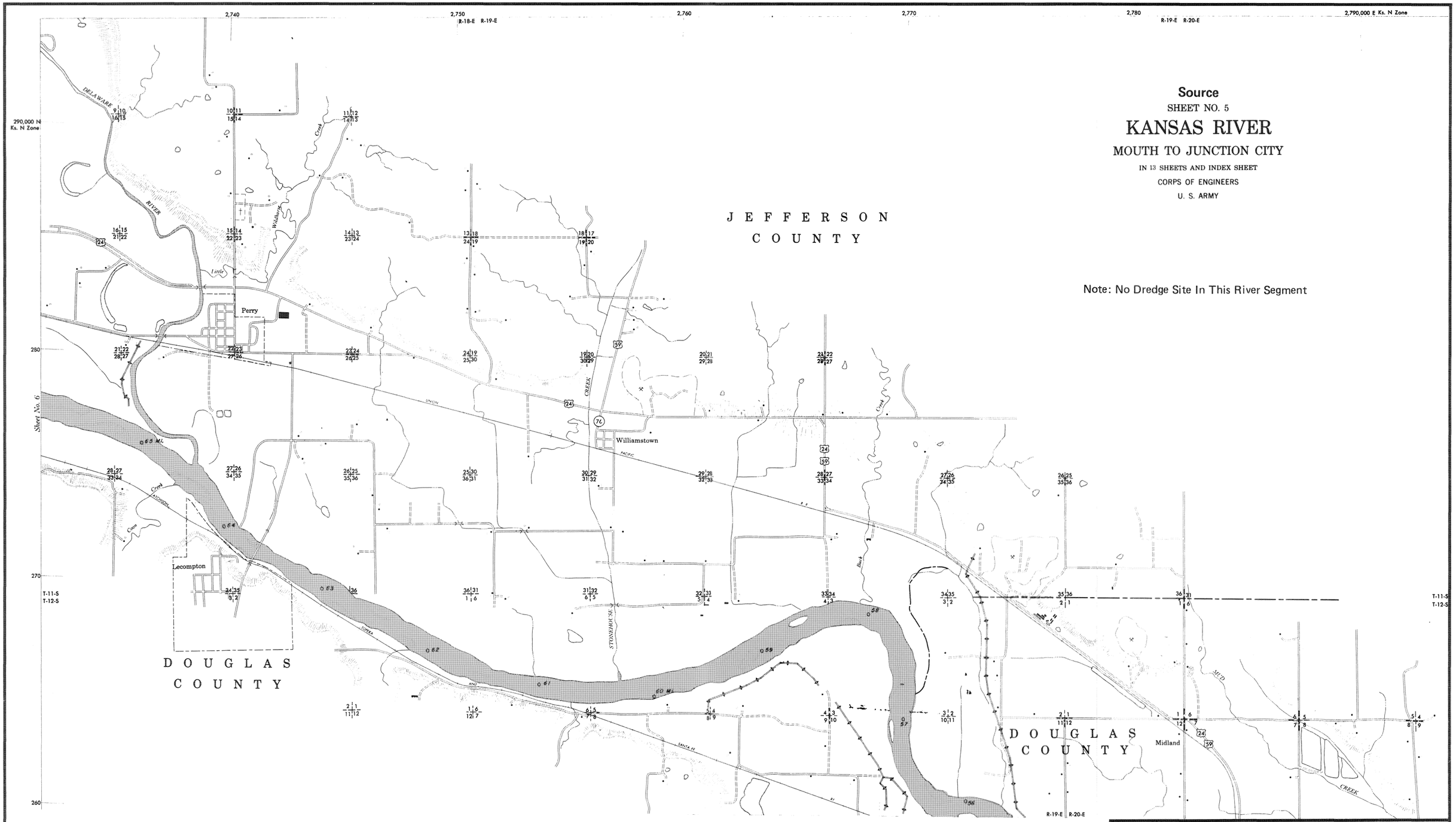


Figure F-4

KANSAS RIVER COMMERCIAL DREDGING STUDY AREA – RIVER MILE 42.8-55.8



NOTES

Topography by Corps of Engineers standard photogrammetric process from aerial photographs taken in 1971.

From the mouth to Junction City the Kansas state plane coodinate system (Lambert) is indicated at 10,000 feet intervals by tick marks at the limit of each map sheet.

River distances, indicated in miles above the Mouth refer to thalweg as established in 1956.

2000 0 2000 4000 6000

SCALE IN FEET

LEGEND

Miles Above Mouth of the Kansas River (1956 Adjusted) 150 0

Road

Trail

Overhead Power Line

Pipeline

Kansas River Levee System

Farm Levee

Dike

Railroad

N

Burns & McDonnell
ENGINEERS - ARCHITECTS - CONSULTANTS

Figure F-5

KANSAS RIVER COMMERCIAL DREDGING STUDY AREA — RIVER MILE 55.8-65.9

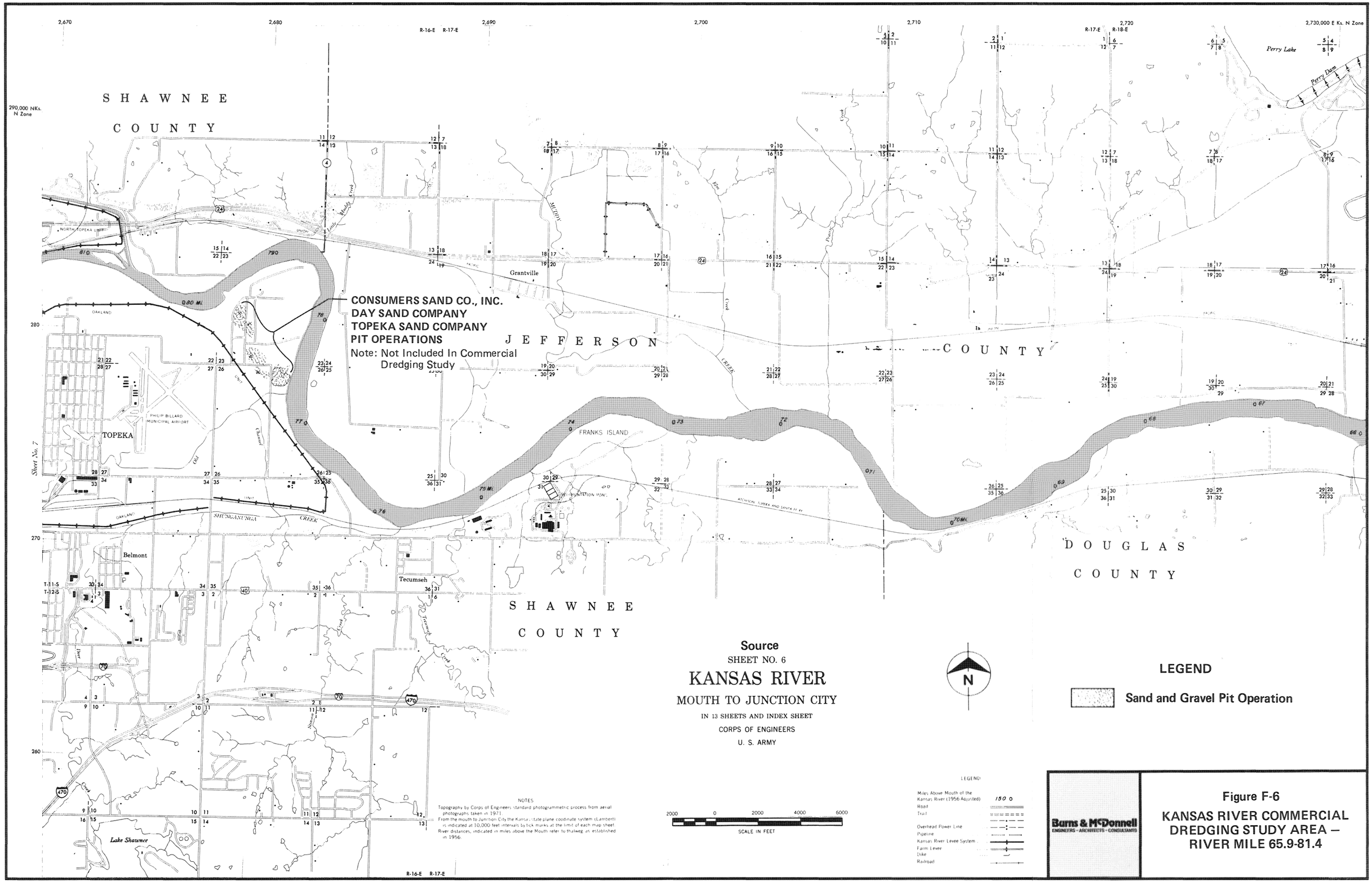


Figure F-6

KANSAS RIVER COMMERCIAL DREDGING STUDY AREA — RIVER MILE 65.9-81.4

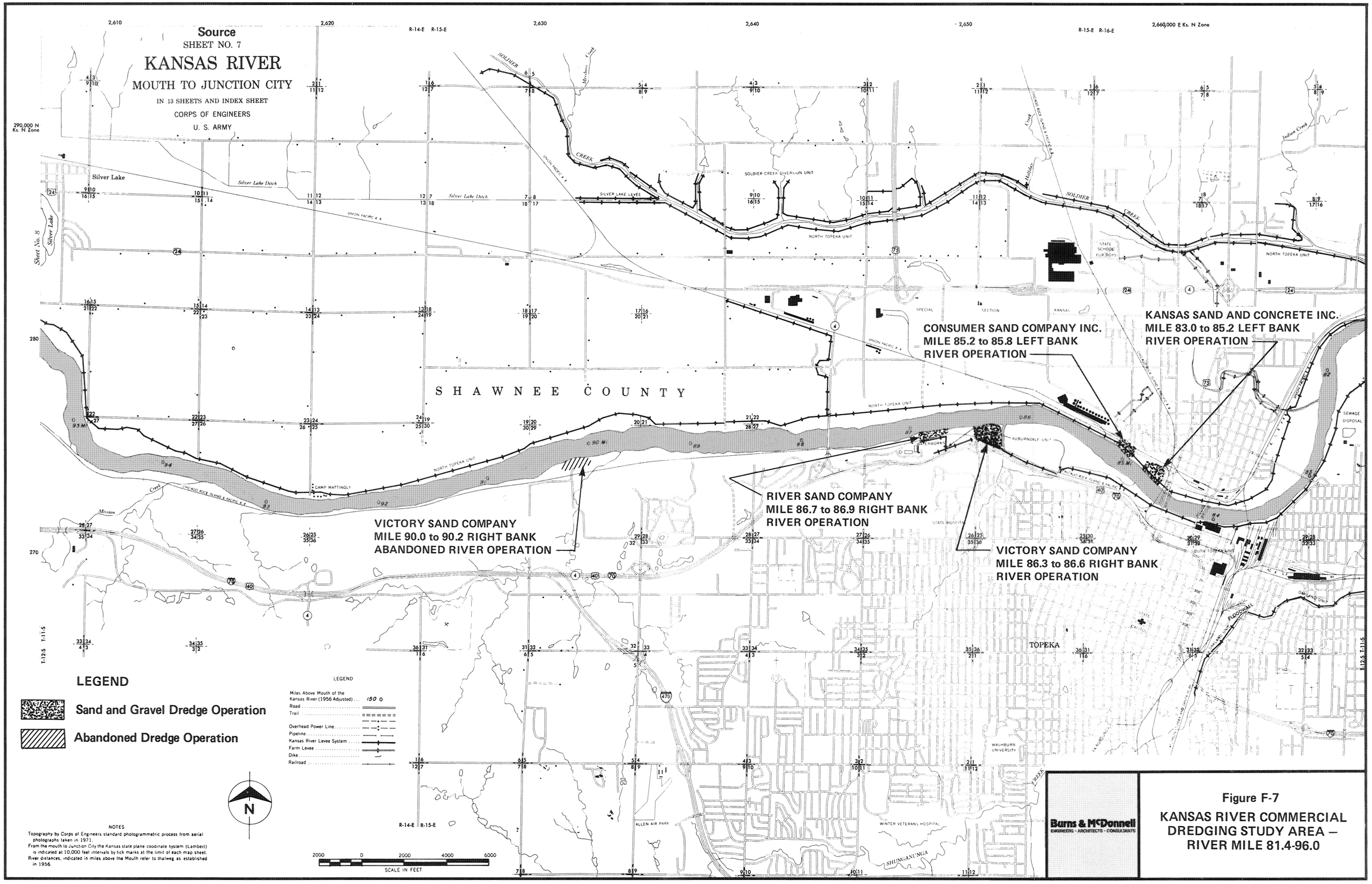


Figure F-7

KANSAS RIVER COMMERCIAL DREDGING STUDY AREA – RIVER MILE 81.4-96.0

NOTES

Topography by Corps of Engineers standard photogrammetric process from aerial photographs taken in 1971.

From the mouth to Junction City the Kansas state plane coodinate system (Lambert) is indicated at 10,000 feet intervals by tick marks at the limit of each map sheet.

River distances, indicated in miles above the Mouth refer to thalweg as established in 1956.

Burns & McDonnell
ENGINEERS - ARCHITECTS - CONSULTANTS

Figure F-8

KANSAS RIVER COMMERICIAL DREDGING STUDY AREA – RIVER MILE 96.0-111.1

SHEET NO. 9

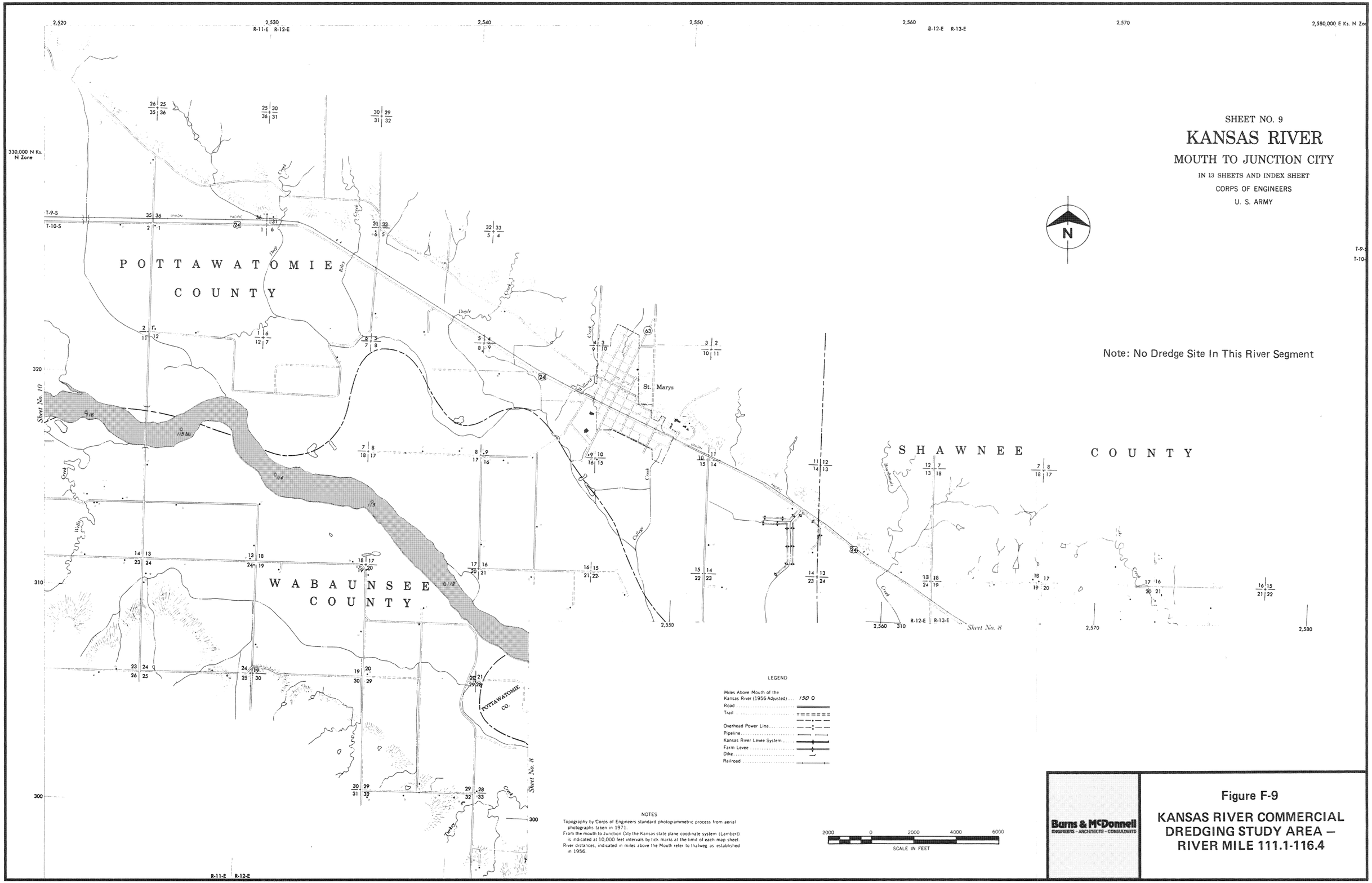
KANSAS RIVER

MOUTH TO JUNCTION CITY

IN 13 SHEETS AND INDEX SHEET

CORPS OF ENGINEERS

U. S. ARMY



Burns & McDonnell
ENGINEERS - ARCHITECTS - CONSULTANTS

Figure F-9

KANSAS RIVER COMMERCIAL DREDGING STUDY AREA — RIVER MILE 111.1-116.4

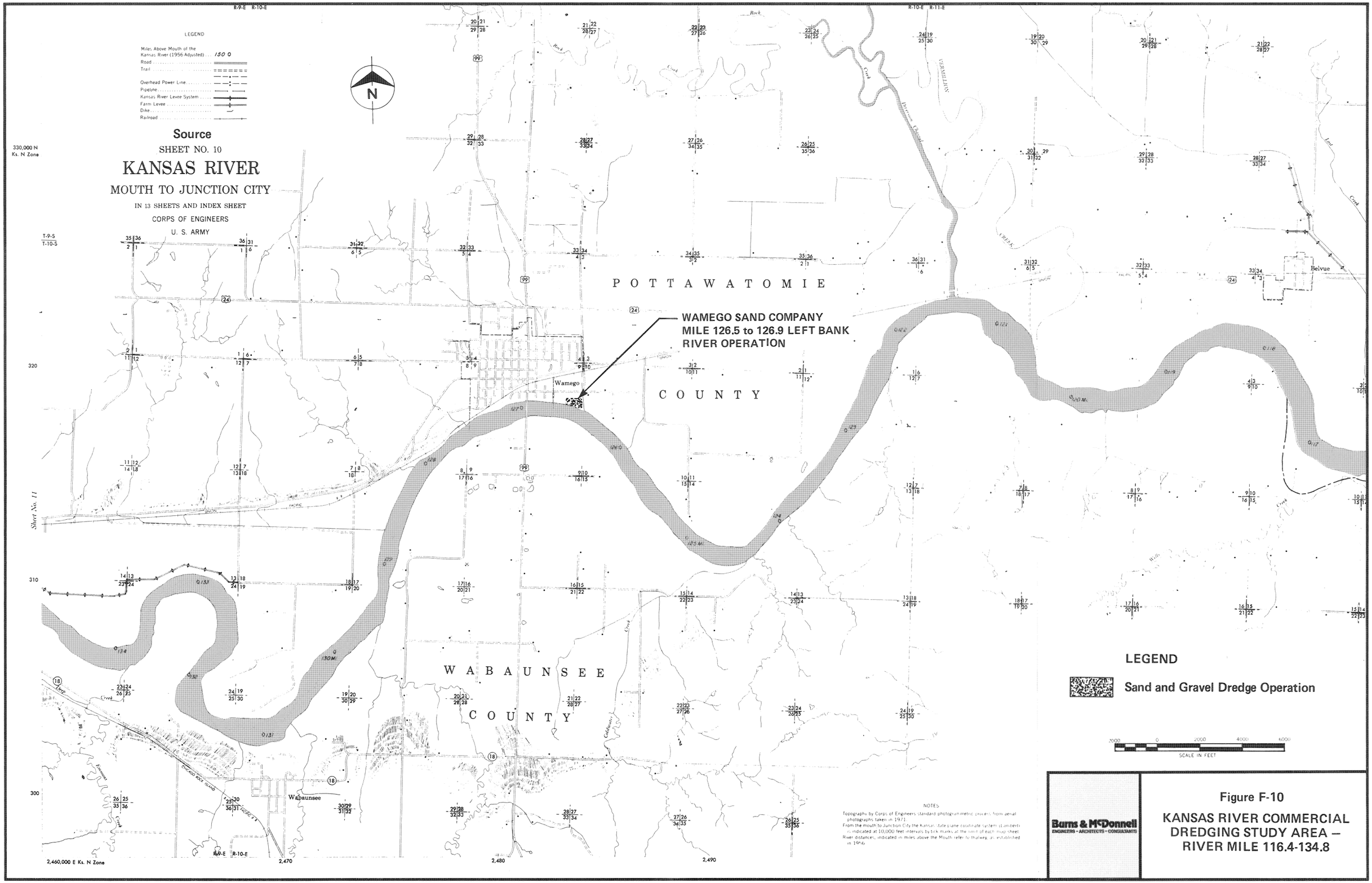


Figure F-10

KANSAS RIVER COMMERCIAL DREDGING STUDY AREA – RIVER MILE 116.4-134.8

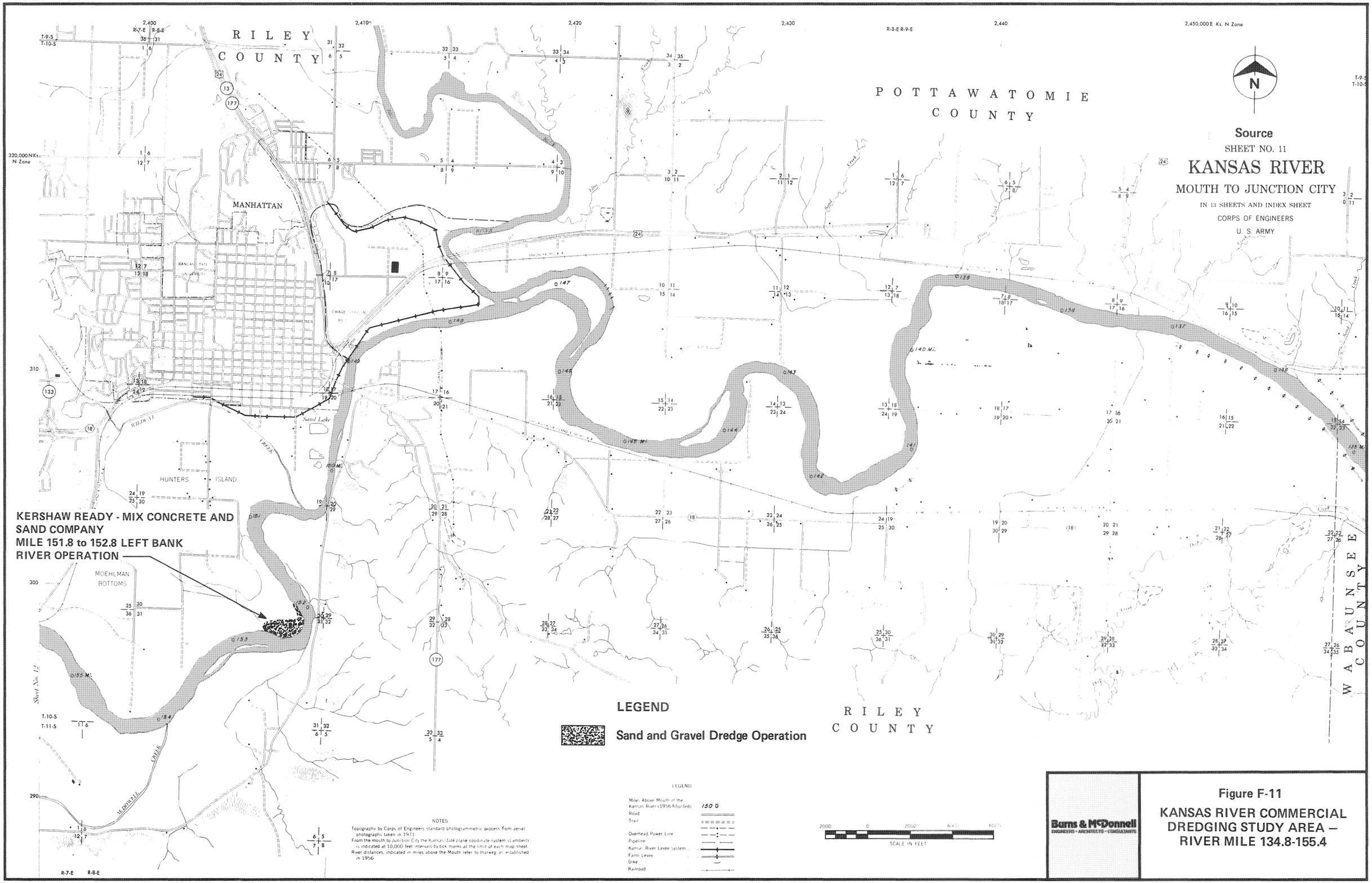


Figure F-11

KANSAS RIVER COMMERCIAL DREDGING STUDY AREA – RIVER MILE 134.8-155.4

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Mr. Michael LeValley	Biology/general, fisheries	1 year, fisheries worker, Iowa Conservation Commission; 3 months, biologist's aide, Kansas Fish and Game Commission; 3 years, environmental studies, Burns & McDonnell Engineering Co.	Effects on biological resources water quality, noise, and air quality.
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Mr. Patrick Sarb	Planning/ socioeconomics, recreation	3 years, planning, socioeconomic and environmental studies, Burns & McDonnell Engineering Co.	Report coordinator, planning considerations, socioeconomic assessment.