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Kansas Water Office and the
U.S. Army Corps of Engineers,
Kansas City District

Update of 1982 Six State High Plains Aquifer Study

Alternate Route B

Funded through Federal Planning Assistance to States Agreement (PAS) by the U.S. Army Corp of Engineers,
the Kansas Water Office and Southwest Kansas Groundwater Management District No. 3

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Update of 1982 Six State High Plains Aquifer Study

Executive Summary

Introduction

The Water Resources Development Act of 1976 authorized the Six-State High Plains-Ogallala Aquifer Regional Resources Study (High Plains Study) to address the problem of depleting High Plains Ogallala aquifer water supplies. The U.S. Department of Commerce, in coordination with the U.S. Army Corps of Engineers (Corps) and other federal, state and private entities, examined the feasibility of various alternatives to provide adequate water supplies to “assure continued economic growth and vitality of the High Plains region.” The High Plains study included state-level research completed by each of the six states (Colorado, Kansas, Nebraska, New Mexico, Oklahoma and Texas), regional economic and policy assessments and a study of interbasin water transfers.

The Corps studied four alternative transfer routes and completed reconnaissance level designs and cost estimates for ranges of transfer quantities. The 1982 Alternative Route B Reconnaissance Study (1982 Study) evaluated a route beginning on the Missouri River upstream of St. Joseph, Missouri and terminating in western Kansas. It is that route that was reevaluated in this update.

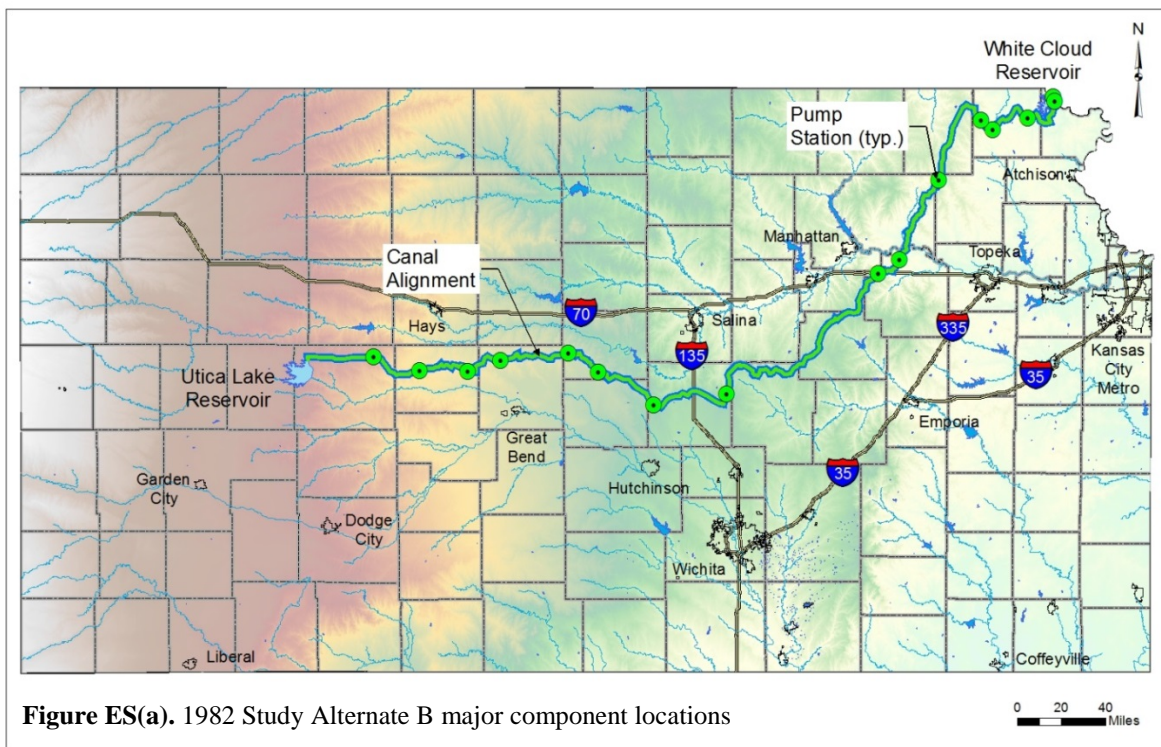


Figure ES(a). 1982 Study Alternate B major component locations

Study Purpose and Authority

The Kansas Water Office (KWO) and the U.S. Army Corps of Engineers Kansas City District (Corps) entered into a Federal Planning Assistance to States (PAS) Agreement to update the 1982 Study. The KWO partnered with the Southwest Groundwater Management District No. 3 (GMD 3) for financial assistance, as well as coordination, public input and review. The Corps retained the services of HDR Engineering, Inc. to evaluate the engineering aspects of the water transfer system and cost estimates. The KWO and GMD 3 contracted with Pope consulting, LLC who subcontracted with Leland Rolfs Consulting, to complete the review of legal and legislative issues and provide a preliminary political assessment.

Updates include refinement and mapping of the proposed alignment, projections of water demand and estimation of the range of quantities of water available. Financial considerations include updates to the total estimated construction cost, project cost per unit of transferred water and annual cost of energy and maintenance. The current study does not address the water distribution systems that would be needed to supply end users from the terminal reservoir. The study does not

provide an economic analysis of costs or benefits. The study also did not evaluate impact to local units of government in the project areas. The update provides a legal review and a preliminary political assessment.

This study is not a federal feasibility study or a federal interest determination. The purpose of this update is not to put forward a specific plan to construct the transfer system conceptualized in 1982, rather it is to evaluate the various merits and impacts such a project would have for the State of Kansas. Many assumptions and generalizations have been made to accomplish this update. Many topics were raised during the course of this study that would need to be addressed if a project of this nature were to move forward.

Stakeholder Coordination

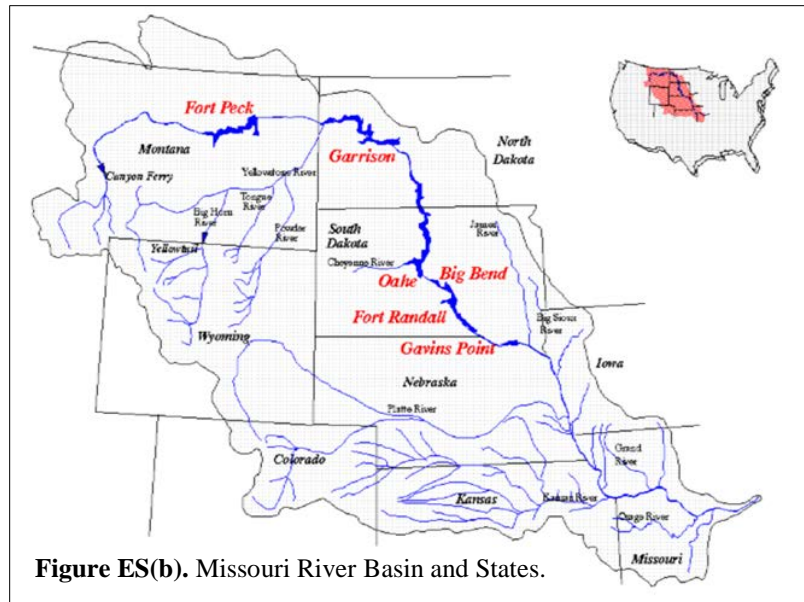
A Stakeholder Advisory Committee was formed comprised of individuals located geographically within the Ogallala portion of the High Plains aquifer study area, in the area of the proposed source reservoir, in areas along the proposed project route and those that use the Missouri River. (For the purposes of this report, the High Plains – Ogallala aquifer and Ogallala aquifer are used interchangeably and refer to the region of Kansas where the Ogallala formation exists). Stakeholders represented various use and interest categories such as city, county and tribal governments; public utilities; groundwater management districts; industries; agriculture and financial institutions.

The Stakeholder Advisory Committee convened at meetings held throughout the state to review findings from the technical, environmental, financial and legal reviews. The Committee also assisted in identifying other issues impacting the feasibility of a Kansas aqueduct project and in providing recommendations on components of the study that would need further review. The Committee was not asked to approve the update.

Missouri River Background

The Missouri River is the largest river that flows through or adjacent to the State of Kansas. It is also the longest river in North America and its basin covers one-sixth of the lower 48 states. The mainstem reservoir system includes six large dams that have the capacity to store over 74 million acre feet (MAF), not counting exclusive flood control storage, about three times the river's average annual runoff above Sioux City, Iowa, located just downstream of the last reservoir on the mainstem reservoir system. The upper three reservoirs are the first, second and third largest Corps reservoirs in the country.

While issues related to the use of water from the river are complex, it potentially provides a very large water supply for use in Kansas. The history and the hydrological record indicate that the flows of the Missouri River are highly variable experiencing large floods and major droughts in the basin. In 2007, the system was at record low levels; in 2011, a record flood occurred.



Water Demand

The 1982 Study demand analysis was for irrigation and without consideration of new irrigated areas. This current study updated the irrigation demands; municipal needs were also considered in this update. Municipal use includes industrial uses supplied through a city or rural water district. It does not include industrial use water with individual water appropriations, the largest of those generally being energy related.

Irrigation is the largest water use in Kansas, accounting for an average of 85% of reported water use between 1991 and 2011. For this study update, current reported water use for irrigation in the areas overlying the Ogallala - High Plains aquifer was summarized and projections were made to determine how much water is needed to sustain current levels as the aquifer continues to be depleted. Irrigation demands in the counties adjacent to the 1982 aqueduct route were also evaluated, recognizing that demands may increase in these counties if a supplemental water source is made available. Additionally, farm acreage in counties adjacent to the 1982 route was evaluated for potential conversion from dry land farming to irrigated farming.

An update of demand assumed replacement of current irrigation levels once 400 gallons per minute could not be supported. Full replacement would require over 1.8 million acre feet (MAF) in 50 years and over 2.6 MAF in 100 years. Adding potential demand for irrigation along the route would increase to a total for irrigation ranging from 4.2-6.5 MAF. The estimated annual requirement in 1982 was only 862,000 acre feet (AF). Consideration is given in the study to the possibility of supplementing reservoir storage in surface water basins along the route that are expected to have shortages in the next 50 years, however this amount has not yet been quantified.

For this study update, municipal demand was estimated using average gallons per capita per day (GPCD) multiplied by population estimates. The GPCD was compared to actual reported water use for calibration.

Projected demand for 2040 totals 16,480 million gallons (MG) for municipal use in the 21 counties along the proposed aqueduct; the annual quantity authorized totals 31,185 MG. The five counties along the I-135 corridor is an area of significant economic importance that has looked at transporting water into the region as early as 1982. The projected annual demand for these five counties (Harvey, McPherson, Reno, Saline and Sedgwick) is 31,256 MG for 2040 of an authorized annual quantity of 92,080 MG. The annual quantity authorized for municipal use in Ellis, Rush and Trego counties, the counties that experienced issues during the recent drought (2011 – 2014), totals 3,331 MG; projected annual demand in 2040 totals 1,777 MG. While sufficient water appropriations exist to meet estimated 2040 demand, as demonstrated by the recent drought, actually obtaining that water can be problematic.

The total projected municipal demand for 2040 for all three areas evaluated totals 44,513 MG (0.1 MAF). (The total is not equal to the sum of the three areas due to overlap of counties).

Water Availability

Under the Corps 1982 Study, quantification of water availability was simplified through assumptions. This update continues this simplified assumption. Availability is assumed when Missouri River flows exceeded the navigation and water supply intake structure targets; 41,000 cfs during navigation support season and 15,000 cfs outside of the navigation support season. It is important to recognize that this assumption probably overestimates the quantity that could be available, because it does not include the overall operation of the Corps' Bank Stabilization and Navigation Project. That analysis is beyond the scope of this study.

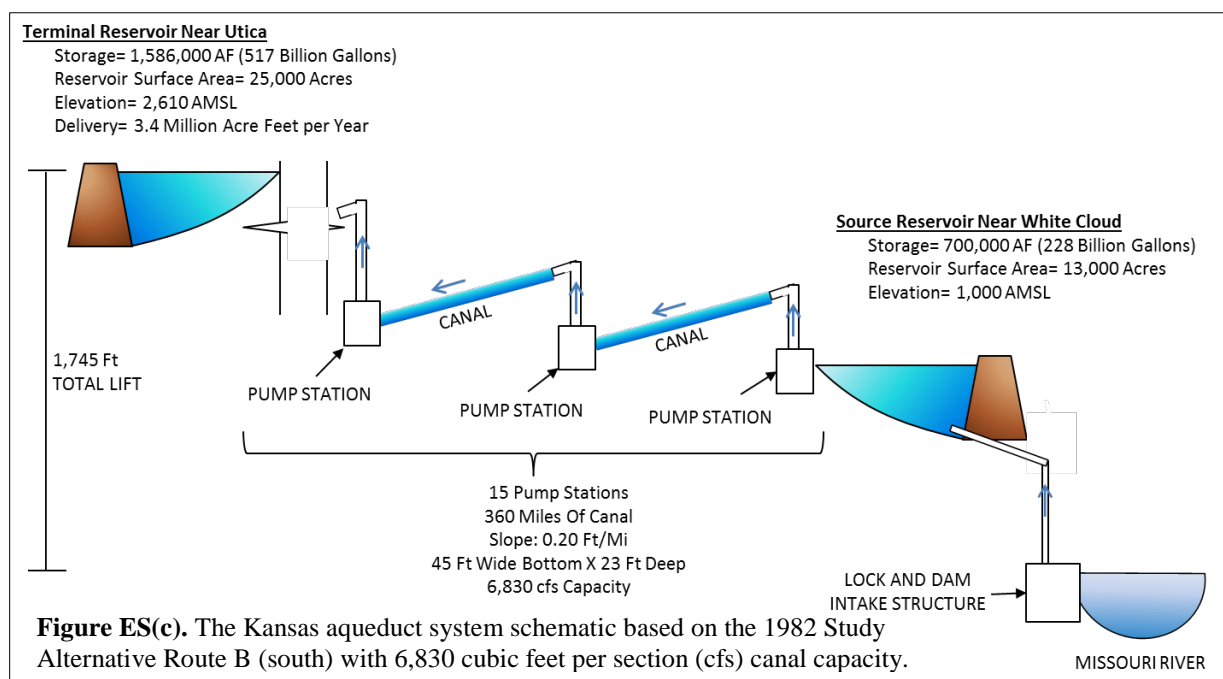
The amount of water available for transfer is dependent not only on what is in the river, but on the engineered components of the water transfer system. For this study update, an Excel model was developed to assist with evaluating the different components of the Kansas Aqueduct to optimize the transfer and beneficial use of the available water.

The update assumes diversion rates of 6,000; 10,000; 20,000 and 30,000 cfs. Transfer rates of 2,000; 6,000 and 10,000 cfs were evaluated. The amount of water available for transfer is dependent on the engineered components of the water transfer system. The diversion pumping rates, the source and terminal storage reservoir size and transfer canal capacity all impact the amount of water that could be transferred.

The model estimates that flows above navigation and water supply intake structure targets over the period of record using a maximum diversion rate of 30,000 cfs results in an average annual yield of 6.9 million acre feet (MAF). However, this does not account for the limitations of storage capacity and transfer capabilities. Therefore, the model was used to determine the range of water available with different transfer system components. The results show the average annual yield that can be expected to be available at least fifty percent of the time ranges from 0.9 MAF at the lowest end to 3.2 MAF at the highest end of pumping and storage capacity.

Water Transfer System

The water transfer system formulated in the 1982 Study is shown in Figure ES(c). The engineering aspects of the project are interdependent with the yield of the system. Diversion rates of 6,000; 10,000; 20,000 and 30,000 cfs were evaluated.



A 360 mile long concrete-lined canal and 15 pump stations would be required to transfer the water to western Kansas which is 1,745 feet uphill (net). Canal capacities of 2000, 6000 and 10,000 cfs were evaluated for consistency with the 1982 Study. The canal would follow a ridge line generally along the southern watershed divide of the Kansas River. The canal route would transect a large portion of the state and multiple infrastructure relocations would be required. The pumps would be electrically driven and would have a large electrical load. A hydroelectric plant near the Kansas River was proposed in the 1982 Study to partially offset the external electrical usage.

The irrigation demand is seasonal whereas the canal will flow at a uniform rate. The difference between the canal capacity and peak demand during irrigation season results in a need to construct a terminal reservoir. The 1982 Study included a terminal reservoir near Utica, Kansas. A range of yields to the farm head gates were calculated ranging from 0.9 to 3.2 MAF annually depending on the component sizing. The stated yields include source reservoir, canal, terminal reservoir and distribution system seepage and evaporation losses.

Preliminary Opinion of Probable Costs

This study presents updates to various components of the 1982 Study, including a high-level conceptual update of potential costs based on available information. The projected costs use the 1982 Study cost items and industry recognized escalation factors and costs indices. Costs from the 1982 study were multiplied by a factor of 3.27872, the engineering standard construction cost index (CCI). Using this methodology may underestimate certain costs, such as land values, however the development of detailed construction quantities and associated cost estimating is beyond the scope of this study.

The project was evaluated for water transfer delivery systems of 2,000, 6,000 and 10,000 cfs. It is assumed that construction would occur over a 20 year period. The updated total construction costs for the system found to be the most cost efficient (6,000 cfs transfer capacity) is \$12,231,000,000. The interest during a 20 year construction period is estimated to be \$5,788,000,000 bringing the total investment cost to \$18,019,000,000. Interest during the 20 year construction period was 7 3/8% in the 1982 study but only 3 1/2% for this update. This change was made during the course of the study and changed the initial cost of water that was discussed. It is recognized that interest rates are variable and can have a significant impact on project costs.

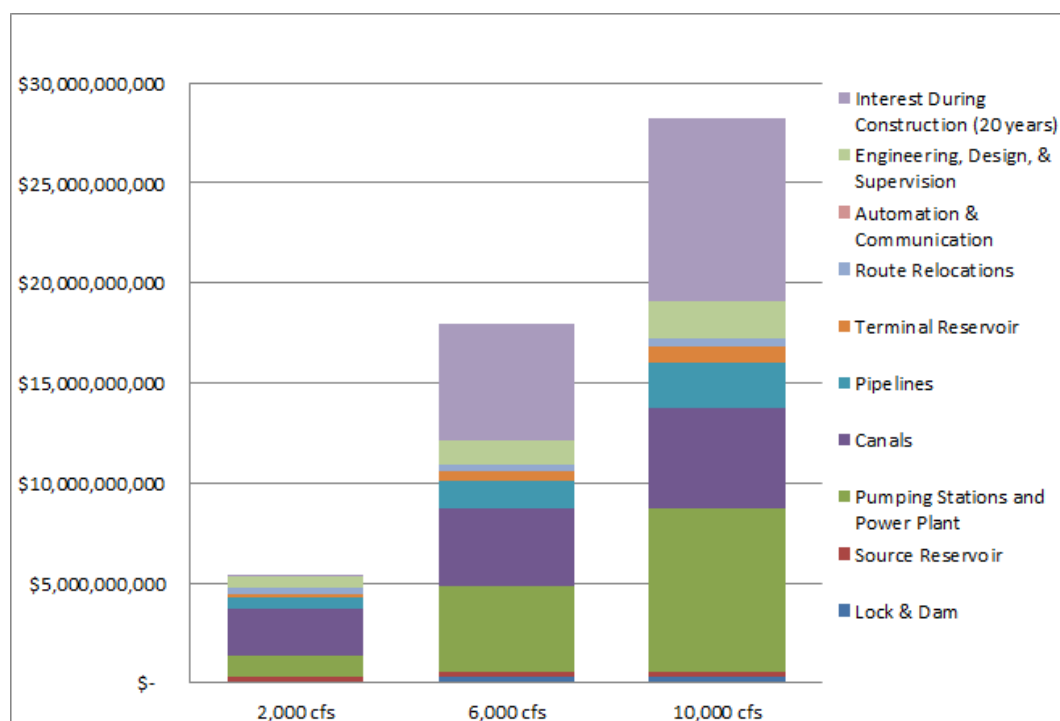


Figure ES(d). Estimated Construction Costs.

Assuming the 6,000 cfs diversion rate, the annual costs including operation and maintenance, interest and amortization and energy costs were determined to be \$1,084,161,000. The annual energy costs were estimated to be \$395,000,000, which assumes a total of 8.78 million megawatt hours needed to operate the system annually. No attempt is made to determine where that energy would come from.

The very preliminary estimate of the 2014 delivered water costs is approximately \$450 per acre foot.

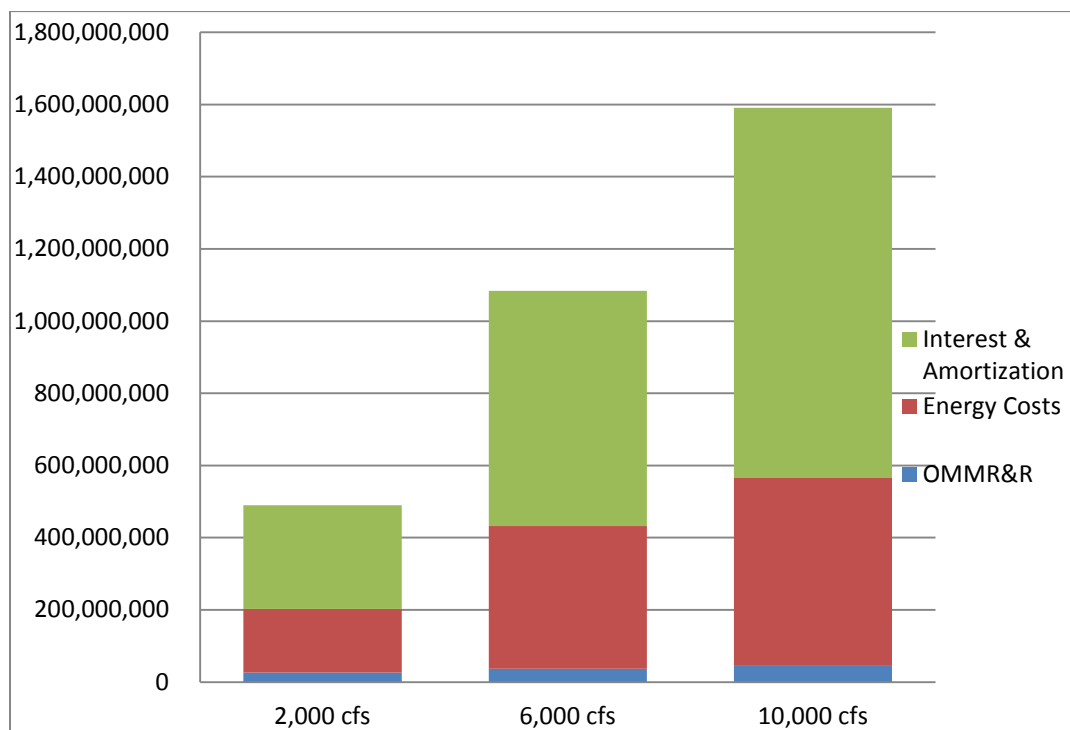


Figure ES(e). Annual Operation and Maintenance Costs.

Review of Legal and Legislative Issues

This section is organized into legal issues in obtaining water at the source, transporting and delivering water along the route and to the destination. In addition, the type of entity that could build and operate a project is addressed. The Missouri River basin ranges in general application of the Prior Appropriation Doctrine in the seven states located partially or totally west of the 98th meridian in the drier portions of the basin, to the general application of the Riparian Doctrine in the State of Missouri and a permit system in Iowa and Minnesota, all located in the wetter, eastern and southern part of the basin.

Federal Reserved Water Rights exist for Indian Tribes throughout the Missouri River basin under a 1908 Supreme Court ruling called the Winter's Doctrine. At this time, however, many of them remain undetermined as to rate and quantity, including the reserved water rights for the four Indian reservations in Kansas: the Sac and Fox Nation of Missouri in Kansas and Nebraska; the Iowa Tribe of Kansas and Nebraska; the Kickapoo Tribe in Kansas and the Prairie Band Potawatomi Nation. The ultimate determination of the extent of these rights will affect the rate and quantity of water available to the state of Kansas from the Missouri River. Several federal laws have also been passed to help protect historic and cultural resources of the American Indian Tribes. This is also briefly addressed in Chapter 6, Environmental Considerations.

A brief review of the Missouri River Basin Project authorized by the 1944 Flood Control Act is included due to its extremely important impact to the flows of the Missouri River, operation of most of the tributary reservoirs operated by the Federal government and the impact to the potential water supply for the Kansas Aqueduct Study being evaluated in

part herein. The Act recognizes the interests and rights of the states in determining the development of the watershed within their borders and in water utilization and control.

There is not a basinwide compact, congressional allocation or U.S. Supreme Court Equitable Apportionment that fully allocates the waters of the Missouri River among the states and tribes. Until this is done, the State of Kansas cannot be guaranteed any specific percentage, flow or quantity of the Missouri River. This matter should be resolved prior to the state investing significant study dollar amounts in any such major transfer project. The Flood Control Act of 1944, other Federal statutes, the Corps Master Manual and Annual Operating plans, are considered the Law of the Missouri River and could have significant bearing on what Kansas' equitable share of the Missouri River is whenever the decision is made. The four interstate water compacts to which Kansas is a party probably would not play a major role in building an aqueduct as described, unless an out of basin transfer of water is proposed from the Big Blue Compact area.

Under the Kansas Water Appropriation Act (KWAA) at least three applications to appropriate water for beneficial use would have to be filed and approved by the Chief Engineer, Kansas Department of Agriculture, Division of Water Resources (Chief Engineer) to allow appropriation of water from the Missouri River, by the source reservoir, and by the terminal reservoir. The application to appropriate water from the Missouri River could require a filing fee of up to one million dollars depending on the quantity applied for.

After permits are obtained from the Chief Engineer under the KWAA, or alternatively before water is diverted pursuant to a water reservation right, the entity constructing the aqueduct project must apply for, and receive approval for, a water transfer under the Water Transfer Act. This will involve lengthy public hearings concerning all of the impacts that might be caused by construction and operation of an aqueduct.

This review found that although the aqueduct does not exactly fit the definition of a traditional water right, there are many similarities. The items most out of the ordinary are a) an extremely long time to complete the project, b) an extremely long perfection period, c) an indefinite place of use, d) the requirement that the water right be perfected within a certain definite period of time and e) a large filing fee. Alternative options seem to be: 1) make the project fit under the KWAA; 2) modify the State Water Plan Storage Act so that it can be used to permit this project or 3) have the legislature create an entirely new type of water right.

An entity or entities would have to be created to finance, build, maintain and operate an aqueduct. This could include having the legislature create a new type of entity based on the model of the Kansas Turnpike Authority. A decision will also need to be made as to whether such an operating entity for an aqueduct will also deliver water from the terminal reservoir, or whether existing entities, such as public wholesale water supply districts, irrigation districts, water districts, municipalities and groundwater management districts should be given the responsibility of distributing the water from the terminal reservoir. Issues will arise concerning the delivery of the water from the terminal reservoir to either aquifer recharge projects or end users, such as the need for additional easements for pipelines or canals to deliver the water.

Permits would need to be obtained from the Chief Engineer under the Kansas Obstructions in Streams Act and Kansas Levee Law for the alteration of the course, current or cross-section of any stream in Kansas, including the construction of the source reservoir and terminal reservoir dams, and the construction of any levee or any project that has the effect of a levee. The Obstructions in Streams Act in turn requires compliance with the Water Projects Environmental Review Act which requires review of the project to determine if the proposed project will have detrimental environmental impacts. In addition, federal permits would need to be obtained under Section 404 of the Clean Water Act and Section 10 of the Rivers and Harbors Act.

Easements must be obtained for the entire route of the aqueduct and reservoirs, including where it will cross existing infrastructure, such as roads, highways, power lines, pipelines, railroads and other public and private property. Reasonably adequate provisions must be made for local crossings of the aqueduct for individual landowners who need to get to town or access their property on the other side of the aqueduct. Another law that would be triggered would require an act to be passed by the Kansas legislature and approved by the Governor of Kansas to allow facilities to be constructed on any state owned property, such as roads, highways and the bed and banks of navigable streams in the state of Kansas, including the Missouri River, the Kansas River and the Arkansas River.

Water quality and endangered species issues would have to be resolved prior to construction. This may involve methods to prevent introduction of invasive species or degradation of water quality of other Kansas streams and aquifers. National Pollution Discharge Elimination Permits may be needed for the discharge of aqueduct water to streams or other water bodies. Several of these issues are also addressed in under Environmental Considerations.

Environmental Considerations

A large-scale project such as that envisioned in the 1982 Study would require a comprehensive environmental review, an extensive permitting process and mitigation of the impacts to wildlife and habitat. The costs of these processes and mitigation are not included in the estimates of costs.

The construction of the lock and dam and intake facilities on the Missouri River, construction of the source and terminal reservoirs and the construction of the canal would all be subject to Section 404 of the Clean Water Act 404, which regulates the discharge of dredged or fill material in all waters of the United States and Section 10 of the Rivers and Harbors Act of 1889, which regulates any work or structure in, over or under navigable waters of the United States. The process for consideration of such permits is extensive and would require detailed analysis, review and public comment in compliance with the National Environmental Policy Act (NEPA). A large project such as the aqueduct would require the development of an Environmental Impact Statement and the project in its entirety would be reviewed to assess the cumulative impacts.

The environmental review would include an evaluation of the impacts to federal or state listed threatened or endangered species. There are at least three currently listed threatened species known to inhabit areas along the 1982 aqueduct route as well as federally listed threatened or endangered species on the Missouri River. Any future project will require an extensive review of its impact on threatened and endangered species and a permit placing special conditions to incorporate specific mitigation measures designed to significantly reduce or eliminate a project's adverse impacts to the protected species will be required.

Compensatory mitigation will be necessary to offset the impacts to streams and wetlands using permittee - responsible mitigation, mitigation banking or in-lieu fee mitigation. Stream and wetland mitigation costs for a water transfer system such as this would be substantial with recent projects costs ranging from approximately half of the overall construction costs, to surpassing the total cost of the project.

Water quality issues will have to be addressed under both state and federal laws related to the transfer of water from the Missouri River into other receiving bodies and potential risk of introducing invasive species and disrupting the nutrient and sediment balances.

From an environmental standpoint, some of the most significant challenges to address for a project like this would likely be the threatened and endangered species on the Missouri River and throughout Kansas, and the compensatory mitigation requirements under Section 404 of the Clean Water Act.

Preliminary Political Assessment

The Missouri River Basin covers one-sixth of the lower 48 states. The mainstem of the river flows through or adjacent to seven states – Montana, North Dakota, South Dakota, Nebraska, Iowa, Kansas and Missouri. The basin also includes portions of Colorado, Wyoming and Minnesota, and a small portion of Canada. In addition to the ten states located partially or totally in the basin, twenty eight American Indian Tribes are located in the basin, generally on reservations established by the treaties with the United States or congressional action. As mentioned in the Legal review section, there is not a basinwide compact, congressional allocation or U.S. Supreme Court Equitable Apportionment that fully allocates the waters of the Missouri River among the states and tribes. Until this is done, the state of Kansas, nor any other state or tribal nation, can be guaranteed any specific percentage, flow or quantity of the Missouri River.

Possible objectors to an aqueduct project will be: 1) other states; Indian tribes or federal agencies in the Missouri River Basin; 2) landowners in Kansas who are concerned about having their land taken to build and operate the project; 3)

environmental groups who are concerned about such issues as the potential degradation of water quality in Kansas streams and aquifers, the introduction of invasive species across Kansas and destruction of wildlife and fish habitat and 4) those concerned with how the project will be financed and who will pay any new taxes or fees, versus who is expected to receive the benefits.

However, given the potential to meet important water needs in a broad area of the state, provide a sustainable supply of water to maintain the local, regional and state economy generated by the productive irrigated agricultural and related agribusiness in High Plains – Ogallala aquifer area, as well as to provide water for economic development and stability in Kansas, the project may also receive a large amount of support.

Conclusions and Recommendations for Future Study

This study update provided an opportunity to reevaluate the concept of a large-scale water transfer system for the State of Kansas. Through participation of stakeholder committee members representing diverse areas and interests, a dialogue was opened about what a project like this would look like today in terms of the engineering feasibility, costs, legislative issues, political acceptability and environmental constraints. The stakeholder committee provided input on components of the study and identified issues that would require more attention.

Some of the positive outcomes of the study voiced by the committee members included the opportunity to learn about other parts of the state and getting local perspectives on the project concepts, getting started on a process to find a long-term solution to diminishing water resources in Kansas and preparing for future regional planning processes with other states.

The study update also shed light on negative aspects of the project, particularly the potential future impacts to landowners in the areas of the reservoirs and aqueduct route. Some felt that the study update did not go far enough to identify the willingness of consumers to pay for the water that would be delivered by such a system, nor did it address the cost to the state economy to not do the project. Others felt that the study did not go far enough to provide a path forward.

Many topics were identified as needing further study in the future including a more indepth look at the cost and willingness to pay by future users, the costs of the end user distribution network, the issue of tribal reserved water rights and economic impacts to landowners and localities if such a project were ever constructed. Much, but not all, of the committee voiced the need to explore the ability to access the Missouri River as the first necessary step. Working through the apportionment process with other Missouri River states and ensuring Kansas laws will allow such a water transfer are areas that will definitely need further exploration.

Update of 1982 Six State High Plains Aquifer Study

Chapter 1: Water Demand

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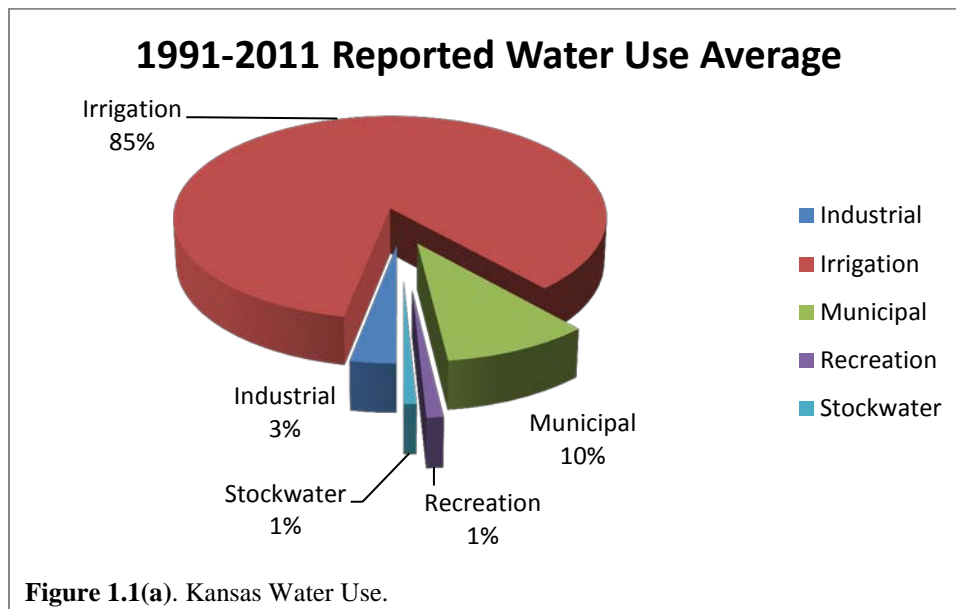
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1.1 Introduction to Water Demand

The 1982 Study estimated demand for water to replace High Plains aquifer irrigation as estimated in 1977. The six states that lie wholly or partly over the High Plains aquifer is an important U.S. agricultural area with an estimated 90 million acres of irrigable land in 1982. Deterioration of the agricultural based economy was believed to have grave consequences for business and financial communities outside as well as within the region.

Although the 1982 Study did not look at demands other than irrigation, it was important in this update to do so. Therefore, municipal needs have also been considered. In many cases municipal use includes industrial as it is supplied through a city or rural water districts. However it does not include industrial use that has individual water appropriations, the largest generally energy related. Figure 1.1(a) shows how water has been used within Kansas in recent years.



1.2 Summary of 1982 Ogallala Water Transfer Demand

The 1982 Study provided costs on a range of flows to restore and maintain the maximum amount of irrigated lands projected to go out of production between 1977 and 2020 into the High Plains region from adjacent areas. The quantities required were generated by the states and provided to the U.S. Army Corps of Engineers (Corps) by the general contractor. The annual Kansas requirement was 862,000 acre feet (AF) of a total of 4,056,000 AF for the six states. The transfer alternative being updated in the present effort was Route B through Kansas in the original study.

1.3 Irrigation Demand

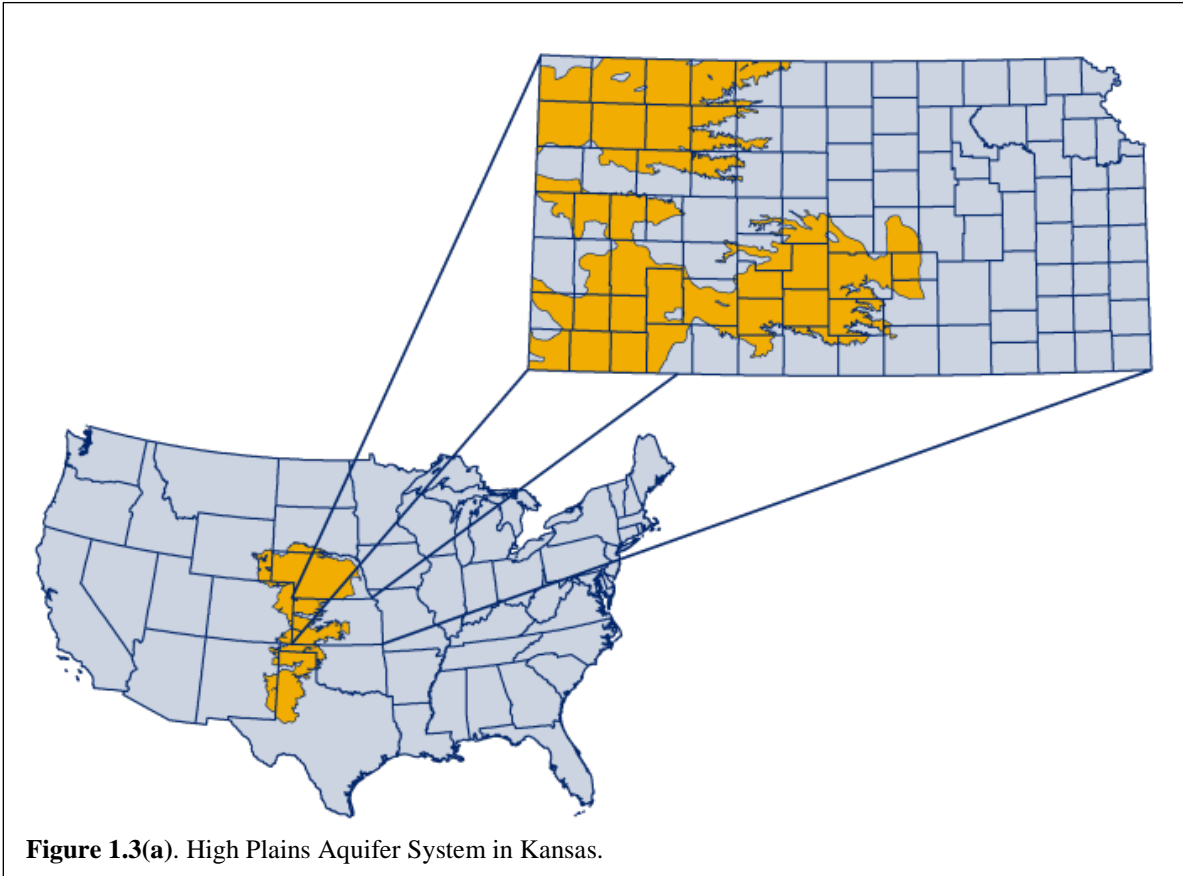
Irrigation is the largest water use in Kansas, accounting for an average of 85% of reported water use between 1991 and 2011. Approximately three million acres in Kansas are used for irrigated agriculture. Irrigation is most prevalent in western Kansas where average rainfall is less than 20 inches per year. Groundwater supplies more than 90% of irrigation water use in Kansas. The majority of groundwater used for irrigation comes from the Ogallala portion of the High Plains aquifer.¹

For this study update, current reported water use for irrigation in the areas overlying the Ogallala - High Plains aquifer was summarized and projections were made to determine how much water is needed to sustain current levels as the aquifer continues to be depleted. Irrigation demands in the counties adjacent to the 1982 aqueduct route were also evaluated, recognizing that demands may increase in these counties if a supplemental water source is made available. Additionally, farm acreage in counties adjacent to the 1982 route was evaluated for potential conversion from dry land farming to irrigated farming.

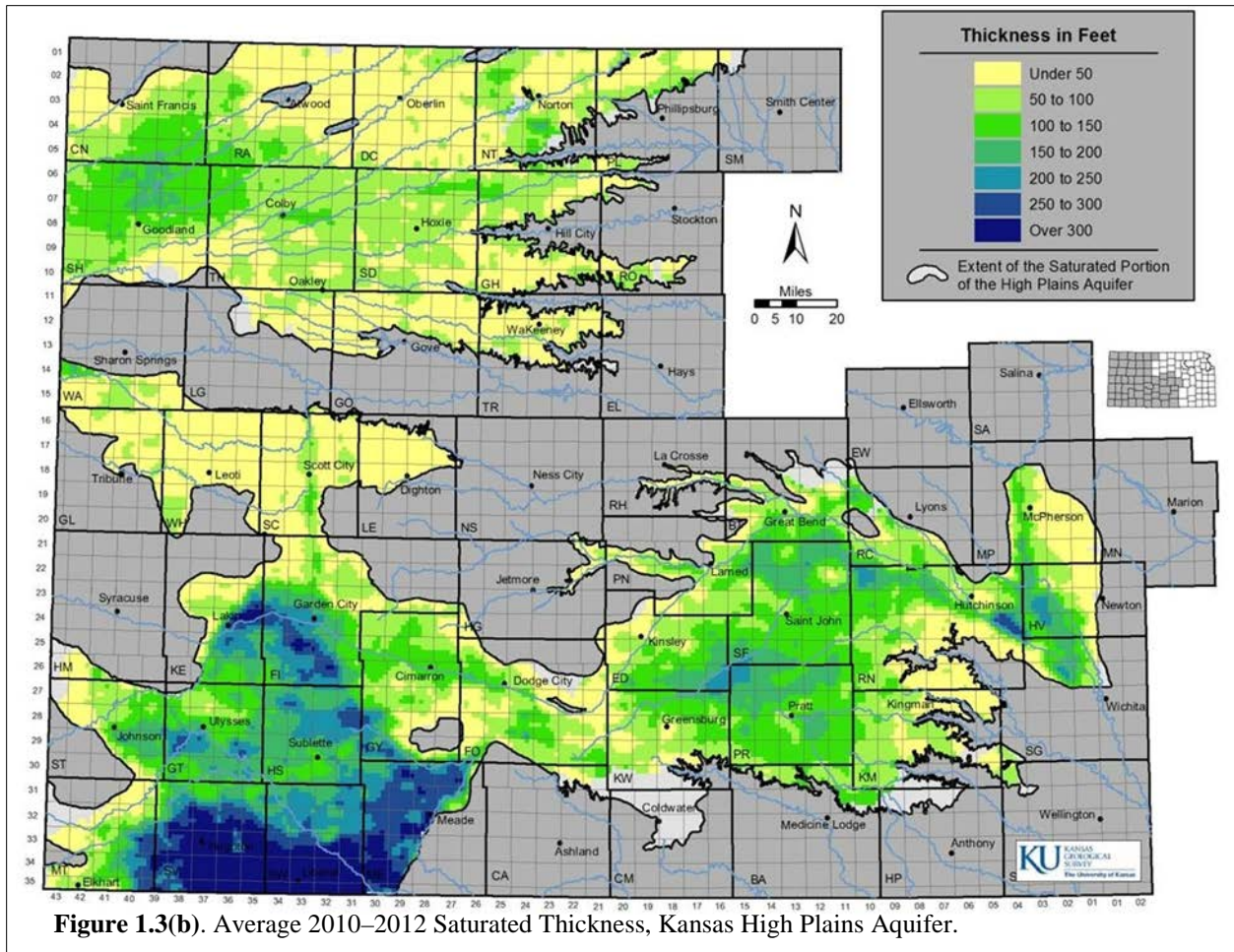
1.3.1 Irrigation in the High Plains Aquifer Region

The High Plains aquifer is a regional aquifer system which lies beneath parts of eight states in the Great Plains, including approximately 30,500 square miles of western and central Kansas.

The High Plains aquifer Figure 1.3(a), consists of several smaller sub-regional aquifers including the Ogallala formation in western Kansas and shallower and geologically younger Great Bend Prairie and Equus Beds aquifers in south central Kansas. The Ogallala formation and associated younger deposits is the primary source of water in western Kansas, with irrigation being the primary use.



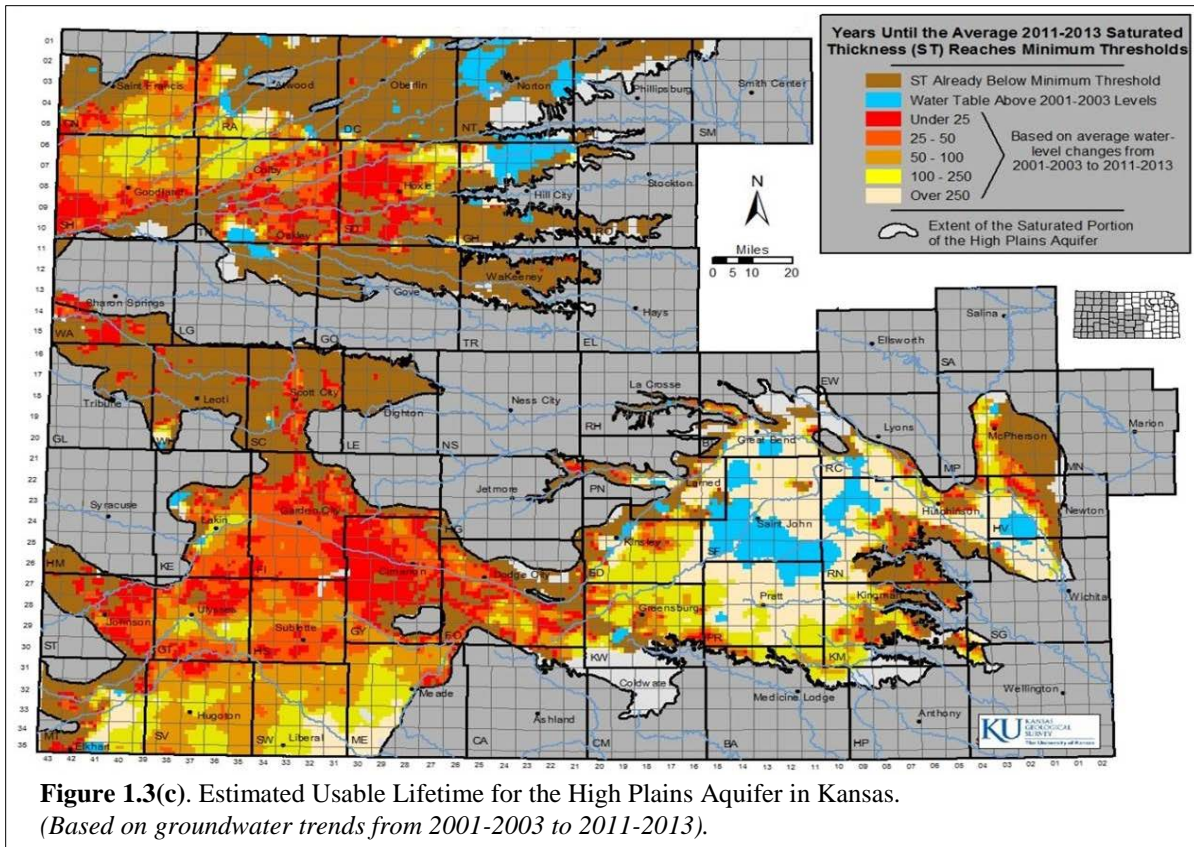
One measure of the amount of groundwater available in the aquifer is saturated thickness, the distance from the water table to the base of the aquifer. The saturated thickness of the aquifer has been studied fairly extensively. The Kansas Geological Survey (KGS) utilizes groundwater well monitoring data to make projections about the aquifer based on past trends in water level declines. The saturated thickness in the aquifer varies greatly across the state. In general, the thickest groundwater deposits are found in southwestern Kansas.



1.3.2 Estimated Usable Life of the High Plains Aquifer

KGS developed a methodology for estimating the usable lifetime of the aquifer based on the relationship between saturated thickness of the aquifer and well yields. The method estimates how many years it would take to reach the point that the saturated thickness of the aquifer is too low to sustain a 400 gallon per minute (gpm) well, the approximate flow required to operate a low-pressure sprinkler irrigation system.²

Figure 1.3(b) illustrates the variability of saturated thickness in the aquifer. Figure 1.3(c) illustrates the estimated time the aquifer would support a 400 gpm well. Areas in brown are already below the 400 gpm threshold while areas in blue have experienced an increasing trend. Areas in red, orange and yellow are the areas projected to decline to levels unable to support 400 gpm over the next hundred years or less if current pumping rates continue. The estimated usable lifetime dataset combined with an estimate of current irrigation water use, provides a tool to quantify irrigation demands in the High Plains over time.



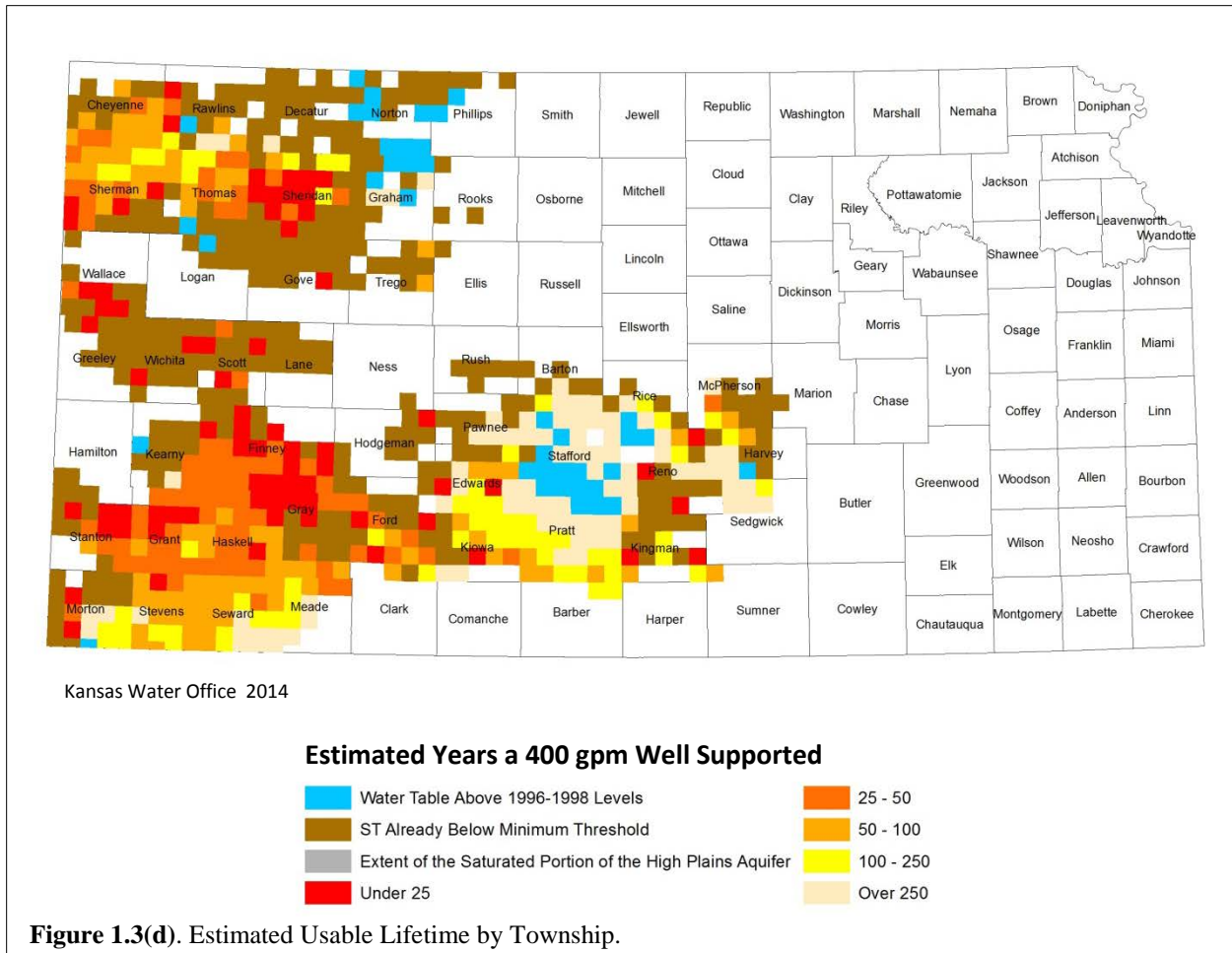
1.3.3 Current Irrigation Levels in the High Plains Aquifer

In Kansas, the administration of water rights and regulation of water use are the responsibility of the Kansas Department of Agriculture, Division of Water Resources (DWR). Water right owners are required to report annually on the amount of groundwater diverted and the total number of acres irrigated. The reported water use data are available from the Water Information Management and Analysis System (WIMAS), which is publically accessible online.³

Reported irrigation water use for the years 2007-2012 was obtained from WIMAS for the townships that overlie the aquifer. These years represent the most recent years for which complete water use data is available and they span both wet and dry years. The total quantity reported in acre feet (AF) for each township was summed and averaged for each of the five years.

While the annual water use report includes a reporting of the quantity of acres irrigated for that year, the report does not designate the particular acres irrigated. In addition, Kansas' system of water rights allow for overlapping places of use and points of diversion between water rights. Township averages cannot account for the complexity of reported water use data but are an appropriate estimation for this level of large-scale demand analysis.

The estimated usable lifetime map was aggregated by township in Figure 1.3(d). The process of aggregation results in some loss in resolution of the data since each township is assigned a single value for time to deplete.



By using the five year average water use and projecting that out over 100 years against the time to deplete, the approximate amount of water needed to replace current irrigation levels is derived.

Table 1.3(a). Quantity of Water Needed to Replace Current Irrigation Demand Over Time	
Years	Irrigation Demand in acre feet (AF)
5	354,420
10	528,731
25	1,000,433
50	1,862,620
100	2,657,808

In one respect, this methodology may over predict irrigation demand to some extent because it assumes that irrigation ceases once the 400 gpm threshold is met. The reality is that irrigation continues in areas that are already below the threshold today. When wells can no longer sustain rates to fully irrigate, limited irrigation continues. Irrigators make changes to their operations such as using different crop varieties and rotations or decreasing plant density. In another respect, the estimate under predicts demand because it assumes that current irrigation levels would remain steady. If additional supply is made available to areas that are no longer able to sustain full irrigation, demand could be higher than present day in those areas.

1.3.4 Additional Demand along Aqueduct Corridor

Although the areas overlying the High Plains aquifer account for the majority of irrigated lands in Kansas, other portions of the state may experience increasing demand if new supply becomes available, particularly in the areas near the water transfer system.

Potential demand along the water transfer system was evaluated by comparing the amount of current irrigation water use to the net irrigation requirements in each county adjacent to the 1982 route. Net irrigation requirement (NIR) values are the water needs for a specified crop over and above effective rainfall and carryover soil moisture. NIR values for Kansas were developed by what is now the Natural Resource Conservation Service in consultation with Kansas State University through its experiment stations.⁴ Values are calculated for each county for both the 50% and 80% chance rainfall. Kansas statutes related to authorized quantities for water rights are based on the NIR for the 50% chance rainfall for corn.

The NIR values for the 50% chance rainfall were used to calculate the number of acre feet required to grow corn on currently irrigated lands in those counties along the route. That amount was compared to 2007-2012 irrigation water use to determine the deficit between NIR and current rates. Some counties along the route are already using water to the extent needed to meet NIR for the acres in irrigation. Table 1.3(b) summarizes the counties that had deficits between their current water use and the NIR application rate, indicating a potential new demand should additional supply be available.

Table 1.3(b). Deficit Between NIR Application Rate and Current Irrigation Water Use in Acre Feet (AF)	
County	Quantity
Barton	5,430
Brown	857
Dickinson	3,175
Doniphan	47
Ellis	2,431
Ellsworth	1,203
Geary	1,640
Jackson	747
Marion	3,808
McPherson	4,562
Morris	1,246
Nemaha	245
Ness	2,021
Pottawatomie	1,355
Rice	4,460
Rush	1,323
Riley	405
Russell	145
Saline	848
Trego	4,552
Wabaunsee	1,226
Total	41,726

If additional supply becomes available in areas along the water transfer system, counties may experience a shift from dry land to irrigated farm acreage. To evaluate potential demand resulting from this shift, county-level data were obtained

from the National Agricultural Statistics Service to determine how many acres are currently in dry land farms.⁵ Net irrigation requirements were applied to the acreage to calculate quantities for each county.

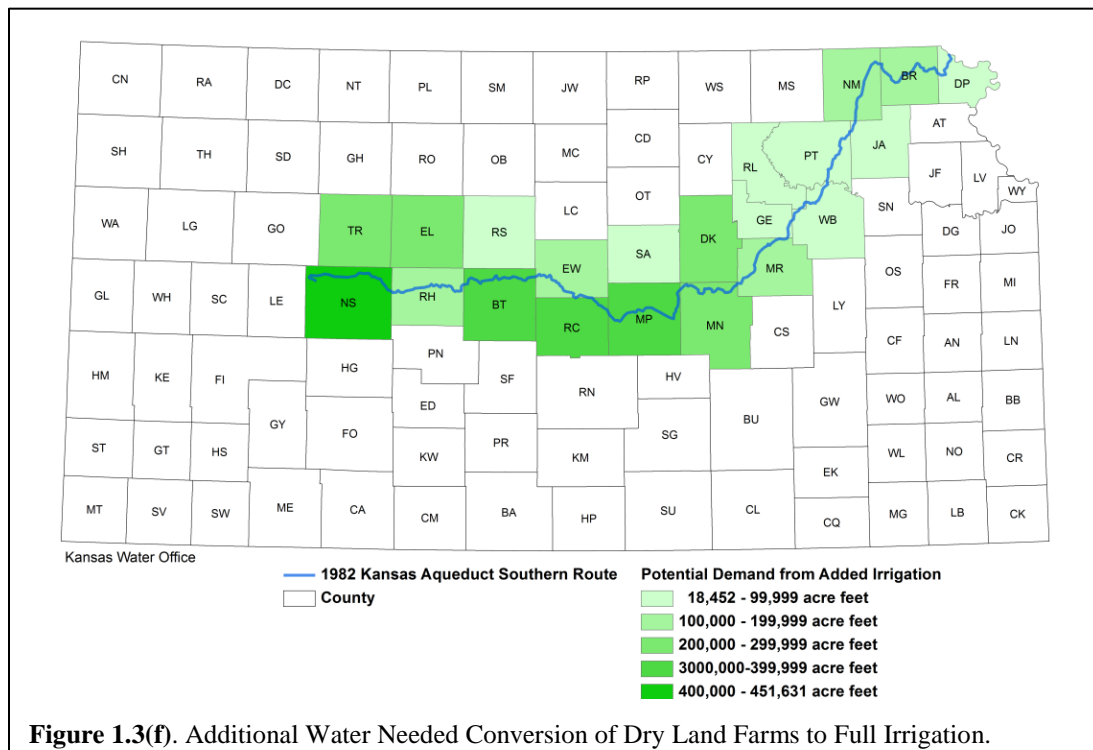
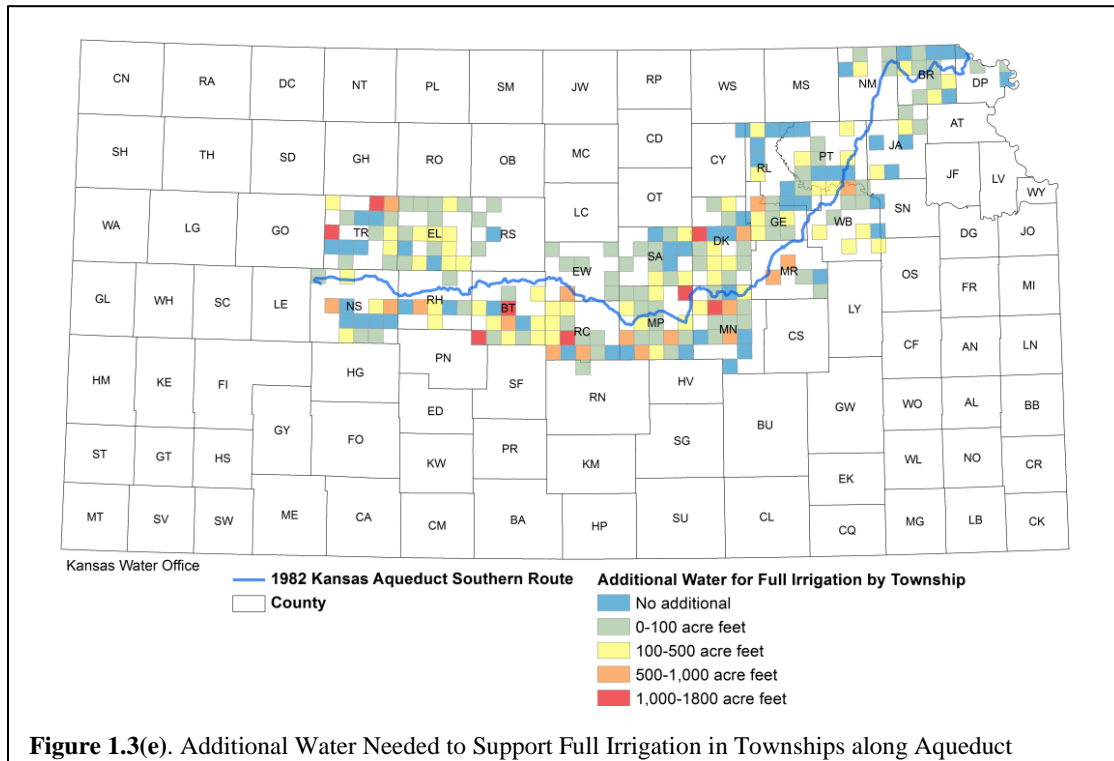


Table 1.3(c). NIR Applied to Land Currently in Dry Land Farms in Acre Feet (AF).	
County	Quantity
Barton	382,122
Brown	134,530
Dickinson	259,349
Doniphan	80,689
Ellis	255,779
Ellsworth	174,560
Geary	37,976
Jackson	83,442
Marion	269,600
McPherson	330,175
Morris	108,685
Nemaha	167,756
Ness	451,631
Pottawatomie	96,569
Rice	318,483
Rush	67,474
Riley	133,695
Russell	84,330
Saline	18,452
Trego	270,908
Wabaunsee	65,397
Total	3,791,603

1.3.5 Summary of Irrigation Demand

Demand for additional supply in areas that are currently irrigated over the High Plains aquifer would increase over time as the aquifer is depleted. If trends in water level declines continue, in the next 25 years over one million acre feet of additional water would be needed to sustain current levels of irrigation. That amount increases to approximately 2.7 million acre feet (MAF) over the next 100 years.

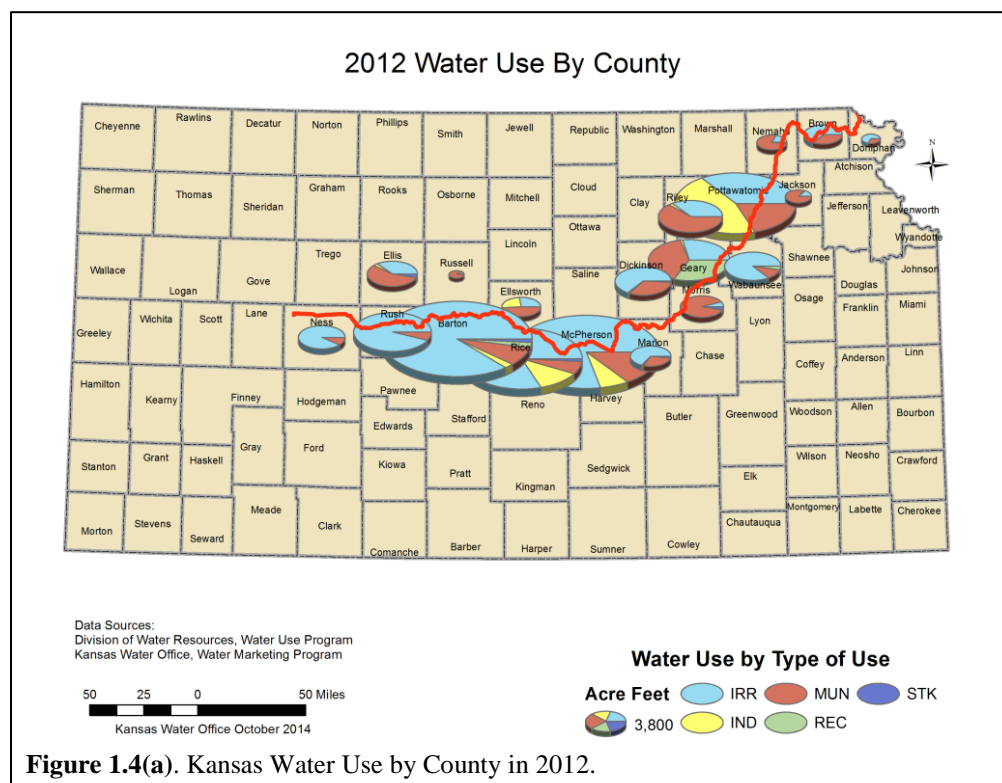
As water is transferred across the state, additional irrigation demand may increase in counties along the way. Over 40,000 AF is needed to supply the deficit between current water use and net irrigation requirements for the currently irrigated acres in counties along the route. In order to convert dry land farms to irrigated corn in those counties, an additional 3.8 MAF is needed.

Based on current trends and available data for areas overlying the High Plains aquifer and those areas adjacent to the aqueduct, the total potential irrigation demand ranges between 4.2 and 6.5 MAF. Future irrigation demand in Kansas would ultimately be determined by a variety of factors including market trends, energy prices, climate and the return on investment to irrigate.

1.4 Municipal Demand

Municipal or public water supply, water use is the second largest water use in Kansas, accounting for an average of 9.9% of reported water use between 2008 and 2012. In eastern Kansas, the primary source of water is surface water; in western

Kansas, the primary source is groundwater. In general, the percentage of municipal use increases from west to east across the aqueduct route being evaluated. (Figure 1.4(a)).



An important metric to measure and compare municipal water use by PWS systems is the amount of water used per person per day, called gallons per capita per day (GPCD). Average GPCD is calculated for eight regions that are composed of tiers of counties which correspond to general patterns of precipitation and per capita use. Average GPCD is also determined for different sizes of public water suppliers in the eastern half of the state so that individual systems can be compared to the average used by systems of similar size and geography. In 2012, the average GPCD by region ranged from a high of 316 in the western most counties to a low of 81 for small PWS systems in eastern Kansas. The five year average ranges from 272 to 80 GPCD.⁶

1.4.1 Estimation of Demand

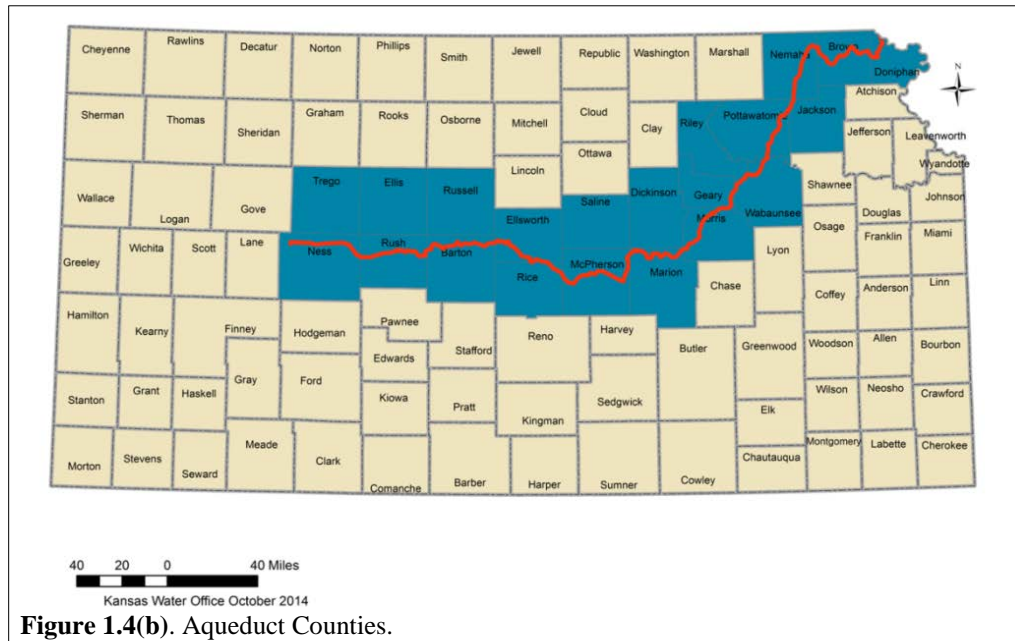
For this study update, municipal demand was evaluated for three different groups of municipal users: 1) the 21 counties along the aqueduct route; 2) the counties along the I-135 corridor in south central Kansas and 3) counties that experienced significant drought issues from 2011-2014.

For each group of counties, a current (2010) demand was determined and a projected future demand was estimated. Current demand utilized actual municipal reported water use summarized by county as available through the Kansas Department of Agriculture, Division of Water Resources (DWR), Water Information Management and Analysis System (WIMAS).

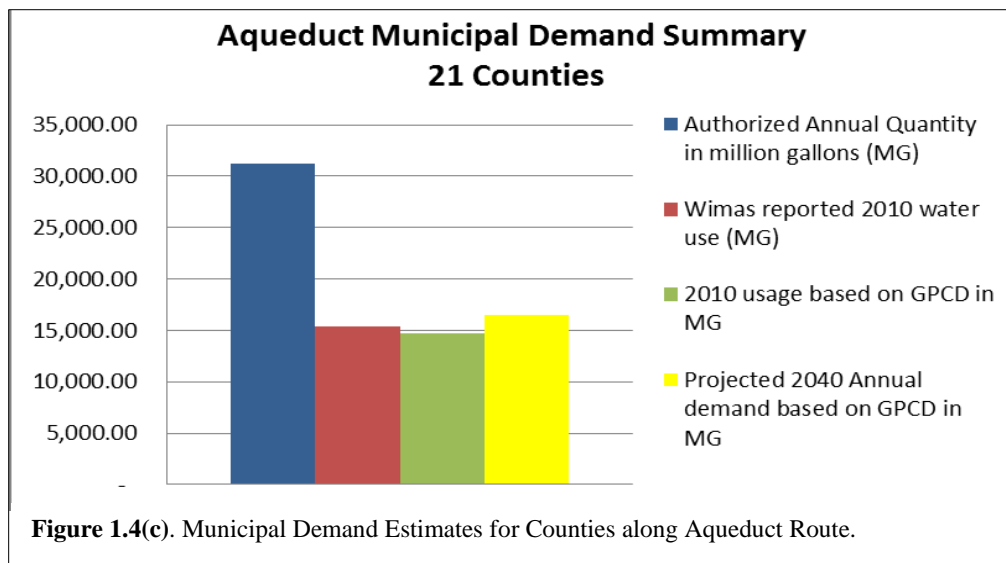
Population and per capita usage is utilized to estimate future demand. To verify the approach, 2010 census population data for the counties in each of the three groups was collected and compared with an averaged GPCD.⁶ This compared very favorably with actual reported use for those counties. Future demand was then estimated using the GPCD and populations projected for 2040 by Wichita State University.⁷

1.4.2 Demand along Aqueduct Corridor

The annual quantity authorized for municipal use in the counties along the proposed aqueduct route totals 31,185 million gallons (MG). The reported 2010 use for the 21 counties (Figure 1.4(b)) along the aqueduct route was 15,413 MG for the year, 49% of the authorized annual quantity. Estimated usage based on regional GPCD and population was 14,678 MG.



Projected demand for 2040 totals 16,480 MG. As can be seen in the Figure 1.4(c), this is still significantly less than the authorized quantity, though authorized quantity does not necessarily reflect water availability.



Population for these 21 counties in 2040 is projected to increase by about 4% from 2010 population. Individual counties varied from decreases in population of 49% to increases of 50%. Demand for the individual counties only exceeded authorized quantity in Doniphan County; however this county only has 232 MG authorized for municipal use, a very small percentage of total use in the corridor. The Doniphan County projection estimated 10.1 MG per year additional water would be needed in 2040. The entire group has a total authorized quantity exceeding 2040 demand by 14,705 MG

per year. Reported 2010 water use for the 21 counties is slightly below the projected 2040 annual demand of 16,480 MG. Projections indicate Barton, Dickinson, Doniphan, Ellis, Ellsworth, Geary, Jackson, Marion, Morris, Riley and Wabaunsee counties' annual demand in 2040 would exceed 2010 reported use. The remaining ten counties are projected to use less water than in 2010 (Figure 1.4(d)).

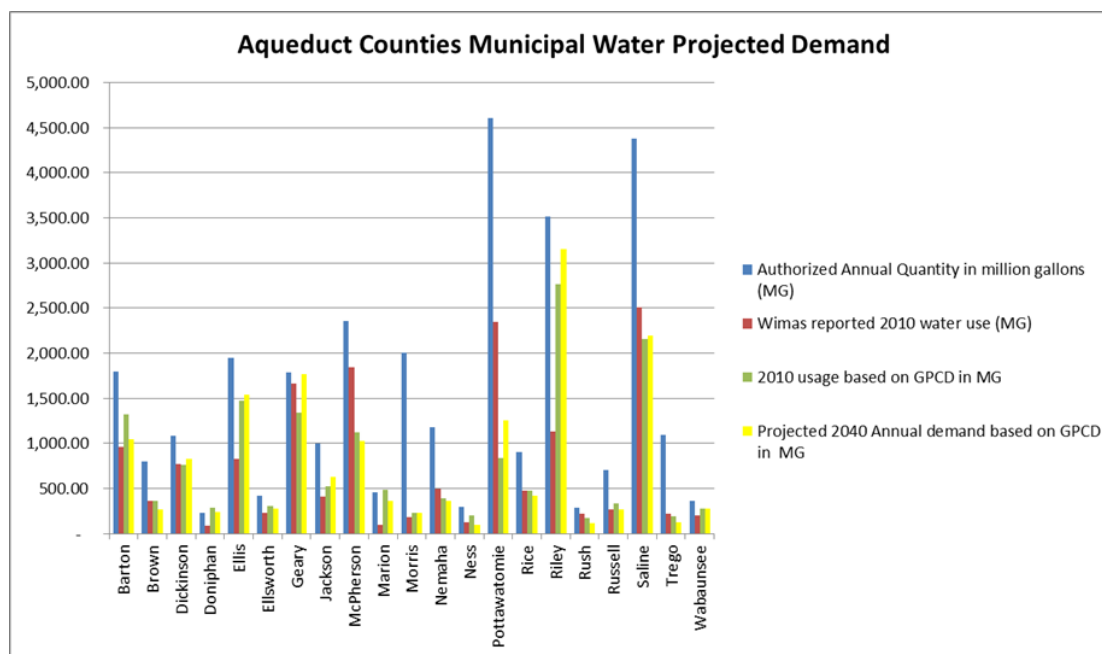
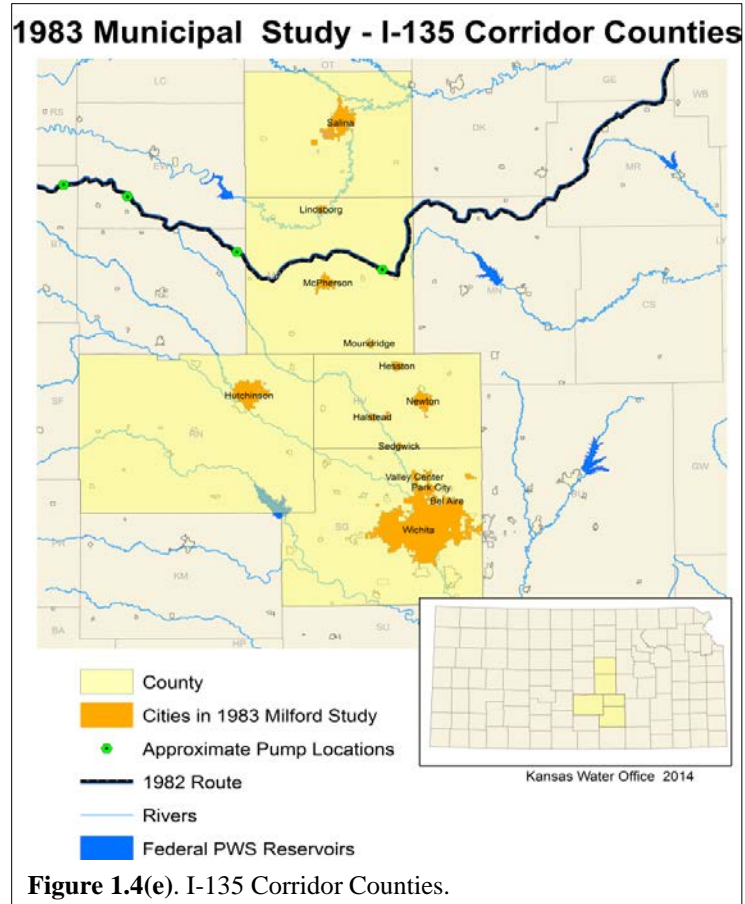


Figure 1.4(d). Municipal Demand Estimates Aqueduct Counties – Method Comparison.

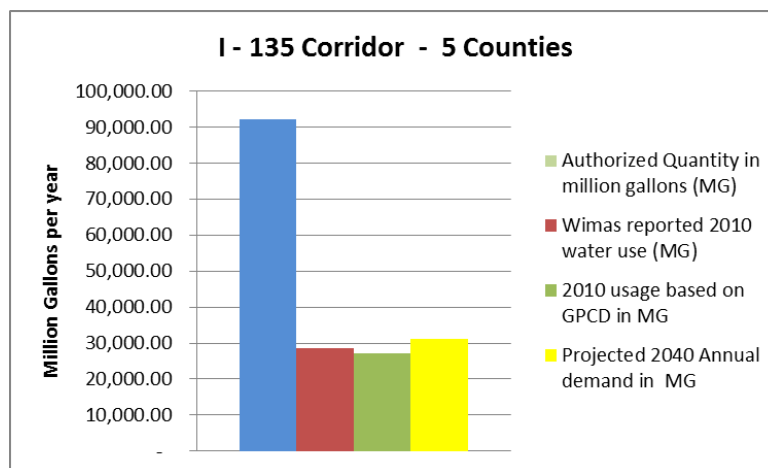
1.4.3 Demand in I-135 Corridor

The counties along Interstate-135 from Salina to Wichita contain major population centers in south central Kansas, including Hutchinson, Lindsborg, McPherson, Newton, Salina and Wichita. Many of these communities supply water to other communities and rural water districts, while others in the area continue to have their own sources of supply, including Bel Aire, Halstead, Hesston, Mound Ridge, Park City, Sedgwick and Valley Center. This area represents a population of 677,511. As early as 1982, this area was looking at the possibility of cooperating on a project to transport water into the region from Milford Reservoir. Though that project did not proceed, the area is one of significant economic importance. This area was evaluated to determine what kind of demand may be exerted if an aqueduct project could be designed to drop off or pipe water to this area.

The five counties evaluated for this area are shown in Figure 1.4(e). The reported use for the counties in 2010 was 28,515 MG for the year, only 35% of the authorized annual quantity of 92,080 MG. Estimated 2010 usage based on regional GPCD was just slightly less at 27,042 MG (Figure 1.4(f)).



Projected demands for Harvey, McPherson, Reno, Saline and Sedgwick counties totaled 31,256 MG for 2040, slightly more than estimated GPCD 2010 usage but slightly less than actual reported water use in 2010 (Figure 1.4(g)). Sedgwick County's demand for 2040 exceeds reported 2010 use while the other four counties 2040 demand is less than 2010 reported use.



1.4.4 Demand Related to Drought

Communities in central Kansas that obtain water from local alluvial aquifers had wells with major declines and little or no recharge during the recent drought (2011-2014). Communities that enacted emergency conservation stages include Ellis, Hays, McCracken, Trego County Rural Water No. 2 and Victoria (Figure 1.4(g)). An analysis was made to determine demand that may be exerted if an aqueduct was able to deliver water.

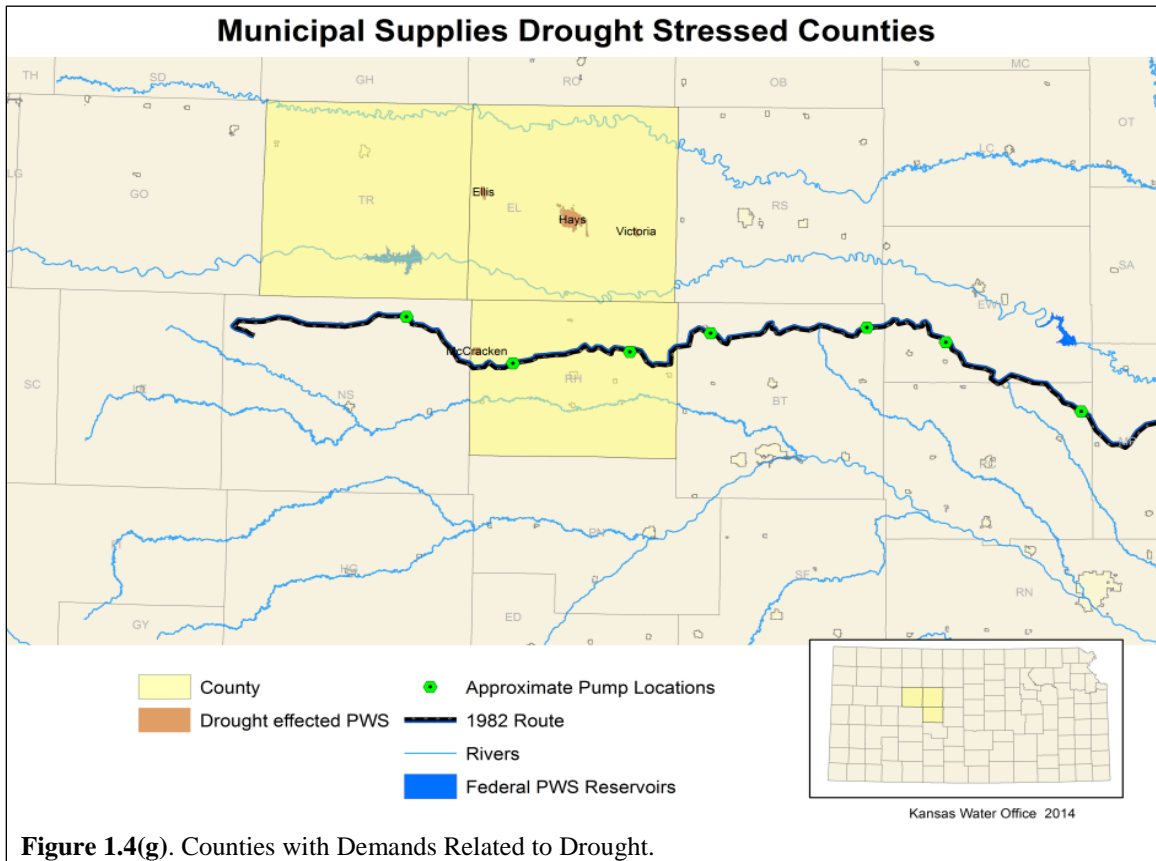


Figure 1.4(g). Counties with Demands Related to Drought.

The annual quantity authorized for municipal use in Ellis, Rush and Trego counties totals 3,331MG. Reported 2010 water use was 1,270 MG. Estimated usage based on GPCD was 1,834 MG. Projected demand in 2040 totals 1,777 MG, less than estimated usage but an increase from 2010 reported use (Figure 1.4(h)). The total, as well as all three counties individually, have sufficient water appropriations to meet estimated 2040 demand, but as demonstrated by the recent drought, actually obtaining that water can be problematic. Only Ellis County municipal supplies are estimated to need additional water in 2040.

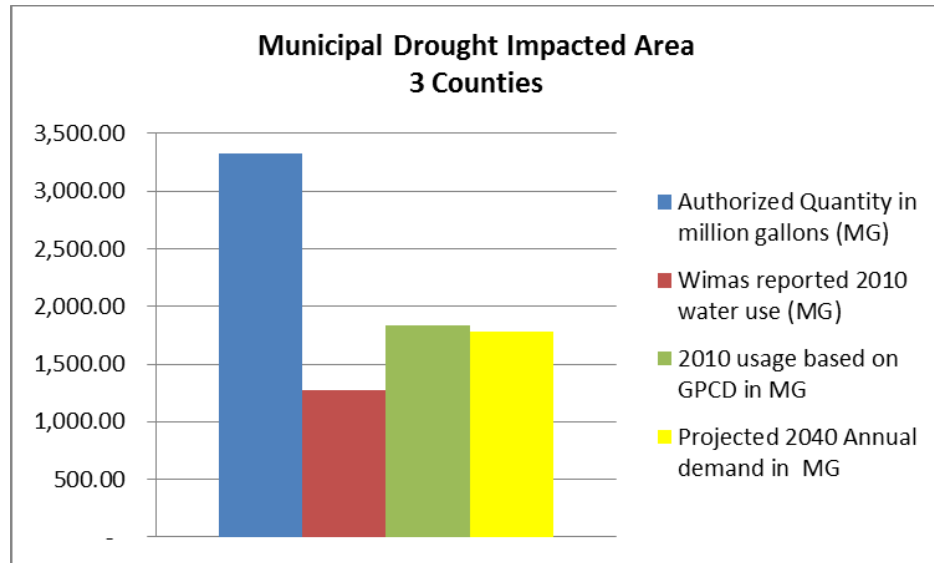


Figure 1.4(h). Drought Impacted Counties Municipal Water Use.

1.4.5 Total Demand for Identified Counties

A summary of information for all counties analyzed shown in Table 1.4(a). Even with all three areas added together, the total of 44,513 MG is barely 137,000 AF, compared to the projected demand for irrigation of 2.7-6.5 MAF.

County	Authorized Annual Quantity	Reported 2010 Water Use	2010 Usage Based on GPCD	Projected 2040 Annual Demand Based on GPCD
Barton	1,796.42	956.75	1,319.26	1,044.78
Brown	797.43	362.18	360.80	262.71
Dickinson	1,080.96	768.91	761.92	824.25
Doniphan	231.63	86.64	287.11	241.69
Ellis	1,944.31	823.36	1,473.73	1,536.20
Ellsworth	416.57	227.13	308.98	281.25
Geary	1,785.82	1,663.06	1,337.91	1,768.25
Harvey	22,692.71	5,280.17	1,336.38	1,539.14
Jackson	997.64	408.24	522.24	626.04
McPherson	2,352.76	1,843.73	1,121.23	1,028.97
Marion	454.08	100.71	487.17	363.73
Morris	2,001.32	178.35	227.53	226.05
Nemaha	1,178.06	496.38	390.39	366.31
Ness	292.16	126.67	197.89	100.80
Pottawatomie	4,609.53	2,344.17	838.12	1,253.57
Reno	4,537.48	3,327.24	3,073.84	2,797.21
Rice	902.29	477.57	480.02	417.63
Riley	3,514.23	1,128.07	2,764.20	3,155.23
Rush	289.96	224.68	169.48	113.82
Russell	699.52	267.55	331.19	268.33
Saline	4,377.48	2,507.34	2,154.00	2,194.64

Table 1.4(a)
County Municipal Use and Estimated Demands in Million Gallons (MG)

County	Authorized Annual Quantity	Reported 2010 Water Use	2010 Usage Based on GPCD	Projected 2040 Annual Demand Based on GPCD
Sedgwick	62,373.25	18,757.20	19,356.91	23,696.71
Trego	1,097.09	221.83	190.26	127.33
Wabaunsee	365.55	199.23	273.97	278.70
Total	120,788.25	42,777.17	39,764.53	44,513.33

1.4.6 Municipal Demand – Qualitative Considerations

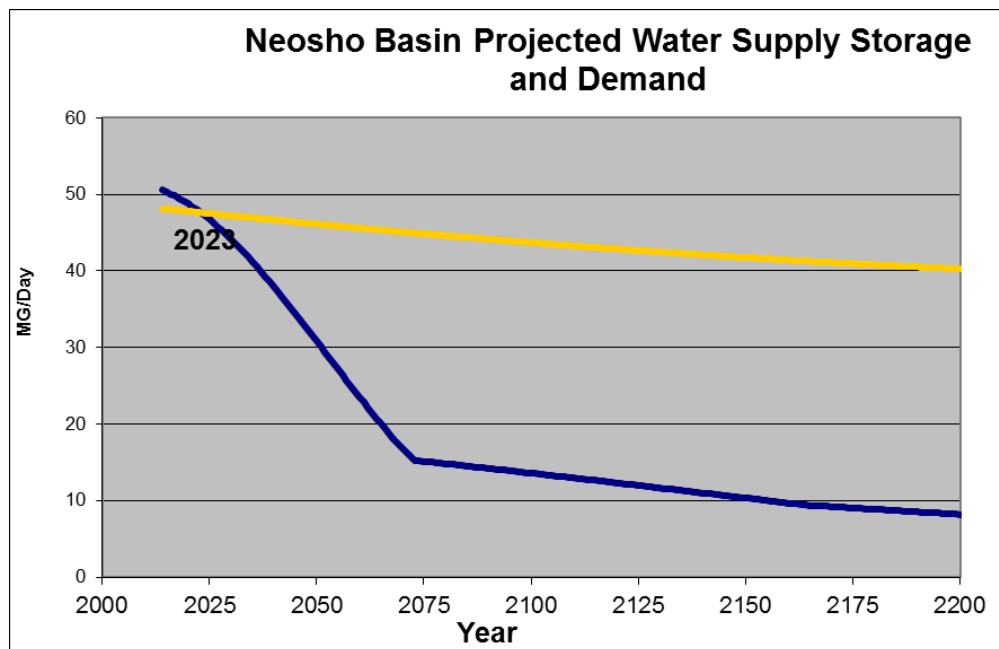
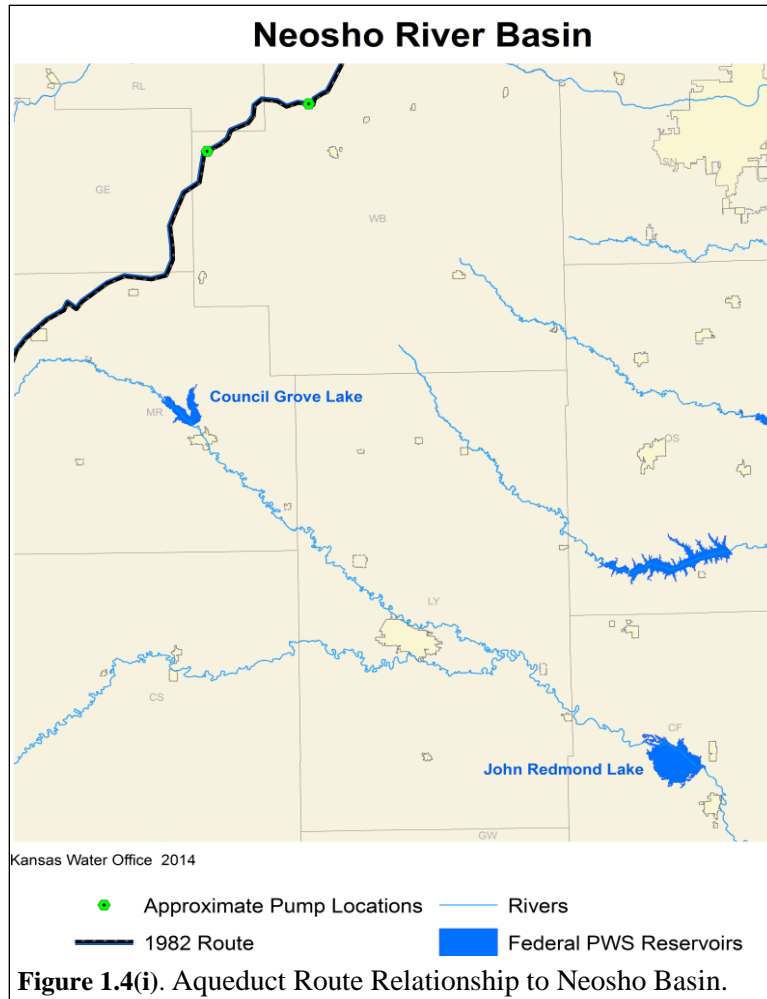
There are vast differences in treatment of ground and surface water to produce a potable water supply that meets Safe Drinking Water Act standards. More than half of the municipal demand analyzed in this section is currently supplied from groundwater. Surface water treatment would have to be developed. In addition, public water supply demand is a 24/7 demand; supply that could be delivered from an aqueduct would be intermittent, at best. The planning horizon on a project of this scale would be decades long and construction itself also decades long. Most of the large municipalities in the state that could benefit from an additional supply are currently in the planning process to meet their needs 50–60 years into the future.

1.4.7 Surface Water Basins

The aqueduct design as proposed in 1982 would run along ridge lines to take as much advantage as possible of gravity flow between pump stations. The proposed route opens the possibility of dropping off water into surface water basins that are anticipated to run short of supply in the future, especially the Neosho and the Kansas.

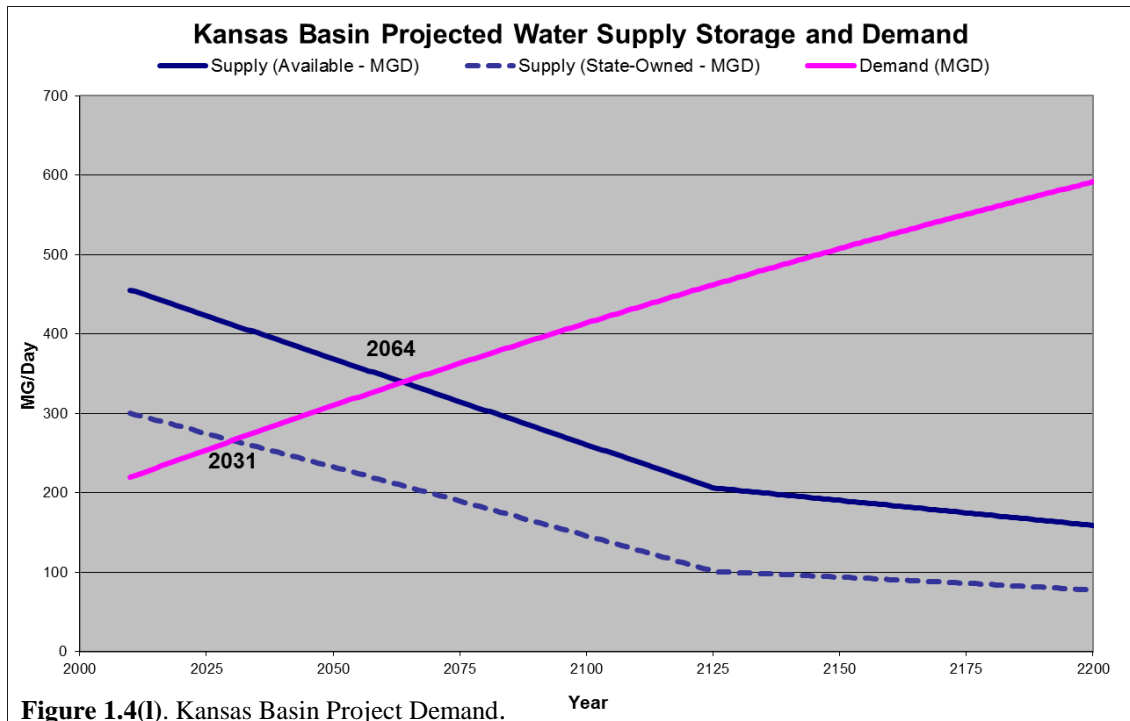
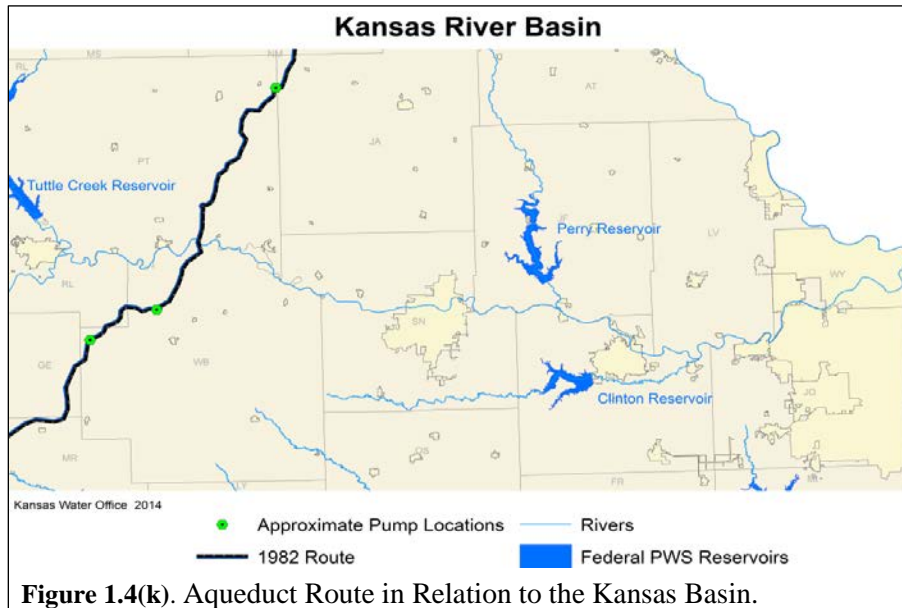
1.4.7.1 Neosho Basin

The 1982 aqueduct route follows the ridge adjacent to the upper end of the Neosho River (Figure 1.4(i)). This basin has faced much scrutiny since a 2006 analysis of supply and demand in eastern Kansas basins indicated that the Neosho basin could experience supply deficit during an extended drought as early as 2012. Focused efforts have pushed that time out to 2023 (Figure 1.4(k)).



1.4.7.2 Kansas Basin

The Kansas basin is the most populous of the 12 major river basins in the state. Surface water makes up almost 59% of the water used in the basin for all uses; 43% of the surface water in the basin is for municipal purposes. The aqueduct route offers two possibilities for supplementing supply in this basin. The aqueduct would cross the upper end of the Delaware River above Perry reservoir. In addition, the aqueduct crosses the Kansas River east of Manhattan (Figure 1.4(k)). Supply and demand estimates indicate this basin does not experience shortages until 2064 with all storage under contract being utilized (Figure 1.4(l)). Tuttle Creek Reservoir has lost almost 43% of storage to sedimentation.



1.4.8 Summary of Municipal Demand

While an important consideration, municipal demand is small in comparison to agricultural needs. When all counties evaluated are totaled, demand does not exceed existing water appropriations. It is recognized that reported water use less than authorized quantities may be due to lack of need or inability to access the groundwater source. Projected 2040 demand is only 37% of authorized annual quantity and less than 2,000 AF more than reported used in 2010.

Other interests for water that may be met with dropping off water along the way, has not been further evaluated.

1.5 Summary of Findings

An update of demand assumed replacement of current irrigation levels once 400 gallons per minute could not be supported. Full replacement would require over 1.8 million acre feet (MAF) in 50 years and over 2.6 MAF in 100 years. Adding potential demand for irrigation along the route would increase to a total for irrigation ranging from 4.2-6.5 MAF. Municipal demand along the route for the areas with known drought concerns adds only another 0.1 MAF of demand. Consideration is given in the study to the possibility of supplementing reservoir storage in surface water basins along the route that are expected to have shortages in the next 50 years; however this amount has not yet been quantified.

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- ¹ Kenny, J.F., and Juracek, K.E. 2013. *Irrigation trends in Kansas, 1991–2011*. U.S. Geological Survey Fact Sheet 2013–3094. 4 p. <http://pubs.usgs.gov/fs/2013/3094/>.
 - ² Water Information Management and Analysis System (WIMAS) for the Web. <http://hercules.kgs.ku.edu/geohydro/wimas/index.cfm>.
 - ³ Wilson, B.B., Young, D.P., and Buddemeier, R.W. 2002. *Exploring Relationships between Water Table Elevations, Reported Water Use, and Aquifer Lifetime as Parameters for Consideration in Aquifer Subunit Delineations*, 19. http://www.kgs.ku.edu/HighPlains/OHP/2002_25D.pdf.
 - ⁴ USDA Natural Resource Conservation Service. 2007. *National Engineering Handbook Part 652 Irrigation Guide: KS652.048 State Supplement – Water Requirements*. 1-2.
 - ⁵ National Agricultural Statistics Service. 2012. *Census of Agriculture County Data: Table 1. County Summary Highlights: 2012*.
 - ⁶ Kansas Department of Agriculture and U.S. Geological Survey. 2011. *Kansas Municipal Water Use 2011*.
 - ⁷ Wichita State University. 2012. *County Population Forecast: 2010 to 2040*. <http://webs.wichita.edu/depttools/depttoolsmemberfiles/wsunews/Population%20forecast.pdf>.

Update of 1982 Six State High Plains Aquifer Study

Chapter 2: Water Availability

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Under the U.S. Army Corps of Engineers (Corps) 1982 Reconnaissance Study, quantification of water availability was simplified through assumptions. Availability would occur when Missouri River flows exceeded the baseflow established for navigation, i.e. “Withdrawals from the Missouri River would not be taken when the streamflow was equal to or less than an established navigation baseflow.” Storage of the diverted water would take place in a source reservoir 35 miles upstream of St Joseph, Missouri, and would then eventually undergo aqueduct transfer 360 miles westward to a terminal reservoir in western Kansas to support aquifer recharge, crop irrigation and other beneficial water uses.

The current study updates the water availability portion of the 1982 Study. Additional hydrologic data have been considered and the operation of the Missouri River mainstem projects for downstream needs has been incorporated. The study incorporates Missouri River flow data at Saint Joseph from 1898 through 2013.

The amount of water that could be available for transfer is dependent upon the diversion rate, the storage capacity of the reservoirs and the transfer rate of the aqueduct. This is discussed more fully in Chapter 3 Water Transfer System.

2.1 Summary of 1982 Study Water Availability

The 1982 Study utilized stream gage data through 1975, considering diversions of 10,000 cubic feet per second (cfs), 20,000 cfs and 30,000 cfs when flows exceeded that needed for navigation or winter flow targets. The annual available volume estimated for each diversion rate is provided in Table 2.1(a).

Table 2.1(a) 1982 Study Water Availabilities.			
Peak Missouri River Diversion Rate	1982 Average Annual Available Volume in Million Acre Feet (MAF)		
	1975	2000	2020
10,000 cfs	2.9	2.1	1.6
20,000 cfs	3.8	2.7	2.1
30,000 cfs	4.1	2.9	2.2

These diversion rates are based on the maximum pumping rates while flows above required levels are available. An analysis of delivery system reliability and drought operations was not provided in the 1982 Study is now included in this update.

The study also determined that the ability to meet demands did not rest solely on water availability and pumping rates, but that terminal storage and canal capacity would also affect the ability to meet demands.

2.2 Methodology and Approach

Rather than determining specific constraints for the size of aqueduct components, an interactive program (model) was developed by the Corps to provide different water availability amounts based on user determined assumptions. The goal was to maintain a maximum amount of flexibility to create a useful tool for analysis.

2.2.1 Water Availability Constraints

The Missouri River extends 2,341 miles from Three Forks, Montana, to the confluence with the Mississippi River in Saint Louis. The River includes water draining from portions of ten U.S. States and two Canadian provinces. The Missouri River basin has been extensively developed for irrigation, flood control and the generation of hydroelectric power.

The Corps has constructed and operates six dams (Fort Peck, Garrison, Oahe, Big Bend, Fort Randall and Gavins Point) on the Missouri River mainstem that are operated for multiple beneficial purposes. The purposes include benefits from the

lakes themselves and downstream uses. The operation of the dams for these purposes alters the natural flow of the Missouri River near Saint Joseph.

One of the purposes for the mainstem dams is support of downstream Missouri River navigation. Navigation support requires minimum Missouri River flow rates during the navigation support season. The season typically extends from the beginning of April until the beginning of December each year. Full navigation support at the Kansas City gage (82 miles downstream of Saint Joseph) requires 41,000 cubic feet per second (cfs). Saint Joseph does not have a specific navigation flow requirement.

During the non-navigation support season, the mainstem projects support downstream water supply intake structures. Minimum flows for these diversions are maintained to insure that downstream users are able to remove water for municipal and industrial purposes. Generally a minimum flow of 15,000 cfs is required to insure sufficient stage for the user's' intake structures. More water may be required during Missouri River icing conditions.

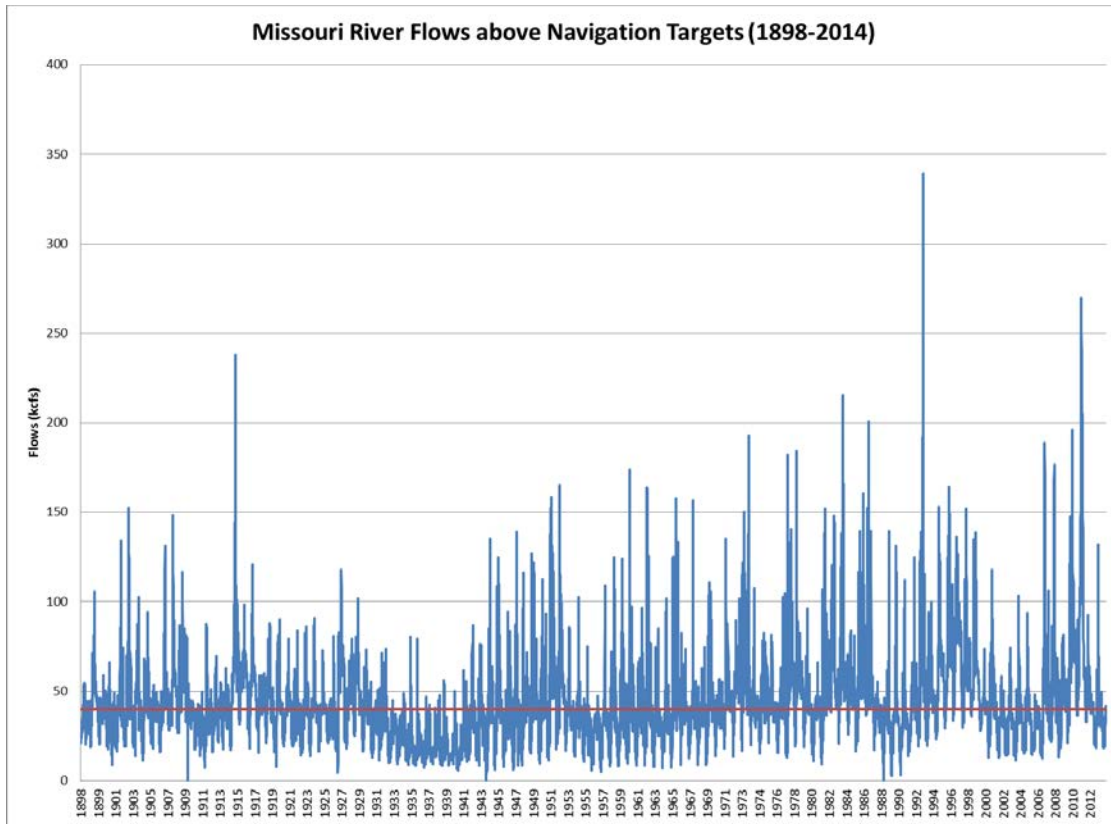
Navigation target flows provide the authorized, navigable channel depth during the navigation support season. However, the Missouri River Bank Stabilization and Navigation Project (BSNP), as a system, is very dependent on regular, periodic flows above those discharges in order to maintain the self-scouring characteristics of the channel. The Missouri River Operation and Maintenance (O&M) documents note several seasonal and flow events that occur where sustained flows above the navigation targets are needed to re-establish or maintain the channel through higher rates of sediment transport. These include recommendations for up to 10,000 cfs above the navigation targets when the water is available.

Taking water off of the channel at flood stage would probably not impact the channel function, but diverting water just above or even close to navigation flows would likely have a detrimental impact on channel reliability downstream. Further study would be needed to determine a more realistic cutoff somewhere between the navigation target flow and flood flow where "excess" flow would not impact the function of the BSNP.

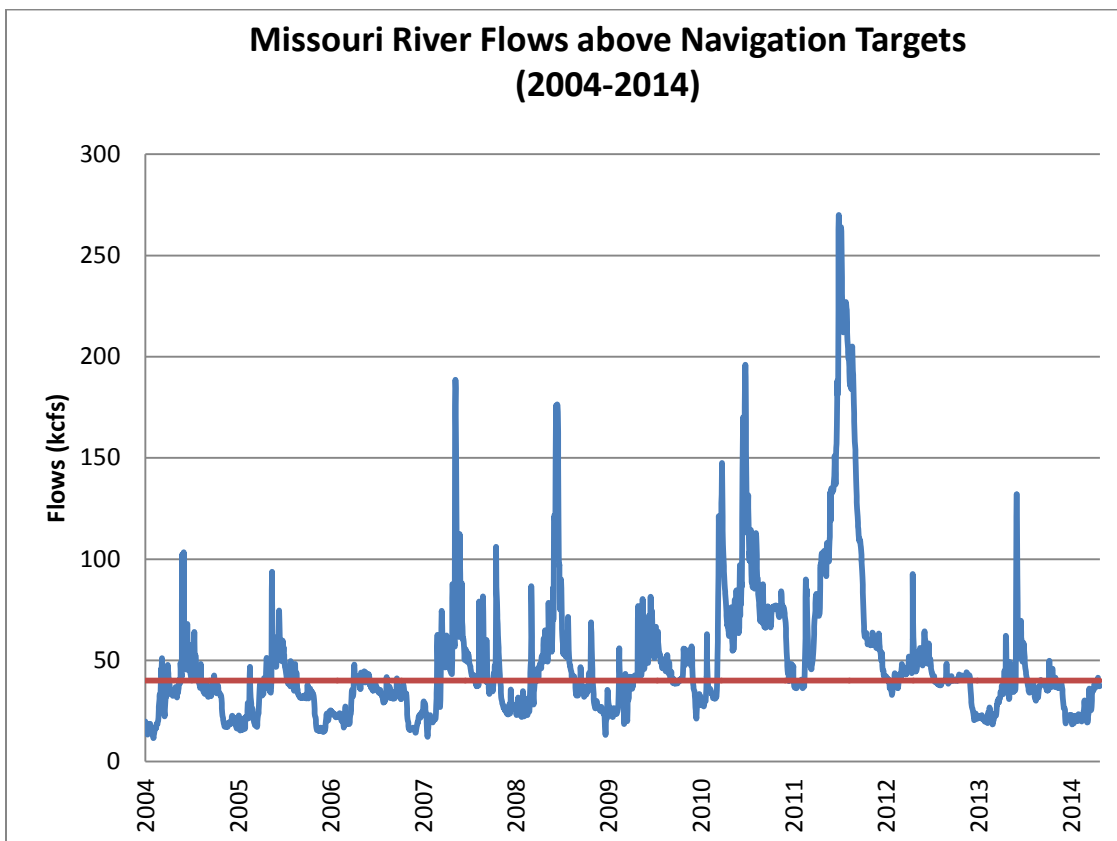
The River is open to navigation all year long. The navigation support season is eight months, but navigators would use the River whenever they have adequate flows -- even outside the navigation support season. Because of this, taking available flows below the navigation targets even outside of the navigation support season could interfere with navigation of the river. While these issues are important to consider, they are not factored into the current study update which uses the same assumptions as the 1982 Study to determine water availability.

2.2.2 Data Requirements

The Missouri River Basin Water Management (MRBWM) Division has determined Missouri River flows that result from the operation of the six lake projects. The flows were developed from hydrologic records that extend from 1898 to 2010. The flows have been adjusted to account for Missouri River dam operation and land use effects based on the 2010 conditions. The flows for the Saint Joseph gage has been obtained from the MRBWM and used in this study. The data has been updated through 2013 using the U.S. Geological Service data for Missouri River flows at Saint Joseph.



Figures 2.2 (a). Historical Flows.



Figures 2.2 (b). Recent Flow History.

2.3 Model Development

An Excel model was developed to assist planners with evaluating the effect of different components of a Kansas aqueduct to optimize the beneficial use of the available water. The model was developed in an interactive manner to provide user input of different criteria.

2.3.1 Model Input

The Missouri River water availability depends on the capacity of: the diversion structure, the source reservoir and the transfer facility. The amount of water available also depends on the amount of water needed to support instream requirement for Saint Joseph and downstream. The user inputs each of these criteria into the model as shown in Table 2.3(a).

Table 2.3(a) Model Input- Example.		
Component	Input Values	Units*
Storage Reservoir	700.00	KAF
Transfer Rate	6.83	KCFS
Max Diversion Rate	10.00	KCFS
Start Storage Reservoir	700.00	KAF
Navigation Flow	41.00	KCFS
Winter Flow	15.00	KCFS
* KAF=1000 Acre Feet, KCFS=1000 cubic feet per second		

These input values represent:

- **Storage Reservoir:** The size of offstream storage in thousand acre feet
- **Transfer Rate:** The size of the aqueduct to western Kansas
- **Maximum Diversion Rate:** The capacity of the Missouri River diversion structure
- **Start Storage Reservoir:** The assumed offstream storage at the beginning of the study period
- **Navigation Flow:** Missouri River flow needed during the navigation support season, a minimum of 41,000 cfs
- **Winter Flow:** Missouri River flow needed during the non-navigation support season, a minimum of 15,000 cfs.

Daily values from 1930 to 2013 were input in order to best represent present conditions at Saint Joseph, Missouri. The data prior to 1930 was developed from the available hydrologic record, but sometimes this entailed converting monthly flow data to daily values. The certainty of the daily values cannot be assured and is believed critical for the purposes of this study. Flow criteria were used for navigation and non-navigation support season. The physical properties of the aqueduct system provide the other variables. The runs discussed further represent the variables used in the design of the system.

2.3.2 Model Output

After the user has input data as described above, the model calculates the availability of water supply for transfer. The output is the annual supply in thousand second foot day (KSFD) and million acre feet (MAF). The values are provided in Table 2.3(b) and graph of percentiles at 10% intervals Figure 2.3(a) as illustrated below. The output below is based on the same assumptions as the 1982 Study. The user can alter these assumptions as desired. The model does not account for lake evaporation at the two reservoirs or account for transmission losses. Full navigation season is assumed every year, April through November.

Table 2.3(b) Example Model Output Table Annual Available From Missouri River.		
Percentile (%)*	KSFD**	MAF**
0	140	0.278
10	468	0.928
20	894	1.773
30	1041	2.065
40	1271	2.522
50	1474	2.924
60	1709	3.391
70	2207	4.378
80	2465	4.888
90	2493	4.945
100	2500	4.958
*1930--2013 Data, Percent of values LESS than criteria **KSFD= thousand second foot day, MAF=Million Acre Feet		

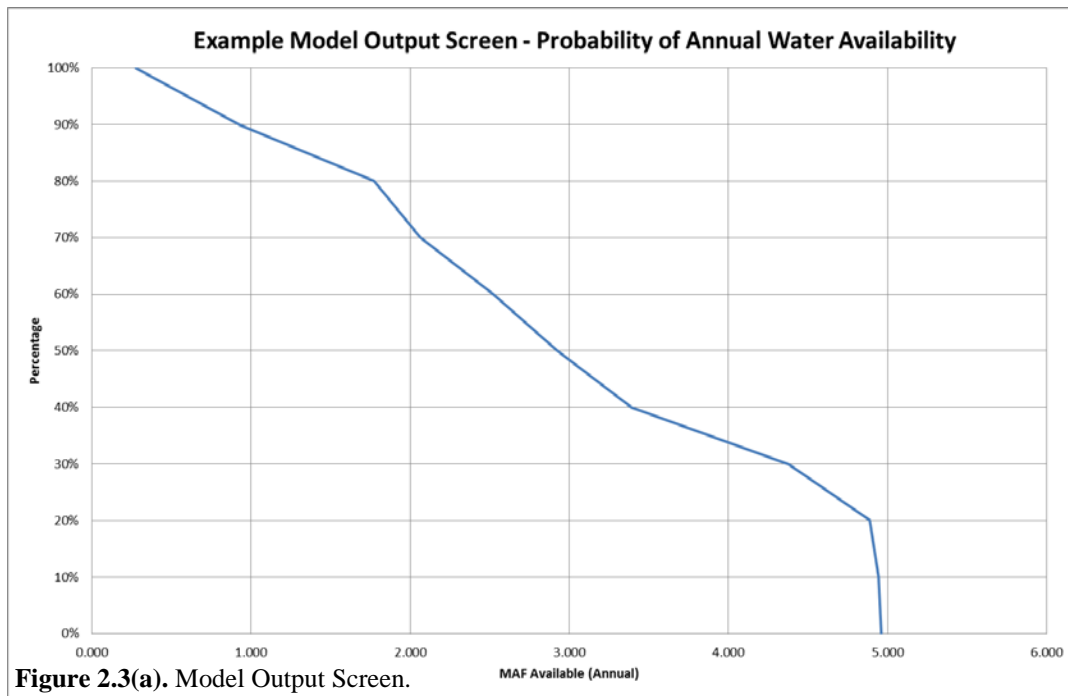
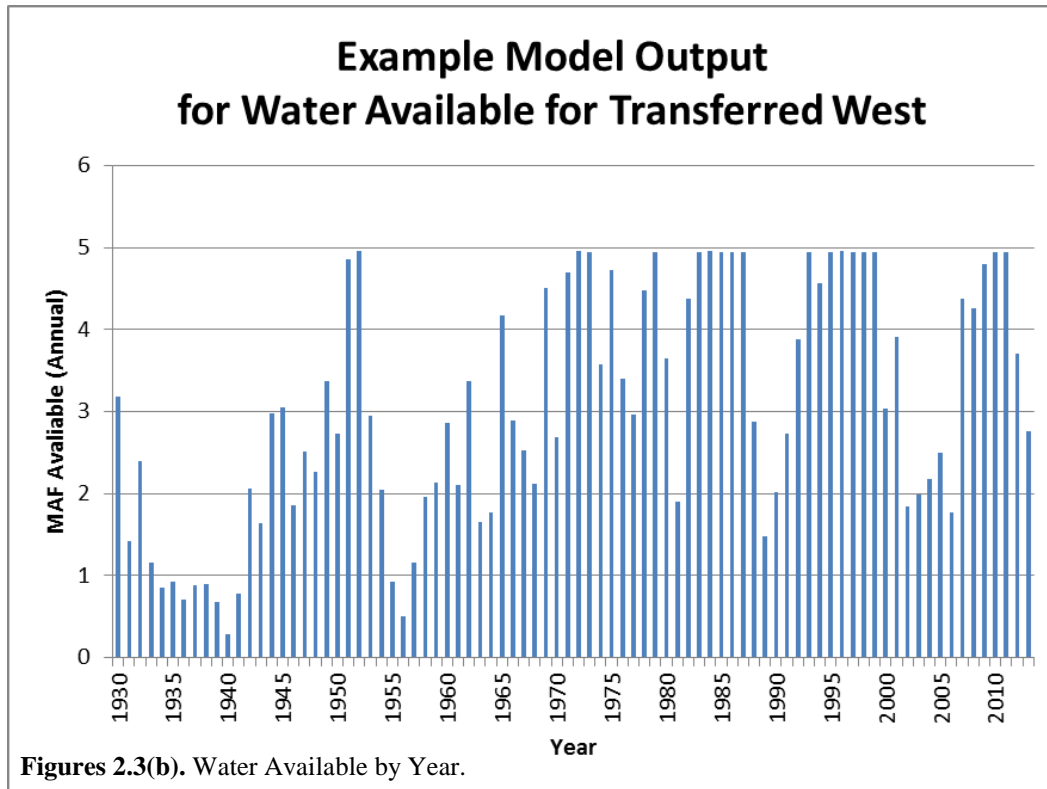


Figure 2.3(a). Model Output Screen.

The output data is also provided in a bar graph of water available by year, Figure 2.3(b).



2.4 Overview of Water Availability

The model estimates that flows above navigation targets over the period of record using a maximum diversion rate of 30,000 cfs results in an average annual yield of 6.9 MAF. However, this does not account for the limitations of storage capacity and transfer capabilities. Therefore, the model was used to determine the range of water available with different transfer system components. A more detailed discussion of the varying sizes of each of the components and their impacts on yield are discussed in the next chapter. The results show that the average annual yield that can be expected to be available at least fifty percent of the time ranges from 0.9 MAF at the lowest end to 3.2 MAF at the highest end of pumping and storage capacity.

Update of 1982 Six State High Plains Aquifer Study

Chapter 3: Water Transfer System

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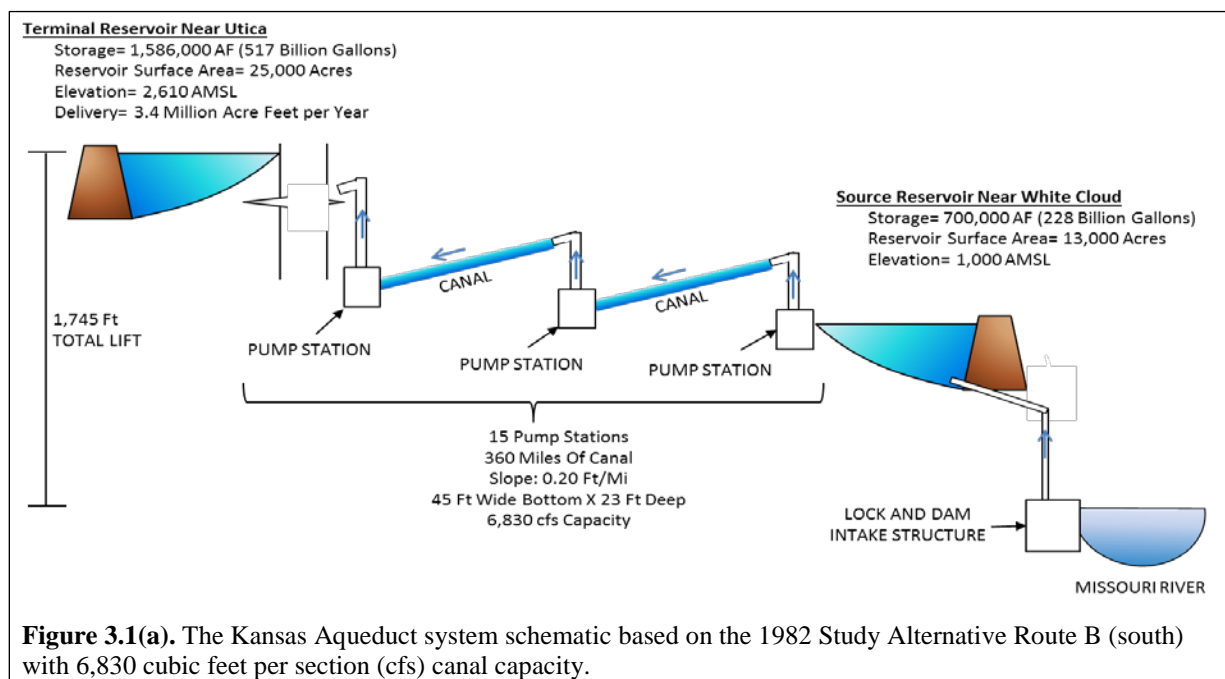
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3.1 Water Transfer System Introduction

The water transfer system formulated in the 1982 Study is shown as a schematic in Figure 3.1(a). In general, the system begins at the Missouri River with a diversion structure. Under most scenarios evaluated in the 1982 Study, the diversion structure was anticipated to be a lock and dam across the Missouri River. Alternative diversion structure options in 1982 included the use of radial collector wells or accepting a reduced diversion rate capacity. Flows above navigation and water supply intake structure targets in the Missouri River would be pumped to a “source reservoir”. The source reservoir would be located close to the diversion structure to minimize the cost of the pumping and conveyance facilities from the river to the reservoir. The source reservoir allows a more steady flow in the long-distance canal system, thereby minimizing the cost of this major project component. The canal transfer system would be a concrete-lined canal that would flow westerly approximately 360 miles. Along the route, a series of pump stations would lift the water to the next section of canal. A terminal reservoir located in western Kansas and overlying the Ogallala aquifer, would store water until needed during the irrigation season, thereby reducing the direct withdrawals from the Ogallala aquifer.



The 1982 Study Alternate B water transfer system components (reservoirs and conveyance systems) are presented in this chapter in light of updated GIS data, water demand forecasts and water availability. Conceptual-level alternatives to the 1982 Study are documented with a brief summary of advantages and disadvantages associated with each alternative. Many of the alternatives presented were brought forward through stakeholder meetings as potential cost savings or yield improvements.

3.2 Summary of 1982 Ogallala Water Transfer System Components

3.2.1 Missouri River Diversion Structure

Three alternatives for maximum diversion capacities were considered in the 1982 Study; 10,000 cubic feet per second (cfs), 20,000 cfs and 30,000 cfs. These diversion capacities were then used to calculate the amount of water that can be pumped from the Missouri River when the flows were above the minimum flow (flows above navigation and water supply intake structure targets) as discussed in Chapter 2. The 1982 Study utilized Missouri River stream gage data up through 1975. The predicted cumulative upstream Missouri River water diversions were also taken into account and reduced the projected water availability in the future. Table 3.2(a) summarizes the volume of available diversion presented in the 1982 Study compared to the water availability using the diversion tool discussed in Chapter 2.

Table 3.2(a)
Comparison of the 1982 Study and Kansas Aqueduct Study Annual Volume Available for
Diversion From the Missouri River at Three Maximum Diversion Capacities.

Missouri River Peak Diversion Rate in Cubic Feet per Second (cfs)	1982 Study Average Annual Diversion in Million Acre Feet (MAF)			Kansas Aqueduct Study Average Annual Diversion in Million Acre Feet (MAF)
	1975	2000	2020	2013
10,000	2.9	2.1	1.6	3.7
20,000	3.8	2.7	2.1	5.8
30,000	4.1	2.9	2.2	6.9

For 1975, the 1982 Study base year, the average annual available diversion presented in Table 3.2(a) for the updated Kansas Aqueduct Study is approximately 28% to 53% greater than the 1982 estimate. For 2020, the available diversion is nearly three times larger than predicted in 1982. Part of the increase is likely due to nearly forty years of additional stream gage data, and also may be due to an updated Missouri River Mainstem Reservoir System Master Water Control Manual adopted in 2006. The current Master Water Control Manual includes the integrated operation of both Missouri River Mainstem Reservoir System and tributary reservoir water control plans so that an overall plan for flood control and conservation operations exists with the entire Missouri River basin. The updated Master Water Control Manual likely has an impact on both the frequency and duration of water availability, although a detailed analysis has not been performed.

The diversion rates shown in Table 3.2(a) are the maximum pumping rates that could operate while flows above navigation and water supply intake structure targets are available. During flooding events, the flows above navigation and water supply intake structure targets could be large but the peak pumping rate would be reached and additional volume could not be pumped. The duration of the flows above navigation and water supply intake structure targets is also limited so the peak pumping rates could only be sustained during this short duration. As the flows above navigation and water supply intake structure targets diminish, the pumping rates would also be lowered to match the available flow amount. Ultimately, a reduced volume could be pumped before the river would return to minimum navigation stage. The Missouri River average annual flow potentially available for diversion is approximately 8.7 MAF based on the Chapter 2 determination of flows above navigation and water supply intake structure targets; however, the peak capacity of the pumping system limits the diversions to those shown in Table 3.2(a).

An example is presented to further illustrate the relationship between total Missouri River flows, flows above navigation and water supply intake structure targets potentially available for diversion and the limitations of a peak diversion rate. Figure 3.2(a) presents Missouri River flows in year 2000 and shows when water would have been available for diversion using a 10,000 cfs peak diversion capacity. This year was selected for illustrative purposes because it has periods of available flows and periods in which diversions would be precluded. Each year in the study period has varying flows and potential diversions. In 2000, a large amount of flow would not have been diverted in the January-April time period because the flows above navigation and water supply intake structure targets would exceed the diversion capacity of a Kansas aqueduct system. In the April-June timeframe, however, all flows above navigation and water supply intake structure targets would have been captured. The August-November time window had minimal flows above navigation and water supply intake structure targets and very little could have been diverted.

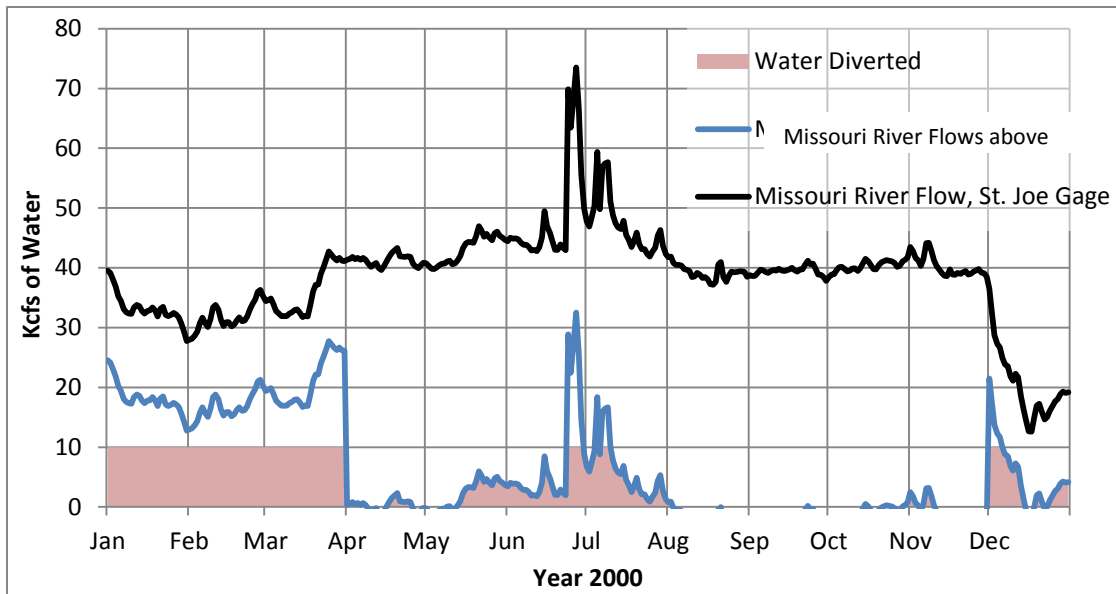


Figure 3.2(a). Missouri River flows, flows above navigation and water supply intake structure targets and potential diversions in year 2000 for a 10,000 cfs maximum diversion capacity. Flows are expressed as 1,000 cfs (Kcfs)

Diversion rates above 6,000 cfs would likely require the construction of a lock and dam structure on the Missouri River. The location identified for the lock and dam in the 1982 Study is 35 miles upstream of St. Joseph, Missouri. The lock and dam would raise the water level of the Missouri River such that high withdrawal rates could be accomplished without an excessive drop in the river water surface. A lock is required to allow barge traffic to pass from the lower water elevation up to the higher water elevation on the upstream side of the dam. Similar types of lock and dams are in use along the Mississippi River. Figure 3.2(b) shows Mississippi River Lock and Dam 9 near Lynxville, Wisconsin, which would be similar to a lock and dam on the Missouri River needed for the higher diversion capacities for a Kansas aqueduct.



Figure 3.2(b). Lock and Dam 9 on the Mississippi River near Lynxville, Wisconsin. A similar structure would likely be required on the Missouri River for diversion rates in excess of 6,000 cfs.

The 1982 Study indicated the lock and dam would impact flood elevations, sediment transport and navigation traffic. Further study and analysis would be necessary to address these impacts. The lock and dam may also require modification of the Master Water Control Manual. In addition, the construction costs are significant and are presented in Chapter 4. For these reasons, the Kansas aqueduct stakeholders expressed a desire to evaluate options that did not involve a lock and dam. One potential option, radial collector wells, is presented in Section 3.4. Other potential options are limited to river intake structures with 6,000 cfs or less capacity. Table 3.2(b) summarizes the average annual diversion capacity for peak diversion rates of 6,000 cfs or less. Diversion rates below 10,000 cfs were not evaluated in the 1982 Study. Lowering the Missouri River peak diversion capacity from 10,000 cfs to 6,000 cfs would result in a reduced diversion of approximately 1.2 MAF annually (from 3.7 MAF to 2.5 MAF per year).

Table 3.2(b). Potential Missouri River Average Annual Diversion Using Peak Diversion Rates that do not Require a Lock and Dam.	
Peak Diversion Capacity from Missouri River (cfs)	Average Annual Diversion (MAF)
2,000	0.9
4,000	1.7
6,000	2.5

3.2.2 Source Reservoir

The 1982 Study called for a new reservoir to be located 2.5 miles southeast of White Cloud, Kansas. The design capacity of the reservoir was 0.7 MAF and would have a reservoir surface area of 13,000 acres when full. The reservoir, buffer, embankment and associated facilities would require 19,000 acres. Figure 3.2(c) shows the location of the reservoir and the pool area. The environmental and cultural resources impacts are discussed in Chapters 6 & 7, the water rights implications in Chapter 5 and the construction costs are presented in Chapter 4.

The purpose of the source reservoir is three fold:

1. Supply a near uniform flow to the transfer canal,
2. Store excess water during wet periods for subsequent use during droughts and
3. Capture sediment to reduce the canal sedimentation maintenance.

Diversions from the Missouri River would not be available at a uniform rate as discussed in the prior section. The difference between the transfer system capacity and the Missouri River diversion capacity necessitates a storage reservoir. If the transfer canal capacity matched the river diversion capacity, the canal system would operate in surges and would completely stop flowing for extended periods. This discontinuous flow could cause major operations and maintenance problems with the transfer canal concrete lining, frequent pump cycling and would likely impact the longevity of the transfer system. Winter operations would be especially problematic due to the potential for ice jams.

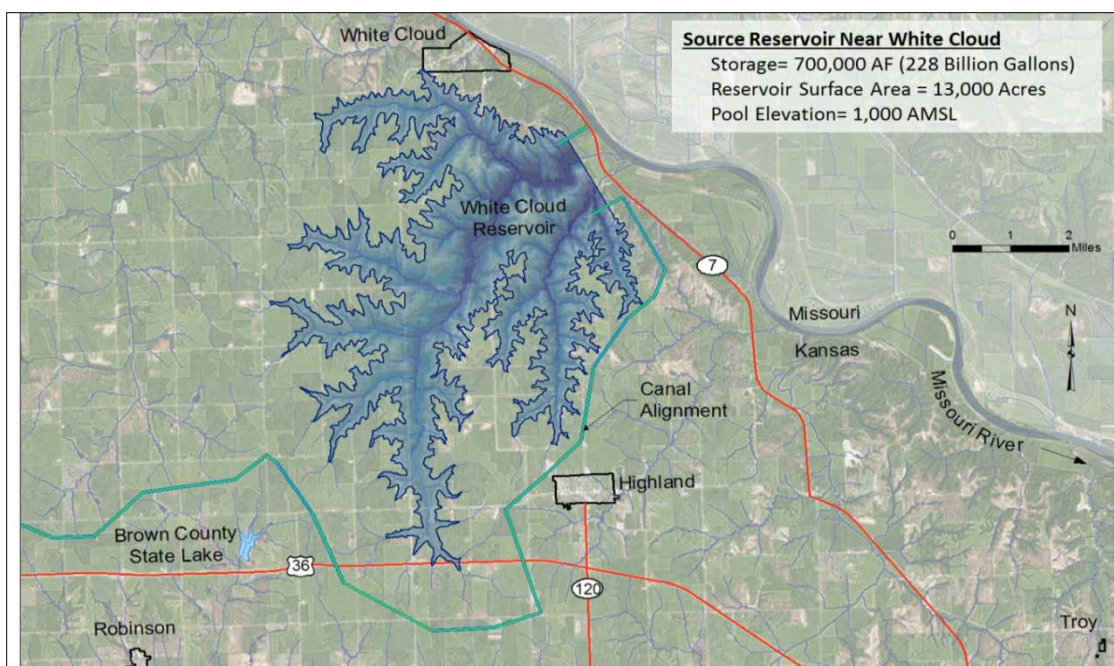


Figure 3.2(c). Source reservoir pool area near White Cloud, Kansas (White Cloud Reservoir) based on the 1982 High Plains Study.

Three Missouri River diversion rates were evaluated in the 1982 Study but only one source reservoir size was presented. Table 3.2(c) summarizes the amount of flows above navigation and water supply intake structure targets that could be diverted if storage was unlimited and also shows the impacts of a 0.7 MAF storage limitation. For options that include a low Missouri River diversion rate, the source reservoir is periodically under-utilized. During times of flows above navigation and water supply intake structure targets, the low diversion capacities can only capture a limited volume and hence a limited amount of storage is needed. This indicates a smaller reservoir may have nearly the same yield and would be more economically viable for a low diversion rate. Under high diversion capacities, a larger reservoir would be advantageous. With high diversion capacities, the reservoir would quickly fill with no room for additional storage. A larger reservoir would also be advantageous during droughts. The reservoir could help supply water when flows above navigation and water supply intake structure targets are not available in the Missouri River and would result in a more reliable yield to western Kansas. An analysis of drought operations and overall delivery system reliability was not provided in the 1982 Study documents and also not included in this update.

Table 3.2(c). Comparison of the Potential Average Annual Volume that can be Diverted from the Missouri River and the Amount that can be Stored in the Source Reservoir.		
Peak Diversion Capacity from Missouri River (cfs)	Average Annual Diversion ⁽¹⁾ (MAF)	Average Annual Diversion with Storage Limit ⁽²⁾ (MAF)
2,000	0.9	0.86
4,000	1.7	1.5
6,000	2.5	2.2
10,000	3.7	3.0
20,000	5.8	4.4
30,000	6.9	5.0
¹ Assumes no limitation on canal transfer or storage. Analysis based on Missouri River flow data from 1898-2013 (period of record).		
² Assumes no limitation on canal transfer capacity, but includes source reservoir storage limit (700,000 AF) and 5% evaporation and seepage loss.		

The type of reservoir embankments evaluated in the 1982 Study included concrete, rockfill and earthfill dams. The reservoir site is located on Cedar Creek and Mill Creek. The watershed contributing drainage area is approximately 48 square miles which would provide stormwater runoff and sediment to the reservoir. The watershed yield from Cedar Creek and Mill Creek was not included in the transfer volume and may provide some additional flow if the necessary water rights were to be obtained. Evaporation and seepage loss was estimated at 5% of the volume diverted from the Missouri River and is shown in Table 3.2(d). The sediment storage in the 1982 Study is based on 28.8 AF per year for 100 years and therefore impacts only 0.4% of the 0.7 MAF active storage volume.

The crest of the emergency spillway, unless a gated spillway is selected, would be located at the top of the conservation pool. Flood surcharge capacity was provided above the conservation pool because the design flood was assumed to pass through the emergency spillway atop a full conservation pool. This resulted in additional dam height and land requirements beyond that needed for the conservation pool. In addition, freeboard was provided above this flood surcharge elevation to provide a factor of safety against the dam being overtopped during passage of the design flood.

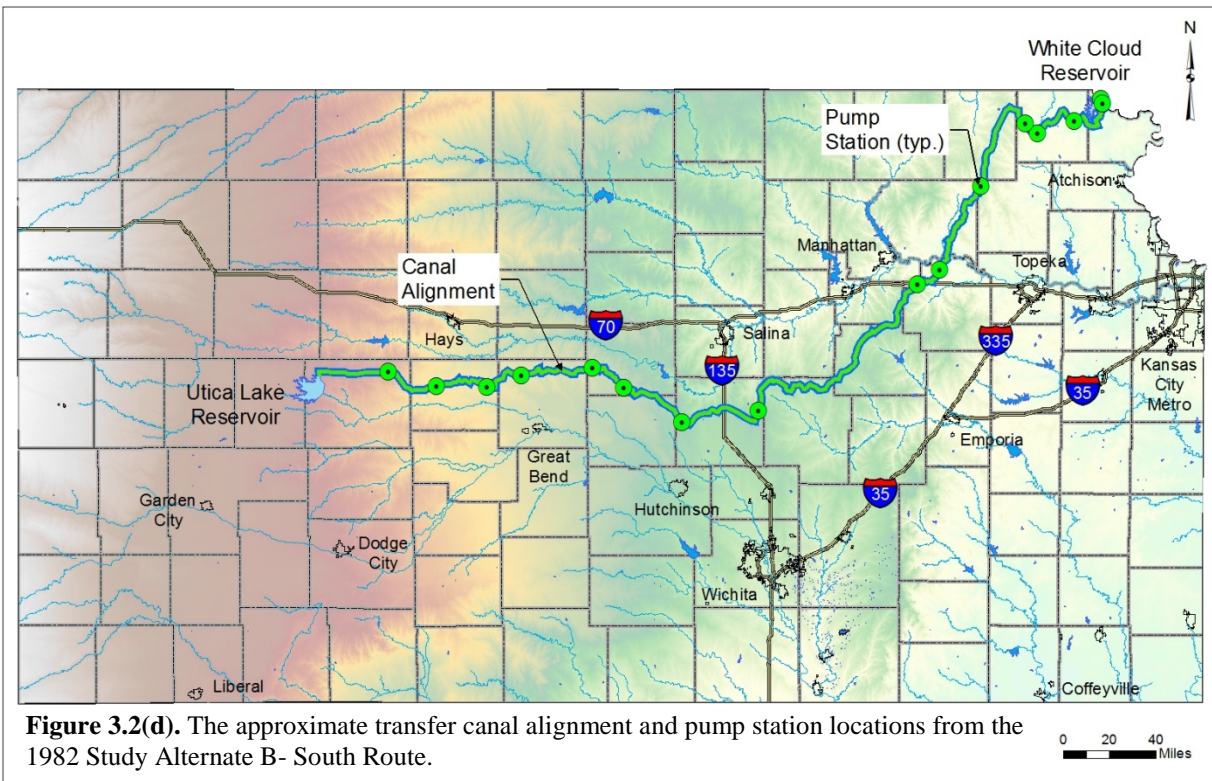
The 1982 Study used regression curves to estimate the stormwater runoff volume and no detailed runoff modeling was performed. The estimated flood volume for the Probable Maximum Flood (PMF) is 52,800 AF and 21,120 AF for the Standard Project Flood (SPF). The spillway capacity was based on passing 65% of the peak PMF inflow atop a full conservation pool. The top of dam was based on eight feet of freeboard over either storing 50% of the SPF volume or conveying the SPF peak flow atop the conservation pool. The type and size of the outlet works to convey the flood flows was not provided. The cost for these structures however was estimated based on regression equations related to the available head times the square root of the capacity. The procedures used to estimate required reservoir pool volumes, spillway capacity, outlet capacity and dam crest elevations will need to be reconsidered using current design criteria if more detailed assessments of a Kansas aqueduct project are conducted.

Table 3.2(d) The 1982 Study Estimated Percentage of Annual Yield Lost to Evaporation and Seepage.	
System Component	Percent Annual Seepage and Evaporation Loss
Source Reservoir ⁽¹⁾	5%
Transfer Canal ⁽²⁾	10%
Terminal Reservoir ⁽¹⁾	5%
Distribution System ⁽³⁾	10%
Cumulative System Losses ⁽⁴⁾	30%
¹ Water loss in the reservoir calculated as a percentage of annual diversion volume from the Missouri River. ² Includes water losses in the canal between the source reservoir and terminal reservoir. ³ Includes water losses in the distribution system between the terminal reservoir and the farm head gate. ⁴ Project annual water yields are equal to the annual volume diverted from the Missouri River times 0.7 to account for the 30% cumulative seepage and evaporation loss within the system.	

3.2.3 Transfer Canal

Water stored in the source reservoir would be pumped into a concrete-lined trapezoidal canal and conveyed westward into the terminal reservoir. The canal route westward followed the ridge line on the southern side of the Kansas River watershed divide. The approximate 1982 Study Alternate B South route is shown in Figure 3.2(d). The color shading in Figure 3.2(d) represents the topographic relief across the route. Pump stations are required along the canal route to lift the water approximately 1,745 feet from the source reservoir to the terminal reservoir. The route was chosen to avoid rough terrain and environmentally sensitive areas and to minimize the pumping plants and siphons. This route is the approximate location since the actual route in the 1982 Study was difficult to discern from the map scales provided. The 1982 Study identified the route as being 360 miles long however the route presented in Figure 3.2(d) is approximately 420 miles long.

The difference could be due to the 1982 Study route being straighter and or not strictly following the ridge line as shown Figure 3.2(d). In future phases, the uncertainty with the canal length and alignment could be reduced by developing a more accurate alignment using GIS based toolsets. For consistency with the 1982 Study, a 360 mile long canal is used for cost estimating in Chapter 4.



The 1982 Study evaluated the yield and costs for three canal sizes. The canal capacities and dimensions are presented in Table 3.2(e) and additional canal details and typical sections are presented in Figure 3.2(e). The canal would slope to the west but the topography generally slopes to the east. The canal would need to be excavated into the landscape to accommodate the westward canal slope and pump stations would be needed to lift the water at each location where the excavation depth for the canal becomes excessive. In order to balance earthwork, sections of the canal downstream of the pump stations would be constructed above the existing grade using material excavated from the cut sections of the canal to create the above-grade canal banks.

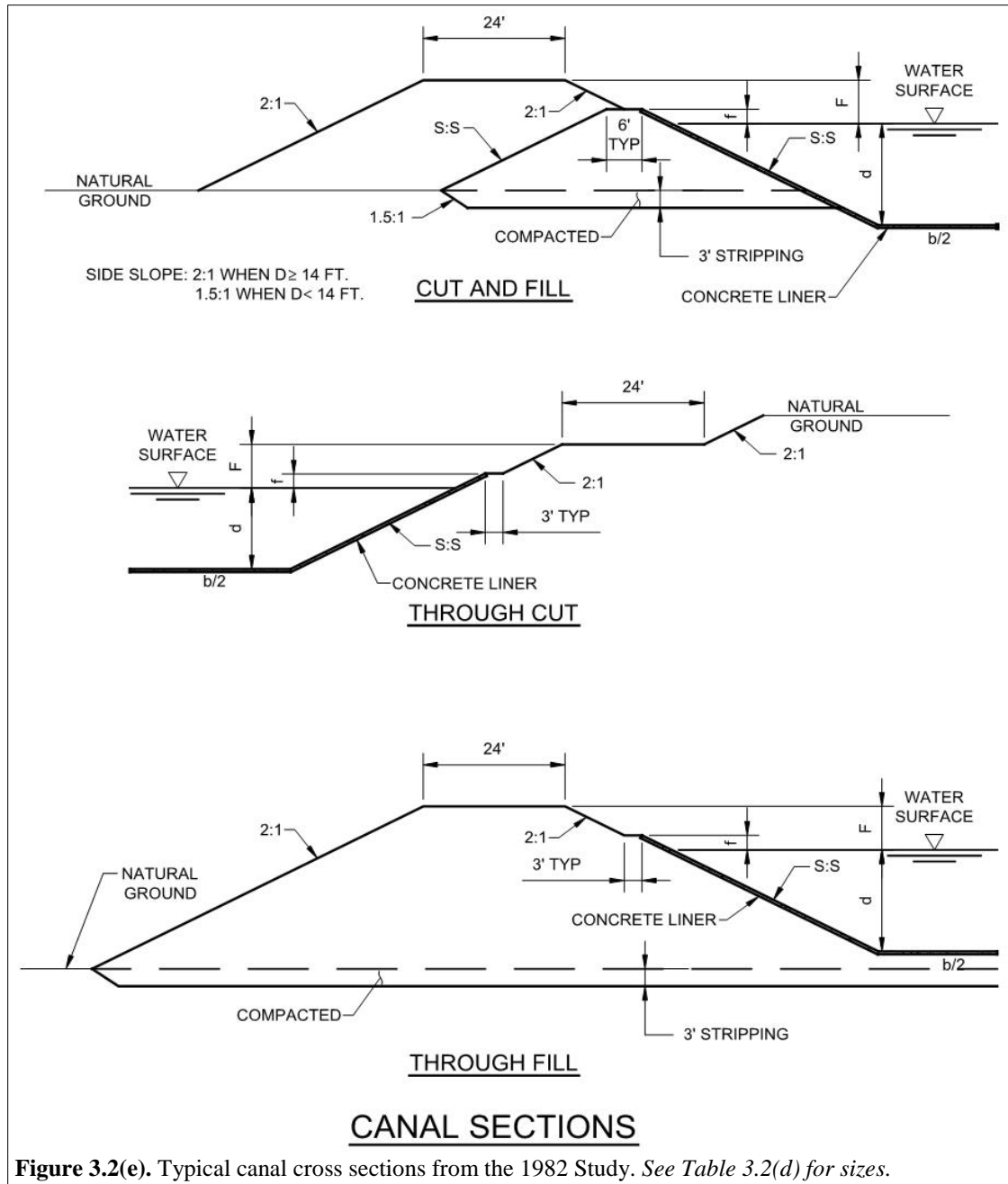
Table 3.2(e). Transfer Canal Sizes Presented in the 1982 Study to Convey the Flows West by Gravity.							
Canal Capacity	Slope	Water Top Width	Bottom Width (b1)	Water Depth (d ¹)	Water Velocity	Minimum Freeboard (F ¹)	Concrete Liner Freeboard (f ¹)
cfs	%	feet	feet	feet	feet/sec	feet	feet
2,000	0.0125	60	24	12	4	4.0	2.5
6,000	0.0044	126	42	21	3.4	5.0	2.5
10,000	0.0033	158	54	26	3.5	5.3	2.7
¹ Distances in Figure 3.2(e)							

The capacity of the canal (yield) was determined based on an 85% duty cycle assuming the canal and/or pump stations would be inoperable due to weather constraints and planned and unplanned maintenance 15% of the time. Outside of the outages, the canal would flow at a uniform rate to the terminal reservoir. In addition to the 15% down time, losses of water in transit because of evaporation and seepage were assumed to be 10% of the flow as shown in Table 3.2(d) and

would further limit the yield. Table 3.2(e) summarizes the required canal sizes to convey the average annual water deliveries stored in the source reservoir as calculated for this study.

The sizing of the three components of the aqueduct system: diversion capacity, storage volume and canal capacity are all inter-related. For example, Table 3.2(e) shows that a Missouri River peak diversion capacity of 10,000 cfs, with a source reservoir storage volume of 0.7 MAF, would need a 4,800 cfs canal to move the average amount water in storage westward. A smaller canal would not be able to convey the average annual volume in storage. A canal larger than 4,800 cfs would not flow full for the complete year since the volume in storage would be depleted. The larger canal would therefore benefit from a larger storage reservoir and a higher peak diversion capacity. The 1982 Study did not attempt to optimize the three components for each of the alternatives, which is common for high-level planning studies. In future efforts, optimization of the components sizing could result in lower costs per acre foot and/or higher yields. It should also be noted that these calculations are based on sizing the canal to drain the average annual volume of diverted water stored in the source reservoir. The terminal reservoir could be sized to provide additional drought storage.

Table 3.2(f). Alternative Peak Diversion and Average Canal Capacity Requirements Considering the Effects of Source Reservoir Storage.			
Maximum Diversion Capacity from Missouri River (cfs)	Average Annual Water Delivery⁽¹⁾ (MAF)	Average Annual Water Delivery Including Storage Limits⁽²⁾ (MAF)	Canal Capacity Required⁽³⁾ (cfs)
2,000	0.9	0.86	1,400
4,000	1.7	1.5	2,400
6,000	2.5	2.2	3,500
10,000	3.7	3.0	4,800
20,000	5.8	4.4	6,900
30,000	6.9	5.0	8,000
¹ Average Annual Water Deliveries are based on the maximum diversion capacities and excess flow availability using the period of record. It does not include storage or canal limits. ² The maximum storage of 700,000 AF reduces the average annual water deliveries. Calculations include 5% evaporation and seepage loss from the reservoir as discussed in the 1982 Study. ³ Canal capacity includes 15% down time for maintenance and weather related impacts.			



The canal would transect a large portion of the state. Relocations of roadways, highways, major pipelines, major power lines and railroads were included in the 1982 project cost elements, but a map of the relocations is not available. The text indicated the planned frequency of canal crossings included Federal Aid Secondary Highway Bridges at a six mile interval on average, but no secondary county road bridge crossings were included in the costs. The costs for the relocations and the new bridges are included in Chapter 4. In the 1982 Study, check gates are planned at approximately four mile intervals. The check gates would allow a section of the canal to be dewatered for maintenance.

3.2.4 Canal Pump Stations

The canal route has 1,745 feet of static elevation rise from the source reservoir located near White Cloud, Kansas to the terminal reservoir located near Utica, Kansas. Fifteen pump stations were included in the 1982 Study along the route to lift the water. The approximate lift station locations are presented in Figure 3.2(d). Each lift station would need to have the

same capacity as the canal. The pumping plants would utilize up to ten turbine type centrifugal pumps driven by electric motors. The number of pumps may be as few as three units with lower capacity options. The pumps would discharge into concrete pipes for delivery to higher elevations where the water would again flow by gravity to the next pump station. The plants were envisioned to be semi-attended indoor plants and include one pumping unit on operational standby. The operations and communication systems were assumed to be located at a single control point, with controls for pumps and gates and with data feedback and alarm systems.

At the stakeholder meetings, it was discussed that the existing Central Arizona Project (CAP) in many ways is similar to the concept of a Kansas aqueduct project. The CAP is designed to bring about 1.5 MAF of Colorado River water per year to Pima, Pinal and Maricopa counties, Arizona. CAP carries water from Lake Havasu near Parker to the southern boundary of the San Xavier Indian Reservation southwest of Tucson. It is a 336-mile long system of aqueducts, tunnels, pumping plants and pipelines and is the largest single source of renewable water supplies in the State of Arizona. The pumping capacity varies based on location but is generally in the 2,250 to 3,000 cfs range and has a total static lift of 2,900 feet. Figure 3.2(f) is a picture of one of the CAP pumping stations which would have many similar features as a pump station on a Kansas aqueduct project.

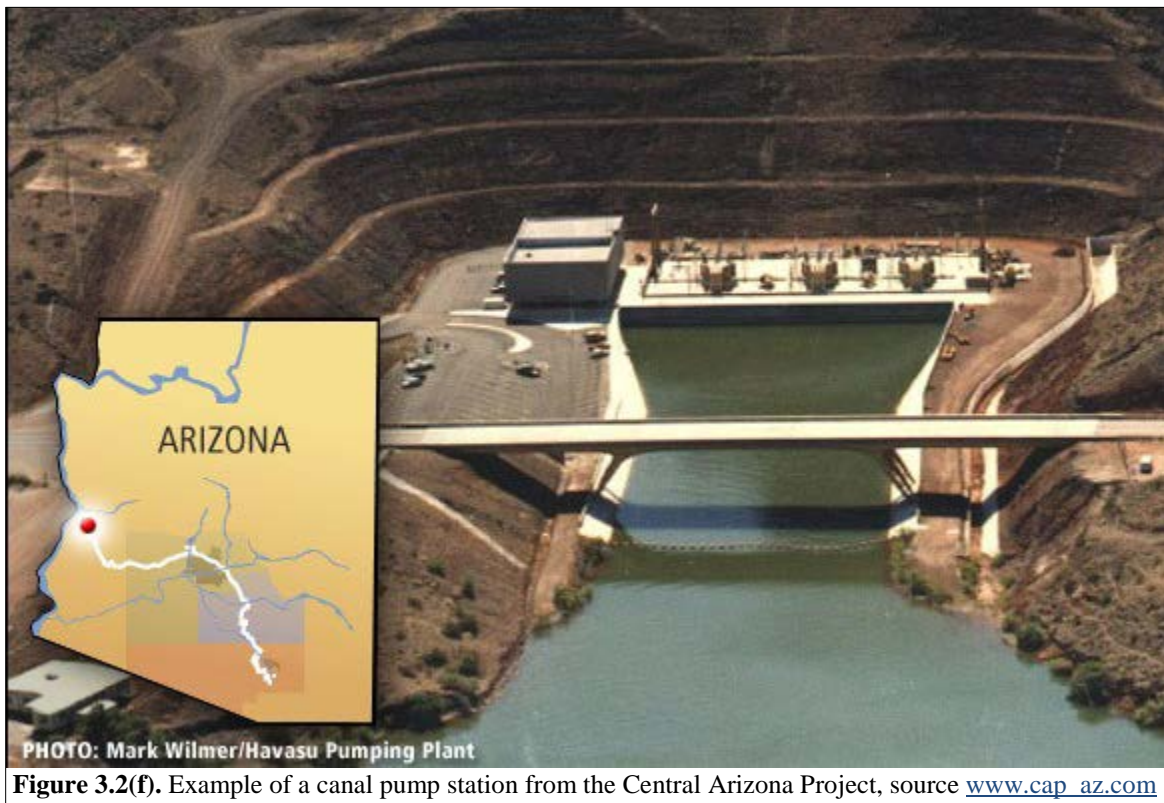


Figure 3.2(f). Example of a canal pump station from the Central Arizona Project, source www.cap.az.com

The electrically driven pumps would require construction of large electrical transmission lines and would have large electrical power consumption. The electrical transmission lines construction and the electrical operating costs are discussed in Chapter 4. The 1982 Study discussed installation of a hydroelectric generation plant adjacent to the Kansas River to partially offset the electrical consumption and this is discussed in Section 3.2.5. Construction of wind generation turbines and a pumped hydroelectric system was also investigated and is presented in Section 3.4.

3.2.5 Kansas River Crossing Siphon and Hydroelectric Generation

An advantage of siting the canal on the ridge line is it would minimize the number of stream crossing structures. Fewer structures reduce the environmental impacts, construction costs and maintenance. There would, however, be a large siphon required at the Kansas River crossing in Pottawatomie County. The 1982 Study found to cross broad river valleys by canal/drop inlets or pipeline results in significant head losses. There would be approximately 300 feet of drop as the

water descends from the ridge line and into a long siphon under the Kansas River. The 1982 Study performed a reconnaissance level analysis of alternative means to cross the valley. The reconnaissance analysis found adding hydropower generation to the system would reduce the net head loss. The power generated while dropping the water down the side of the valley would be used to pump the water up the other side. The hydroelectric plant would be operated at a uniform rate since there is no storage in the canal system. The 1982 Study did not include a detailed benefit-cost analysis of the hydropower plant feasibility.

3.2.6 Terminal Reservoir

The water would be conveyed westward at a near uniform rate, however the demand for the water is not constant. The primary use of the water would be for crop irrigation which peaks in the summer months and is very low in the winter months. The difference when the water is delivered and when it is withdrawn can be used to determine the capacity needed in one or more terminal reservoirs. Table 3.2(f) summarizes the use by month that was utilized in the 1982 Study. The usage shown in Table 3.2(f) is for average weather conditions. A dry spring, for instance, could change when the irrigation water is required over the projected demands shown in Table 3.2(f).

Table 3.2(g). Average Seasonal Irrigation Water Needs for the Northern High Plains.	
Month	Percent of Total Demand (%)
January	0.5
February	1.0
March	5.0
April	10.0
May	18.0
June	12.0
July	19.0
August	25.0
September	7.0
October	1.0
November	1.0
December	0.5

The storage volume for the terminal reservoir would be the difference between the steady canal supply and the amount being withdrawn for irrigation. The canal, for instance, would be able to supply the entire demand over the winter months and the excess water that is delivered would be placed into storage. During the peak usage in the summer, the entire canal supply would be needed plus water withdrawn from the terminal reservoir. The 1982 Study did not perform detailed modeling or perform a drought analysis to develop the size of the terminal reservoir required. Instead a factor was used to calculate the peak storage needs as a function of the peak demand from the difference in canal capacity and Table 3.2(f). The 1982 Study determined that to meet a demand of 3.404 MAF at the farm head gate, an annual required terminal storage of 1.586 MAF would be required (0.466 factor). The factor includes 10% evaporation and seepage loss in the distribution system from the terminal storage reservoir to the farm head gate. It also includes a 5% evaporation loss within the terminal storage facility. The distribution system from the terminal reservoir to the farm gate would require additional canals and pump stations, but no details or costs are presented within the 1982 Study.

The proposed terminal reservoir would be an impoundment built on the North Fork Walnut Creek near Utica, Kansas. The terminal storage facility (Utica reservoir) layout as developed in the 1982 Study is presented in Figure 3.2(g) and represents the 1.586 MAF of storage. The contributing drainage area to the terminal reservoir is 431 square miles. This part of the state has limited number of potential reservoir sites due to the flat terrain. The reservoir site is within the

Ogallala aquifer and was chosen over a location on the Arkansas River near Dodge City, Kansas and a location near Oberlin, Kansas on Sappa Creek. The PMF and SPF curves discussed previously were used in conjunction with the contributing drainage areas to estimate spillway, sediment storage, surcharge and freeboard elements.

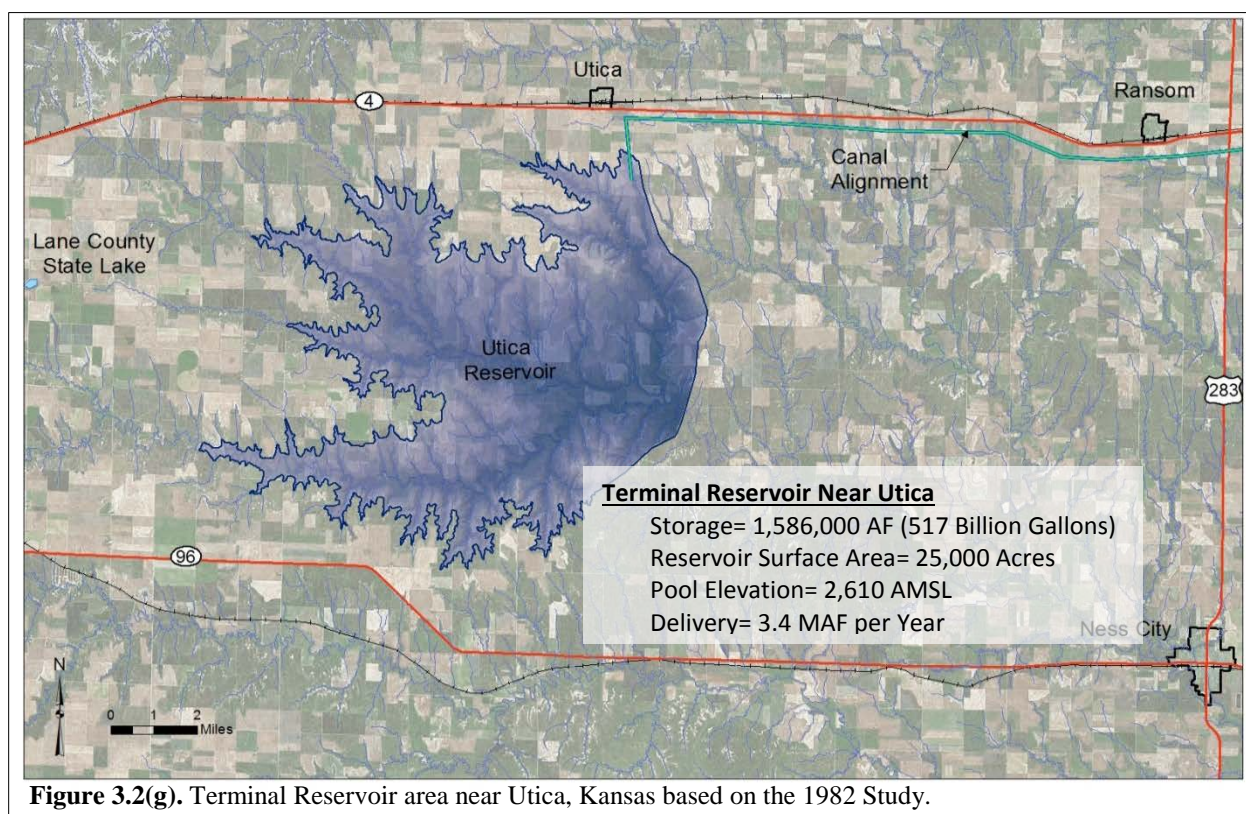


Figure 3.2(g). Terminal Reservoir area near Utica, Kansas based on the 1982 Study.

3.3 Water Transfer Rate Impacts on Water Yield

The 1982 Study did not appear to evaluate component sizing in consideration of the availability of flows above navigation and water supply intake structure targets in the Missouri River nor attempt to optimize project components to reduce the cost per acre foot of water delivered. The 1982 Study determined the cost per acre foot of yield based only on canal sizing. The following section updates the 1982 Study findings by evaluating the yield using availability of flows above navigation and water supply intake structure targets and various system limitations. Table 3.3(a) summarizes the differences in project yield with alternative diversion rates, source reservoir sizes and three alternative canal capacities ranging from 2,000 to 10,000 cfs. Source reservoir capacities range from 0.4 to 1.3 MAF compared to the 0.7 MAF capacity presented in the 1982 Study. Additional optimization of system sizing could be performed in future studies if more detailed cost information is developed and a more detailed site evaluation is performed.

Table 3.3(a).
Project Yields for 2,000, 6,000 and 10,000 Cubic Feet per Second (cfs) Transfer Canals with Alternative Missouri River Maximum Diversion and Source Reservoir Capacities in Million Acre Feet (MAF).

Transfer Canal Capacity⁽¹⁾	Missouri River Diversion⁽²⁾	Source Reservoir Size	Terminal Reservoir Size	Average Annual Yield to Farm Headgates⁽³⁾
cfs	cfs	MAF	MAF	MAF
2,000	3,000	0.4	0.43	0.92
2,000	4,000	0.4	0.44	0.94
2,000	4,000	0.5	0.47	1.02
2,000	4,000	0.6	0.47	1.02
2,000	5,000	0.5	0.47	1.02
2,000	5,000	0.6	0.47	1.02
2,000	6,000	0.5	0.47	1.02
2,000	6,000	0.6	0.47	1.02
6,000	6,000	0.1	0.73	1.58
6,000	6,000	0.7	0.73	1.58
6,000	8,000	0.5	0.90	1.94
6,000	8,000	0.7	0.91	1.95
6,000	10,000	0.6	1.00	2.15
6,000	10,000	0.7	1.02	2.19
6,000	10,000	0.8	1.04	2.23
6,000	20,000	0.7	1.11	2.37
10,000	20,000	0.6	1.39	2.98
10,000	20,000	0.7	1.42	3.05
10,000	20,000	0.8	1.46	3.14
10,000	30,000	0.6	1.44	3.08
10,000	30,000	0.7	1.48	3.17
10,000	30,000	0.8	1.50	3.21
10,000	30,000	0.9	1.51	3.23

¹ Includes 15% down time for maintenance and weather impacts.

² Calculations based on pumping flows above navigation and water supply intake structure targets and Missouri River flow data from 1898-2013.

³ Includes 10% seepage and evaporation transmission loss source reservoir to the terminal storage, 5% evaporation at the source and terminal reservoir and 10% seepage and evaporation from the terminal storage to the farm headgates.

3.3.1 2,000 cfs Transfer System Component Sizing

For a 2,000 cfs capacity transfer canal, Table 3.3(a) summarizes the yield differences with alternative diversion rates and source reservoir capacities. It shows that a source reservoir larger than 500,000 AF and a source diversion rate greater than 4,000 cfs may not increase the average annual water yield due to the limit of a 2,000 cfs transfer canal. As mentioned previously, a larger diversion capacity and source reservoir offer significant benefits during droughts, especially prolonged, multi-year droughts. It is unclear if the 1982 Study developed costs using a source reservoir smaller than 700,000 and the capacity of the diversion system was not stated. It is anticipated that this option would not require a lock and dam across the Missouri River since the peak diversion rate would be below 6,000 cfs.

3.3.2 6,000 cfs Transfer System Component Sizing

Table 3.3(a) indicates that Missouri River diversion capacities up to 20,000 cfs would continue to increase yield when paired with a 700,000 AF source reservoir and a 6,000 cfs canal. The yield gain however diminishes with diversion capacities greater than 10,000 cfs. The options that use a Missouri River diversion capacity above 6,000 cfs would likely require a lock and dam across the Missouri River. A lock and dam structure would impact flood elevations, sediment transport and navigation traffic. Further study and analysis would be necessary to address these impacts. As mentioned previously, a larger diversion structure and larger reservoir may offer significant benefits during droughts, especially prolonged, multi-year droughts.

3.3.3 10,000 cfs Transfer System Component Sizing

Table 3.3(a) indicates that Missouri River diversion capacities up to 30,000 cfs would continue to increase yields when a 10,000 cfs canal is used. The yield gain begins to diminish when a reservoir capacity greater than 800,000 AF is paired with a 30,000 cfs peak diversion. The largest terminal reservoir size presented in the 1982 Study is based on an annual yield at the farm headgates of 3.4 MAF. To achieve this yield of 30,000 cfs diversion capacity, a 1,300,000 AF source reservoir and a 10,000 cfs transfer canal system would be required. The possibility of developing up to 1.3 MAF of source reservoir storage through one or more reservoirs would need to be evaluated in future studies. All of the options evaluated with a 10,000 cfs canal would require a lock and dam across the Missouri River. As mentioned previously, a large diversion capacity and large reservoir may offer significant benefits especially during prolonged, multi-year droughts.

3.4 Alternative Components

3.4.1 Missouri River Horizontal Collector Wells

In the 1982 Study, the water intake structure on the Missouri River would be a surface water intake. It is envisioned in this study that a lock and dam on the Missouri River would be required for options with diversion capacities in excess of 6,000 cfs. This section presents information related to the feasibility of constructing horizontal collector wells instead of a surface water intake that involves a lock and dam across the river. Horizontal collector wells (HCWs), also referred to as Ranney™ wells and radial collector wells, have been used in raw water diversion systems in the United States for over 70 years. As of 2008, there were approximately 220 active U.S. systems.¹ The following section presents general information about HCWs and also discusses the potential application of HCWs as a raw water diversion system for a Kansas aqueduct project.

3.4.1.1 General Concepts

HCWs are typically constructed in unconsolidated sand and gravel deposits, and consist of a reinforced concrete-caisson wet well that supplies water to the pump station, with horizontal well screens projected from within the caisson out into the aquifer to divert large quantities of water. HCWs are typically installed adjacent to surface-water sources; rivers primarily. Inducing infiltration from an adjacent river is referred to as riverbank filtration when improvements in water quality are being considered. This infiltration process pre-filters river water as it moves through the riverbed sediments through the sand and gravel deposits and to the well screens. As water levels adjacent to the river are lowered by pumping, the hydraulic gradients in the alluvial aquifer draw the water from the adjacent river. Hydrogeologic investigations and groundwater modeling studies performed by the manufactures indicate that, typically, 90% or more of the water produced by a HCW is through induced infiltration of the surface water body and 10% or less is from depletion of groundwater storage. A cross-sectional view of a typical HCW is shown below in Figure 3.4(a).

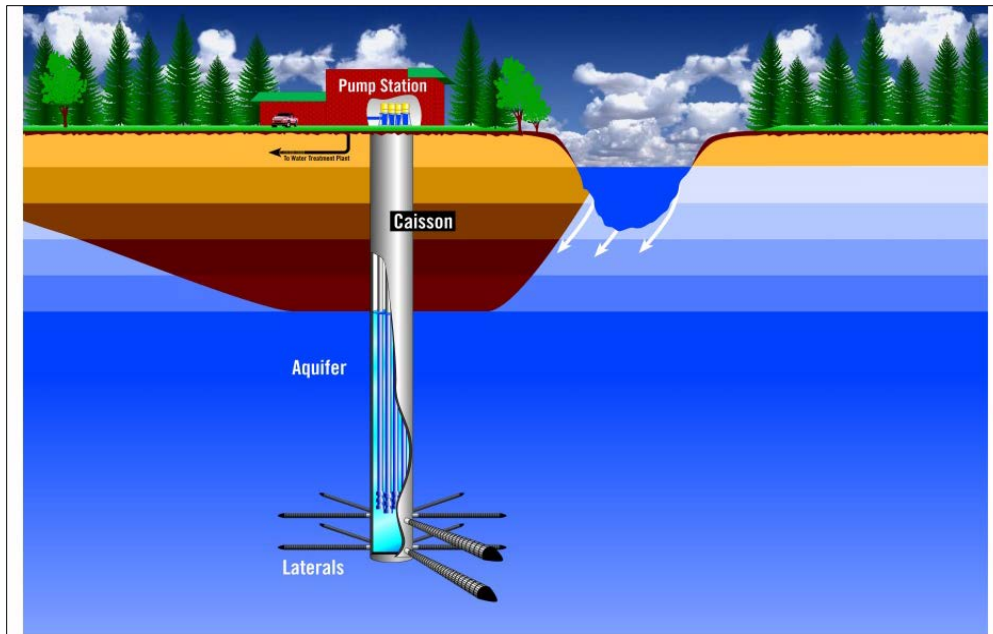


Figure 3.4(a). Typical Riverbank Filtration collector well application, Courtesy of Ranney® Collector Wells.

3.4.1.2 Collector Well Construction

The centerpiece of a HCW is the steel reinforced concrete caisson, which typically has an outside diameter that ranges from 10 to 24 feet. The central caisson consists of sections of large-diameter, steel-reinforced concrete pipe that are either prefabricated or are fabricated onsite with water-tight joints. Soil is excavated from within the caisson as it is being advanced downward with hydraulic rams, which causes the caisson to sink downward to the designed depth. The sinking process continues until the lower portion of the caisson reaches the design depth for projection of the lateral well screens. Once the caisson has been placed to its design depth, a reinforced concrete bottom sealing plug is poured to enable the interior of the shaft to be dewatered for screen installation. The caissons can be installed to depths of 150-feet using normal construction methods.² In alluvial systems, the bottom of the caisson is generally set near the top of bedrock, which in the Missouri River alluvium typically ranges from 70 to 100 feet below ground surface. Figure 3.4(b) shows the typical above grade structures associated with a HCW, which consist of the central caisson and the pump house.



Figure 3.4(b). Example Horizontal Collector Surface Facilities-Collector Well No. 2 Olathe, KS (Courtesy of the City of Olathe).

Specially designed wall-port openings are placed in the walls of the caisson through which the horizontal well screens (also called laterals) are placed. It should be noted that laterals are typically placed several feet above the top of bedrock, but can be placed in more than one plane if the aquifer thickness allows.³ The laterals are installed just above the top of the bedrock surface in order to maximize the available drawdown in these wells. The laterals are typically constructed of wire-wrapped stainless steel well screen, which is the same material used for traditional water supply well screens.

The laterals are typically installed by hydraulically jacking outward from the vertical shaft. As the laterals are placed, packers are used to control the inflow of water from each lateral until construction is completed. The interior of the caisson must be continually dewatered during the installation of the laterals so that work on the laterals can take place. Currently, the length of the laterals used for water supply is typically 120 to 240 feet.⁴

Once installed, the well screens are developed to remove fine-grained formation materials from around the screens. The development process is performed along the full length of each lateral to ensure that all sections of the well screen get uniformly developed. Re-development of the lateral well screens (i.e., well maintenance) is typically minimal as the laterals are designed so that the velocity of fluid entering the screens remains very low.

3.4.1.3 HCW Applications in the Kansas City Area

A number of communities and industries near Kansas City obtain raw water using HCWs constructed either in the Kansas River or Missouri River alluvium. These include:

- City of Independence, Missouri – One (1) HCW in the Missouri River alluvium.
- City of Olathe, Kansas – Four (4) HCWs, constructed in the Kansas River alluvium.
- Kansas City Kansas Board of Public Utilities (BPU) – Two (2) HCWs in the Missouri River alluvium.
- Kansas City Power and Light (KCP&L) Iatan Station – One (1) HCW in the Missouri River alluvium.
- Tri-County Water Authority (Missouri) – One (1) HCW in the Missouri River alluvium.
- Water District No. 1 of Johnson County, Kansas (Water One) – One (1) HCW in the Missouri River alluvium.

The yield of a HCW is a function of the well design (number and length of laterals), aquifer properties (transmissivity, saturated thickness, etc.) and the recharge from the surface water source. In general, the yield of a HCW increases with increased depth to bedrock, because of increased aquifer transmissivity and available drawdown above the top of the lateral well screens. The caisson of a HCW constructed in the Missouri River alluvium is typically between 70 to 100 feet below ground surface, although deeper depths are possible.

The largest collector well in the world is the BPU Well No. 2, which has been pumped at rates of up to 55 million gallons per day (MGD) (85.1 cfs).⁵ The depth to bedrock at these wells in the Kansas River alluvium is 150 feet, which is likely deeper than the Missouri River alluvium in the vicinity of the potential Kansas aqueduct diversion. A more typical range of well yield for HCWs installed in the Missouri River alluvial aquifer near Kansas City is from 10 to 30 MGD (15.5 to 46.4 cfs). This range in well yields can be used for planning purposes to evaluate the feasibility of using HCWs as a raw water source for a Kansas aqueduct.

As with any well, a HCW would eventually require maintenance to restore lost capacity. The frequency and degree of maintenance needed to preserve well capacity varies on well by well basis and is difficult to project. Most of the wells listed above were installed between the mid-1990s to the mid-2000s. Some of these wells have experienced limited declines in performance and have had little to no maintenance work performed. However, some of the wells listed above have experienced declines in performance and have had some well maintenance performed. From the operational history of the wells listed above, it can be estimated that a cleaning and redevelopment of the lateral well screens would be needed once every 10 to 15 years of operation. For budgeting purposes, the cost to clean the well laterals for the City of Olathe HCW No. 2 was \$134,000.⁶

3.4.1.4 Benefits of HCWs

In addition to providing recharge to the aquifer, riverbank filtration also improves the quality of the water produced by HCWs, which is typically a blend of surface water and groundwater. During the RBF process, objectionable characteristics of the river water, such as turbidity and microorganisms, are removed. Because the induced infiltration occurs over a large area, infiltration rates are extremely low, providing a high degree of filtration in most cases.

As a possible intake system for a Kansas aqueduct project, HCWs have several advantages when compared to surface water intakes or a lock and dam structure, including:

- Significantly less turbidity;
- Filtering of microorganisms;
- A near constant diversion rate;
- HCWs can operate during floods or droughts;
- HCWs are not significantly impacted by streambed degradation;
- HCWs can maintain a near constant water temperature;
- A HCW does not impede river traffic;
- HCW construction does not require modification of the river channel;
- A HCW has less impact on fish and wildlife;
- HCWs are not impacted by frazil ice and
- HCWs intake screens cannot be plugged by zebra mussels.

3.4.1.5 Limitations to the Use of HCWs for a Kansas Aqueduct

As previously summarized, for a planning level study, an HCW well yield range of 10 to 30 MGD (15.5 to 46.4 cfs) is appropriate. Using the 7,000 cfs diversion capacity from the 1982 Study, a total of 151 to 452 HCWs would be required to supply that flow rate. Well spacing of 1,000 feet between wells is recommended to minimize interference drawdown between wells. Since these wells must be located in close proximity to the recharge source, 29 to 86 miles of continuous property adjacent to the Missouri River would be required. Other limitations for the use of HCWs as a diversion structure for a Kansas aqueduct include:

- The hydrogeology of the Missouri River alluvium is highly variable and the construction of a high yield HCW is not feasible at all locations.
 - Prior to construction of a radial collector well, it is necessary to drill a number of vertical exploratory borings throughout the area to determine the subsurface hydrologic characteristics.
- The Missouri River can exhibit rapidly changing flow conditions, with a slower response exhibited by groundwater levels. Rapid rises in river flows do not necessarily result in increased groundwater availability, unless the high river flows are sustained. Further study would be required to evaluate the groundwater availability during high flows and sophisticated timing of diversion pumping would be required.
- The timeframe for constructing a HCW is approximately 6 to 9 months.
 - Only two contractors in the United States are known to construct these types of wells, therefore construction time could be an issue.
- HCWs require periodic maintenance of the laterals to maintain higher flow rates.
- Potential for conflict with existing water right permit holders.
- In Kansas, separate water rights are required for surface water and groundwater withdrawals. Kansas requires that modeling to determine the surface water/ groundwater percentage be submitted as part of the HCR appropriation application. The surface water component is typically in excess of 90 percent of the total flow it is likely that HCWs would need to operate within the same excess flow limitations as the lock and dam option.
- Could impact existing bottom land irrigators.

3.4.1.6 Horizontal Collector Well Summary

Based on the information and analyses presented herein, following is a list of advantages and disadvantages for using HCWs to supply raw water for a Kansas aqueduct project.

3.4.1.6.1 Advantages

In comparison to a surface water intake and lock and dam system, HCWs offer the following benefits:

- Better water quality with little to no turbidity.
- A near constant diversion rate is possible.
- Stream depletion occurs over a long river reach rather than at a single location.
- Future operation of HCWs should not be significantly impacted by streambed degradation.
- HCW construction does not require modification of the river channel.
- A HCW has less impact on fish and wildlife and therefore may be easier to permit.
- HCWs intake screens cannot be plugged by zebra mussels or frazil ice.

3.4.1.6.2 Disadvantages

- HCWs have the following limitations when compared to surface water intake and lock and dam system:
- Hundreds of wells are needed to supply the design flow.
- HCW river diversions are dependent on rapidly changing river discharges, which do not necessarily result in increased groundwater availability unless the high flows are sustained.
- Extensive subsurface investigation would be required to locate well sites.
- An extremely long reach of property adjacent to the Missouri River would need to be developed with HCWs.
- An extensive network of collection/transmission piping and pump stations would be required to convey the water to the source reservoir.
- Three phase power would be required at all the well sites.
- Only two contractors in the United States are known to construct HCWs and each well requires approximately 6 to 9 months to build.
- Obtaining water rights for hundreds of closely spaced HCWs is uncertain.

3.4.2 Pipeline Conveyance System

As mentioned previously the proposed open canal would transect a large portion of the state and would have significant easement, right-of-way and/or land acquisition costs. An alternative to using an open canal is a pipeline conveyance system. The required pipe sizes would vary from one, 17-foot diameter pipe for the 2,000 cfs option up to four, 19-foot diameter pipes for the 10,000 cfs option. The manufacture, shipping and construction of such large diameter pipe segments may prove impractical and, if so, more pipes would be required. A pipeline system would have fewer highway and roadway relocation costs. Bridges also would not be needed and the overall alignment could be straighter, thereby reducing the total construction costs and the amount of land rights required. The land above the pipeline system should either be in a permanent easement or be directly purchased. Access roads and electrical transmission mains would still be required. The pipeline system would have additional frictional losses over a canal requiring either larger or more frequent pump stations and would have an increased electrical demand. Although technically feasible, this option is much more expensive than the open canal option. The costs are presented in Chapter 4.

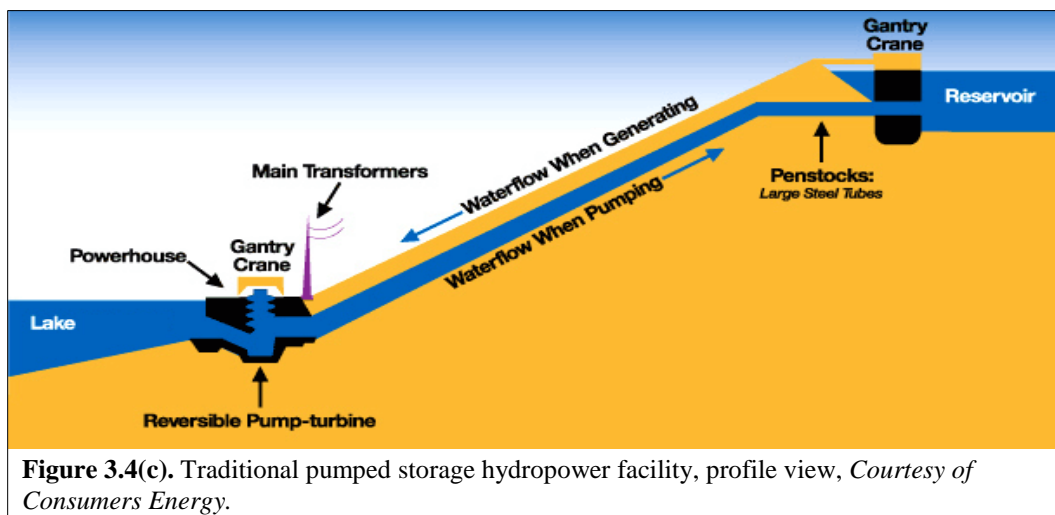
3.4.3 Renewable Energy Generation Corridor

The idea of a renewable energy corridor was mentioned by the stakeholders and this section discusses the concept of locating renewable wind generation turbines and pumped-storage hydropower along the canal route. The 1982 Study includes one hydroelectric generation plant be constructed on the east side of the Kansas River as water descends off of the ridge line and into the siphon under the river. Potentially, the development of wind generation in the high plains of

central and western Kansas, coupled with conventional and pumped-storage hydropower at one or more locations along the alignment of the canal, would help to subsidize the operational costs of the project. While several canal capacities were analyzed in the 1982 Study, for this evaluation, a design capacity necessary to allow for an average design flow of 6,000 cfs has been assumed. The concepts presented were developed at the planning level of detail and additional analysis would be needed to verify the viability.

3.4.3.1 Viability of Renewable Energy Facilities along Aqueduct Corridor

The terrain surrounding the route was reviewed to identify possible pumped storage hydropower facility sites. Traditional pumped storage projects cycle water between an upper and lower reservoir using reversible pump-turbines (see Figure 3.4(c)). Historically, these projects were constructed by utilities to provide supplemental power to complement base-load generation sources such as nuclear and coal-fired generation, utilizing the base generation during off-peak demand hours to pump water into the upper reservoir, and then supplementing the base generation during peak demand hours by moving the water into the lower reservoir and driving the pumps as turbines.



Over the past decade, pumped storage projects have been designed or retrofitted to provide even greater flexibility in generation or pumping response, and are now being utilized for the integration of renewable energy sources such as wind or solar whose generation cannot be scheduled to follow electrical loads. The dispatch of these renewable-energy projects to electrical grids presents difficulties for the utilities. The fast response times offered by pumped storage hydropower are an ideal pairing for these variable, relatively unpredictable generating resources. Conventional hydropower with adequate forebay and afterbay storage can also provide a more flexible resource to pair with variable renewable generation, if designed properly.

Cost-effective pumped storage locations have a high head differential between the upper and lower reservoirs and a relatively short distance between the two pools, allowing for reduced infrastructure cost associated with tunnels and or high-pressure penstocks. Based upon review of the topography along the entire length of the Kansas aqueduct South Route, it was determined that there is not a suitable site for a traditional, two-pond pumped storage facility. However, a potentially-viable three-reservoir pumped storage alternative was identified in the Kansas River valley, in the vicinity of the location where the 1982 Study envisioned a conventional hydropower facility and the largest consecutive pair of pumping facilities.

In the 1982 Study, the conventional hydropower plant would operate under around 300 feet of head, utilizing the elevation differential from the canal's ridge line alignment into the valley. Two pumping stations, in series, would lift the water approximately 500 feet back to the top of a ridge on the southwestern side of the valley. The hydropower production would partially offset the load requirements of the pump stations. No reservoir storage was envisioned under this operating scheme; the only ponds that would be necessary would be small "header boxes" where the canal transitions to

pipeline. These facilities would limit air entrainment that could adversely affect the turbines and pumps, and also provide proper back pressure to the draft tube of the hydropower turbine in order to prevent cavitation damage. A potential disadvantage of this layout would be a possible need to upsize the Kansas River siphon.

3.4.3.2 Kansas Aqueduct Pumped Storage

The pumped storage alternative would add three small reservoirs, and require a slight modification of the route as shown in Figure 3.4(d). It is assumed for the purposes of this study that the capacity factor for a wind project in this region of Kansas is 0.40, based on data from the National Renewable Energy Laboratory (NREL; see Figure 3.4(e)). The concept involves expanding upon the originally-envisioned hydropower facility by incorporating a modest amount of reservoir storage. The first reservoir forebay, located in the Lost Creek watershed near the City of Belvue, would be sized to have a useable storage of approximately 50,000 acre feet and a maximum pool elevation of roughly 1,050 feet above mean sea level. This arrangement allows for the production of approximately 95 MW of hydropower (6,000 cfs design flow at 225 feet of net head, with a 90 percent assumed net efficiency), located at the northeastern end of the forebay. The hydropower turbines would have the ability to be fully or individually bypassed for maintenance, allowing continuous operation of a Kansas aqueduct system.

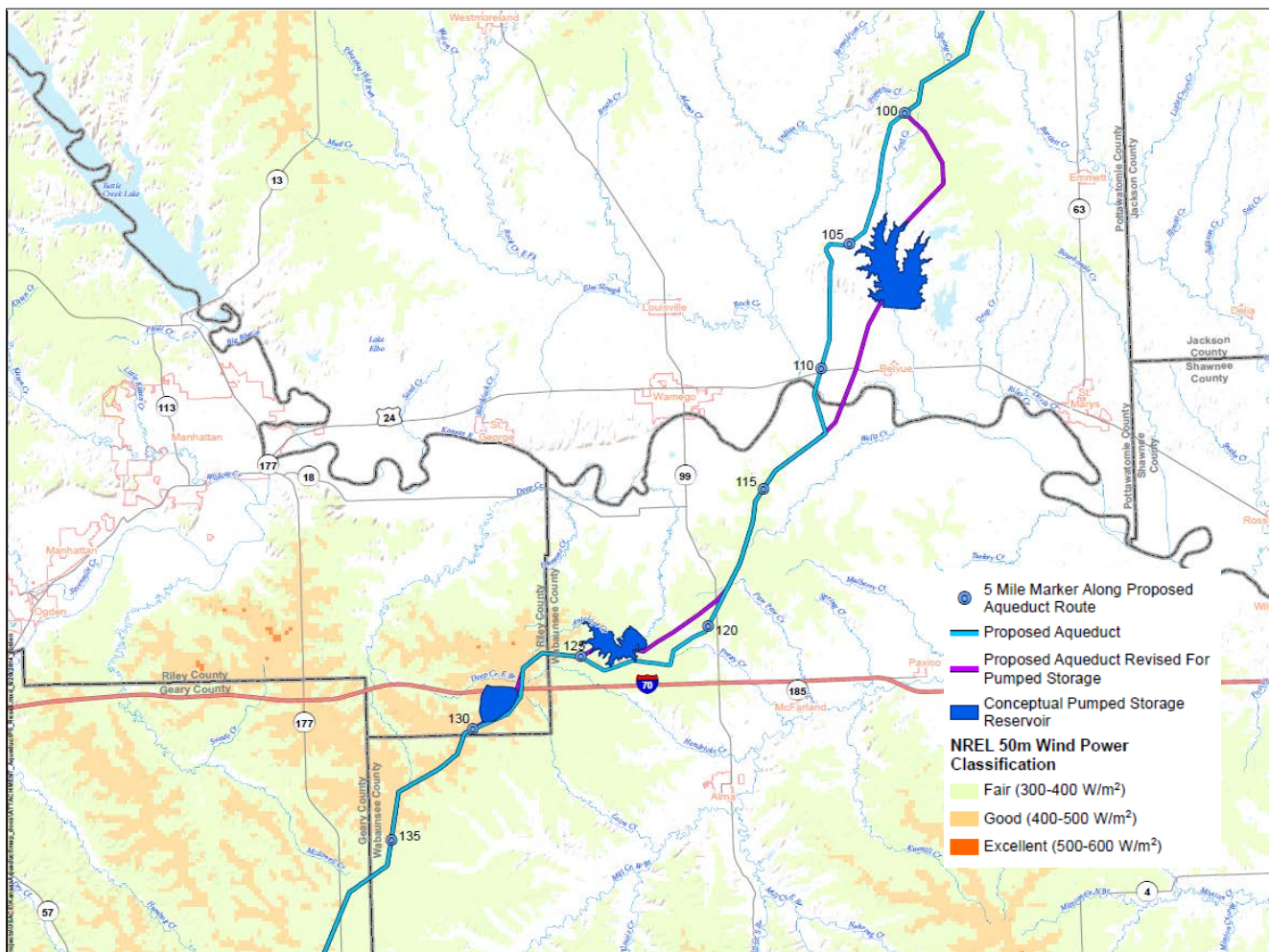
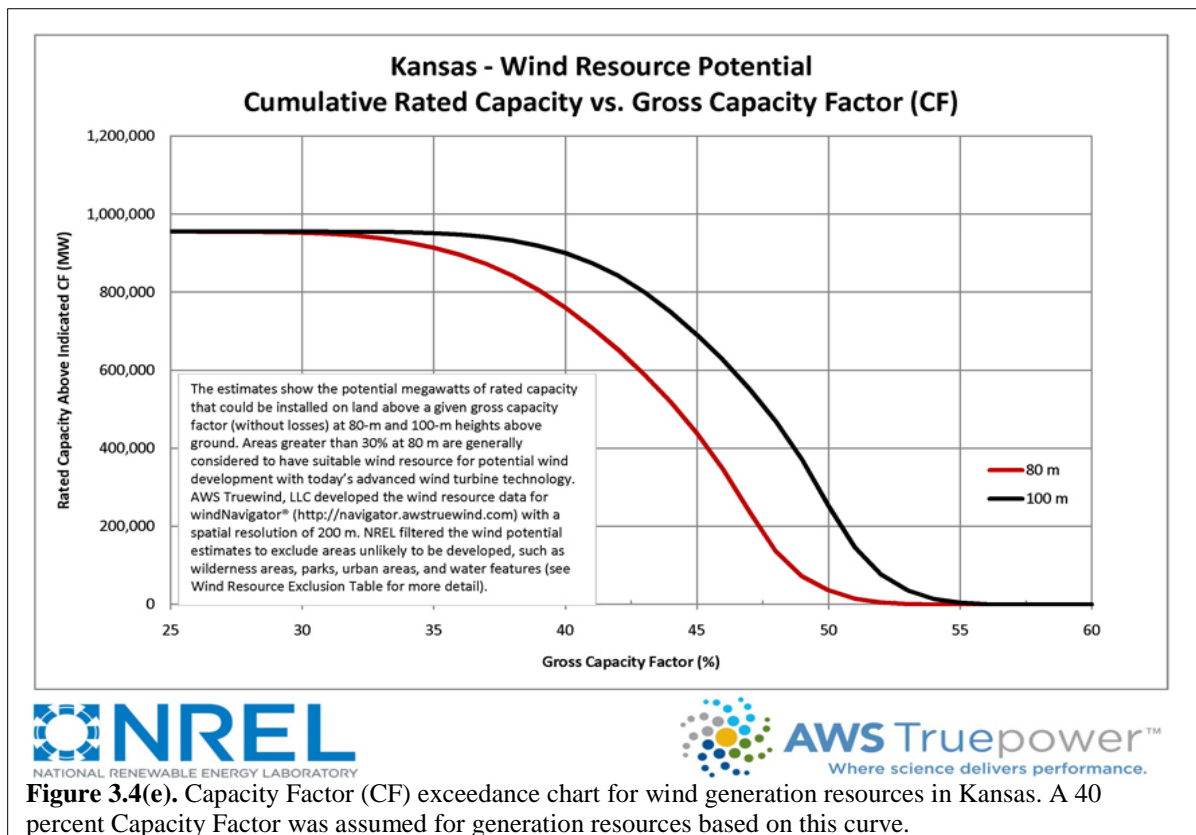


Figure 3.4(d). Conceptual location of additional storage reservoirs for use in a pumped hydropower generation facility.

With a 6,000 cfs near-constant inflow from the upstream canal, the forebay would have a storage capacity of approximately four days (assuming a complete “empty-to-full” cycle). When put into another context, this storage would allow the project to pump in excess of the 6,000 cfs supply for several days, and then have flexibility to pump less than 6,000 cfs for several days, allowing inflows from upstream to refill the forebay. It is this storage flexibility, along with

additional downstream storage, that creates the opportunity for pumped storage. The first of two pump stations would pump water from the forebay under the Kansas River to a second reservoir, the interbay, located in the upper Antelope Creek watershed near the City of McFarland with a useable storage of 20,000 acre feet and a maximum water surface elevation of around 1270 feet.

The pump station between the forebay and the interbay would include 2,000 cfs of fixed-speed, continuous pump capacity and 10,000 cfs of adjustable-speed pump capacity. Fixed speed pumps work best under a narrow range of flow and head, with significant drops in efficiency outside of this range. Adjustable-speed pumps provide the ability to maintain a high efficiency through a large range of flow rates and head conditions, but carry considerably higher up-front capital costs. The fixed-speed capacity pumps would be designed to run continuously, which would reduce the amount of water cycling needed to be performed by the reservoirs and provide protection against long durations of low wind generation availability. The adjustable-speed pumps would be used to provide a balancing resource to a potential wind generation corridor to be developed adjacent to the project (the details of the wind portion of this potential system are described later in this report). If the wind generation projects are developed to directly offset pump loads of the adjustable-speed machines at the project, these pumps can be sized such that they match this capacity factor. Because each pump station needs to be sized for 6,000 cfs on average, this would allow the adjustable-speed pumps to be sized for 10,000 cfs, but to provide 4,000 cfs on average (a 0.40 capacity factor, matching the wind generation profile). When combined with the 2,000 cfs fixed-speed pump flows, a net of 6,000 cfs is achieved. The 20,000 acre foot storage of the interbay allows for fluctuations in pumping over multiple days; the storage capacities envisioned by this preliminary design allow for either zero wind load or maximum wind load for up to 36 straight hours, with the appropriate starting reservoir conditions.



For the pump station between the forebay and the interbay, the fixed speed pumps are assumed to have a capacity of 45 MW (2,000 cfs at a net pumping head of 250 feet, with an overall efficiency of 90%) and the adjustable-speed pumps are assumed to have a capacity of 225 MW (10,000 cfs with the same head and efficiency parameters). A second and final pump station would lift water from the interbay to a third reservoir (afterbay), located at the top of the ridgeline adjacent to Interstate 70 with a useable storage of 20,000 AF and a maximum water surface elevation of approximately 1,500 feet

above mean sea level. This pump station would be designed and operated identically to the lower pump station, with a bank of fixed-speed and adjustable-speed units. The reservoirs and pipelines would be sized such that the capacities of the upper pump station match the lower pump station, in order to achieve efficiencies in manufacturing of equipment and in long term operation and maintenance costs. Water would then be released by gravity from the afterbay back into a Kansas aqueduct near canal mile 130, as shown on Figure 3.4(d).

Reviewing the remainder of the downstream alignment of a Kansas aqueduct, and in particular the proposed pump stations, no other viable locations for pumped storage projects were apparent. A lack of topography for adjacent reservoir storage was the dominant factor in downstream pumped storage opportunities being technically infeasible.

3.4.3.3 Utica Hydropower

As mentioned previously in this report, a conventional hydropower facility, while not mentioned in the 1982 Study, may also be viable at the base of Utica Dam, with an afterbay to provide both adequate tailwater pressure on the turbine and re-regulating storage flexibility for the hydropower plant (Figure 3.4(f)). The feasibility of coupling this Utica hydropower plant with other renewable power generating resources could be considered for meeting electricity demand for industrial, agricultural and residential uses in the Dodge City-Utica vicinity. A Utica Hydropower Plant, coupled with a re-regulating afterbay that provides enough storage to buffer 24 to 48 hours of wind generation variability, could provide a combined wind-hydro output that is predictable based on a preferred “load shape”, as demanded by a single or aggregated set of customers. The hydroelectric generating capacity of the Utica powerhouse would be based on the size of the afterbay storage and the potential up-sizing of the flow capacity through the powerhouse (i.e. the powerhouse could theoretically be designed with a capacity far in excess of 6,000 cfs, thereby enabling it to balance more wind capacity. It would, however, need adequate afterbay storage. Since the reservoir is relatively shallow, the available head would need to be carefully evaluated with respect the pool level changes that would occur through the irrigation season.

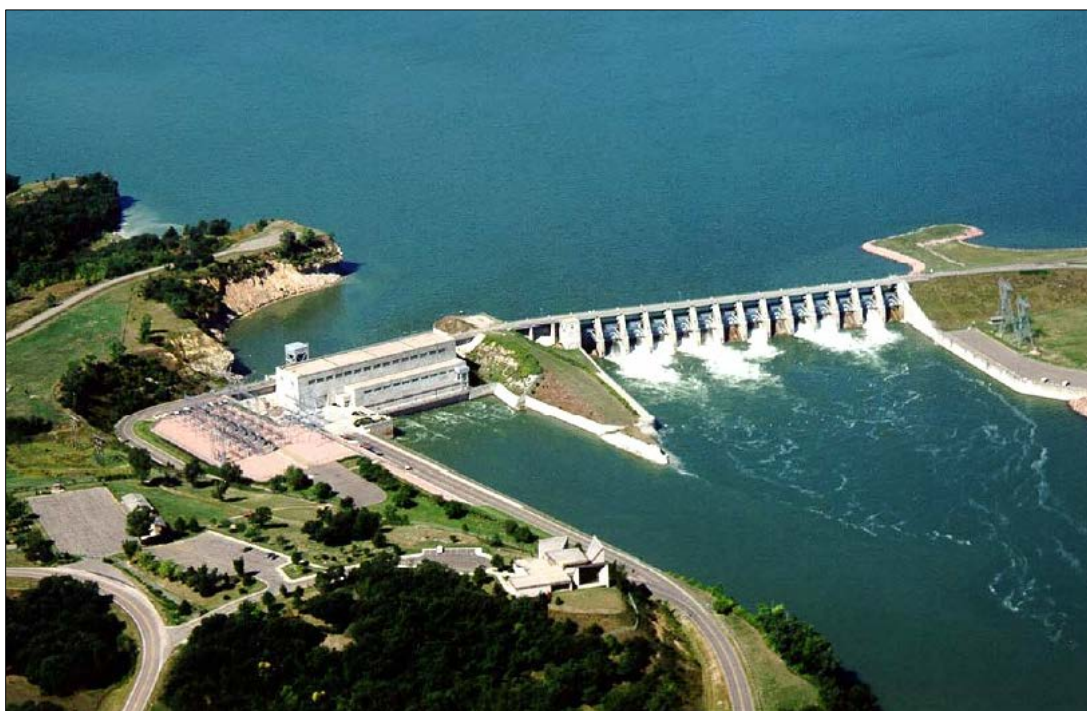


Figure 3.4(f). Conventional hydropower example from Gavins Point Dam on the Missouri River (source: www.nwd-mr.usace.army.mil/rcc/reports/pdfs/MissouriRiverFloodingUpdate18-June.pdf).

3.4.3.4 Development of Wind Generation Adjacent to Conceptual Hydro Facilities

As described previously, the hydropower alternatives would work well in conjunction with variable-dispatch renewables, namely wind power. Kansas has extensive existing wind-power generation, with a current installed wind power capacity of nearly 2,700 MW and a projected 7,000 MW to be installed by 2030. Kansas is also one of the nation's leading wind turbine manufacturing states.⁷

The variable nature of wind generation demands a “firming” resource, so that the net generation profile coming from the aggregated system is more stable and easier to dispatch to meet loads on the power supply grid. These resources are various forms of flexible generation or, more recently, various forms of energy storage. Conventional and pumped storage hydropower is often an ideal candidate to provide the firming capability that variable generation requires.

The wind resources located in the vicinity of the conceptual pumped storage project can be seen in Figure 3.4(d). The ridgeline provides mostly “Good” with a few small areas identified as having “Excellent” wind resources, as rated by the National Renewable Energy Laboratory (NREL), with generating densities at 50-meter turbine height ranging from 400 to 600 W/m².⁸ A wind power project co-located with the pumped storage project would reduce the combined project cost by reducing the need for lengthy transmission, additional substations and civil infrastructure. Based on an overall adjustable-speed pump capacity of 450 MW at the conceptual pumped storage project, there would be sufficient area in the region southeast of Manhattan (located generally along and across the Riley-Geary and Riley-Wabaunsee county lines) to construct a wind farm of adequate size to provide this type of capacity. The proximity to Kansas State University (KSU) may also be an opportunity for collaboration; KSU's Wind Application Center has already developed the Zond Wind Energy Project directly adjacent to campus in collaboration with the U.S. Department of Energy, which went through a rigorous Environmental Assessment to gain the project approvals and funding.

Wind generating potential in the vicinity of a Utica hydropower project is even more favorable. In this portion of western Kansas, wind resources are rated as generally “Excellent” by NREL, with generating densities at 50-meter turbine height ranging from 500 to 600 W/m². With relatively little land development, several hundred megawatts of wind resources could potentially be firmed and shaped by the Utica powerhouse, depending on the configuration of the afterbay storage and the ultimate size of the powerhouse. These wind resources, in aggregate with the Utica powerhouse, could be used to power both the immediate upstream pump station of a Kansas aqueduct or could be made available to local commercial or agricultural off-takers, as mentioned previously.

It is unlikely that additional sources of distributed wind generation, coupled directly with the other pump stations that make up a Kansas aqueduct project, would be viable without some form of firming resource such as a distributed, off-grid energy storage facility. These facilities (e.g. those with large lithium-ion battery banks) are relatively expensive, generally have a much shorter design life than the other components of the system, and would likely make the off-grid wind development economically infeasible. However, if the wind project could be tied into the regional electrical grid and firmed through other, regional resources, the viability of the project would be enhanced. Given the relatively remote locations of the central and western portions of a Kansas aqueduct, it has been assumed that these are not likely alternatives at this time.

3.4.4 Discussion of Other Alternatives

Several other alternatives were mentioned during stakeholder meetings and have been considered as potential concepts during the completion of this study. The alternatives are generally intended to reduce negative project impacts or lessen expected capital and long-term costs of the project. The following discussion introduces preliminary concepts; however, these alternatives have not been closely evaluated even at a planning level. These alternative concepts have been grouped based on which project component they could affect.

3.4.4.1 Water Demand Alternatives

3.4.4.1.1 Kansas Municipal and Industrial Users

The original project purpose was to supply irrigation water to western Kansas with no additional users along the canal alignment. Since the proposed canal alignment follows the ridge line, there are multiple communities along the route that would be down gradient from the canal. Turn-outs could be constructed along the canal alignment to provide water to these communities for public drinking water or industrial water supply. The turn-outs could be aligned with existing streams or new pipelines could be constructed. The municipal and industrial water demand is discussed in Chapter 1. Since these demands are much lower than irrigation demands, a pipeline could be feasible. The water supply could either be the primary supply or could be used to enhance water supply reliability and resiliency.

Municipal and industrial users may also be able to support a higher rate structure than an exclusively agricultural base. This higher rate structure may help with project financing similar to the Central Arizona Project (CAP) regional water supply project in Arizona. The cost structure for the CAP is presented in Chapter 4. It should be noted that the CAP project has a much higher municipal and industrial base and only about 25% of the total supply is used for irrigation. Using the projected 2040 demands presented in Chapter 1, a Kansas aqueduct project would have 1.5% to 4.8% municipal and industrial water supply demand. It is unlikely that this low percentage of municipal and industrial users would be able to significantly reduce the agricultural unit cost of the water to be supplied as it did for the CAP. The water supply to these communities, however, would be valuable and allow for future growth.

3.4.4.1.2 Project Phasing

The 1982 Study envisioned construction of the entire project before water distribution would begin. The construction costs and interest charges would accumulate until the entire system was fully built. Project phasing may allow either a smaller system or a shorter system to be initially built and water delivery to begin in shorter time interval. One option would be to provide a canal alignment connecting to Milford and Tuttle Creek reservoirs. Milford and Tuttle Creek reservoirs would be used as the terminal reservoir during this first phase. The canal would supply water for municipal, industrial and irrigation users downstream of the canal alignment and these reservoirs. Communities near and downstream of Manhattan and Topeka could possibly be served. A canal turn-out and transfer system could potentially service the Neosho Basin. A smaller source reservoir and transfer canal system would be needed during this first phase.

Another phasing plan would be constructing the aqueduct westward to supply water to Wichita, irrigation users and nearby communities. Under this phasing plan, the canal transfer system would be smaller west of Milford and Tuttle Creek, since some of the demand would already be satisfied. This “telescoping” type of canal system is common for water supply projects. The upstream sections of the canal are larger and the canal size decreases in the downstream direction as water is diverted to satisfy demands along the route. Since there is not a terminal reservoir near Wichita, the system west of Milford and Tuttle Creek would not flow at a steady rate. The rate would be dependent on the seasonal demand.

Disadvantages to the phasing plan are related to the low initial demand volume. A much smaller system would be difficult to enlarge in future phases. For instance a pipeline system or a narrow canal could be viable during this first phase. Future phases would need a parallel system or complete reconstruction or expansion of the first phase. The irrigation demand increases toward the west. A phasing plan that ends in the eastern portion of the state would not be able to address the majority of the need.

3.4.4.1.3 Extend Canal to Adjacent States

The unit costs (dollars per acre foot delivered) presented in Chapter 4 are higher than can typically be supported by an agricultural dominated user base. The original 1982 Study anticipated the distribution system would extend into adjacent states. Adjacent states may potentially have significant municipal and industrial demands and be able to subsidize the agricultural use, similar to the pricing structure for the CAP regional water supply project in Arizona. This concept may also be able to leverage additional funding sources outside of the State of Kansas.

The disadvantages are related to lack of adequate supply for a multi-state system and coordination complexity. This raises questions on the amount of supply that would remain in Kansas versus transported to adjacent states. As the system is extended into multiple states, the overall construction costs would grow and coordination complexity would likewise grow.

3.4.4.2 Water Supply Alternatives

3.4.4.2.1 Kansas River Intake

A Kansas aqueduct would involve construction of a large siphon under the Kansas River east of Tuttle Creek Reservoir. There would be a pump station on the downstream side of the siphon to pump water up the ridge line so the flow can continue west. An intake structure on the Kansas River could be constructed and utilize the proposed pump station on the southwest side of the river. The additional flow volume would be transported and stored in the terminal reservoir thereby increasing the project yield. It is assumed the intake would be operated to skim flows above navigation and water supply intake structure targets when the Kansas River is above minimum stage.

The disadvantages mainly relate to the lack of a reservoir near the Kansas River intake. The flows from the Kansas River would not be constant since it would only be capturing flows at times of excess. The canal system and pump stations are intended to operate at a uniform rate and highly variable flows could cause significant operational concerns. A second concern is the addition of sediment to the canal. Both of these concerns can be mitigated with a new reservoir placed near the Kansas River intake or re-purposing either Milford or Tuttle Creek reservoirs. A new reservoir or re-purposed reservoir could lessen the flow variability and then release water at a uniform rate to the canal system. This reservoir could possibly be combined with a pump back hydropower system discussed in Section 3.4.3.

3.4.4.2.2 Watershed Yield

The watershed yield from the source reservoir and terminal reservoir was not included in the project yields. If the source reservoir is sited on a large river in the eastern portion of the state, additional flow volumes could be captured and routed into the system. It would be important to locate the source reservoir near the Missouri River to reduce the cost of the system between the Missouri River and the source reservoir. A portion of these flows are likely already being calculated as Missouri River flows above navigation and water supply intake structure targets and hence the increase in yield over the results presented in this study may not be substantially larger. The terminal reservoir has a large contributing drainage area (431 square miles) but the watershed yield is much lower than the eastern portion of the state. In addition, there could be a large number of water rights downstream of the terminal reservoir that would need to be addressed.

3.4.4.3 Minimize Source and/or Terminal Reservoir

3.4.4.3.1 Distributed Storage

Another potential alternative involves the construction of multiple smaller reservoirs along the canal alignment instead of a large source or terminal reservoir. The smaller reservoirs on the east end of the state would provide storage to lessen the flow variations from the Missouri River diversion and hence reduce the size of the source reservoir. The canal capacity to these eastern reservoirs would need to be large to handle the entire diversion capacity. The western reservoirs would store the flows above navigation and water supply intake structure targets until needed during the irrigation season and hence reduce the need for a terminal reservoir. The western reservoirs could be located closer to the irrigation demand locations (farm headgates).

Multiple smaller reservoirs offer reliability and operational advantages. For instance, a few reservoirs could be taken out of service without shutting down the entire system. The smaller reservoirs would be easier to site and may be able to better avoid or reduce impacts to sensitive environmental or cultural resource areas. If recreation is added to these reservoirs, the economic benefit could be distributed across the state rather than just being focused at either end.

This option was not studied in detail but it is anticipated the costs for multiple smaller reservoirs would likely exceed the costs of a large source and terminal reservoir. The canal size in the eastern portion of the state would need to be larger than the 1982 Study plan which would add cost. The canal size on the western end of the state, however, could be smaller since multiple turn-outs would be provided to service users and the canal size would be reduced downstream of each turn-out.

3.4.4.3.2 Canal Sizing to Match Missouri River Diversion Rate

As mentioned previously, if the canal has a capacity equal to the Missouri River diversion rate, then a source reservoir is not needed for storage. The flow rate in the canal would not be a constant rate but rather would peak and diminish as flows above navigation and water supply intake structure targets become available within the Missouri River. Much of the time, there would be a large amount of unused canal and pump station capacity.

Under this option, it is anticipated that the canal would need to be considerably larger than the 1982 Study plan. The canal capacity could be as large as 30,000 cfs to optimize the project yield. For instance a 6,000 cfs diversion capacity could be paired with a 6,000 cfs canal and no source reservoir. This option would be expected to provide an annual yield of 1.6 MAF compared to 2.4 MAF when a source reservoir is used with a similar canal capacity. It is anticipated the construction costs and maintenance costs would be much higher than the system presented in the 1982 Study.

3.4.4.3.3 Aquifer Recharge System

Western Kansas primarily irrigates using groundwater and already has the infrastructure in place to utilize groundwater. If the terminal reservoir could be replaced with an aquifer recharge system, then this could eliminate the need to build a canal distribution system from the terminal reservoir to the farm head gates. The aquifer recharge system would receive a uniform flow rate from the canal year-round and the water either injected or infiltrated into the regional groundwater table. The agricultural producers would continue to irrigate with groundwater under this option.

There are several smaller aquifer recharge systems operating in Arizona with a combined recharge capacity of 0.653 MAF annually. The combined recharge capacity, although substantial, is below most of the yields presented in this study. The Tamarack project in Colorado on the South Platte River uses a series of recharge ponds to augment approximately 10,000 acre feet per year but only for shallow return flows back to the river. The construction cost was approximately \$150 to \$300 per AF infiltrated. Applying this cost to the anticipated annual yield of 2 MAF, results in a system cost of \$300 to \$600 million. This cost exceeds the construction cost of the terminal reservoir; however, the costs for the distribution system to the farm head gates were not calculated. The distribution system costs would need to be added to the terminal reservoir cost, whereas the aquifer recharge system would not require a separate distribution system.

3.4.4.3.4 Utilize Existing Reservoirs

Tuttle Creek and Milford Lake

Utilization of existing reservoirs was discussed briefly in Section 3.4.4.1.2 Project Phasing, where these existing reservoirs could serve as terminal storage for the first phases of canal construction. Another option would be to incorporate these reservoirs as a means to decrease the source reservoir size. The disadvantage with either of these options is the lack of existing, dedicated storage volumes to serve this additional function. This is partially due to reservoir sedimentation, but also because the reservoirs were not designed to provide the 0.7 MAF of storage a Kansas aqueduct project could require. It is likely the dam height would need to be increased for either of these reservoirs to offer substantial additional storage.

Lewis and Clark Reservoir (Gavins Point Dam)

Instead of constructing a new 0.7 MAF source reservoir in Kansas, the existing 0.47 MAF Lewis and Clark Reservoir near Yankton, South Dakota could be considered. Lewis and Clark Reservoir is a Missouri River mainstem reservoir and could have similar water availability as the proposed diversion location near White Cloud, Kansas. Several major rivers within

Iowa and Nebraska enter the Missouri River below the diversion, and hence it is anticipated the potential volume of flows above navigation and water supply intake structure targets would be reduced. The amount of flows above navigation and water supply intake structure targets at Lewis and Clark Reservoir has not been evaluated.

A canal system would be built southwesterly across Nebraska with a major river crossing on the Platte River. The canal alignment would not be able to follow a ridge line and multiple river and stream crossings are anticipated. A western alignment might be advantageous if it is the intent to provide irrigation water to western Nebraska along the route to western Kansas. If desired, the route could provide augmentation flows to the South Platte River, North Platte River, the Republican River and the Kansas River before reaching the terminal reservoir location near Utica, Kansas. The route has the potential to benefit multiple states and support the preservation of threatened and endangered species.

3.5 Summary of Findings

The 1982 Study was reviewed to evaluate those project components based on updated Missouri River stream gage data and in light of the current Missouri River Mainstem Reservoir System Master Water Control Manual. A spreadsheet-based modeling tool was developed to evaluate the availability of Missouri River flows above navigation and water supply intake structure targets, and the effects of component sizing on project yield. The analysis indicates that up to 6.9 MAF of excess Missouri River flows (average annual) could be pumped using a 30,000 cfs Missouri River diversion capacity. The average annual yield is nearly 4 times higher than the 1.6 MAF average annual yield determined in the 1982 Study. The increase in yield is due to the additional years of stream gage data, updates to the Missouri River Mainstem Reservoir System Water Control Manual and changes in estimated upstream water diversions that would occur through year 2020. Missouri River diversion rates above 6,000 cfs would require the construction of a new lock and dam on the Missouri River. A 6,000 cfs maximum diversion capacity may avoid construction of a lock and dam but would reduce the potential project yields to 2.5 MAF annually, which still exceeds the yield from the 1982 Study. These yields are before seepage and evaporation losses are included from project components and hence the delivered volume to the farm head gates would be lower.

The pumped water would be stored in a source reservoir and the 1982 Study proposed a reservoir located near White Cloud, Kansas. The purpose of the source reservoir is to reduce flow variability so that a canal can convey water westward at a nearly uniform rate. The proposed size of the source reservoir was 0.7 MAF which would support a yield of 3.0 to 5.0 MAF annually using the Missouri River diversion rates between 10,000 and 30,000 cfs. Yield impacts from alternative reservoir sizes were evaluated with various canal capacities and diversion rates. The project yields are sensitive to the sizing of the diversion capacity and the source reservoir size. A larger source reservoir would be better able to supply water during extended droughts. The stated yields take into account evaporation and seepage losses from the source reservoir.

A 360 mile long concrete-lined canal and 15 pump stations would be required to transfer the water to western Kansas which is 1,745 feet uphill (net). Canal capacities of 2,000, 6,000 and 10,000 cfs were evaluated for consistency with the 1982 Study. The canal would follow a ridge line generally along the southern watershed divide of the Kansas River. The canal route would transect a large portion of the state and multiple infrastructure relocations would be required. The pumps would be electrically driven and would have a large electrical load. A hydroelectric plant near the Kansas River was proposed in the 1982 Study to partially offset the external electrical usage. A range of yields were evaluated ranging from 1.3 to 4.6 MAF annually which includes source reservoir and canal seepage and evaporation losses.

The irrigation demand is seasonal whereas the canal would flow at a uniform rate. The difference between the canal capacity and peak demand during irrigation season results in a need to construct a terminal reservoir. The proposed terminal reservoir is near Utica, Kansas and would be within the Ogallala aquifer. A range of yields to the farm head gates are calculated ranging from 0.9 to 3.3 MAF annually depending on the component sizing. The stated yields include source reservoir, canal, terminal reservoir and distribution system seepage and evaporation losses.

Several additional alternatives were discussed to various degrees of detail in response to stakeholder input. Some of the alternatives discussed may merit further study. These alternatives are listed in Table 3.5(a) and include options to increase

or diversify the water supply users; project phasing; methods to increase yield by using sources in addition to the Missouri River; minimizing the source and terminal reservoir capacities; aquifer recharge and methods to utilize existing reservoirs.

Table 3.5(a). Alternative Concepts and Primary Component(s) Affected.	
Alternative Concept	Primary Affected Component
Missouri River Horizontal Collector Wells	Missouri River Lock and Dam
Renewable Energy Generation Corridor	Electrical Costs
Kansas Municipal and Industrial Users	User Base
Phase I- Missouri River to Tuttle Creek & Milford Lake	Terminal Reservoir, User Base
Extend Canal to Adjacent States	User Base
Kansas River Intake	Project Yield
Watershed Yield to Source and Terminal Reservoir	Project Yield
Distributed Storage	Source and Terminal Reservoir
Canal Sizing to Match Missouri River Diversion Rate	Eliminate Source Reservoir
Aquifer Recharge System	Eliminate Terminal Reservoir
Re-purpose Tuttle Creek and Milford Lake	Reduce Source and Terminal Reservoir
Re-purpose Lewis and Clark Reservoir	Eliminate a new Source Reservoir

At the conceptual planning level of detail in this study, a system similar to the 1982 Study Route B 9 appears to offer a technically feasible method to transfer water to western Kansas to satisfy a portion of the irrigation demand and potentially some municipal demands. System size optimization and further project definition is needed in order to further evaluate the appropriate sizing and location of the major project elements. Other alternative concepts for water transfer systems have been identified in this study and may merit further development and consideration.

¹ U.S. Department of the Interior, Bureau of Reclamation. 2008. *Research and Development for Horizontal/Angle Well Technology*. Desalination and Water Purification Research and Development Program Report No. 151. October.

² Sterrett, R. J. 2007. *Groundwater and Wells, 3rd Edition*. New Brighton, Minnesota: Johnson Screens.

³ Hunt, H. C. 2002. *United States experience in installing horizontal collector wells*. In *Riverbank Filtration: Improving Source Water Quality*, C. Ray, G. Melin, and R. Linsky (eds.). Kluwer Academic Publishers, Dordrecht, The Netherlands.

⁴ Ibid.

⁵ Sterrett, R. J. 2007. *Groundwater and Wells, 3rd Edition*. New Brighton, Minnesota: Johnson Screens.

⁶ City of Olathe. 2012. Olathe City Council Regular Session Meeting Notes. October 2.

Update of 1982 Six State High Plains Aquifer Study

Chapter 4: Preliminary Opinion of Probable Costs

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Preliminary opinions of probable capital and operating costs have been developed under Study Task 7 – Cost Estimates. Task 7 is limited to updating the Six-State High Plains-Ogallala Aquifer Regional Resources Study (1982 Study); Alternate B South Route projected costs to 2014 base year costs. Estimates of construction quantities are not included in this update of a Kansas aqueduct; nor is the development of new unit costs of construction line items. The projected costs include a breakout of construction-related costs, anticipated annual recurring costs for maintenance and repair of the overall system and energy costs. A resulting cost per acre foot of water delivered has been calculated using various water availability and delivery factors. The projected costs associated with potential environmental mitigation requirements were not developed in the 1982 Study and are discussed in Chapter 6. Estimation of environmental related costs are beyond the scope of this update.

Alternatives to selected components of the 1982 Study Route B water transfer system have been developed along with their respective capital costs. Selected regional water supply systems have been examined for comparison of capital construction costs or delivered water costs per acre foot of water (as appropriate) to those shown for the 1982 Study Alternate B South Route.

An initial risk analysis has been developed to identify areas of potentially significant project risk and the associated effects on project cost uncertainty. Initial risk mitigation strategies are presented as potential measures to reduce projected cost uncertainties in the longer term.

The preliminary opinions of probable costs provided herein are based only on high-level conceptual reviews of available information. The projected costs rely on the 1982 reported cost items and industry-recognized escalation factors and costs indices. The development of detailed construction quantities and associated cost estimating is beyond the scope of this study.

4.1 Introduction

The Six-State High Plains-Ogallala Aquifer Regional Resources Study (1982 Study) included an examination of a Missouri River water diversion and an aqueduct to western Kansas. Under the 1982 concept, water would be diverted during Missouri River flows occurring over and above the navigation requirement, then be stored and transferred to western Kansas (and/or other western states) and eventually be used to help offset the rate of depletion occurring in the Ogallala aquifer.

The U.S. Army Corps of Engineers (Corps) Kansas City District assisted in the 1982 Study, by preparing the Reconnaissance Study Alternate Route B Water Transfer from the Missouri River to Western Kansas in September, 1982. This Reconnaissance Study was included as *Appendix B* to the *Six-State High Plains-Ogallala Aquifer Regional Resources Study*. The objectives of this Reconnaissance Study were to:

- Determine the engineering feasibility of water transfer.
- Estimate the costs of constructing, operating and maintaining a water transfer system.
- Identify the general environmental effects associated with the action.

Two potential Route B alignments, a north route and a south route, were evaluated. The Alternate B South Route was found to have one of the lowest investment costs, the least expensive energy costs, the lowest unit cost (dollars per acre foot) for water transfer, and the shortest transfer distance at 360 miles. Water transfer facilities were sized and costs were developed in the 1982 Study; *Appendix B-Reconnaissance Study Alternate Route B Water Transfer from Missouri River to Western Kansas*. This document is used as the source of background descriptions and costs for the Alternate B South Route.

The U.S. Army Corps of Engineers (Corps) Southwestern Division assisted in the 1982 Study, by preparing the Cost and Design Manual in August, 1980. This Cost and Design Manual was included as *Appendix E* to the *Six-State High Plains-Ogallala Aquifer Regional Resources Study*. The purpose of this Cost and Design Manual was to provide guidance for the Corps in preparing reconnaissance level design, cost estimates and environmental assessments for large water transfer facilities including:

- Laying out water transfer systems.
- Developing estimates of project costs.
- Assessing environmental effects along each alternative transfer route.

This Cost and Design Manual was used to identify the Corps procedures for design and cost estimate development for Alternate B South Route.

The *1982 Study; Appendix B-Reconnaissance Study Alternate Route B Water Transfer from Missouri River to Western Kansas* is a reconnaissance level study, not a detailed design of the facilities. The AACE International (formerly referred to as the Association for the Advancement of Cost Engineering) has developed recommended practices for cost estimating. Recommended practices No. 17R-97-Cost Estimate Classification System and No. 18R-97-Cost Estimate Classification System-As Applied in Engineering, Procurement, and Construction for the Process Industries present cost estimate classification matrixes based upon the maturity level of the project definition. This matrix provides an expected accuracy range of a cost estimate based upon the maturity level of project definition deliverables along with the typical end usage for the cost estimate. For the purposes of this study, the “concept screening” category appears to be representative of the current project stage. The AACE International recommended practices give the information presented below related to the expected level of accuracy for these types of end usages. This information is presented to suggest potential levels of uncertainty associated with the projected costs provided. Additional factors contributing to uncertainties in the projected costs are presented in other locations below.

Table 4.1(a). Cost Estimate Expected Accuracy Range for Concept Screening and Feasibility Study.		
End Usage General Purpose of Cost Estimate	Project Maturity Level Expressed as % of Complete Definition	Expected Accuracy Range Typical Variations in Low and High Ranges
Concept Screening	0% to 2%	Low: -20% to -50% High: +30% to +100%
Feasibility Study	1% to 15%	Low: -15% to -30% High: +20% to +50%
Information selected from AACE International Recommended Practice 18R-97		

4.2 Alternate Route B Projected Costs

4.2.1 Cost Elements Originating from 1982 Study

The Cost and Design Manual used by the Corps in the 1982 Study identifies the following major cost elements:

- Lands and Damages.
- Relocations.
- Dams and Reservoirs.
- Pumping Plants and Hydropower.
- Pipelines.
- Canals.
- Siphons.
- Tunnels.
- Automation and Communication.
- Cultural Resources.
- Environmental Mitigation.

A summary description of the approach to projecting costs for the 1982 Study for each of these elements is provided below. The Cost and Design Manual used in the 1982 Study (Appendix E-1982 Study) is included as Appendix 1 of this report.

4.2.1.1 Lands and Damages

Project land requirements primarily include the canal and reservoirs, although relatively smaller amounts of land would be required for pumping stations, special drainage accommodations and other needs. The unit value used for Kansas was \$1,300 per acre. Figures 7 through 10 (Appendix E-1982 Study) show land costs per mile of canal based on water transfer system design flows.

4.2.1.2 Relocations

Relocation costs are divided into two general categories: those associated with conveyance facilities, and those associated with a dam and reservoir. Relocation cost elements for conveyance facilities include highways, railroads, major pipelines, major power lines and miscellaneous relocations (including Federal-aid secondary and county roads, electrical distribution lines, rural waterlines and telephone lines).

- Highway relocations include interstate, U.S. and state highways. Figure 11 (Appendix E-1982 Study) shows the highway bridge and approach costs based on water transfer system design flows. These cost curves are based upon site topography conditions requiring assumed amounts of cut and fill for approaches to canal crossings. More severe site topography could increase these costs.
- Railroad bridge and approach costs based on water transfer system design flows are shown in Figure 12 (Appendix E-1982 Study), based upon a single track. These cost curves are based upon site topography conditions requiring assumed amounts of cut and fill for approaches to canal crossings. More severe site topography could increase these costs.
- Pipeline relocations are assigned a \$75,000 relocation cost per pipeline due to site topography not being sufficiently defined at the time of the study.
- Powerlines of 115 kilovolts or greater are assigned an \$80,000 relocation cost per powerline.
- Miscellaneous relocation costs are shown in Figure 13 (Appendix E-1982 Study) using minor relocations costs per mile of canal based on water transfer system design flows. These costs are a composite of the estimated costs of Federal-aid secondary and county roads, electrical distribution, rural waterlines and telephone line relocations.

Relocation cost elements for dams and reservoirs include highways, railroads, transmission pipelines (natural gas, crude oil, oil products), powerlines (transmission and distribution), telephone lines and rural waterlines. Relocation costs are shown in Figure 14 (Appendix E-1982 Study) based upon the cost per mile of relocation for highways, railroads, transmission pipelines, powerlines, telephone lines and rural water lines. These costs assume typical Midwestern relocation (moderate slopes, adequate soil depths, moderate rock excavations, etc.). A contingency factor of 25% is included to account for atypical situations. The relocation costs reflect the following assumptions:

- Highways and railroads are based upon typical site topography conditions. More severe site topography could increase these costs. Costs for major bridges (exceeding 500 feet in length) are not included as none were identified for construction in the 1982 Study. Land costs are included.
- Pipeline costs include easement, clearing, surveying construction.
- Powerline costs are based upon above-ground installations and include easement, clearing, surveying, drilling and construction.
- Telephone line costs are for underground installation.

4.2.1.3 Dams and Reservoirs

It is assumed that the principal function of the reservoirs is storage of diverted water. Therefore, it is assumed that only sediment and conservation storage would be provided. The crest of the emergency spillway would be located at the top of

the conservation pool, unless a gated spillway is provided. Flood surcharge capacity would be above the conservation pool level to allow the design flood to pass the emergency spillway above the conservation pool level resulting in additional dam height and land requirements beyond that needed for the conservation pool.

- Concrete dam structure costs are shown in Figure 15 (Appendix E-1982 Study) based upon the direct cost (\$/CY) versus the volume of the concrete. The cost relationship is based upon the dam structure, spillway, outlet works, other items and contingencies.
- Earthen dam costs are presented separately for embankment, spillway and outlet works.
 - Figures 16 and 16a (Appendix E-1982 Study) show the costs for earthen and rock fill dams based upon the direct cost (\$/CY) versus the embankment volume and is applicable to earthen and rock fill dams.
 - Figure 17 and 17a (Appendix E-1982 Study) show the costs for spillways based upon the head from dam crest to streambed and spillway capacity.
 - Figure 18 and 18a (Appendix E-1982 Study) show the costs for outlet works based upon the head from dam crest to streambed and outlet works' capacity.
- Diversion dam costs with gated and ungated spillways (or weirs) are shown in Figures 19 and 20 (Appendix E-1982 Study) based upon the width and height of the dam.
- Canal headwork's costs are shown in Figure 21 (Appendix E-1982 Study) based upon discharge capacity.

4.2.1.4 Pumping Plants

Pumping plants would be semi-attended indoor plants equipped with turbine-type centrifugal pumps driven by electric motors. Costs for pumping plants are provided in Figure 22 (Appendix E-1982 Study) based upon pumping plant capacity and head.

4.2.1.5 Pipelines

Pipelines (discharge conduits) would convey water from the pumping plants to higher elevations. Pipelines are assumed to be precast, prestressed concrete cylinder pipe using a minimum of three feet of soil cover and a maximum diameter of 20 feet. At locations requiring a pipe greater than 20 feet in diameter, multiple pipes are used. Pipeline (pumping plant discharge conduit) costs are shown in Figure 23 (Appendix E-1982 Study) based upon linear feet of pipeline for a given total discharge.

4.2.1.6 Canals

The canal costs include the concrete used for construction of the lining. The waterway costs include excavation (common and rock), borrow, compacting embankments and trimming the canal for the concrete lining. Major factors impacting canal costs include the amounts of excavation (common and rock), compacted fill, concrete, canal lining, slope of canal and length of canal. Figure 24 (Appendix E-1982 Study) shows canal costs per mile versus flow rate plus a 25% contingency and 10% for miscellaneous items for concrete canals flowing from 500 cfs to 30,000 cfs with different percentages of rock excavation to total excavation. Excavation in rock is considerably more expensive than removal of overburden and soils and can cause a great variation in cost per mile; therefore separate curves are shown for different percentages of rock excavation. Actual costs could vary by about 10% +/- based upon minor items.

4.2.1.7 Siphons

Costs for siphons are provided in Figure 25 (Appendix E-1982 Study) based upon linear feet of siphon versus discharge. These costs include 25% contingency and 10% for miscellaneous items.

4.2.1.8 Tunnels

Costs for tunnels are provided in Figure 26 (Appendix E-1982 Study) based upon linear feet of tunnel versus discharge. The maximum practical tunnel diameter is assumed to be 50 feet. These costs include excavation, concrete lining, cement, steel supports, timber lagging, 25% contingency and 10% for miscellaneous items.

4.2.1.9 Automation and Communication

Automation includes both hardware and software for remote monitoring and control of pumping and other canal works from a centrally located control center. Redundant controls are assumed at pumping plants. Costs are assumed to be similar to those experienced by the California State Water Project (Appendix E-1982 Study).

4.2.1.10 Cultural Resources

Public Law 93-291, “An Act for the Preservation of Historic and Archeological Data”, authorized up to 1% of the total amount authorized for a project to be spent on the preservation of cultural resources. Although a limited investigation of cultural resources was performed, the investigation indicated the area is rich in cultural resources. Based upon this and the rapidly rising costs for cultural resources investigations, the entire 1% of authorized project costs is used to estimate costs for the preservation of cultural resources.

4.2.2 Basis of Construction Costs and Projections

The costs for engineering, design and construction supervision and administration (EDSA) are added to the construction costs to arrive at the first costs. The costs of interest during the construction period (based upon the total first costs taken to the anticipated midpoint of construction) are added to the first costs to obtain the investment cost. The 1982 Study considered construction durations of 10, 15 and 20 years to evaluate the impact of interest on total first costs. It was decided during the course of this investigation to focus on a 20 year construction duration and a base year 1979 for escalation of construction costs to 2014. Costs were not developed in the 1982 Study for the distribution canals or water distribution systems required from the terminal reservoir to the use areas. This would be a significant cost that has not been investigated and is beyond the scope of this study.

The costs identified for construction by the 1982 Study include:

- **Lock and Dam.** This includes a Lock and Dam (for Missouri River diversions of 6,000 cubic feet per second (cfs) in capacity and greater) on the Missouri River. It should be noted that this cost was omitted from the 1982 Study for the 6,000 cfs capacity system but is shown in the tables below for the 1979 costs.
- **Source Reservoir.** This includes a 700,000 acre foot reservoir southeast of White Cloud, Kansas.
- **Pumping Stations and Power Plant.** This includes 16 pumping stations (including one at the Missouri River), each having up to 10 pumping units, to move water upwards along the transfer system. A single hydropower site was included to generate power.
- **Canals.** This includes approximately 360 miles of canals from a source reservoir to a terminal reservoir.
- **Pipelines (conduit).** Siphons are used to cross major streams and some highways and railroads. Pumping stations discharge into prestressed, precast concrete pipe to higher elevations then released into a canal to flow by gravity to the next pump station.
- **Terminal Reservoir.** This includes a reservoir in the vicinity of Utica, Kansas. The size of this reservoir varies according to the yields as discussed in Chapter 3.
- **Route Relocations.** This includes relocations of highways, railroads, major pipelines, major powerlines and miscellaneous relocations (Federal-aid and secondary county roads, electrical distribution, rural waterlines and telephone lines) required for conveyance facilities and those associated with a dam and reservoir.
- **Automation and Communication.** This includes costs for both hardware and software for remote monitoring and control of pumping and other canal works from a centrally located control center.

- **Engineering, design and construction supervision and administration (EDSA).** The costs for engineering, design and construction supervision and administration (EDSA) were assumed to be 11% of the construction cost.

Costs presented in the 1982 Study were expressed as either year 1977 or year 1979 cost base. 1982 Study costs contained herein are expressed in year 1979 cost base and then projected to the year 2014 cost base.

The 1982 Study costs were projected to year 2014 (August) costs using the Engineering News Record Historical Construction Cost Index (CCI). This is a composite index using reference costs from labor, standard structural steel shapes, Portland cement and lumber. It provides an industry reference for estimating construction costs from a base year to another year. It was used to escalate costs from 1979 to 2014 by multiplying year 1979 costs by the ratio of the August, 2014 CCI (9846) to the 1979 CCI (3003). The composite ratio used was 3.27872.

The interest rate used in the 1982 Study was the Fiscal Year 1981 Federal Water Resources Council rate of 7 3/8%. The costs herein reflect the use of the 7 3/8% interest rate for all year 1979 costs. The current Fiscal Year 2014 Federal Water Resources Council rate of 3 1/2% is used for all year 2014 projected costs.

4.2.3 First Costs and Total Investment Costs in 1982 Study

The year 1979 construction cost components, EDSA and interest during construction based upon a 20 year period at 7 3/8% interest rate are given in Table 4.2(a) for water transfer system capacities of 2,000 cfs, 6,000 cfs and 10,000 cfs.

Table 4.2(a).			
Year 1979 Investment Costs for Route B Water Transfer System.			
Item Description	Item Costs for Water Transfer System Size		
	2,000 cfs	6,000 cfs	10,000 cfs
Lock & Dam	\$0	\$82,000,000	\$82,000,000
Source Reservoir	90,000,000	90,000,000	90,000,000
Pumping Stations and Power Plant	325,000,000	1,300,000,000	2,489,000,000
Canals	709,000,000	1,191,000,000	1,523,000,000
Pipelines (conduit)	168,000,000	421,000,000	690,000,000
Terminal Reservoir	55,000,000	140,000,000	257,000,000
Route Relocations	107,000,000	114,000,000	120,000,000
Automation & Communication	23,000,000	23,000,000	23,000,000
Subtotal Construction	1,477,000,000	3,361,000,000	5,274,000,000
EDSA (@ 11%)	162,000,000	370,000,000	580,000,000
Total First Costs	1,639,000,000	3,731,000,000	5,854,000,000
Interest During Construction (20 years at 7 3/8%)	1,862,000,000	4,237,000,000	6,649,000,000
Total Investment Costs	3,501,000,000	7,968,000,000	12,503,000,000

4.2.4 Projected First Costs and Total Investment Costs Adjusted to 2014

The year 2014 projected construction cost components; EDSA and interest during construction based upon a 20 year period at 3 1/2% interest rate are given in Table 4.2(b) for water transfer system capacities of 2,000 cfs, 6,000 cfs and 10,000 cfs. The FY 2014 general interest rate for water resources planning is 3 3/8%, however, the water supply rate adds another 1/8% interest for a total of 3 1/2%.

**Table 4.2(b).
Year 2014 Cost Base Projected Investment Costs for Route B Water Transfer System.**

Item Description	Item Costs for Water Transfer System Size		
	2,000 cfs	6,000 cfs	10,000 cfs
Lock & Dam	\$0	\$269,000,000	\$269,000,000
Source Reservoir	295,000,000	295,000,000	295,000,000
Pumping Stations and Power Plant	1,066,000,000	4,262,000,000	8,161,000,000
Canals	2,325,000,000	3,905,000,000	4,993,000,000
Pipelines (conduit)	551,000,000	1,380,000,000	2,262,000,000
Terminal Reservoir	180,000,000	459,000,000	843,000,000
Route Relocations	351,000,000	374,000,000	393,000,000
Automation & Communication	75,000,000	75,000,000	75,000,000
Subtotal Construction	4,843,000,000	11,019,000,000	17,291,000,000
EDSA (@ 11%)	533,000,000	1,212,000,000	1,902,000,000
Total First Costs	5,376,000,000	12,231,000,000	19,193,000,000
Interest During Construction (20 years at 3½%)	2,544,000	5,788,000,000	9,083,000,000
Total Investment Costs	7,919,000	18,019,000,000	28,276,000

4.2.5 Limitations and Precautions

The nature of a reconnaissance report prohibits performing site investigations, obtaining extensive site information or developing detailed design concepts. Generally available site information is used to develop assumptions for site conditions that influence construction operations and costs. Design tasks are limited to providing general information regarding the scope and extent of project facilities to be constructed. Limitations on the information presented herein pertain to assumptions made regarding the nature of the construction work that could be required to construct a project and assumptions made pertaining to projected costs.

Some assumptions discussed in the 1982 Study include:

- Highway relocations cost curves are based upon site topography conditions requiring assumed amounts of cut and fill for approaches to canal crossings. More severe site topography could increase these costs.
- Railroad bridge and approach cost curves are based upon site topography conditions requiring assumed amounts of cut and fill for approaches to canal crossings. More severe site topography could increase these costs.
- Pipeline relocations are assigned a \$75,000 relocation cost per pipeline due to site topography not being sufficiently defined at the time of the study.
- Powerlines of 115 kilovolts or greater are assigned an \$80,000 relocation cost per powerline.
- Miscellaneous relocation costs are a composite of the estimated costs of Federal-aid secondary and county roads, electrical distribution, rural waterlines and telephone line relocations.
- Relocation cost elements for highways, railroads, transmission pipelines (natural gas, crude oil, oil products), powerlines (transmission and distribution), telephone lines and rural waterlines assume typical Midwestern relocation (moderate slopes, adequate soil depths, moderate rock excavations, etc.).
- The major cost elements for canals are the canal and the waterway. The waterway costs include excavation (common and rock), borrow, compacting embankments and trimming the canal for the concrete lining. Major factors impacting canal costs include the amounts of excavation (common and rock), compacted fill, concrete, canal lining, slope of canal and length of canal. Rock excavation to total excavation causes a great variation in cost per mile. Actual costs could vary by about 10% +/- based upon minor items.
- Contingencies were assumed for construction activities, generally this was 25%. This contingency factor may not be adequate to account for cost increases due to project unknowns that are encountered during construction.
- Automation costs are assumed to be similar to those experienced by the California State Water Project.

- Projected costs were not developed in the 1982 Study for the distribution canals or water distribution systems required from the terminal reservoir to the use areas. This would be a significant cost that has not been investigated and is not shown here.

The AACE International recommended practices presented in Table 4.1(a) provide the expected level of accuracy for these types of end usages.

The limitations discussed above could result in significant changes to project facilities and costs if actual conditions vary significantly.

4.3 Alternate Route B Annual Costs

4.3.1 Annual Cost Elements Originating from 1982 Study

The U.S. Army Corps of Engineers (Corps) Southwestern Division prepared the Cost and Design Manual that was included as Appendix E to the Six-State High Plains-Ogallala Aquifer Regional Resources Study. This Cost and Design Manual provided guidance for the Corps in preparing reconnaissance level design, cost estimates and environmental assessments for the 1982 Study. The Cost and Design Manual identifies the following major cost elements for estimating annual costs:

Interest Rate. The interest rate used is the interest rate established for each fiscal year by the Water Resources Council.

Period of Analysis. This is defined as the period beginning at the end of the construction period over which project benefits and annual costs would accrue.

Interest During Construction. This includes the actual interest paid on the expenditures (first costs) to construct a project as presented in Section 4.2.

Investment Cost. Investment cost includes the first costs and interest during construction as presented in Section 4.2.

Interest and Amortization Cost. The annual cost necessary to pay off project costs at the specified federal interest rate to spread the costs over the project life.

Operation, Maintenance and Replacement Costs. The annual costs for materials, equipment, services and facilities to operate a project and make the repairs and replacements necessary to maintain project facilities in good operating condition during the period of analysis.

Energy Costs. Electrical power costs to operate project facilities, primarily costs for pumping the water from the pumping stations uphill to the next canal.

The annual costs are then divided by the annual quantity of water delivered to the terminal reservoir to obtain the cost per acre foot (\$/AF) of water for use.

4.3.2 Basis of Annual Costs 1982 Study

The following provides details regarding how the annual cost elements were determined.

- **Interest Rate.** The Federal interest rate for the year 1979 costs is 7-3/8%. For the year 2014 costs the interest rate is 3-1/2%.
- **Period of Analysis.** A 100-year period is appropriate for use with the 1982 Study.
- **Interest During Construction.** A period of 20 years is used herein.
- **Operation, Maintenance, Repair, Replacement and Rehabilitation (OMRR&R) Costs.**

- The annual operations and maintenance costs projected for dams and reservoirs is shown in Figure 27 (Appendix E-1982 Study) based upon total volume of controlled storage. Operation and maintenance costs for pumping stations are shown in Figure 28 (Appendix E-1982 Study) based upon pumping plant capacity at various discharge heads and include costs for personnel, materials, supplies and repairs. Operation and maintenance costs for conveyance facilities are shown in Figure 30 (Appendix E-1982 Study) based upon flow and annual costs per mile for two levels (normal and high) of maintenance. These costs include canals, check gate structures, metal bridges and lateral drainage structures. These costs also include replacement of fencing, dirt roads, paved roads, radial gates (< \$100,000), small motors and small computers.
- Repair, replacement and rehabilitation costs for pumping stations are shown in Figure 29 (Appendix E-1982 Study) based upon an annual rate of \$0.003 per dollar of first cost for pumps and prime movers.
- **Energy Costs.** Electrical power costs for pumping stations are shown in Figure 31 (Appendix E-1982 Study) based upon kilowatt hours per acre foot for total pumping head. Head loss was assumed to include the actual elevation between the Missouri River and the terminal reservoir, 15 feet of head loss through each pump station and power plant, friction losses in canals and siphons, 18% head loss during power generation (turbines at 82% efficiency). Energy usage assumes pumping efficiency of 82% and includes a 5% contingency. The value obtained from Figure 31 must be multiplied by an appropriate rate per kilowatt hour. Electrical power costs are given as 22.69 mils/kWh (year 1977) in the 1982 Study and are adjusted to 25.33 mils/kWh for year 1979. An electrical power cost of 45 mils/kWh was used for year 2014 costs. Power costs are applied at the rate of 1.333 kWh/acre foot/foot head based upon Appendix E-1982 Study.

4.3.3 Annual Costs 1982 Study

The annual costs for operations and maintenance costs, energy costs and interest and amortization of first costs for the 2,000 cfs, 6,000 cfs and 10,000 cfs water transfer systems are shown in Tables 4.3(a), 4.3 (b) and 4.3(c) respectively for year 1979 costs. All costs are based upon a 20 year construction period and a 100-year project first costs amortization.

Table 4.3(a). Year 1979 Annual OMRR&R Costs for Route B Water Transfer System.			
OMRR&R Facility	Water Transfer System Size		
	2,000 cfs	6,000 cfs	10,000 cfs
Canal OMRR&R	\$3,115,000	\$3,221,000	\$3,322,000
Pipelines (conduits) OMRR&R	\$148,000	\$151,000	\$156,000
Plant O&M	\$2,582,000	\$3,945,000	\$5,245,000
Plant RR&R	\$1,348,000	\$2,059,000	\$2,739,000
Automation & Communications	\$48,000	\$48,000	\$48,000
Source Reservoir	\$510,000	\$510,000	\$510,000
Terminal Reservoir	\$370,00	\$700,000	\$930,000
Lock & Dam	0	\$700,000	\$700,000
Totals	\$8,121,000	\$11,334,000	\$13,650,000

Table 4.3(b).
Year 1979 Annual Energy Costs for Route B Water Transfer System.

Cost Factors	Water Transfer System Size		
	2,000 cfs	6,000 cfs	10,000 cfs
Supplied Acre feet/Year	\$1,000,000	\$2,400,000	\$3,200,000
Multiplier for Acre feet in System	1.235	1.235	1.235
System Equivalent Head (Feet)	2,377	2,223	2,204
kWh/Acre feet Head	1.333	1.333	1.333
Energy Costs (\$/kWh)	0.02533	0.02533	0.02533
Total Annual Energy Costs	\$99,000,000	\$222,000,000	\$294,000,000

Table 4.3(c).
Year 1979 Interest & Amortization Costs for Route B Water Transfer System.

Interest & Amortization Costs for Year 1979	Water Transfer System Size		
	2,000 cfs	6,000 cfs	10,000 cfs
Interest & Amortization Costs	\$258,000,000	\$588,000,000	\$923,000,000

4.3.4 Projected Annual Costs Adjusted to 2014

The projected annual costs for operations and maintenance costs, energy costs and interest and amortization of first costs for the 2,000 cfs, 6,000 cfs and 10,000 cfs water transfer systems are shown in Tables 4.3(d), 4.3(e) and 4.3(f) respectively for year 2014 costs. All costs are based upon a 20 year construction period and a 100-year project first costs amortization. OMRR&R costs were adjusted from year 1979 to year 2014 using the ENR Historical Construction Cost Index of 3.27872.

Table 4.3(d)
Year 2014 Projected Annual OMRR&R Costs for Route B Water Transfer System.

OMRR&R Facility	Water Transfer System Size		
	2,000 cfs	6,000 cfs	10,000 cfs
Canal OMRR&R	\$10,213,000	\$10,561,000	\$10,892,000
Pipelines (conduits) OMRR&R	\$485,000	\$495,000	\$511,000
Plant O&M	\$8,466,000	\$12,935,000	\$17,197,000
Plant RR&R	\$4,420,000	\$6,751,000	\$8,980,000
Automation & Communications	\$157,000	\$157,000	\$157,000
Source Reservoir	\$1,672,000	\$1,672,000	\$1,672,000
Terminal Reservoir	\$1,213,000	\$2,295,000	\$3,049,000
Lock & Dam	0	\$2,295,000	\$2,295,000
Totals	\$26,626,000	\$37,161,000	\$44,753,000

Table 4.3(e).
Year 2014 Projected Annual Energy Costs for Route B Water Transfer System.

Cost Factors	Water Transfer System Size		
	2,000 cfs	6,000 cfs	10,000 cfs
Supplied Acre feet/Year	\$1,000,000	\$2,400,000	\$3,200,000
Multiplier for Acre feet in System	1.235	1.235	1.235
System Equivalent Head (Feet)	2,377	2,223	2,204
kWh/Acre feet Head	1.333	1.333	1.333
Energy Costs (\$/kWh)	0.04500	0.04500	0.04500
Total Annual Energy Costs	176,000,000	395,000,000	522,000,000

Table 4.3(f)
Year 2014 Projected Interest & Amortization Costs for Route B Water Transfer System.

Interest & Amortization Costs For Year 1979	Water Transfer System Size		
	2,000 cfs	6,000 cfs	10,000 cfs
Interest & Amortization Costs	\$287,000,000	\$652,000,000	\$1,024,000,000

4.3.5 Limitations and Precautions

The limitations and precautions related to the annual costs are associated with the assumptions used in developing the operation, maintenance, repair, replacement and rehabilitation costs; electrical power costs and interest and amortization costs. Operations, maintenance and replacement costs were projected based upon data from other existing systems. If a Kansas aqueduct performs differently than these comparison systems there could be significant variations from the projected costs. Electrical power costs are developed based upon a number of assumptions relating to system head, the kWh requirements per acre feet of water pumped and energy costs. No detailed energy or electrical studies were performed within the scope of this study.

4.4 Alternate Route B Delivered Water Costs

The costs per acre foot of water delivered to the terminal reservoir were found by adding all of the annualized costs (operations, maintenance, repair, replacement and rehabilitation; energy costs and interest and amortization of first costs) then dividing this total annual cost by the annual acre feet of water delivered.

4.4.1 Delivered Water Costs 1982 Study

Delivered water costs for year 1979 are provided in Table 4.4(a).

Table 4.4(a)
Year 1979 Delivered Water Costs (\$/AF) for Route B Water Transfer System.

Annual Cost Items	Water Transfer System Size		
	2,000 cfs	6,000 cfs	10,000 cfs
OMRR&R	\$8,121,000	\$11,334,000	\$13,650,000
Energy Costs	\$99,000,000	\$222,000,000	\$294,000,000
Interest & Amortization	\$258,000,000	\$588,000,000	\$923,000,000
Total Annual Costs	\$365,121,000	\$821,334,000	\$1,230,650,000
Annual Acre feet Delivered	1,000,000	2,400,000	3,200,000
Total Delivered Water Costs (\$/AF)	\$365	\$342	\$385

4.4.2 Projected Delivered Water Costs Adjusted to 2014

Projected delivered water costs for year 2014 are provided in Table 4.4(b).

Table 4.4(b)			
Year 2014 Delivered Water Projected Costs (\$/AF) for Route B Water Transfer System.			
Annual Cost Items	Water Transfer System Size		
	2,000 cfs	6,000 cfs	10,000 cfs
OMRR&R	\$26,626,000	\$37,161,000	\$44,753,000
Energy Costs	\$176,000,000	\$395,000,000	\$522,000,000
Interest & Amortization	\$287,000,000	\$652,000,000	\$1,024,000,000
Total Annual Costs	\$489,626,000	\$1,084,161,000	\$1,590,753,000
Annual Acre feet Delivered	1,000,000	2,400,000	3,200,000
Total Delivered Water Costs (\$/AF)	\$490	\$452	\$497

4.4.3 Limitations and Precautions

Limitations and precautions for using the delivered water costs reflect all previously stated limitations and precautions resulting from the development of the first costs, investment costs and annual costs. Additionally, the cost per acre feet assumes that the water transfer system is able to operate satisfactorily to deliver the projected quantities of water. Significant interruptions to water delivery would result in increases to the actual delivered water costs by decreasing the annual delivered water quantity. Further, all costs presented herein are considered preliminary and subject to change. For the purposes of this study update, the cost information should be viewed as a range of costs as discussed in 4.7 Summary of Findings.

4.5 Examination of Route B Alternatives and Selected Regional Water Supply Projects

In addition to revisiting and escalating the costs of the 1982 Study, other investigations were performed to evaluate the concepts and costs of the original study. These investigations included:

- Evaluation and investigation of construction costs for alternatives to selected elements of the 1982 Study for Route B.
- Comparison of construction costs of elements of other regional water systems to those provided in the 1982 Study.
- Comparison of delivered water costs of other regional water systems to those provided in the 1982 Study.

4.5.1 Route B Alternatives Projected Construction Costs

Construction costs have been projected for potential alternatives to elements of a Kansas aqueduct as described in the 1982 Study. These alternatives include using a different approach to collect the source water from the Missouri River and using pipelines instead of canals for conveyance from the source reservoir to the terminal Reservoir.

4.5.1.1 Missouri River Horizontal Collector Well System

This alternative considered the potential to use horizontal collector wells (HCWs) to collect source water from the Missouri River from a well field along the west river bank. Costs to install HCWs vary by depth and yield. The depth of the well has the greatest impact on HCW cost due to the labor associated with sinking the well caisson. Deeper HCWs typically yield more water which requires larger pumping equipment. A specialized HCW contractor was contacted to obtain budgetary costs for constructing HCWs within Missouri River alluvium. The budgetary costs include the below grade and above grade HCW structures, including well house, pumps, valves and controls. These budgetary costs do not include costs for easements, construction of water transmission lines to connect the wells and discharge into the source

reservoir, construction of required electrical services or costs to pump the water from the HCWs to the source reservoir. Figure 4.5(a) provides a summary of the variability of the HCWs budgetary costs depending upon the diversion rate of the well system and based upon an assumed average HCW yield of 20 MGD.

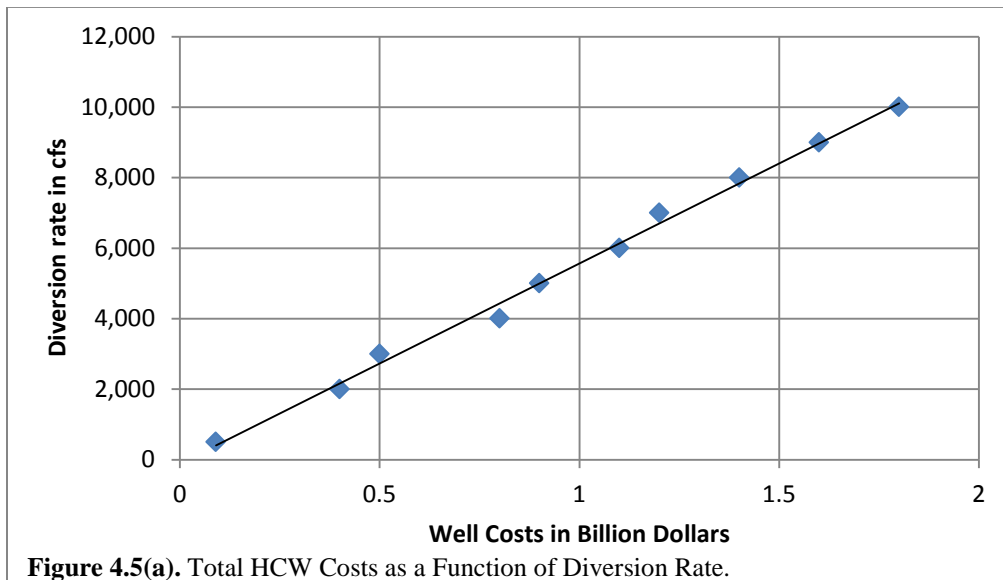


Figure 4.5(a) shows that using HCWs as the source of water at the Missouri River would not be economically justified. As shown in Table 4.2 (b), for a 10,000 cfs system the projected costs for a lock and dam of \$269,000,000 are much less than the \$1,750,000,000 for the HCWs in Figure 4.5(a). Additional costs to construct a HCW system as described would also be required and further increase the additional HCW costs versus those of the 1982 Study source. The logistical considerations of well field construction also make this alternative less attractive.

4.5.1.2 Pipeline Conveyance Alternative

An alternative that uses pipelines instead of canals was considered to assess its potential impacts on costs. The cost advantages of using piping were anticipated to result from the pipeline using a shorter alignment (length) due to its being a pressure system, less excavation than for a canal, fewer relocations due to the ability to tunnel beneath obstacles and less land requirements due to its being buried. A simple straight line alignment between the source reservoir and the terminal reservoir yielded a total length of 280 miles. Approximately 10% (30 miles) was added to the pipeline alignment to account for potential required deviations from a straight line length due to unknowns. This alignment resulted in a pipeline length of 310 miles versus the 360 miles used for the canal.

The 1982 Study Appendix E-Cost and Design Manual was used as the basis for considering the pipeline alternative to be consistent with the original Alternate B, along with the following assumptions:

- Pipes are assumed to be prestressed, precast concrete pipes.
- Pipes are assumed to be installed with three feet of minimum cover.
- The maximum pipe diameter is 20 feet.

The pipe diameter and resulting numbers of parallel pipes were established using the formula below:

$$D = 0.981 \times Q^{0.375}$$

Where: D = Pipe diameter in feet.
Q = Pipe discharge in cfs.

The number of pipes for a given water transfer system size is shown in Table 4.5(a).

Table 4.5(a). Number of Pipes, Diameters and Flow Velocity for Route B Water Transfer System.			
Water Transfer Discharge (cfs)	Number of Pipes	Diameter of Pipes (feet)	Flow Velocity (FPS)
2,000	1	17	8.64
6,000	2	20	9.56
10,000	4	19	9.13

Costs were developed by using the cost data provided in the 1982 Study Appendix E-Cost and Design Manual. Unit costs include:

- Furnishing and laying pipe.
- Excavation and backfill of trench.
- Structures, manholes, valves and crossings.
- Site restoration.
- Unit costs include 10% miscellaneous items and 25% for contingencies.
- Unit costs are based upon pipes with a maximum diameter of 20 feet and using multiple pipes as required.
- The cost curve for 250 feet head pipe was used.
- Prices are price based to January 1979.
- Unit costs selected for use were:
 - \$2,200/LF for 2,000 CFS Option.
 - \$5,400/LF for 6,000 CFS Option.
 - \$8,500/LF for 10,000 CFS Option.

The number of tunnels was estimated using readily available maps and yielded an estimated total of 16 highway crossings and 21 waterway crossings. It is assumed that all tunnels were 300 linear feet in length and the total length is increased by 25% to account for unknowns. Unit costs for tunnels are developed by using the cost data provided in the 1982 Study Appendix E-Cost and Design Manual. Unit costs included:

- Excavation.
- Concrete lining.
- Cement.
- Steel supports.
- Timber lagging.
- Unit costs include 10% miscellaneous items and 25% for contingencies.
- Prices are price based to January 1979.
- Unit costs selected for use were:
 - \$4,300/LF for 2,000 CFS Option.
 - \$10,500/LF for 6,000 CFS Option.
 - \$15,500/LF for 10,000 CFS Option.

The same number of pumping stations is used as in the 1982 Study. Unit costs for pumping stations were developed by using the cost data provided in the 1982 Study Appendix E-Cost and Design Manual. Unit costs assumptions include:

- All pump station costs were based upon using identical pump stations with 250 feet of total head.
- Prices are price based to January 1979.
- Costs are estimated to be:
 - \$42M per pump station for 2,000 cfs Option.
 - \$115M per pump station for 6,000 cfs Option.

- \$186M per pump station for 10,000 cfs Option.
- Per the 1982 Study, a 33.3% allowance was included for two pumps per station per flow option to account for the Storage reservoir and River Intake facilities.

Construction cost comparisons between the canal conveyance and pipeline conveyance systems are shown in Figure 4.5(b). From this figure, it can be seen that construction of the pipeline conveyance system is much more costly than using a canal system.

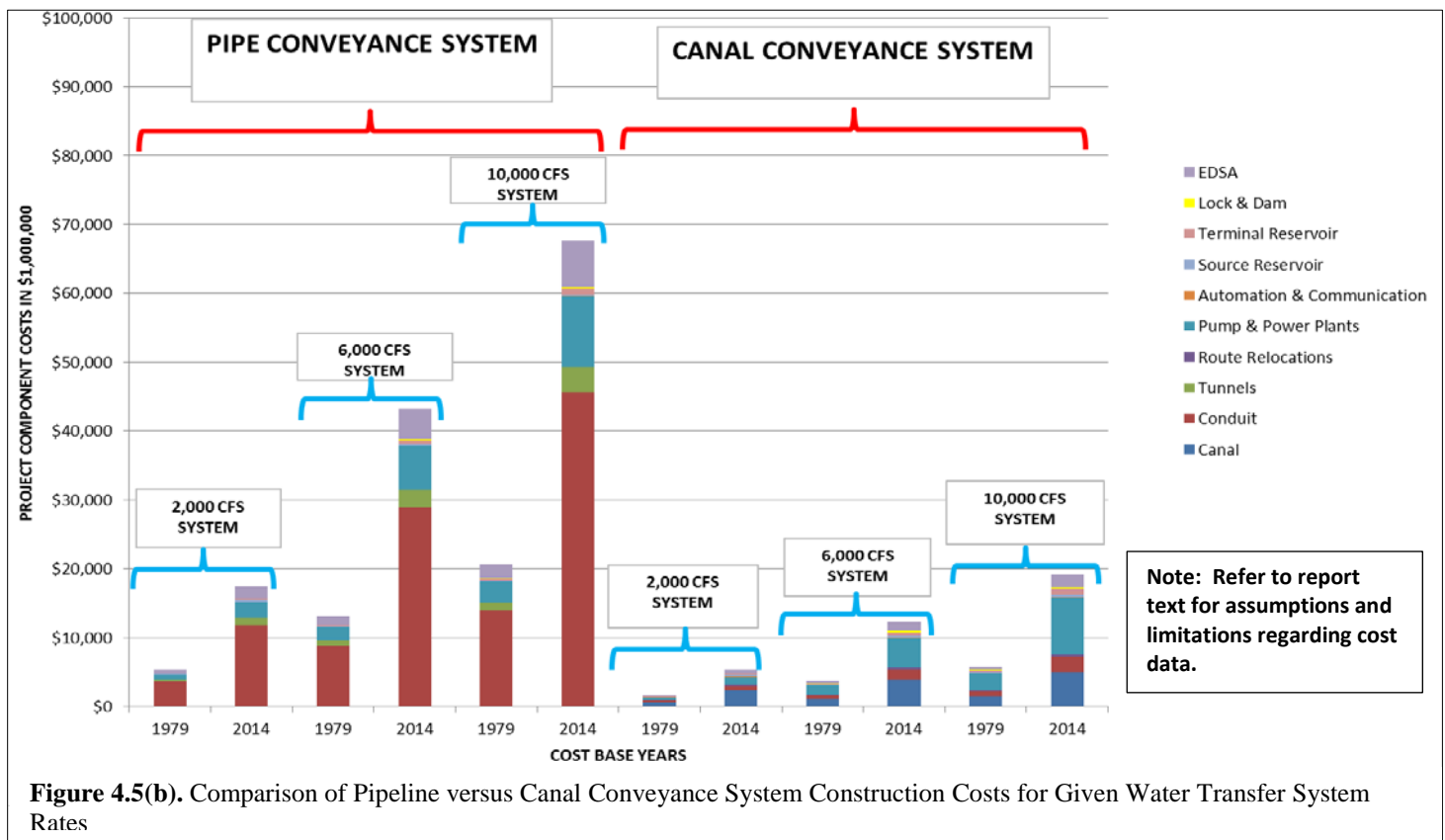


Figure 4.5(b). Comparison of Pipeline versus Canal Conveyance System Construction Costs for Given Water Transfer System Rates

Costs for land acquisition were developed based upon the 1982 Study Appendix E-Cost and Design Manual. Land costs of \$1,300 per acre (year 1979) are taken from the reference along with the required number of acres for canals based upon discharge rates, which are:

- 52 acres/mile for the 2,000 cfs system. Width calculated to be 429 feet.
- 87 acres/mile for the 6,000 cfs system. Width calculated to be 718 feet.
- 108 acres/mile for the 10,000 cfs system. Width calculated to be 891 feet.

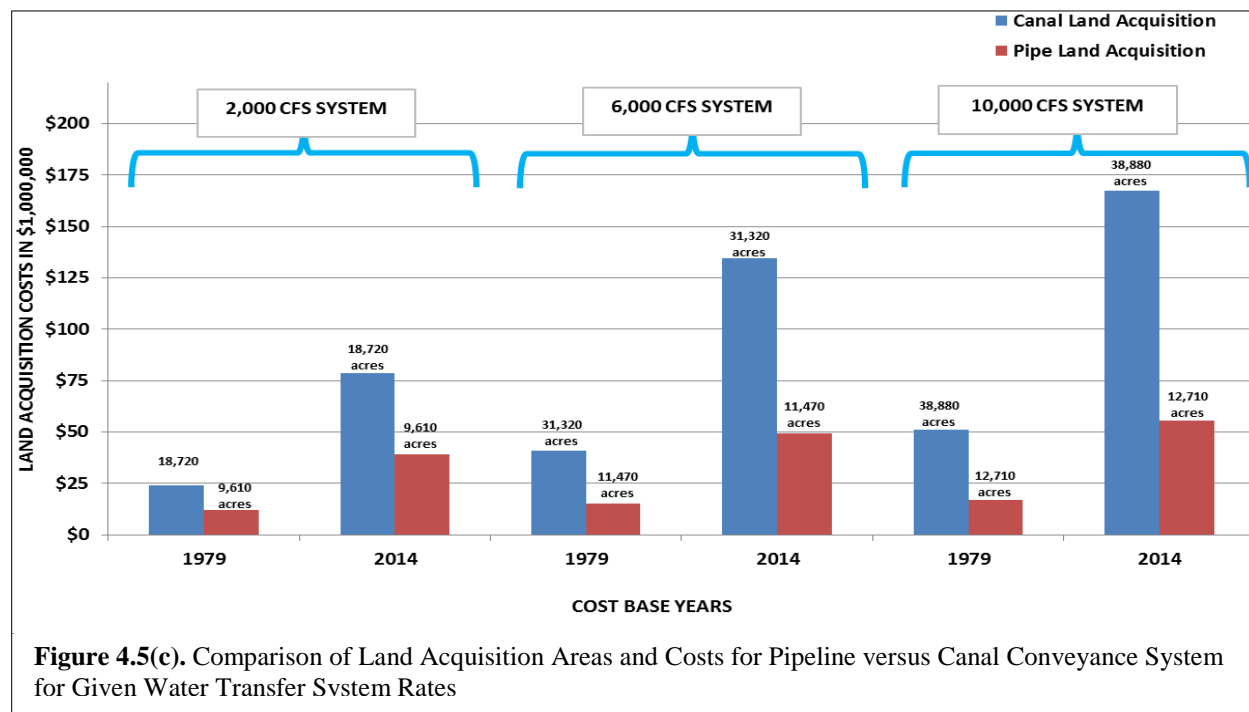
Land requirements for the pipelines were estimated based upon the following width assumptions:

- Total width of pipes.
- Providing two pipe diameters on each side of the pipes.
- Providing an additional width of 200 feet.

These assumptions yield the following area and width requirements for the pipelines.

- 31 acres/mile for the 2,000 cfs system. Width calculated to be 255 feet.
- 37 acres/mile for the 6,000 cfs system. Width calculated to be 305 feet.
- 41 acres/mile for the 10,000 cfs system. Width calculated to be 340 feet.

Cost comparisons for land acquisition between the canal conveyance and pipeline conveyance systems are shown in Figure 4.5(c). From this figure it can be seen that although the pipeline conveyance system land acquisition costs are less than for a canal system, they do not offset the large construction cost increases for a pipeline conveyance system.

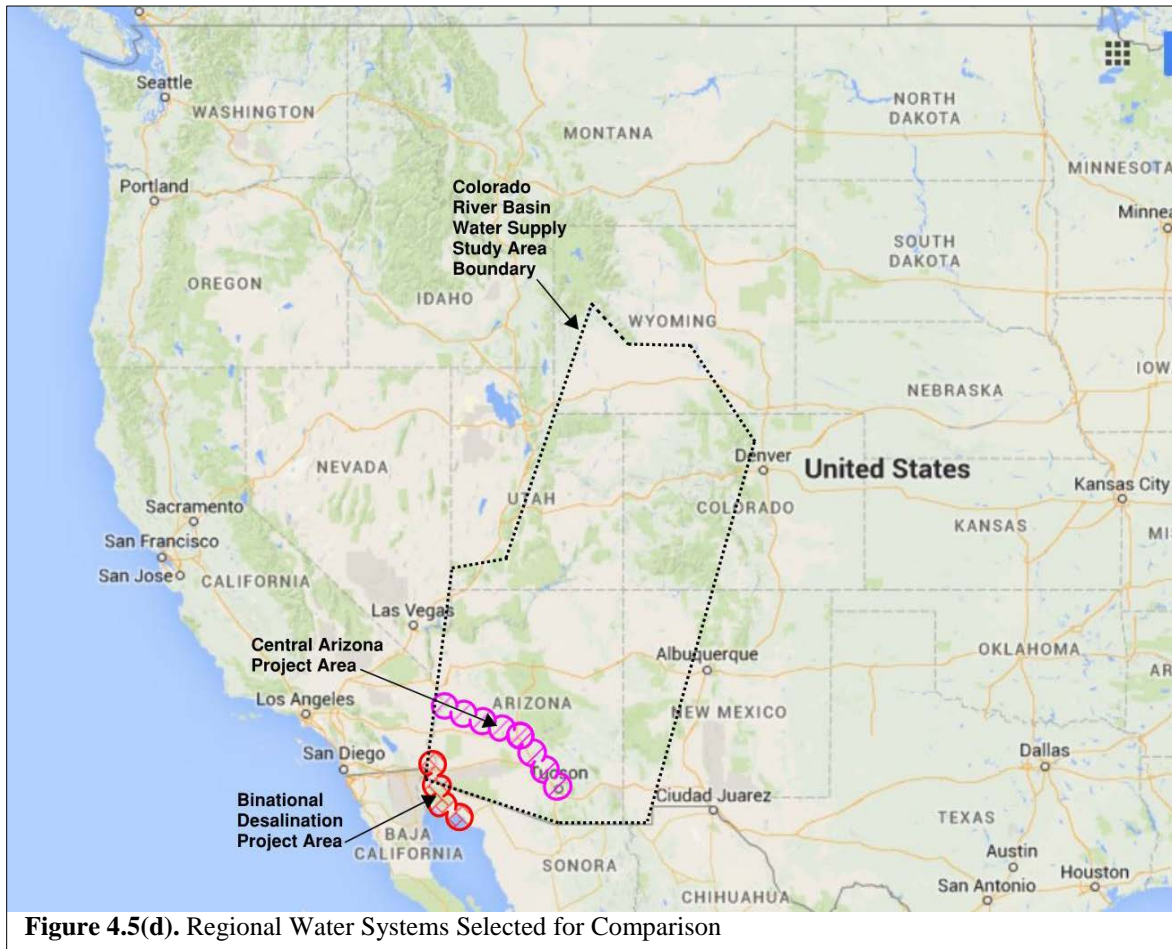


Figures 4.5(b) and 4.5(c) show the canal conveyance system is the lesser cost alternative for the water transfer system.

4.5.2 Construction Cost Comparisons with Selected Regional Water Supply Studies and Projects

Locations of the other regional water systems selected for comparison to a Kansas aqueduct are shown in Figure 4.5(d) and are summarized below:

- **Binational Desalination Project.** This project is being investigated by the Salt River Project (SRP) and Central Arizona Project (CAP), in consultation with the Arizona Department of Water Resources (ADWR), United States Bureau of Reclamation and the Comision Estatal del Agua, Sonora (CEA) to deliver 1.2M AF/Y of Gulf of California water to the Imperial Dam in California. The water source would be a desalination plant near Puerto Penasco, Mexico and use 168 miles of canal for conveyance.
- **Colorado River Basin Study.** This study presents information on major regional water conveyance projects with the Colorado River as the source of supply. The study defines imbalances in water supply and demand through 2060.
- **Central Arizona Project.** The CAP is a major regional water supply project that was constructed from 1973 to 1993. It diverts water from the Colorado River via canals for multiple uses.



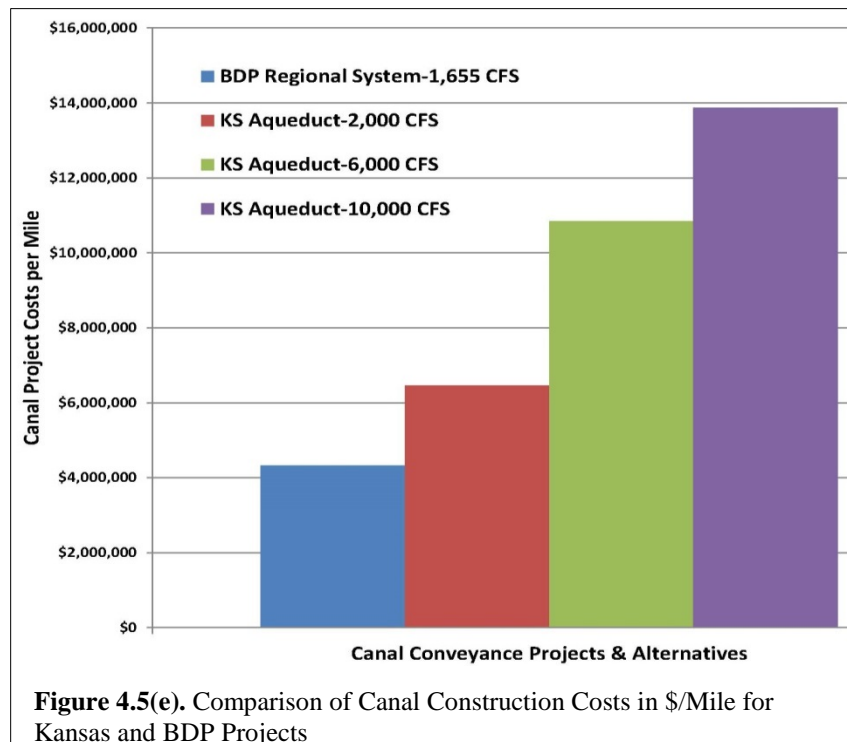
Projected construction costs for a Kansas aqueduct were contrasted against selected construction costs for the Binational Desalination Project and the Central Arizona Project.

4.5.2.1 Binational Desalination Project

The Binational Desalination Project (BDP) would use a canal system to convey water to its point of use similarly to a Kansas aqueduct as described in the 1982 Study. A comparison of features of these two projects is provided in Table 4.5(b).

Table 4.5(b). Comparison of Kansas Aqueduct and BDP Project Features.		
Project Features	Kansas Aqueduct	BDP
Aqueduct Canal Length (miles)	360	168
Aqueduct Canal Bottom Width (feet)	24-54	24
Aqueduct Capacity (cfs)	2,000-10,000	1,655
Aqueduct Water Depth (feet)	12-26	NA
Vertical Lift (feet)	1,610	181
Storage Reservoirs	2	0
Pumping Stations	15	4
Hydro-Generation/Pumping Stations	1	0
Water Delivered (1,000,000,AF/year)	1.0-3.2	1.2

Canal construction costs per mile are compared between a Kansas aqueduct and the BDP in Figure 4.5(e).



The site conditions vary between these projects, such as types of soils, amount of rainfall, groundwater, geotechnical conditions, number of water courses that must be crossed and other factors that would impact the costs for each project differently and therefore only a general comparison of costs can be made.

4.5.2.2 Central Arizona Project (CAP)

The Central Arizona Project (CAP) uses a canal system to convey water to its point of use similarly to a Kansas aqueduct. A comparison of features of these two projects is provided in Table 4.5 (c). Data related to a Kansas aqueduct is taken from the 1982 Study and data related to the CAP is from the Bureau of Reclamation website on the Central Arizona Project.

Table 4.5(c). Comparison of Kansas Aqueduct and CAP Project Features.		
Project Features	Kansas Aqueduct	CAP
Aqueduct Canal Length (miles)	360	336
Aqueduct Canal Bottom Width (feet)	24-54	12-80
Aqueduct Capacity (cfs)	2,000-10,000	2,250-3,000
Aqueduct Water Depth (feet)	12-26	10-25
Vertical Lift (feet)	1,610	2,900
Storage Reservoirs	2	1
Pumping Stations	15	14
Hydro-Generation/Pumping Stations	1	1
Water Delivered (1,000,000,AF/year)	1.0-3.2	1.5

Project construction costs are compared between a Kansas aqueduct and the CAP in Table 4.5(d). All costs are expressed in year 2014. The comparison of first costs in Table 4.5(d) (does not include interest costs).

Table 4.5 (d). Comparison of Kansas Aqueduct and CAP Project Construction Costs.	
Project	Construction Costs
KS Aqueduct @ 2,000 cfs w/1.0 MAF/Year	\$5,376,000,000
KS Aqueduct @ 6,000 cfs w/2.4 MAF/Year	12,231,000,000
KS Aqueduct @ 10,000 cfs w/3.2 MAF/Year	19,193,000,000
CAP @ 2,250-3,000 cfs w/ 1.5 MAF/Year	7,895,000,000

4.5.3 Delivered Water Costs for Selected Regional Water Supply Projects

Available water costs (\$/AF) are compared for selected regional systems against those projected for a Kansas aqueduct in Figure 4.5(f).

4.5.3.1 Colorado River Basin Study

The Colorado River Basin projected anticipated water costs for a number of different sources including:

- Imports to Colorado Front Range from Missouri or Mississippi Rivers.
- Imports to Green River from Bear, Snake or Yellowstone Rivers (high).
- Imports to Green River from Bear, Snake or Yellowstone Rivers (low).
- Desalination-Gulf of California.
- Desalination-Pacific Ocean California.
- Desalination-Pacific Ocean Mexico.
- Reuse-Municipal Wastewater.

The range of delivered water costs is from \$700/AF to \$2,100/AF depending upon the source. These costs are all greater than the range of \$452/AF to \$497/AF projected for a Kansas aqueduct.

4.5.3.2 Central Arizona Project (CAP)

The CAP uses a number of different rate structures for delivered water depending upon the category of customer based upon rate information approved on June 5, 2014, and provided in the Central Arizona Groundwater Replenishment District website. The highest rate for 2014 is \$189/AF for certain municipal customers. This value is shown in Figure 4.5(f).

The delivered water rates comparison shown in Figure 4.5(f) indicates that the projected delivered water rates are within the range of the rates currently being charged by CAP, and are less than the rates of other regional projects under consideration in the Colorado River Basin.

4.5.4 Limitations and Precautions

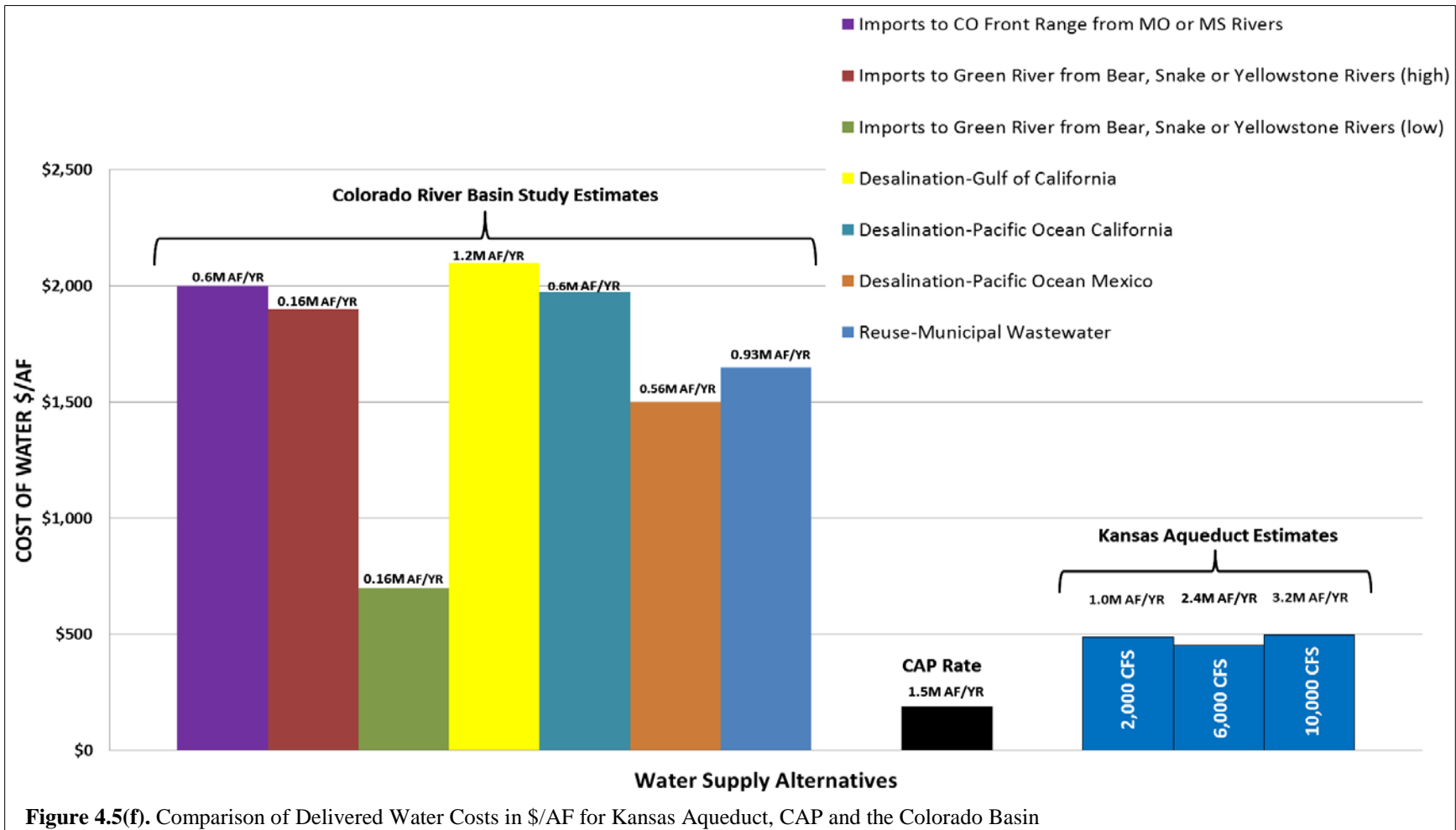
Previous limitations and precautions regarding a Kansas aqueduct cost projections apply to these costs comparisons. In addition, these comparisons are based on high-level, aggregated cost information of similar, but different systems. Unknowns related to these other systems may cause inaccuracies in the presented cost comparisons.

4.6 Cost Risk Analysis and Potential Mitigation

A risk analysis for the projected costs has been developed to identify areas of significant project risk and the associated effects on project cost uncertainty. Risk mitigation strategies that may help reduce projected cost uncertainties are presented.

4.6.1 Areas of Significant Project Risk

Areas of significant project risk may be broadly categorized as risks associated with project definition and risks associated with project costs.



Note: Refer to report text for assumptions and limitations regarding cost data.

4.6.1.1 Risks associated with project definition encompass the level of understanding and recognition of project cost elements such as:

- Construction of the water supply and transfer system elements such as intakes, dams, reservoirs, canals, pipelines (conduits), pumping stations, hydropower facilities, pumping stations, automation and communication, route relocations and other project facilities that are constructed. Developing construction costs for these items is reliant upon the information available at the time the costs are estimated. A reconnaissance level study such as the 1982 Study was not able to develop detailed information regarding details relating to site conditions and the facilities to be constructed. Assumptions were used to account for these cost elements, however the accuracy of the costs estimated are directly related to the accuracy of these underlying assumptions.
- Construction of water distribution system elements downstream of the terminal reservoir required for conveying water to the customers. The 1982 Study did not define, investigate and develop costs for this water distribution system.
- Operation and maintenance costs are dependent upon the facilities constructed, staffing, system management, level of service desired and funding being available to support these efforts. These specifics are yet to be determined.
- Repair, replacement and rehabilitation costs are dependent upon the facilities constructed and the operations and maintenance program.
- Environmental costs rely upon the scope of environmental assessments to be performed; impacts identified and required environmental mitigation measures. Environmental mitigation measures typically impact the approach to facility design and construction, and their associated costs. The 1982 Study environmental assessment was a broad-based reconnaissance level effort that concentrated on significant environmental impacts, only considered impacts associated with the construction of the canals or other transfer facilities and the physical effects along the canal routes during operation and was based primarily on data found in published sources and available files at the time. Current environmental constraints are discussed further in Chapter 6-Environmental Constraints.
- A limited investigation of cultural resources was performed in the 1982 Study and indicated the area is rich in cultural resources. For the purposes of this study, the entire 1% of authorized project costs was used to estimate costs for the preservation of cultural resources.
- Legal requirements associated with a project may require significant expenditures of time and funds. Legal requirements are investigated and discussed further in Chapter 5-Legislative and Legal Review.
- Political requirements and building consensus to support a project may require significant expenditures of time and funds. Political requirements are investigated and discussed further in Chapter 7-Political Assessment.
- Funding and cost recovery sources needed to support a project's implementation were not identified or investigated. This includes identifying potential sources of funding for project implementation and for amortization of initial project costs and annual expenses. A customer base and ability to pay the necessary rate structure would be required.
- Site conditions greatly impact project costs. Site conditions include existing facilities that would be impacted by construction such as utilities, roads, railroads and other improvements; changes to the site since the original 1982 Study; environmental conditions such as streams, rivers, lakes and other features; geotechnical conditions that can impact both design and construction; contaminated sites along a project that may require special permitting and construction materials and techniques; restrictions on land usage that may require additional length or costs to accommodate and other conditions.

4.6.1.2 Risks associated with project cost include the sources of data used to develop the actual costs applied to the elements described by project definition and include:

- Construction cost sources including other projects, information provided by contractors and suppliers, estimating guides and other sources. Other projects costs are based on other projects that may differ from those encountered on this project. Estimating guides provide general costs that would not reflect disproportionate costs of high value special equipment such as large pumps.

- Operations and maintenance cost sources including other facilities, service company quotations, manufacturer recommendations, estimating guides and other sources. These sources reflect factors from other projects or general industry data that may not apply to this project.
- Energy cost sources including information from utilities, consultants, published rates and other sources. These are generalized costs that may not reflect the actual costs for this project.
- Interest and amortization cost sources including lending institutions, the Federal Water Resources Council (used for the 1982 Study) and other sources. It is not known that these interest rates would be available for this project or if higher rates would be required.
- Cultural investigation and mitigation cost sources including other projects, specialty consultant estimates and other sources. These costs are based upon other projects that may differ in scope and cost from this project.
- Potential volatility and uncertainty of construction materials availability, pricing, labor, energy and land acquisition.
- Funding and cost recovery sources may include experience on past projects, published data on funding sources, published data on potential customer needs, published rate studies and other sources. The funding source and customer base would be specific to this project and have not been investigated. A project may not be able to be constructed if funding cannot be secured along with a customer base that is able to pay for project amortization at an acceptable rate.
- Industry-accepted cost indexes were used to adjust costs from one year to a different year or from one location to another. Use of these indices relies on the accuracy of the original (base) year estimates, and does not account for project-specific cost factors.
- Contingencies were used to account for unknowns and sources may include past projects, past practices, published guidelines and other sources. Contingencies need to be revisited and refined as a project progresses.

4.6.2 Potential Mitigation Measures for Cost Risks

As a project matures and moves forward, an increasing level of resolution will become available for both project definition and cost estimating. Potential mitigation measures for reducing risks of inaccuracies and uncertainties in project costs should focus on:

- Improving the resolution of project definition.
- Improving the relevancy of the sources of cost data including compiling recent construction bid tabulations and assessing the relevancy of the construction elements to the specifics of a Kansas aqueduct project.
- Development of updated construction quantities.
- Accounting for cost elements that were not included in the original 1982 Study such as the cost of a water distribution system from the terminal reservoir to the end users.

4.7 Summary of Findings

The project was evaluated for water transfer delivery systems of 2,000, 6,000 and 10,000 cfs. It is assumed that construction would occur over a 20 year period. The updated total construction costs for the system found to be the most cost efficient (6,000 cfs transfer capacity) is \$12,231,000,000. The interest during a 20 year construction period is estimated to be \$5,788,000,000, until deliveries to western Kansas can begin, bringing the total investment cost to an estimated \$18,019,000,000.

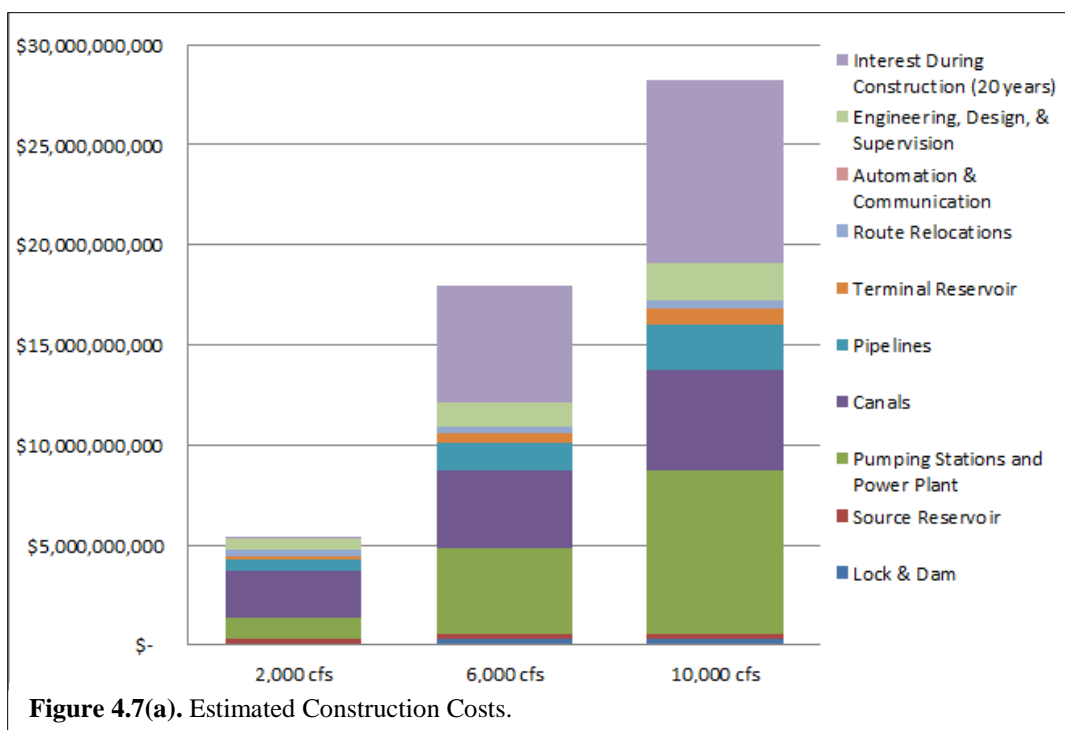


Figure 4.7(a). Estimated Construction Costs.

The annual costs including operation and maintenance, interest and amortization and energy costs were determined to be \$1,084,161,000. The very preliminary estimate of the 2014 delivered water costs is approximately \$450 per acre foot. (Note: Costs from the 1982 study were multiplied by a factor of 3.27872, the engineering standard construction cost index (CCI). Interest during the 20 year construction period was 7 3/8% in the 1982 study; the 2014 cost is 3 1/2%).

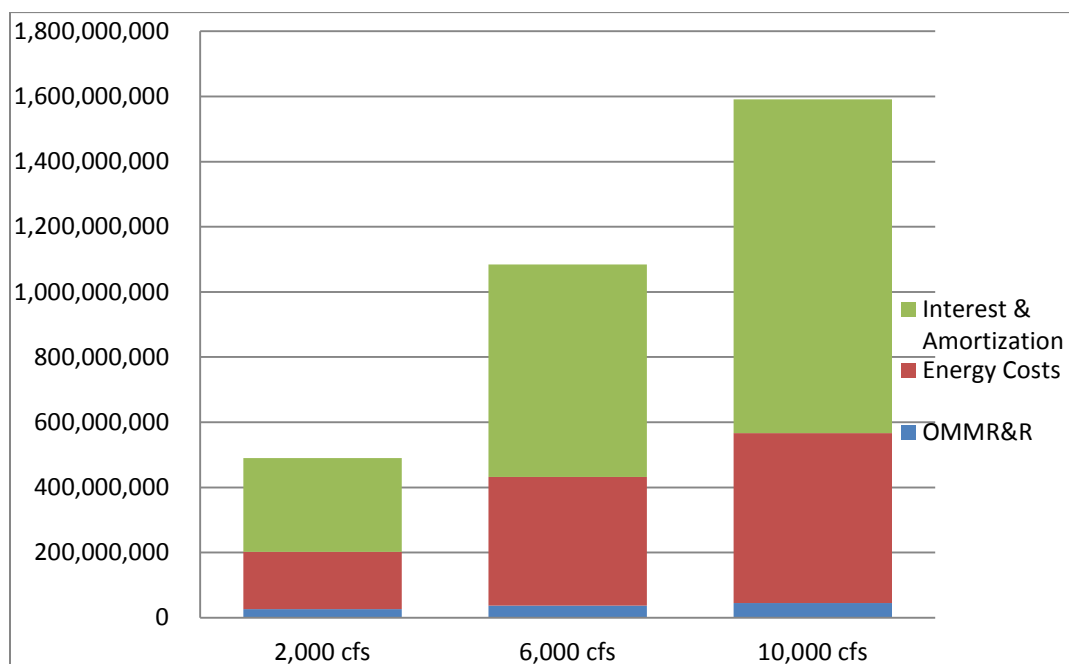


Figure 4.7(b). Annual Operation and Maintenance Costs.

A summary of the findings of Chapter 4-Cost Estimates is presented below.

1. A Kansas aqueduct was evaluated and defined in the High Plains-Ogallala Aquifer Regional Resources Study and its Appendix B - Reconnaissance Study Alternative Route B Water Transfer from the Missouri River to Western Kansas in September, 1982. These documents along with other appendices provided the assumptions for project definition and cost elements used in this task.
2. This study presents updates to various components of the 1982 Study, including a high-level update of potential costs. For the purposes of this study update, the updated cost information should be viewed as a range of costs. The updated cost information presented herein is very preliminary, is based on readily available information, many assumptions and is subject to change. Project definition may be considered to be at the conceptual stage, with many project components yet to be determined. Many of the related cost implications are yet to be determined and quantified. Table 4.1 (a) presents cost range information for projects at the conceptual stage. By applying mid-range percentages from Table 4.1 (a) to the cost information presented in Figure 4.5 (f) and Table 4.4 (b), the 2014 delivered water costs may be in the range of \$300 per acre foot to \$800 per acre foot.
3. A project was evaluated for water transfer delivery systems of 2,000 cfs, 6,000 cfs and 10,000 cfs.
4. The Engineering News Record Historical Construction Cost Index to adjust costs from 1979 to 2014 (August) is (9846/3003) which yields a composite adjustment of 3.27872.
5. The FY 2014 Federal Water Resources Council published rate of 3-1/2% was used for amortization and computation of the 2014 annualized project costs.
6. An evaluation of using horizontal collector wells for the source at the Missouri River or pipelines instead of canals for conveyance indicated that this alternative was not economically attractive.
7. The delivered water costs for a Kansas aqueduct were found to be within the range of the rates currently being charged by the Central Arizona Project.
8. The delivered water costs for a Kansas aqueduct were found to be less than the rates of other regional water supply systems under consideration in the Colorado River Basin.
9. There are potential risks and uncertainties associated with the current projected project costs. These risks and uncertainties may be reduced by increasing the level of resolution for project definition and the project cost sources.

Update of 1982 Six State High Plains Aquifer Study

Chapter 5: Review of Legal and Legislative Issues

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5.1 Legal Review Introduction

The Legal review was submitted to Kansas Water Office (KWO) by Pope Consulting, LLC as an issue evaluation for a Kansas Aqueduct Study. The purpose of the evaluation is to review various legal, institutional and social-political issues related to the potential transfer of water from the Missouri River to western Kansas. The principals who conducted this review are David L. Pope of Pope Consulting, LLC and its subcontractor, Leland E. Rolfs of Leland Rolfs Consulting. The scope of work for this project was based generally on the Scope of Study from the Cost Sharing Agreement for Planning Assistance to States between the U.S. Army Corps of Engineers (Corps) and KWO (Appendix 2).

In general, this paper includes an evaluation of whether a Kansas aqueduct concept conflicts with existing legislation and what process and criteria would be required to comply with Kansas laws and requirements, including: the Kansas Water Appropriation Act; the interstate river compacts to which Kansas is a party; the possibility of storing water in existing lakes and reservoirs along the aqueduct route; requirements of the Kansas Stream Obstructions Act, including environmental review; the relationship of such a project to the provisions of the 1944 Flood Control Act (Pick-Sloan Program), and potential water quality implications and impacts along the aqueduct corridor at a general level. In addition to background information, the major sections of this paper will examine: 1) legal issues in obtaining water at the source; 2) legal issues in transporting and dropping off, water along the aqueduct; 3) legal issues at the destination; 4) institutional issues and 5) a general political assessment.

5.2 Legal Issues in Obtaining Water at the Source

5.2.1 Missouri River Background

The Missouri River is the largest river that flows through or adjacent to the State of Kansas. While issues related to the use of water from the river are complex, it potentially provides a very large water supply for use in Kansas. Beginning in the Rocky Mountains near Three Forks, Montana, the Missouri River flows east and south for 2,341 miles before entering the Mississippi River north of St. Louis, Missouri, making the Missouri River the longest river in North America and a major waterway in the central United States. The Missouri River Basin covers one-sixth of the lower 48 states.¹ The mainstem of the river flows through or adjacent to seven states – Montana, North Dakota, South Dakota, Nebraska, Iowa, Kansas, Missouri and the lands of many of the American Indian Nations in the Missouri River Basin. The basin also includes portions of Colorado, Wyoming and Minnesota and a small portion of Canada. It is an extremely diverse basin in many respects. Its geography varies from the mountains of the upper basin to the low lands of Missouri. There are sparsely populated rural areas, Indian reservations, major cities, grasslands and rich agricultural areas, valuable natural and environmental resources and significant cultural diversity among the basin's people.

The Missouri River Basin is also one of the most complex basins to manage in the country because of its size and the vast differences that exist in geography, hydrology, climate, culture and other characteristics. From a water law standpoint, the general body of water law ranges from the general application of the Prior Appropriation Doctrine in the seven states located partially or totally west of the 98th meridian in the drier portions of the basin, to the general application of the Riparian Doctrine in the State of Missouri and a permit system in Iowa and Minnesota, all located in the wetter, eastern and southern part of the basin. In addition to the ten states located partially or totally in the basin, twenty eight American Indian Tribes are located in the basin, generally on reservations established by the treaties with the United States or congressional act.



The history and the hydrological record indicate that the flows of the Missouri River are highly variable due to large floods and major droughts in the Missouri River Basin. The water source is derived from mountain snowpack, plains snowpack and rainfall runoff or a combination of the three at any given time. Numerous large flood events on the Missouri River occurred prior to the construction of the six large Missouri River mainstem reservoirs authorized by the 1944 Flood Control Act. While damage caused by floods has been substantially decreased since the construction of these large reservoirs and the other smaller tributary reservoirs that were constructed in the basin, some flooding along the Missouri River still occurs, including recent large floods in 1993 and 2011. On the other extreme of the hydrological cycle, the drought of the 1930's caused major economic losses and social disruption in the Missouri River Basin. Other significant droughts have also occurred in more recent years.

Finally, historic water resources development has changed land and water use in the basin in a major way, especially as a result of the Missouri River Basin Project, (now known as the Pick-Sloan Program), that was authorized by the Flood Control Act of 1944. Just after the Flood Control Act of 1944² was passed, Congress also enacted the 1945 River and Harbors Act³ that authorized a nine foot deep navigation channel downstream of Sioux City, Iowa. This was an expansion of the six foot navigation channel previously authorized from Kansas City to the mouth in 1912 and to Sioux City in 1927. This ultimately resulted in the establishment of what is now known as the Missouri River Bank Stabilization and Navigation Program (BSNP) from Sioux City, Iowa to the mouth of the Missouri River near St. Louis, Missouri. As a result of this, the Missouri River Mainstem Reservoir System operated by the Corps, is a dominating feature of water resources development in the basin. Its operation has a profound effect on the flows of the river, the availability of water for various purposes along the river and has historically had a major effect on water issues, environmental resources and the associated relationships among the States, Tribes and other interests in the basin.

5.2.2 Native American Issues

5.2.2.1 Federal Reserved Rights

In 1908 the United States Supreme Court ruled in the Winter's case⁴ that it was implied when the federal government agreed to the establishment of Indian Reservations, that a sufficient amount of water was reserved to satisfy the intended purposes of the Indian reservation. This effectively exempted Federal Reservation Rights from normal state laws related to the appropriation of water because this water was reserved and a priority date established, as of the date the reservation was created. While water already appropriated prior to the date of the reservation was created is not available to fulfill the reservation right, in reality, there are very few appropriation rights in Kansas that would precede the date of any Indian reservation in Kansas. This is known as the Winters Doctrine.

Later, in 1963, the United States Supreme Court held⁵ that the amount of water reserved should not be measured by the reasonably foreseeable needs of the reservation, or the number of Indians, but by the amount of water necessary to irrigate the practicably irrigable acres (PIA) on the reservation. Later court decisions have expanded or altered that standard to include waters necessary for fish spawning or habitat, etc.⁶

Other issues involve what the water can be used for, whether it can be used off reservation and whether the Winters Doctrine applies only to surface water, or whether groundwater can be included when these rights are quantified. These federal reserved rights are not subject to abandonment so long as they remain owned by the Tribe or its individual members.⁷

American Indian Tribes on the Indian Reservations located within the State of Kansas each have Federal Reserved Rights. There are an additional twenty four American Indian Tribes in the Missouri River Basin that have Federal Reserved Water Rights located upstream of the proposed point of diversion on the Missouri River. Many of these rights have not been quantified, so the specific amounts and other parameters of them are not known, but the Winters Doctrine indicated that they are to be sufficient to satisfy the intended purposes of the Indian Reservation for use by the Tribe or Tribes. This amount of water could be quite significant. While much of this water is not currently being used, if and when in the future it is utilized, it could affect the rate and quantity of water available from the Missouri River at White Cloud, Kansas. The existence of these rights and their potential effect on the supply of water available are issues that will need to be considered if an aqueduct project is to be built.

The primary ways to quantify Federal Reserved Water Rights are through a negotiated settlement process or litigation. The McCarran Amendment⁸ provides that the United States waives its sovereign immunity so that federal reserved water rights may be determined in a state court in conjunction with general stream adjudication, so that all the water rights in a given common hydrological area could be determined and administered as a system. Two states in the Missouri River Basin have sought to resolve Federal Reserved Water Rights as a part of their general stream adjudication processes. The State of Wyoming litigated issues related to such rights for many years with Tribes located on the Wind River Reservation.

The State of Montana established a Reserved Water Rights Compact Commission in 1979 to conclude compacts for the equitable apportionment of water between the State and the Indian Tribes claiming Federal Reserved Water Rights in Montana, as well as such rights claimed by the Federal Government on land held for National Parks, National Forests and other purposes. Since its inception the Commission has negotiated and the Legislature approved 17 compacts with six Tribes and five federal agencies in Montana.⁹

5.2.2.2 Potential Tribal Water Supply

Kansas four Indian reservations: 1) The Sac and Fox Indian Reservation, 2) the Iowa Tribe reservation, 3) the Kickapoo Reservation and 4) the Prairie Band Potawatomie Nation, are all located in the vicinity of the aqueduct diversion, the source reservoir and/or aqueduct route in northeast Kansas. While the water supply of each of the Tribes was not evaluated in the 1982 Study, the potential need for water supply by the Kansas Tribes is an issue that should be considered carefully. It is well known that the Kickapoo Tribe is short of water during periods of drought. The Kickapoo Tribe

currently obtains its water from a small reservoir located on the upper reaches of the Delaware River. During times of low flow the reservoir cannot supply sufficient water to meet the tribe's needs and at times water has had to be trucked in to meet even minimal needs of the tribe. The aqueduct route crosses the Delaware River just upstream of the Kickapoo Reservation and could likely be used to provide a supplemental water supply to that reservation. It is possible that some or all of the other Tribes could benefit from an additional supply of water from an aqueduct project.

5.2.2.3 Historic and Cultural Resources

Historic and cultural resources are extremely important to the American Indian Tribes in the Missouri River Basin, including the four Tribes located in Kansas. Several federal laws have been passed to help protect these resources, including the Native American Graves Protection and Repatriation Act¹⁰, the Archeological Resources Protection Act,¹¹ and the National Historic Preservation Act¹². See also the Kansas Historic Preservation Act¹³. The current Indian reservations for the Kansas Tribes are in the vicinity of the aqueduct facilities. The historic and cultural resources of Native Americans could be affected along the entire area and route of the aqueduct and in the vicinity of the source and terminal reservoirs. As a result, during project studies, planning and any future construction, careful consideration will need to be given to the impact of an aqueduct project on these historic and cultural resources in any area affected by the project.

5.2.3 1944 Flood Control Act and the Pick-Sloan Program

A brief review of the Missouri River Basin Project authorized by the 1944 Flood Control Act¹⁴ is included herein due to its extremely important impact to the flows of the Missouri River, operation of most of the tributary reservoirs operated by the Federal government and the impact to the potential water supply for the Kansas Aqueduct Study being evaluated in part herein. In the 1940's, congressional debate occurred on the 1944 Flood Control Act¹⁵ (1944 FCA), legislation that would provide for installation of the enormous dams on the Missouri River and many other smaller dams on the tributaries. During the debates, the Congress recognized ongoing damage to various facilities, as well as the loss of agricultural production caused by the flooding and the value of storing high flows for later use during periods of drought. Other significant reasons for passage of the 1944 FCA were to create large federal irrigation projects, the production of hydropower and to provide storage for navigation, water supply and other uses.¹⁶ The U.S. Army Corps of Engineers (Corps) and U.S. Bureau of Reclamation (Bureau) had each developed competing plans for water resources development in the basin. Ultimately, these differing plans were reconciled in a Joint Report and approved by Congress when the 1944 FCA was passed. The Report states that the basin's development is to secure benefits for "flood control, irrigation, navigation, power, domestic and sanitary purposes, wildlife and recreation". In 1970, Congress officially changed the name of the Missouri River Basin Program to the Pick-Sloan Missouri Basin Program (Pick-Sloan Program), acknowledging the coordination of the Corps developed "Pick Plan" and the Bureau developed "Sloan Plan" into the comprehensive plan authorized in 1944.¹⁷

Some important language was included in the 1944 FCA that appears to be relevant to a potential Kansas aqueduct from the Missouri River. The 1944 FCA¹⁸ declared that it was "...the policy of the Congress to recognize the interests and rights of the States in determining the development of the watersheds within their borders and likewise their interests and rights in water utilization and control, as herein authorized to preserve and protect to the fullest possible extent established and potential uses, for all purposes, of the waters of the Nation's rivers; to facilitate the consideration of projects on a basis of comprehensive and coordinated development; and to limit the authorization and construction of navigation works to those in which a substantial benefit to navigation will be realized there from and which can be operated consistently with appropriate and economic use of the waters of such river by other users." The 1944 FCA also included the 'O'Mahoney-Millikin Amendment'¹⁹ which includes the following language:

"The use for navigation, in connection with the operation and maintenance of such works herein authorized for construction, of waters arising in states lying wholly or partly west of the ninety-eighth meridian shall be only such use as does not conflict with any beneficial consumptive use, present or future, in States lying wholly or partly west of the ninety-eighth meridian, of such waters for domestic, municipal, stock water, irrigation, mining or industrial purposes."²⁰

The Missouri River Basin Project, authorized by the 1944 FCA and known as the Pick-Sloan Program, envisioned a comprehensive system of flood control, navigation improvement, irrigation, municipal and industrial water supply and hydroelectric generation facilities within the 10 states in the Missouri River Basin. As originally planned, the project was to include 213 single and multiple-use projects, providing 1.1 million kilowatts of hydroelectric capacity and irrigation for 5.3 million acres of farmland. The plan was only partially completed; however, it completely changed water resource development in the basin. There are 548,578 acres of farmland irrigation currently being served through twenty-six Bureau irrigation units that were constructed through the Pick-Sloan Program, including four in Kansas. The reduction in the amount of irrigated farmland from the amount originally planned to that actually constructed is largely the result of the large irrigation projects in the upper portion of the basin not being completed, including the Oahe Unit in South Dakota and the Garrison Unit in North Dakota. However, the Garrison Unit was reformulated later to include a relatively small amount of irrigated land. More recent projects in both North Dakota and South Dakota have focused on construction of large rural water projects to distribute potable water to rural areas of these states from the Missouri River, although the total amount of water use is relatively small. In addition, 2,980.8 megawatts (2.98 million kilowatts) of hydroelectric capacity has been installed at Pick-Sloan projects, including 2501 megawatts at the six Corps mainstem dams.²¹ This is almost three times the amount originally planned. In addition to the twenty-six Bureau projects and the six mainstem reservoirs, the Corps constructed a number of tributary reservoirs in the basin, primarily for flood control, water supply and recreation, including seven reservoirs in the Kansas portion of the basin.

The Missouri River Mainstem Reservoir System continues to be operated in accordance with the 1944 FCA for the eight authorized purposes. The reservoir system is operated in accordance with a Master Water Control Manual (Master Manual) and Annual Operating Plans developed each year by the Missouri River Basin Water Management Division of the Corps in Omaha, NE, a part of the Northwestern Division headquartered in Portland, OR.²² While the future envisioned by the framers of the 1944 FCA did not materialize as expected, the operation of the reservoir system has a huge effect on water management and the social, political, economic and environmental values in the basin. The construction of the mainstem reservoir system and other works resulted in more beneficial economic development in some parts of the basin than others. Large project benefits occurred from some of the authorized purposes, such as flood control, hydropower and water supply, while much less benefits resulted from others. The large irrigation projects proposed in the upper basin were not constructed. While the navigation system was constructed, the amount of cargo shipped has been far less than expected. Recreation has emerged as an important use, especially from the mainstem reservoirs in the upper basin, and water supply is important throughout the basin. Largely unforeseen at the time, the 1944 FCA also created substantial negative impacts on the economies and resources of the American Indian Tribes, primarily through the inundation of tribal land when the reservoirs were constructed. In addition, the Tribes did not share in much of the economic benefits from the Pick-Sloan Program, whether from the mainstem reservoirs or the many tributary projects.

The mainstem reservoir system includes six large dams that have the capacity to store over 74 million acre feet, not counting exclusive flood control storage, about three times the river's average annual runoff above Sioux City, Iowa, located just downstream of the last reservoir on the mainstem reservoir system.²³ The upper three reservoirs are the first, second and third largest Corps reservoirs in the country. Some of Missouri River in eastern Montana and most of the Missouri River in North Dakota and South Dakota is inundated by the six reservoirs. For comparison, Milford Reservoir, the largest of the Federal reservoirs constructed in Kansas, is currently estimated to store 343,885 acre feet at the normal conservation pool level, not counting the flood pool.

In response to a protracted drought in the 1980's, shifting priorities and a request from some of the States in the basin, the Corps undertook a revision to the Master Manual in 1989.²⁴ This review process was the subject of much dispute over a period of 14 years. The revised Master Manual was finally adopted in 2004, followed by extensive litigation in the basin.²⁵ Ultimately the Federal Courts upheld the Revised Master Manual, but also rendered some significant legal decisions about various contested issues in the basin. In addition to major disputes during the Master Manual process between upstream and downstream interests over how much water should be stored for upstream uses, such as recreation, versus downstream releases for navigation, water supply and power plant cooling, major environmental concerns were also identified through the National Environmental Policy Act (NEPA) process and the preparation of the Environmental Impact Statement (EIS). By then it was well known that the construction and operation of the reservoirs and the BSNP had caused large environmental losses, such as wetlands and habitat for a number of native species. This resulted in the establishment of the Fish and Wildlife Mitigation Program for the reaches of the Missouri River below Gavins Point

Reservoir. However, the listing of three of these species as threatened or endangered resulted in a substantial additional issue during the Master Manual review process. Ultimately, the Missouri River Recovery Program was established to recover these species, mitigate the environmental losses by creating new habitat and restore the ecosystem. At certain times, releases of water from the Missouri River Reservoir system are adjusted to avoid takings of endangered species. There were additional limited revisions to the Master Manual in 2006 related to the criteria for a spring pulse for the benefit of the endangered pallid sturgeon, but later studies have also occurred regarding the effectiveness of the spring pulse. In any event, the three currently designated threatened or endangered species, as well as other environmental issues on the Missouri River, could impact the construction of an intake on the Missouri River and the withdrawal of water from the river.

While operation of the Missouri Mainstem Reservoir System in accordance with the 1944 FCA is important and determines how much water is stored and released from the reservoir system, the diversion criteria assumed during the 1982 Study and this review is not dependent on specific releases from the reservoir system for an aqueduct project. Water is stored and released in accordance with criteria in the Master Manual and Annual Operating Plans adopted by the Corps, which in turn are based the projected and actual water supply, the hydrology of the basin and how to satisfy the project's authorized purposes to the extent possible, within other constraints. In general, except for flood control releases, releases are made to meet certain flow targets during the navigation support season depending on flow conditions and the amount of water in storage the mainstem reservoir system. For example, when a sufficient amount of water is in storage for full service navigation, the target flow at Kansas City is normally 41,000 CFS during the navigation support season. The flow targets and/or length of the normal navigation support season are reduced if sufficient water is not available. Lower target flows are set in the non-navigation/winter months to provide sufficient water for uses other than navigation.

The water management, economic, social and environmental issues associated with the Pick-Sloan Program will likely continue to affect the views of various officials and stakeholders in the basin relationships in the basin well into the future. This could be important if a Kansas aqueduct project is pursued in the future.

5.2.4 Interstate Water Issues related to the Missouri River

5.2.4.1 Overview of Interstate Issues

There are several interstate river compacts between states on major tributaries in the Missouri River Basin, including the Yellowstone River Compact (Wyoming, Montana and North Dakota), the Belle Fourche River Compact (Wyoming and South Dakota), the South Platte River Compact (Colorado and Nebraska), the Republican River Compact (Colorado, Nebraska and Kansas) and the Big Blue River Compact (Nebraska and Kansas). In addition, as noted in Section I B 1, the State of Montana has entered into seventeen compacts with various American Indian Tribes and the United States regarding resolution of Federal Reserved Water Rights held by tribes in Montana. However, there is not a basinwide compact, congressional allocation or U.S. Supreme Court Equitable Apportionment that fully allocates the waters of the Missouri River among the states and tribes. Therefore, there is not a specific allocation of how much water the State of Kansas can use from the Missouri River or that otherwise restricts its use from the river. This, however, is a two edged sword. While there is currently no specific basinwide legal restriction on how much water can be appropriated, authorized or used directly from the Missouri River by each State or Tribe, it is clear that each of them is entitled to some share of the river basin's water. On the other hand, there is also no specific protection for current or future uses of Missouri River water by the State of Kansas from the depletive effect of current or future upstream water development. In other words, while the potential physical amount of water that may be available from the Missouri River for use by the aqueduct can be estimated based on the hydrology of the river and making various assumptions, that amount could change in the future if the Missouri River is ever equitably apportioned by Supreme Court decree, Congressional apportionment, or interstate river compact. A compact is a contract between the states and the federal government, a state law in each of the signatory states and a federal law.

What does this mean? It means that no matter what Kansas does within our state to grant water rights, reserve water or develop water supplies from the Missouri River, that quantity of water is not protected from use by other states, Indian tribes or the federal government, until an equitable apportionment of the basin takes place within the basin. The United States Supreme Court made this very clear in the *Hinderlider* case²⁶ when it stated, "Whether the apportionment of the

water of an interstate stream be made by compact ... the consent of Congress or by a decree of this Court, the apportionment is binding upon the citizens of each State and all water claimants, even where the State had granted water rights before it entered into the compact.”

In other words water rights or water reservations granted by a state to its citizens are protected only against water right claimants in that state under that state’s law. Until an interstate equitable apportionment has taken place, no state can know for sure how much water it has to allocate to its citizens. Therefore, prior to Kansas undertaking a project of the magnitude of an aqueduct project, it would be highly advisable that Kansas seek to have the river equitably apportioned so that Kansas will know for certain what its equitable share of the river is and what it can allocate with certainty.

The 1982 Study assumed that flows in excess of 41,000 CFS during the navigation support season and 15,000 CFS during the non-navigation support season would be available the aqueduct. However, this does not mean that there would not be concerns from other interests regarding a large diversion of water from the Missouri River. Even without an impact to the operation of the Missouri River Mainstem Reservoir system, there may be apprehension by upstream interests about a large diversion’s effect on the future allocation of water in the basin. Downstream, there could be concern about the effect of aqueduct diversions further downstream on the Missouri River and possibly on navigation on the Mississippi River. At times, the Missouri River supplies about 50% of the flow of the Mississippi River at St. Louis and sometimes the two rivers are in drought at different times. During the Master Manual review process, many concerns were voiced regarding the effect of various options on the interests of states, tribes and various stakeholders. In the past, some officials in the lower basin area expressed strong opposition to upstream water development, especially when the water is to be taken out of the basin and upper basin states expressed concerns regarding the amount of water released from storage for navigation. Issues related to how much water is stored in the Mainstem Reservoir System and subsequently released were generally resolved when the Master Water Control Manual was revised by the Corps and reviewed by the Federal Courts, as noted above. However, since then issues have risen regarding operation of the reservoir system during the flood of 2011 and again in 2012 when the basin returned to drought conditions in both the Missouri River Basin and along the Mississippi River.

During the drought of 2012, Senators of states along the Mississippi River made a request to the Corps to release water from Missouri River storage to support barge traffic on the Mississippi River due to low flows caused by drought conditions. There was opposition to this request from the Governors of Montana, North Dakota, South Dakota and Kansas and the congressional delegations of these same states.²⁷ They argued that releasing water primarily for Mississippi River navigation support would be unlawful, is not authorized by the 1944 FCA, and would cause harm to the other the authorized purposes and the people and business in their states. The Corps declined to release water from the Missouri River storage for navigation support on the Mississippi River, which seems consistent with its historic position. However, the Corps and many others do recognize that there is an incidental benefit to Mississippi River navigation from releases from the Missouri River Mainstem Reservoirs operated in accordance with the Master Water Control Manual. Historically, Kansas officials have also objected to releases of water from tributary reservoirs in Kansas to support navigation on the Missouri River. This position has continued with the current administration.²⁸

While past actions by the states are not necessarily indicative of what might happen in the future, it may be informative to look at a past attempts by states to export water from the Missouri River basin. In 1982 the ETSI Pipeline Project contracted with the Secretary of Interior to withdraw up to 20,000 acre feet of water per year from Lake Oahe. Lake Oahe is a mainstem reservoir on the Missouri River in South Dakota with a capacity of 23 million acre feet. ETSI had already obtained a permit from the state to use the water in a coal slurry pipeline that was to transport coal from Wyoming to the southeast part of the United States. Almost immediately after the contract was signed, the states of Missouri, Iowa and Nebraska sought to enjoin the contract saying that the Secretary of the Interior did not have the authority to contract to sell water from Lake Oahe. These states contended that that authority was limited to the Secretary of the Army. The case was appealed to the United States Supreme Court and a decision was rendered in 1988.²⁹

The authorized purposes of Lake Oahe were to allow “the irrigation of 750,000 acres of land in the James River Basin as well as to provide useful storage for flood control, navigation, the development of hydroelectric power and other purposes.” S.Doc. No. 247, 78th Cong., 2d Sess., 3 (1944).

The Supreme Court stated that,” the District Court found that no water from Lake Oahe has ever been used for irrigation, ... and we are unaware of any such plans in the near future. Under these circumstances, the Interior Secretary is not ‘in conformity with the provisions of’ § 8, and therefore has no authority under the Act to withdraw water from Lake Oahe, whether for irrigation or otherwise.”

The Court went on to hold that “The Flood Control Act speaks directly to the dispute in this case, and congressional intent as expressed in the Act indicates clearly that the Interior Secretary may not enter into a contract to withdraw water from an Army reservoir for industrial use without the approval of the Department of the Army. That is ‘the end of the matter.’” [Id., at 842, 104 S.Ct., at 2781.](#)

So in 1982 year we have a case from the Missouri River basin where one state desired to export up to 20,000 acre feet of water per year from a reservoir with a capacity of 23 million acre feet which immediately drew the of objection of three downstream states. Obviously the quantity of water proposed to be withdrawn was not the real issue, as it amounted to 0.09 of a percent of the reservoirs capacity. And the pipeline was arguably attempting to use water that had never been used because the 750,000 acre irrigation project to be supplied by Lake Oahe had never been built.

Obviously a Kansas aqueduct project presents a proposal that is different from the ETSI Project in significant ways: 1) Kansas is proposing to withdraw the water below all the states in the basin except Missouri and not above three states, 2) in ETSI water was proposed to be withdrawn from storage and the legal authority of the contracting official was in question, whereas an aqueduct project would not be withdrawing water from storage and 3) there are limitations on when water may be diverted from the Missouri River so that ostensibly all other uses of water would be satisfied first. Part of the objection in ETSI came from the fact that all of the water would be used out of the basin. As proposed, a Kansas aqueduct would arguably use only some of the water out of the Missouri River Basin. Even those differences do not guarantee that no other state, tribe or federal agency would not immediately object to an aqueduct project if it proceeds to move forward. In the authors’ opinion, water disputes in the west have in general tended to get more contentious, rather than less.

In 1984 the Denver Water Board sought to build 615 foot high Two Forks Dam at the confluence of the North Fork with the Platte River. The proposed price tag was \$1 billion. It was opposed by the Environmental Defense Fund and 32 environmental groups. In 1989 the Corps announced that it was going to issue a permit for the dam, but on November 24, 1990, EPA Chief Reilly killed the proposed project saying that it violated the Clean Water Act.³⁰

As another example, during the 2006-2007 time period, the Bureau published a draft Environmental Impact Statement (DEIS) for comment on the Red River Valley Water Supply Project that proposed to transfer between 50,000 and 100,000 acre feet at a diversion rate of up to 122 CFS from the Missouri River to eastern North Dakota, primarily for municipal use during the next 50 years. Over 270 comments for and against the project were received from a wide range of interests, including North Dakota officials and residents, environmental groups, American Indian Tribes and representatives from several other states and entities with an interest in the Missouri River Basin. These included objections from the States of Minnesota, Missouri and the Government of Canada, among others. Many of the entities expressing concerns objected to an out of basin division, as well as potential downstream impacts, especially during drought.³¹ As a result, the project has not moved forward, but it is possible other solutions may be pursued by North Dakota officials without Federal involvement.

5.2.4.2 Kansas Interstate River Compacts

Kansas is a party to four interstate river compacts: 1) the Kansas-Nebraska Big Blue River Compact; 2) the Republican River Compact between Kansas, Nebraska and Colorado; 3) the Arkansas River Basin Compact between Kansas and Oklahoma and 4) the Arkansas River Compact between Kansas and Colorado. Each compact is unique in the way it apportions water between the member states, or otherwise restricts the use of water.

5.2.4.2.1 Big Blue Compact

The Big Blue River Compact³² includes a provision regarding “Transbasin diversion”³³ that provides that, “In the event of any importation of water into the Big Blue river basin by either state, the state making the importation shall have exclusive use of such imported water, including identifiable return flows therefrom. Neither state shall authorize the exportation from the Big Blue river of water originating within that basin without the approval of the administration.”

This last provision would require the approval of compact members from both Kansas and Nebraska for an export of water from the Big Blue River, including water from Tuttle Creek Reservoir. However, the 1982 Study did not propose such a transfer for an aqueduct project. The route of the aqueduct crosses the Kansas River east of the junction of the Big Blue River and the Kansas River. Of course, the outflows of water from the Big Blue River and Tuttle Creek Reservoir flow downstream to the Kansas River.

5.2.4.2.2 Arkansas River Basin Compact

The Arkansas River Basin Compact between Kansas and Oklahoma³⁴ covers the drainage of the Arkansas River Basin below the confluence of the Little Arkansas River and the Arkansas River near Wichita, Kansas and the confluence of the Grand-Neosho River and the Arkansas River near Muskogee, Oklahoma. As a result, this includes the tributary areas in Southeast Kansas that drain to the Arkansas River in Oklahoma, such as the Neosho and Verdigris Rivers, as well as the Salt Fork and Cimarron Rivers in Kansas. However, Article VIII of the Compact states that, “In the event of importation of water to a major subbasin of the Arkansas River Basin from another river basin, or from another major subbasin within the same state, the state making the importation shall have exclusive use of such imported waters.” Article C also states that, “Any reservoir storage capacity which is required for the control and utilization of imported waters shall not be accounted as new conservation storage space” that is otherwise limited by the Compact. Given the route of the aqueduct, it is possible that water could be imported into the Neosho River Basin, which is subject to the storage limits of the compact. However, it would appear that the Compact would allow Kansas the full use of such water, although there may be the need to measure and account for any imports in order to ensure it is all available for Kansas use.

5.2.4.2.3 Republican River Compact

The Republican River Compact³⁵ apportions the virgin water supply of the Republican River Basin for beneficial use of the States of Kansas, Nebraska and Colorado. The Compact does not restrict water imported or exported from the basin. However, based on the provisions of the compact and the terms of a litigation settlement reached by the states in 2002, there are provisions in the hydrological model and accounting procedures used by the compact administration to deal with the use of certain water imported into the basin. While there has been a later dispute on how to treat certain imported water, presumably the concepts agreed upon could be used to determine the effect and proper crediting of any water imported into the Upper Republican River Basin. Article IV also provides, “In addition there is hereby allocated for beneficial consumptive use in Kansas, annually, the entire water supply originating in the Basin downstream from the lowest crossing of the river at the Nebraska-Kansas state line. No separate accounting should be needed if aqueduct water was delivered to Milford Reservoir.

5.2.4.2.4 The Arkansas River Compact

The Arkansas River Compact³⁶ only allocates the waters of the Arkansas River “originating above the Kansas-Colorado Stateline, ...excluding waters brought into the Arkansas River Basin from other basins.”³⁷ However, although water imported to the river system is not regulated by the compact, the states have had to historically account for these waters with measurement and hydrologic modeling in order to separate their use from the water allocated by the compact. As a result, there could be monitoring and accounting requirements if water was imported to the affected area in Kansas involving storage in Lake McKinney or diversions by the ditches that divert water from the Arkansas River above Garden City.

5.2.5 Kansas Water Appropriation Act

The Kansas Water Appropriation Act³⁸ (KWAA), enacted in 1945, is the law that governs the use of water in Kansas. The primary tenet of this law is called the Priority Doctrine and is sometimes referred to as, "First in time is first in right." What this means is that the first person that legally acquires a water right in Kansas has the best right to the use of that source of water supply.

5.2.5.1 Application

In Kansas no one can use water for any beneficial use, other than domestic use, with applying for and obtaining a permit to appropriate water in accordance with the KWAA,³⁹ by submitting the application along with the statutorily required filing fee, to the Chief Engineer, Kansas Department of Agriculture, Division of Water Resources (Chief Engineer).⁴⁰ The application is required to contain certain information⁴¹ specified by statute and regulation before it is considered to be in final form.

5.2.5.2 Statutory Criteria for Approval

Once the application is in final form, the Chief Engineer determines whether the application meets the statutory criteria for approval.⁴² These requirements include: a) whether the proposed application will impair a use under an existing water right and b) whether the proposed application will prejudicially and unreasonably affect the public interest.

The requirement that a new application not impair an existing water right means that the new application cannot be approved unless there is sufficient water available to satisfy all existing water rights from that source of water supply and the quantity and rate of water being requested in the new application. The Corps' 1982 Study, assumed that water would not be diverted from the Missouri River unless the target river flow of 41,000 CFS was met at during the navigation support season (eight months) as well as the non-navigation support season target flow of 15,000 CFS (four months), both at Kansas City.⁴³ No water would be diverted unless all water rights upstream from the White Cloud intake are being satisfied and the target flows are being met downstream at Kansas City. The statute⁴⁴ specifies that in order to determine whether a proposed use will impair a use under an existing water right, "impairment shall include the unreasonable increase or decrease of the stream flow."

With the Corps assumptions concerning diversion criteria, it would appear that the proposed diversion of water would not impair existing water rights, but that higher flow levels might need to be set to protect the ability of Kansas to approve reasonable smaller water rights in the future for local use. This would satisfy the requirements of subsection (a) for approving the new application.

Subsection (b) requires that the new application will not "prejudicially and unreasonably affect the public interest." In determining whether a proposed use will prejudicially and unreasonably affect the public interest, the Chief Engineer is required to take into consideration:

1. established minimum desirable streamflow requirements, of which there are none on the Missouri River, or the streams on which the source and terminal reservoirs are located,⁴⁵
2. the area, safe yield and recharge rate of the appropriate water supply;
3. the priority of existing claims of all persons to use the water of the appropriate water supply;
4. the amount of each claim to use water from the appropriate water supply; and
5. all other matters pertaining to such question.

The Corps assumptions about when diversions would take place should ensure that requirements 2) through 4) should be met. Requirement 5) is more difficult to assess, but it is likely that a number of other concerns may be raised regarding a project of this magnitude. It is possible that any such additional issues would be deferred for consideration during the Water Transfer Act process.

Subsection (c) of requires that the application be made in good faith. This usually is interpreted to mean that there is a reasonable likelihood that the project will be built and that the application is not just being filed to block someone else from getting a new appropriation.

Subsection (d) requires that the application be in proper form. The statutes and regulations set forth specific requirements that an application must meet to be in proper form.⁴⁶ These requirements include the source of water supply, the maximum rate at which water would be diverted, the total annual quantity of water sought, the location of the point of diversion and the estimated time for completion of the diversion works and the application of water to beneficial use. The applicant may also be required to demonstrate legal access to, or control of, the point of diversion and other facilities.⁴⁷

The proposed beneficial use or uses must be specified as well as a demonstration of the reasonableness⁴⁸ of the annual quantity of water and maximum instantaneous rate of diversion being requested. In his case, the annual quantity of water requested and the maximum instantaneous rate of diversion are known, however, the reasonableness of these two factors cannot be judged until the customers for this water are identified and the quantities of water they are requesting are known.

At this stage in the project it is not possible to identify the actual proposed place of use as required by statute.⁴⁹ If water is being sold from this project, the place of use may be identified as the point at which the water is sold to the end user from the aqueduct or the terminal reservoir. It may be possible that the authorized place of use could be specified as a corridor paralleling the aqueduct and a certain radius or defined area around the terminal reservoir. Theoretically the authorized place of use could be specified as the area within which water could be sold from an aqueduct project.

5.2.5.3 Filing Fee

The filing fee for a new application is approximately \$20 per 100 acre feet.⁵⁰ For example, the current study estimates a range of acre feet of water that could be diverted. Assuming hypothetically that the maximum of that range could be available for appropriation, the filing fee for direct use of that quantity would be about one million dollars.

The three points of diversions for this aqueduct would require at least three separate applications to appropriate water for beneficial use.

First, there will need to be an application to appropriate water for beneficial use from the Missouri River. This would be a direct diversion by means of an intake in Missouri River to pump water into the source reservoir. The current study estimates that up to five million acre feet of water may be available for diversion, depending on the type of facilities that are built.

To put this quantity of water in perspective, the average annual quantity of water diverted for consumptive use of water in Kansas during the period 1990 through 2008 was 4,366,180 acre feet. This is at the upper end of the range of quantities of water the aqueduct may be able to divert. If the aqueduct is built and operated, it could potentially provide an average annual quantity of water approximately equal to the amount currently diverted for consumptive water use in Kansas, although it is unlikely that the amount of existing groundwater withdrawals would continue, due to water level declines and because the aqueduct would presumably replace a substantial amount of the existing use from the Ogallala aquifer in western Kansas.

A second application to appropriate water will be necessary to divert runoff water from the drainage area being impounded behind the dam of the source reservoir. It does not appear that the source reservoir would inundate part of an Indian reservation.

A third application to appropriate water would be necessary to store water diverted by the terminal reservoir. Although the application fees for the source and terminal reservoirs might be avoided by building and operating those two reservoirs so that they did not store local runoff, operating those two reservoirs so that they do not affect the timing of the rate and quantity of local runoff below the reservoir is more problematic than just filing the applications and getting them approved.

5.2.5.4 Diversion of Water Out of State

If some of the water from an aqueduct project were to be used outside the State of Kansas, an application will need to be filed with the Chief Engineer and approved pursuant to K.S.A. 82a-726. That statute requires that the application comply with the; 1) KWAA, the KTA, and all other state laws relating to the diversion, transportation and use of water; 2) the statutes and common law of the state where the water will be used if the water were diverted in that state and 3) not be water apportioned to Kansas pursuant to an interstate compact. The statute further requires that the approval is conditioned so that the approval can be revoked if the water is necessary to protect the public health and safety of the citizens of Kansas.

5.2.5.5 Summary and Discussion of KWAA Issues

The logical question raised by the issues set forth above concerning using a standard application to appropriate water for beneficial use filed under the KWAA, is whether that type of application will work satisfactorily for this project, or should other alternatives be considered?

The options seem to be: 1) make the project fit under the KWAA, 2) modify the State Water Plan Storage Act⁵¹ so that it can be used to permit this project or 3) have the legislature create an entirely new type of water right.

Although the aquifer project does not exactly fit the definition of a traditional water right, there are many similarities. If aqueduct project applications are filed pursuant to the KWAA, there are certain issues that are a little out of the ordinary. These include: a) an extremely long time to complete the project, b) an extremely long perfection period, c) an indefinite place of use, d) the requirement that the water right be perfected within a certain definite period of time and e) a rather large filing fee. Similar issues have been dealt with to some extent in processing other applications under the KWAA.

For example, municipal water supply projects have required years to complete construction of the infrastructure, such as points of diversion, water treatment facilities, and distribution systems. As long as a reasonable schedule was proposed by the applicant, that extra time to complete the infrastructure could be accommodated in the permit.

Similarly, municipalities are allowed to have 20 full calendar years after the completion of the diversion works to perfect their water rights. This time period may be extended an additional 20 years for good cause.⁵²

Even though all customers will not be known at the time the application is filed, there is a potential solution for that. For example, municipalities and irrigation districts are frequently authorized to divert water within a specified geographic area, such as within the corporate limits of a municipality plus a one half mile corridor surrounding the corporate boundary.⁵³ Irrigation districts are authorized to divert water within the corporate boundaries of the district. In the case of both municipalities and irrigation districts, water is not delivered to all persons or entities within those boundaries.

For the KWAA, each permit issued by the Chief Engineer specifies that the application must be perfected within a specified number of years by applying water to beneficial use in accordance with the terms, conditions, and limitations of the permit. This should be doable under the terms of a permit, especially if a reasonably long time period is allowed by the Chief Engineer for perfecting the water right.

Finally, as mentioned above, there is the matter of a rather large filing fee, which could be up to about one million dollars, that must be filed with the application for a permit to appropriate water before it can be accepted for filing and establish a priority date. Once the application is accepted for filing, it can be processed and additional information acquired so that a decision can be made as to whether it can be approved, and if so under whatever terms, conditions and limitations, etc. This would require the entity constructing the project to have the one million dollars at a very early stage an aqueduct project. Whether that money is available or not at that time would depend largely how an aqueduct project is financed.

5.2.6 Water Reservation Right Alternative

A second alternative may be a potential alteration of the State Water Plan Storage Act⁵⁴, to allow the filing of a water reservation right for an aqueduct project. This act currently authorizes the director of the KWO to apply for water reservation rights in federal reservoirs or other water storage space controlled by the state of Kansas. Once the application is filed with the Chief Engineer and accepted, the water reservation right is deemed to be perfected as of the date of the original filing.⁵⁵

Use of the State Water Plan Storage Act for an aqueduct project would raise several issues. First, in the act's current form, the director of the KWO could not file for a water reservation right to divert water from the Missouri River because the Missouri River is not storage space controlled by the state of Kansas. Secondly, the current act would put the KWO in the position of being the seller of the water under the Water Marketing Program. These are issues that would have to be addressed if a choice was made to use this act.

The advantage to using the State Water Plan Storage Act is that there is no filing fee or perfection requirement. The water right is automatically perfected as of the date of filing. No water use within the terms, conditions and limitations of the Water Reservation Right is necessary. The customers, the places of use, and how shortages of water would be shared, would then be determined by the contracts between the water users and the KWO.

It should also be noted that Professor Peck pointed out that nowhere is it currently provided in statute that water reservation rights are "real property" as are water rights.⁵⁶ Although this is an important difference, it is not clear what ramifications this may have if a water reservation right is used to implement an aqueduct project. The KWO could consider forming a task force to look at recommending amendments to the State Water Plan Storage Act concerning water reservation rights.

There is another example of the use of the water reservation concept in the Missouri River Basin. In 1982, the State of Montana developed a strategy aimed at protecting its share of water from the Missouri River from downstream uses and to insure water availability for Montana's future needs⁵⁷. This effort was apparently precipitated in part due to the High Plains Study being conducted at that time that was examining the potential for diverting and transporting Missouri River water to several portions of the High Plains area, including the 1982 Study aqueduct route being evaluated at this time. Since then, Montana has established a number of "reservations" to reserve water for future use.⁵⁸ It appears this approach purports to reserve water for specific uses projected to be needed in the future for cities, irrigation projects, instream flow and other uses. More detailed review and analysis may be needed to determine what legal standing these "reservations" or other such reservation rights would have at the time of an actual conflict in water use between the States or Tribes in the basin, especially if no actual water is being made of the water. This could be an issue if a case was filed to establish a U.S. Supreme Court Equitable Apportionment in the Missouri River Basin, or perhaps could be a consideration if one of the other methods to determine a basinwide allocation was being undertaken, as referred to above.

5.2.7 Kansas Water Transfer Act

Legal issues related to obtaining water at the source include considerations related to acquisition of water and protection for the area of origin. While the KWAA is the foundation of Kansas water law, and provides for consideration of whether or not water is available for appropriation from any given source of water, or whether the point of diversion, place of use or purpose of use can be changed under an existing water right, the Water Transfer Act (WTA)⁵⁹ provides for an extraordinary process to determine whether significant amounts of water should be allowed to be moved or "transferred" more than a defined distance from one area to another.

According to the WTA, a water transfer "means the diversion and transportation of water in a quantity of 2,000 acre feet or more per year for beneficial use at a point of use outside a 35-mile radius from the point of diversion of such water". The WTA defines various terms like point of diversion and point of use, so that one can determine whether a proposal qualifies as a Water transfer can be determined. However, given the amount of water and distance involved in the 1982 study, there is little doubt that such a project would qualify as a water transfer (transfer) under current Kansas law.

The WTA sets up a process for review of proposed transfers and defines a number of criteria or factors that must be considered before such a transfer can be approved. The law sets up a “water transfer hearing panel” to implement the provisions of the Act. The panel consists of the Chief Engineer, as chairperson, the Secretary of the Kansas Department of Health and Environment (or Director of the Division of Environment, if designated by the Secretary), and the Director of the KWO. The process requires a hearing to be held in accordance with the provisions of the Kansas Administrative Procedures Act, except as specifically provided by the WTA. The hearing is to be conducted by a hearing officer, also known as a presiding officer, who is to be an independent person knowledgeable in water law, water issues and hearing procedures. After consideration of the record from the hearing, the presiding officer shall render an “initial order” approving or disapproving the proposed transfer, including findings of fact, relating to each of the factors to be considered in KSA 82a-1502 (c) of the WTA; the proposed transfer may be approved for a smaller amount of water than requested on such terms, conditions and limitations as the presiding officer deems necessary for the protection of the public interest of the state as a whole. The water transfer panel shall be deemed the agency head for purposes of the Kansas Administrative Procedures Act and shall review all initial orders of the presiding officer.

The Chief Engineer has adopted rules and regulations⁶⁰ related to the water transfer process, setting forth information needed for a water transfer application. Among other things, an application shall not be considered complete unless one of the following has been approved, contingent upon receiving a permit to transfer water: A permit to appropriate water from the source, a change to an existing water right or a contract for purchase of water from state controlled storage in a federal reservoir. In short, compliance with the KWAA or the Kansas Water Marketing Act to acquire water from the source is necessary before applying for a transfer.

Under the criteria in KSA 82a-1502, a transfer shall not be made, unless approved pursuant to the provisions of the WTA. In essence, a transfer is not to be approved which would reduce the amount of water required to meet present and any reasonably foreseeable future beneficial use of water by present or future users in the area from which the water is to be taken unless it is determined that the benefits to the state for approving the transfer outweigh the benefits to the state for not approving the transfer. An extensive list of factors are considered as outlined in the statute and discussed more below.

The WTA indicates that no transfer shall be approved if it would impair water reservation rights, vested rights, appropriation rights or prior applications for permits to appropriate water. The WTA also requires that the applicant has adopted and implemented conservation plans and practices that are consistent with state guidelines, that such plans and practices have been in effect for at least one year before the application is filed, and that they include a rate structure for municipal use that encourages efficient use of water that will result in wise use and responsible conservation and management of water by the system.

To determine whether the benefits of the transfer outweigh the benefits for not approving the transfer⁶¹, the WTA requires the presiding officer to consider nine separate factors, generally described herein: 1) any current beneficial use of the water to be transferred, including minimum desirable streamflow requirements; 2) any reasonably foreseeable future beneficial use of the water; 3) the economic, environmental, public health and welfare and other impacts of approving or denying the proposed transfer; 4) alternate sources of water available to the applicant and present or future users for any beneficial use; 5) measures taken to preserve the quality and remediate any contamination of water currently available for use by the applicant; 6) information regarding the proposed plan of design, construction and operation of the facilities related to the transfer; 7) the effectiveness of conservation plans and practices of the applicant or any other entities to be supplied water; 8) the conservation plans and practices implemented by persons protesting or potentially affected by the transfer which must be consistent with KWO guidelines and 9) any applicable management program, standards, policies and rules and regulations of a groundwater management district.

One of the issues that may be raised is the extent of the impact of an aqueduct project on local tax revenues and potential offsets, including any reduction in local property taxes.

While it is not possible to know what facts and information would be presented during a hearing on a proposed transfer related to an aqueduct project being studied, it should be anticipated that the applicant would need to address each of the nine factors outlined above at a formal quasi-judicial type hearing. In addition, any persons that intervene in the hearing process would need to address any factors of concern to them, as the presiding officer will need to consider and evaluate

evidence related to these factors. After the presiding officer renders an initial order, the water transfer panel must review the initial order, based on the record of the hearing and issue a final order. Finally, the final order may be appealed in accordance with the Kansas Judicial Review Act.⁶²

5.2.8 Corps Required Permits

Most activities involving work in the waters of the United States require authorization of the Corps, through one or both of the following Federal laws: Section 404 of the Clean Water Act,⁶³ and Section 10 of the Rivers and Harbors Act of 1889⁶⁴. In particular, the lock and dam on the Missouri River would likely be considered a major permit issue because of its potential to change the flows of the river and potentially affect the Bank Stabilization and Navigation Project (BSNP). The BSNP was designed to make the Missouri River a free flowing river with a self-souring navigation channel, through channelization and bank protection along much of the river.

Section 10 regulates any work or structure in, over, or under navigable waters of the United States. This includes such items as boat docks, power lines, excavation, filling, etc. In Kansas, this law applies only to the Missouri River, the Kansas River and the Arkansas River. Section 10 approval would be required for the lock and dam and intake facilities on the Missouri River for an aqueduct project. In addition, approval would be required for the crossing of the Kansas River.

“The **navigational servitude**, which exists by virtue of the Commerce Clause in **navigable** streams, gives rise to an authority in the Government to assure that such streams retain their capacity to serve as continuous highways for the purpose of **navigation** in interstate commerce.”⁶⁵

The Missouri River is a navigable river. The federal government, through the Commerce Clause, may regulate construction and withdrawal of water which impairs that navigability. This power is exercised by the Corps under Section 10 of the Rivers and Harbors Act. Anything an aqueduct project would do to impair navigability of a navigable river would likely be challenged by the federal government.

However, the 1944 FCA also included what is known as the ‘O’Mahoney–Millikin Amendment⁶⁶, that appears to subordinate navigation to most beneficial consumptive uses in the states totally or partial west of the 98th Meridian, which includes Kansas. While this provision would presumably override the navigation servitude issue on the Missouri River, that legal issue is unresolved at this time.

Section 404 regulates the discharge of dredged or fill material in all waters of the United States, including rivers, streams, lakes and wetlands. It appears a Section 404 permit would be required for the Missouri River lock and dam and intake facilities, the Kansas River crossing and construction of both the source and terminal reservoirs. It appears aqueduct would mostly be located along a ridge line. However, if any smaller streams or wetlands would be encountered, Section 404 approval may be needed, if the “Waters of the United States” are involved. There has been controversy and litigation in recent years regarding the definition of the “Waters of the United States”, and proposed changes to the rules of the EPA and Corps are pending. Presumably, this issue would be resolved before any construction would take place.

The process for consideration of such permits can be extensive, especially due to the potentially extensive environmental review required. It is anticipated that the dredge and fill, and other construction associated with each of the four components of an aqueduct project mentioned above would require detailed analysis, review and public comment, including compliance with the National Environmental Policy Act (NEPA).⁶⁷ There may also be other smaller streams or water courses, as well as wetlands, also affected by the project that would require various kinds of Section 404 approval or permits, ranging from General Permits to more extensive permits, depending on the specific circumstances.

5.2.9 Obstructions in Streams Act and Levee Law

Kansas law⁶⁸ requires that any person or entity, except the federal governments, who desires to construct a dam, or change or diminish the course, current, or cross-section of any designated stream within Kansas shall, prior to construction, obtain the prior written consent for permit of the Chief Engineer.

Another state law⁶⁹, the Kansas levee law provides that it is illegal to, “construct, cause to be constructed, maintain or cause to be maintained, any levee or other such improvement on, along or near any stream of this state which is subject to floods, freshets or overflows, so as to control, regulate or otherwise change the flood waters of such stream” without first obtaining the approval of plans by the Chief Engineer.

In other words, the construction or modification of any levee, such as to protect the pump station on the Missouri River, or any construction that has the effect of a levee, such as a road, would require a permit to be issued by the Chief Engineer prior to construction. In order to receive that permit an application must be filed and the statutorily required filing fee be paid. A similar permit may be necessary for the aqueduct crossing of the Kansas River, or any other rivers and streams that may be encountered throughout the course of the aqueduct. Often levees are constructed and maintained by Drainage Districts or Levee Districts that can be organized under Kansas law.

The Obstructions in Streams Act⁷⁰ will require a number of different permits for an aqueduct project and will require payment of minor application fees.⁷¹ The first permit required under this statute would be for the construction and maintenance of the lock and dam, the intake and pump station on the Missouri River. It is likely that the construction of this and maintenance of this intake would alter course, current, or cross-section of the Missouri River, at least during the construction phase.

Unless they are constructed by the federal government, two other permits that would be required will be those required for the construction of the dams of the source reservoir and the terminal reservoir. Construction of the dams must meet the requirements of state law and regulations.⁷² In terms of conservation storage, the source and terminal reservoirs would be two of the largest reservoirs ever constructed in Kansas. Since it is assumed that these would not be federally constructed and operated, approval would be needed from the Chief Engineer pursuant to the Obstructions in Streams Act. One of the primary purposes of the act is the protection of life and property. These dams would need to be constructed to meet the dam safety requirements of the law and associated regulations. Because of the size and location, both reservoirs would be considered High Hazard dams, since a breach would inundate significant areas where loss of life could occur, should the dam fail. In particular, portions of the Missouri River valley and floodplain would be inundated by the failure of the source reservoir. The terminal reservoir is located in a rural area, but its size could result in flooding as far away as the upper part of the Walnut Creek drainage.

Permits would also be required under this act any time the construction of the aqueduct alters the course, current or cross-section of the stream subject to the jurisdiction of this act. This requirement applies whether the alteration of the stream channel is only temporary or permanent. For example, the proposed aqueduct alignment would cross the bed and banks of the Kansas River West of Topeka Kansas. If the construction of the inverted siphon would alter the stream channel either during or after construction, a permit would be necessary from the Chief Engineer.

The Water Projects Environmental Coordination Act⁷³ requires that prior to the issuance of a permit, the plans for the Missouri River intake, the crossing of the Kansas River and any other streams subject to the jurisdiction of the Chief Engineer, the source reservoir dam, and the terminal reservoir dam would be subject to review under that act by the environmental review agencies which are: a) Kansas Department of Wildlife, Parks and Tourism; b) the Kansas Forest Service; c) the State Biological Survey, d) the Kansas Department of Health and Environment; e) the State Historical Society, f) the Kansas Department of Agriculture Division of Conservation and g) the State Corporation Commission.⁷⁴ The environmental review agencies shall review the “proposed project for environmental effects. The Chief Engineer is required to “consider their comments in determining whether to approve or issue a permit for such project. The Chief Engineer may condition the approval of more permits for the project in a manner to address the environmental concerns of the environmental review agencies.” The environmental review agencies are required to consider, “the beneficial and adverse environmental effects of a proposed project of water quality, fish and wildlife, forest and natural vegetation, historic, cultural, recreational, aesthetic, agricultural and other natural resources;...”⁷⁵

5.2.10 State of Kansas Owned Property

In addition to the permits required by the obstructions in streams act, permission is also required from the state of Kansas to construct or alter property owned by the State of Kansas. The State of Kansas owns the bed and banks of any navigable

river up to the ordinary high water mark.⁷⁶ The Missouri River, the Kansas River and the Arkansas River are the only navigable streams in Kansas.⁷⁷ In order to get permission to construct facilities on state-owned land, a statute must be passed by the Kansas legislature and signed by the governor authorizing the project to be built on state owned land. For example, this was done when the city of Topeka constructed a weir across the Kansas River to funnel water into its intake.⁷⁸ Obviously a certain amount of lead time is necessary to get the statute passed and an agreement signed. This permission could be granted in the act creating the entity to build and operate an aqueduct project as was done when the KTA was created.

By interstate compact⁷⁹ Kansas owns the bed and banks of the Missouri River out to the centerline. Therefore, if Kansas is constructing diversion works or withdrawing water from the Missouri River on its half of the river, it is doing so on Kansas property. Any lock and dam constructed would by necessity located in both Kansas and Missouri.

5.3 Legal Issues in Transporting, and Dropping Off, Water Along the Way

5.3.1 Transportation of Water in Kansas Streams

Should an aqueduct project be designed to transport water by putting it into a natural stream in Kansas, conveying it downstream and picking it up and putting it back in the aqueduct, a Kansas statute⁸⁰ allows a person to do that outside the priority system. In other words, water could be released from the aqueduct, allowed to run down the stream channel, and re-diverted downstream and put back in the aqueduct or stored in a reservoir. During the time the water is in the stream channel, the Chief Engineer can protect that water from diversion by other water users, but the owner of that water would suffer losses from evaporation and seepage while it is in the stream channel.

It should be noted however that this statute is found under the old irrigation law, so while its language is broad, it could be argued that only water for irrigation could be transported in this manner. If the legislature amended to the KWAA to include this provision in it, that would remove any doubt that this provision applied to all types of beneficial uses.

5.3.2 Storing Water in Existing Lakes and Reservoirs along the Aqueduct Route

While not necessarily envisioned in the 1982 Study, there is a potential opportunity to store water provided by an aqueduct project, involving some of the twenty-four existing Federal reservoirs, seventeen (17) operated by the Corps and seven (7) operated by the Bureau. In addition, there are other potential uses along the aqueduct route that may be able to benefit from a supplemental water supply. An aqueduct is proposed to run along a ridge. For much of its route, it is the ridge separating the Smoky Hill River drainage in the Kansas River Basin and the Wet Walnut Creek drainage in Arkansas River Basin. Existing reservoirs on either side of this ridge may be able to receive water from the aqueduct by gravity flow and/or with limited construction.

In northeast Kansas, not far from the beginning of the proposed aqueduct, it crosses the upper end of the Delaware River. This would seem to be an opportunity to provide water to the river and Perry Reservoir if needed. Tuttle Creek and Milford Reservoirs are located northwest of the aqueduct route. While a spur could be constructed to one or both of them, it may not be justified or necessary. The aqueduct crosses the Kansas River east of Manhattan. If an outflow to the Kansas River was constructed at the crossing, aqueduct water could be provided to the Kansas River to supplement its flow, and provide water for the Kansas River Water Assurance District. This could result in less stored water being released from Tuttle Creek and/or Milford Reservoirs for use further down the Kansas River. This would allow more water for the upper portion of the Kansas River and stabilization of reservoir storage during drought. Water for the Jeffrey Energy Center could be provided from either or both sources.

Two Federal projects, Kanopolis Reservoir operated by the Corps and Cedar Bluff Reservoir operated by the Bureau, are on the Smoky Hill River, located just north of the aqueduct route.

At Kanopolis Reservoir, the potential exists to provide water to enhance storage in the reservoir, especially during drought, and potentially provide supplemental water for other uses in the area. For example, the City of Salina relies on the Smoky Hill River, and its alluvium for its water supply, as do irrigators below the lake. There are periods of water

shortages by these users. In addition, if supplemented by water from an aqueduct project, Kanopolis Reservoir could serve as a potential storage reservoir for various water needs in the adjacent Little Arkansas River Basin, such as public water supply for area communities. The upper reaches of the Little Arkansas River are near the aqueduct route, and it could serve as a potential source of recharge for the Equus Beds Aquifer.

The aqueduct could also be a source for Salina, McPherson, Wichita and other communities in South Central Kansas, including members of the Public Wholesale Water Supply District No. 10, that was organized a number of years ago.

The Cedar Bluff Reservoir project originally included an irrigation function, storage for the City of Russell and water for a National Fish Hatchery. However, no water was available for irrigation after 1978 and the irrigation district disbanded in 1994 due to reduced inflow and a shortage of water. The project was reformulated by Congress, and in place of the irrigation function, a “joint use pool”, operated by KWO and the Kansas Department of Wildlife and Parks, now includes storage for recreation and artificial recharge. Cedar Bluff Reservoir is still short of water and the project would apparently benefit from more water for recreation and perhaps other uses. The Smoky Hill River valley below the reservoir is also in an Intensive Groundwater Use Control Area (IGUCA).⁸¹ It includes significant water restrictions, and the area is normally short of water to meet existing domestic, public water supply, irrigation and other needs. If all the technical, legal and economic issues were resolved, and more water was available for storage at Cedar Bluff Reservoir, this area would likely benefit from increased releases to the water short stream system below the reservoir. This is where the well fields for the City of Hays and a rural water district are located, and water also continues to be used for domestic, irrigation and other uses below the reservoir. Potential water needs for small towns and other uses in the vicinity of Cedar Bluff Reservoir may also exist.

In addition, the Wet Walnut Creek and its alluvial valley are just to the south of the ridgeline in central Kansas, and it would not seem difficult to get water to this stream system. It is also in an IGUCA.⁸² Due to water shortages, this alluvial valley has some of the most restrictive limits on pumping in the state, so additional water added to this system could provide a larger supply of water for various purposes, including, municipal, industrial, irrigation and stockwatering uses, as well as recreation use, since water added to the Wet Walnut Creek system could also be allowed to flow downstream and be diverted into Cheyenne Bottoms. It would also only be a short distance to the City of Great Bend well field. Water quality impacts would need to be considered if the water was used for Cheyenne Bottoms, but by adding water to the upper end of the Wet Walnut Creek, the water quality impacts of using Missouri River water may be less of a concern.

Most of the other Federal reservoirs in Kansas operated by the Corps are located some distance from the aqueduct route, or may not have unused storage capacity on a normal basis, although all portions of Kansas experience drought at times, and serious multi-year drought, on occasion. However, several existing Corps Reservoirs are located in river basins where the upper end of the drainage is not far from the aqueduct route, especially in southeast Kansas. In particular, the upper end of the Neosho River Basin is adjacent to the ridge upon which the aqueduct would potentially run. This could provide access for water to flow by gravity to Council Grove Reservoir on the upper end of the Neosho River and Marion Reservoir on the Cottonwood River, both of which flow downstream to John Redmond Reservoir, and on through Southeast Kansas.

If any of these existing Corps reservoirs were to be used to store water from an aqueduct project, there are many different issues to consider. The reservoirs are generally located further east in the State than the Bureau reservoirs, and are generally not short of water except during periods of drought so there is normally less vacant space available, but that varies by specific project. In addition, the State of Kansas owns Conservation Water Supply Storage in most of these reservoirs and they are a part of either the Kansas Water Marketing Program or Water Assurance Program, administered by KWO to help meet the long terms needs of municipal and industrial users. Water is sold to these users through the Water Marketing Program using long term contracts. KWO has also entered into contracts with Water Assurance Districts in several river basins. Water Reservation Rights are held by the KWO on behalf of the State for these reservoirs. As a result, it is uncertain whether a change in operation of these projects is practical, although it is possible that supplemental water supply could be provided by an aqueduct project to enhance the amount of water available to help meet long term municipal and industrial demand from these reservoirs.

It may be possible to increase the utilization of federal reservoirs in other ways, especially in light of lost storage space over time due to sedimentation. For example, it may be possible in some cases to increase storage capacity in a given reservoir by raising the conservation pool level, or possibly the dam itself. In addition, it is also possible to change the authorized purposes. Each of these potential changes would require extensive study and review pursuant to NEPA. The Federal operating agency would need to be funded to conduct the studies and congressional approval would be required to change the project's authorized purposes or to change the operation of the project beyond the authority of the operating Federal agency. The studies and NEPA process should be expected to be quite extensive, and would need to consider impacts to existing authorized purposes and users, as well as the technical, environmental, economic and social impacts of the proposal.

5.3.3 Water Quality Issues

Water quality implications of a Kansas aqueduct project, and potential impacts to streams along the aqueduct corridor, is an issue to be evaluated herein at a general level, and in more detail in Chapter 6 Environmental Constraints, by others. Generally speaking, any time water from one source is introduced to another stream or water body, there can be a positive or negative water quality impact. For example, a technical analysis would be needed to determine whether Missouri River water contains more or less nitrates, phosphorus or pesticides than any given stream, reservoir or water body in Kansas that would receive aqueduct water. The Missouri River has historically been referred to as the "Big Muddy", apparently due to the sediment load carried by the river, and it may carry more sediment than most streams in Kansas. However, like other smaller scale water bodies, considerable change has occurred in the Missouri River Basin over the years, due to soil and water conservation practices, sediment accumulation in reservoirs, point and non-point source pollution control programs, and other practices that normally reduce the sediment load and contaminants to streams. Like other surface water sources, with treatment, the Missouri River is used as a major source of municipal water supply throughout the basin, including large cities and water districts along the Missouri River in Kansas, such as Water District No. 1 of Johnson County and the Board of Public Utilities in Wyandotte County. Nevertheless, a water quality concern could exist if untreated Missouri River water were directly introduced by an aqueduct into other rivers, streams or reservoirs of higher quality. The existing quality of water in the receiving body, and its uses, would need to be evaluated to determine if there would be stream degradation, impacts to water quality standards or total maximum daily load (TMDL) issues. Invasive species, such as the Zebra Mussel and Asian carp, is another issue to be evaluated if Missouri River water is introduced to different water bodies that have not been infected with such species.

Most point source discharges to a water body are required to be permitted through the National Pollution Discharge Elimination System (NPDES), pursuant to the Clean Water Act.⁸³ The administration of this program and issuance of permits has been delegated to many of the states by the Environmental Protection Agency (EPA), including the Kansas Department of Health and Environment. In some cases, this can be a complex process. Whether such permits are needed for "water transfers" from one water body to another has been litigated in the Federal courts. Since the Federal Circuit courts have reached different conclusions in different areas of the country, this issue may ultimately be resolved by the U.S. Supreme Court. Non-point source pollution control has historically been handled by the states through voluntary incentive-based programs, such as land treatment for erosion control (terraces, waterways, residue management, etc.) and riparian and wetland protection. In Kansas, cost share programs for non-point source pollution control are administered by the Kansas Department of Agriculture, Division of Conservation.

In addition, several water bodies in Kansas have been designated as "Outstanding National Resource Waters" and impacts to these waters would need to be assessed. At this time there have been no rivers or streams designated in Kansas as wild and scenic. In some cases, there might be additional water system treatment requirements for water sources used for public water supply. With some potential exceptions, the sediment load in Missouri River water may be higher than some of the receiving water bodies. However, some sediment may drop out and accumulate in the "source water" reservoir and the "terminal" reservoir. The remaining sediment load in Missouri River aqueduct water would certainly be higher than the sediment load in the groundwater currently used by some of the potential users of aqueduct water, but that does not mean it is unsuitable for irrigation and some other uses without treatment. If Missouri River aqueduct water was used to supplement streamflow, experience with reservoir releases to streams and canal operations indicates that water containing sediment would cause less "head cutting" and erosion than clear water released into a stream. This has been directly observed below reservoirs and in earth-lined canal systems in Kansas, Colorado and other locations.

5.3.4 Construction across Existing Roads, Railroads, Pipelines and Power Lines

As the aqueduct is constructed, the construction will cross or interrupt service to local roads, highways, railroads, pipelines, power lines and other utilities. In addition to this construction cost, there will be various legal issues with the owners and operators of this infrastructure.

Based on a general view of the maps produced by the KWO, it is estimated that this aqueduct would cross approximately 33 existing highways, 13 existing railroads, 14 existing oil and gas pipelines, 14 existing power lines. This would mean that at least 74 easements would have to be purchased or condemned in order to construct the aqueduct. This would mean having to deal with counties, townships, the State of Kansas, utilities, railroads and other entities to secure these easements.

5.3.5 Local Ability to Cross the Aqueduct

The aqueduct would be about 360 miles long and about 280 feet wide. Undoubtedly, it would be fenced off on both sides therefore effectively prohibiting any traffic, including local traffic, from crossing the aqueduct.

To put this in perspective, the Kansas Turnpike is approximately 236 miles long and about 300 feet wide. Throughout its length there are 22 interchanges and 129 other overpasses for a total of 151 ways to cross the turnpike in 236 miles. 236 miles divided by 151 equals one location to cross the Turnpike every 1.6 miles. For the aqueduct to have equivalent access to cross the aqueduct, there would have to be 225 crossings constructed over the aqueduct. (360 miles divided by 1.6 equals 225 crossings.) Whether that is a sufficient density of crossing locations for the aqueduct remains to be seen. It should be expected that protests from local residents and landowners would be voiced if they are unable to cross the aqueduct so that they can go to town, or get to the other portion of their fields on the other side of the aqueduct. It is fairly easy to envision that if the aqueduct is 360 miles long that it might well cross approximately 360 section line roads or highways. Every one of those routes that is blocked, either temporarily or permanently, is likely to evoke protests.

The bottom line is that an aqueduct project would have to construct approximately 225, three hundred foot long bridges, or other type of crossings, to provide access to cross the aqueduct similar to the access provided across the Kansas Turnpike.

5.4 Legal Issues at the Destination

5.4.1 Issues Related to the Distribution of Water from the Terminal Reservoir

The 1982 Study did not deal with the distribution of water from the terminal reservoir or along the route. It is presumed that some form of distribution system would be developed from the terminal reservoir to potential water users including the irrigated areas of the Ogallala aquifer in western Kansas. In all areas of the Ogallala aquifer, this might include conduits or canals to provide water directly to the irrigated land.

Artificial recharge projects in various areas of the Ogallala aquifer may also be a possibility. Aquifer recharge, storage and recovery projects have been operated in other areas, such as the Equus Beds, but there are technical, legal and administrative issues to be resolved. The Chief Engineer has adopted regulations⁸⁴ concerning aquifer storage and recovery. Any proposed artificial recharge project shall meet the requirements of these regulations and include: 1) meeting the Kansas Department of Health and Environment's water quality standards for injected water, including Article 46 of their regulations, 2) identifying the horizontal and vertical extent of the basin storage area, 3) getting a methodology for accounting for water stored and withdrawn from an aquifer approved by the Chief Engineer, 4) preventing impairment of existing water rights in the basin and 5) providing an annual accounting report to the Chief Engineer. The regulations also provide for coordination between the Chief Engineer and any local groundwater management district concerning the recharge project.

There are various ways water could be recharged into the aquifers of western Kansas, such as creating artificial recharge basins, putting water in dry stream beds, or injecting into wells. Each method will have its own set of legal, physical and other issues, such as who would inject the water and who would pay the costs?

For example, in southwest Kansas, it is possible aqueduct water could also be provided to the irrigation distribution systems that have historically diverted from the Arkansas River, but are often short of water. If so, arrangements would need to be worked out with the mutual shareholder irrigation companies that operate the ditches. Water could be used to enhance the flow of the Arkansas River and/or the Cimarron River and provide recharge to the alluvial valleys and enhance riverine habitat.

In west central Kansas, there are limited stream systems, but Ladder Creek could also provide a way to provide recharge to the aquifer and/or provide water to Scott County State Lake.

In northwest Kansas, in addition to the primary distribution of aqueduct water to the irrigated areas of the Ogallala aquifer, there are also a number of stream systems that originate in the aquifer area. These streams have fairly extensive alluvial valleys that provide some water for existing irrigated land or other uses through alluvial groundwater or surface water, but there is normally limited streamflow. Several of these streams also have federal reservoirs located on them. Those reservoirs include irrigation projects and other functions.

These include Keith Sebelius Reservoir on the Prairie Dog Creek, Kirwin Reservoir on the North Fork of the Solomon River and Webster Reservoirs on the South Fork of the Solomon River, all operated by the Bureau. These projects are normally short of water to meet their current authorized purposes and are generally not full. These projects are 60 to 80 miles from the aqueduct route and it may or may not be feasible to provide potential supplemental water supply to some or all of these projects. However, if a canal or conduit were to deliver aqueduct water to northwest Kansas for irrigation, it may be possible to either tie in some or all of these projects, or to release water into the upper end of some or all of the relevant stream systems to replace depleted base flow or increase streamflow. This could enhance recharge to the Upper Republican and/or Solomon River Basin alluvial valleys and increase inflow to these Bureau reservoirs. The primary authorized purpose for these projects is flood control and irrigation, although they are multi-purpose projects that also include recreation use, and in some cases, public water supply. Irrigation districts still operate below Keith Sebelius, Kirwin and Webster Reservoirs when water is available, with each district serving between 5,000 and 11,500 acres of land. Recreation use would also normally be expected to benefit from more water in storage.

Water rights for storage and direct use for these Bureau projects are held by irrigation districts, as well as rural water districts, cities or other local governmental entities with storage contracts. The irrigation districts below Keith Sebelius, Kirwin and Webster Reservoirs have long term contracts to repay their pro-rata share of the cost of constructing and operating the reservoir and irrigation distribution system by the Federal government through the Bureau.

If any involvement with these federal projects was deemed feasible, any potential issues related to the authorized purposes of the Federal reservoirs, water rights, existing contracts, as well as any new contracts for water, would need to be resolved. A change in authorized purposes for a Federal project generally requires congressional approval. Water rights are held by existing irrigation districts or other local governmental entities for each of these Bureau reservoirs, except Cedar Bluff, which now includes storage held by the State of Kansas. The relationship to any new uses would need to be resolved. Under current law, it is possible that a supplemental storage water right to support new purposes for the reservoir, and any new direct uses from the reservoir, could be considered if a new source of water is available from the aqueduct for these projects. Among other things, it would need to be determined that the new use of water was reasonable and the operation would not impair existing water rights or prejudicially and unreasonably affect the public interest. Presumably, detailed operations plans and agreements would need to be developed to sort out how the projects would be operated to satisfy existing uses and water rights, as well as any new uses. Potentially, with State approval, existing water rights could be changed to meet new or different uses, or an existing project and its water rights could possibly be acquired by an aqueduct project sponsor. However, this could be complicated, and would likely require approval by any existing irrigation district, or other entity with a current federal contract, the federal operating agency and the State of Kansas.

5.4.2 Other Issues Related to the Distribution of Water along the Aqueduct and from the Terminal Reservoir

Should limitations be imposed on the type of customers that may purchase water from an aqueduct project? For example, at the present time certain water supply projects are limited to serving water only for irrigation projects. Some of water supply projects on to serving water only for municipal and industrial uses. Should an aqueduct project be allowed only to serve certain types of water uses or should it be allowed to sell water to purchasers for any type of beneficial use authorized by the KWAA? That is a policy decision that will have to be made if the entity to build and operate an aqueduct project is authorized.

To break this issue down into finer categories, if water is authorized to be delivered for irrigation purposes, should any limitations be placed on the quantity of water that may be purchased by irrigation users? For example, should water be allowed to be used only on land that currently is authorized to be irrigated pursuant to the provisions of the KWAA? Should water only be allowed to be used on land that is currently not authorized to be irrigated? Or should water be allowed to be purchased for use on either type of land?

When water is allowed to be used for irrigation purposes, should acreage limitations be imposed which would limit the quantity of water any individual user would be allowed to purchase? For example, should any irrigation user be limited to irrigate only a certain amount of land or should they be allowed to purchase unlimited quantities of water as long as they can afford it?

Should water sold for municipal and industrial purposes be limited in quantity in any way? For example, if a city currently has an adequate supply of water authorized pursuant to the KWAA, should it be allowed to enter into contracts to purchase an unlimited quantity of water if they can afford it?

Another major issue is how, and how far, an aqueduct project would deliver water away from the aqueduct or the terminal reservoir?

It should be noted that while delivering millions of acre feet of water from the source reservoir to the terminal reservoir near Utica Kansas, would be a monumental feat, that water still must be distributed to the various municipal, industrial and agricultural users in western Kansas. Depending on where the water would be utilized, there still would be significant miles of aqueduct and/or pipeline to be constructed, and additional pump stations needed to lift that water to actual users. By the time the water has been delivered to the terminal reservoir, it will have been pushed uphill approximately 1,700 feet and moved west approximately 360 miles. Just picking a few cities in western Kansas as representative of areas where water may be desired, the water still may need to be pushed uphill another 650 feet and over 100 miles further west.⁸⁵

In other words, in order to deliver the water from the terminal reservoir near Utica to various locations throughout Western Kansas, the elevation and the distance would be increased by approximately 1/3 more than was covered by the aqueduct getting from the source reservoir to the terminal reservoir. That is not insignificant in terms of capital cost, operation and maintenance and legal issues concerned with right away, condemnation, land taken from production, environmental issues and so forth.

Would an aqueduct project bear the cost of delivery away from the terminal reservoir and the aqueduct itself, or would that be the purchaser's obligation? To some extent the answer to that question seems to be dependent on where an aqueduct project would need to deliver water in order to have enough customers to make the project financially feasible. Depending on how the water would be delivered from the aqueduct and the terminal reservoir to customers, additional issues would be raised concerning purchase of right-of-way or easements for the pipelines or canals that would be used to deliver water.

Of course, all along the route of the aqueduct and in the vicinity of the source reservoir and the terminal reservoir, issues will arise concerning the impacts on fish and wildlife and their habitats. If it could be guaranteed that none of the water pumped from the Missouri River would enter existing lakes and streams, that guarantee would eliminate the danger of contaminants or invasive species entering local watersheds. On the other hand, it is unlikely that guarantee could be made

as there would always be dangers of breaches in the aqueduct or in end users allowing their water to escape from the project. Water could be released through flooding damage, earthquakes, or local vandalism. Therefore there would be a risk of invasive species being released into local water supplies as the aqueduct water is transported across the state.

Potentially, another method that would ensure that invasive species were not released into other water supplies would be that the water would be treated at some point before it leaves the source reservoir so that any invasive species were killed or removed from the water supply. One such species that could be introduced in the Kansas water supplies if untreated water was allowed to escape would be the Asian carp that have become so prolific in Missouri and Mississippi Rivers.

Further the aqueduct would provide a significant physical barrier to non-flying wildlife from crossing from one side of the aqueduct to the other. To the extent that this interferes with wildlife's access to the habitat and migration routes, this could be a problem. Accommodations might have to be made in some locations for crossings specifically devoted to wildlife.

On the other hand if the water were sufficiently treated or filtered to allowed to be introduced into local habitats, it might serve the purpose of enhancing wildlife habitat and food supplies if aqueduct water could be used to enhance or create habitat for migratory birds.

5.5 Institutional Issues

5.5.1 What type of entity is necessary to build and operate an aqueduct project?

As pointed out by Professor John Peck in his 1982 article⁸⁶, the Kansas Constitution was amended in 1957 and provides in part: "The state shall never be a party in carrying on any work of internal improvement except that: ... (2) it may be a party to flood control works and works for the conservation or development of water resources. ..." ⁸⁷

Peck further notes that the State Water Resource Planning Act⁸⁸ provides that the KWO, upon approval of the Kansas Water Authority, "may include in the state water plan recommendations for the inclusion at state expense of any conservation storage features for water supply in any proposed or authorized or constructed water development project of the federal government of any conservation features for water supply that in the opinion of the office will be needed within the state in the future to achieve the purposes of this act." At the present time there is no proposal that the federal government might be involved in the construction of an aqueduct project, other than the need to have the Corps construct the lock and dam on the Missouri River.

A determination may also need to be made as to whether an aqueduct project is compatible with the state water plan long range goals, such as sound management of surface and groundwater supplies, efficient and economical distribution of those supplies, sound coordination of the development of the water resources of the state, and protection of the public interest.⁸⁹

In order to consider what type of entity would be appropriate to construct and manage an aqueduct project, the section authors looked at several examples of entities that might have similar powers or functions. The first entity looked at is the Central Arizona Project (CAP). In 1969, President Lyndon B. Johnson signed a bill approving construction of the CAP. Later, a local entity was formed to repay the federal government for certain costs of construction when the system was complete. In 1971, the Central Arizona Water Conservation District (CAWCD) was created to provide a means for Arizona to repay the federal government for the reimbursable costs of construction. It manages and operates the CAP. The CAWCD is a municipal corporation and is governed by a 15-member popularly-elected Board of Directors.

In the case of a Kansas aqueduct project at this time it is being assumed that the federal government will not be building the intake, the reservoirs and the aqueduct. Because the CAWCD did not construct the project, obviously major differences exist between the CAP and any Kansas entity.

A second type of entity that might be used as a model to create a new entity to build, maintain and operate an aqueduct project, is the Kansas Turnpike Authority (KTA). The KTA was created by the Kansas legislature on April 7, 1953.⁹⁰ The Authority acts through a board of five members, one of whom is elected chairman by the other members. Two members

are appointed by the Governor of Kansas for four-year terms, two members serve by reason of their legislative positions - one is Chairman of the Kansas Senate Committee on Transportation and the other is a member of the House Transportation Committee, appointed by the Speaker of the House. The fifth member is the Secretary of the Kansas Department of Transportation. The latter three serve as members of the Authority for the duration of their state terms. On July 1, 2013, in accordance with HB 2234, the KDOT Secretary also became the Turnpike's Director.⁹¹

The KTA has constructed 236 miles of toll road and 22 interchanges through the state of Kansas. The average width of the land acquired to construct and maintain the Turnpike is 300 feet. The KTA has acquired at least 8,581 acres of right-of-way [5,280 feet × 236 miles × 300 feet wide divided by 43,560 square feet in an acre = 8,581 acres] in Kansas through purchase or condemnation. Although an aqueduct would be longer in length, many of the Turnpike construction, easements and maintenance issues are analogous to an aqueduct project.

The KTA was created by statute and granted authority to:

- a. determine the locations of highway projects authorized by this act subject to the approval of the secretary of transportation,
- b. determine their design and the materials of construction and construct, maintain, repair and operate the same;
- c. issue revenue bonds payable solely from the tolls and revenues derived therefrom;
- d. fix and collect tolls;
- e. establish rules and regulations for the use of the highway project;
- f. acquire hold and dispose of real and personal property;
- g. determine locations of ingress and egress;
- h. enter into contracts and agreements necessary or incidental;
- i. employ consulting engineers, attorneys, accountants, construction and financial experts, superintendents, managers and such other employees and agents has been may be necessary in its judgment; and
- j. receive federal grants for construction of the project, and do all acts and things necessary or convenient to carry out the powers expressly granted in this act.⁹²

The KTA and its authorized agents and employees were authorized to enter on to any lands, waters and premises in the state for the purposes of making such surveys, soundings, drilling and examinations as they may be necessary. The KTA is also authorized to enter into contracts with landowners for the construction and maintenance of underpasses and bridges. The State consented to the use of all lands owned by it, including lands lying and water, which are deemed necessary for the construction or operation of the project. The KTA is authorized to purchase lands, structures, property, rights, rights of way, franchises, easements and other interest in lands including lands lying underwater in riparian rights, which are located within the state.

The KTA is also authorized and empowered to acquire by condemnation any lands, property, rights, rights of way, franchises, easements and other property including public lands parks and playgrounds reservations, highways, or parkways, or parts thereof.

The KTA is authorized to issue highway revenue bonds within certain limits for the purpose of paying cost of any project; and the principal and interest of such bonds was payable solely from tolls and other revenues.

Finally the KTA is not required to pay any taxes or assessments upon any highway project or any property acquired or used under the provisions of this act and the income therefrom, including any profit, and all bonds issued under the provisions of the act and all sales, transfers and income of or from such bond shall at all times be free from taxation within the state.⁹³

One option would be to have Kansas legislature create by statute a Kansas Aqueduct Project Authority. It would need to have similar powers to those listed above authorized to the KTA. The largest issue would seem to be not which powers are granted to such Authority, but whether an aqueduct project would be able to generate sufficient revenue from the sale of water to retire the revenue bonds. Apparently the KTA was initially financed by the issuance of \$160 million in revenue bonds (\$2.97 billion in 2011 dollars) in 1959. A few years later some federal highway assistance money became available to help with the project. It is being assumed for the purpose of the study the federal government would probably

not be making any federal grants to assist with the construction of this project. Even if a Kansas Aqueduct Project Authority were able to generate sufficient funds to cover the operation and maintenance of this project, would it generate sufficient revenue to also offset the construction of the project?

One issue raised by Peck⁹⁴ was condemnation or eminent domain powers available under existing Kansas law. All of those issues could be resolved by giving a Kansas Aqueduct Project Authority sufficient eminent domain power to construct the project.

In Peck's 1982 article⁹⁵ he has a laundry list of existing kinds of entities that could be considered to build and operate an aqueduct project, such as irrigation districts and public wholesale water supply districts. He concludes, however, that none of them were really designed to deal with a project on this massive scale, and we agree. However, an aqueduct project could be designed so that one entity builds and operates the aqueduct and reservoirs, but that it in effect wholesales water to existing entities in Kansas, such as municipalities, irrigation districts, public wholesale water supply districts and groundwater management districts to distribute the water from the aqueduct and terminal reservoir.

¹ U.S. Army Corps of Engineers. 2006. *Missouri River Master Water Control Manual*, 2006. <http://www.nwd-mr.usace.army.mil/rcc/reports/mmanual/MasterManual.pdf>.

² 33 U.S.C. 701 et seq.

³ 33 U.S.C. Sections 544b and 603a

⁴ *Winters v. United States*, 207 U.S. 564 (1908)

⁵ *Arizona v. California*, 373 U.S. 546 (1963)

⁶ See e.g. *Colville Confederate Tribes v. Walton*, 647 F.2d 42 (9th Cir. 1981)

⁷ *Colville*

⁸ 43 U.S.C. section 666

⁹ http://www.dnrc.mt.gov/wrd/water_mgmt/water_reservations/missouri_riv_basin/default.asp

¹⁰ 25 U.S.C. 3001 et seq.

¹¹ 16 U.S.C. 470 et seq.

¹² 16 U.S.C. 4701 et seq.

¹³ K.S.A. 75-2715 et seq.

¹⁴ 33 U.S.C. 701 et seq.

¹⁵ 33 U.S.C. 701 et seq.

¹⁶ Missouri River Association of States and Tribes. 2009. *White Paper* adopted March 24, 2009.

¹⁷ U.S. Department of the Interior, Bureau of Reclamation, Great Plains Region. 1998. *An Overview of the Pick-Sloan Missouri River Basin Program*.

¹⁸ Leland E. Rolfs. 2009. *Background Report on the Federal Acts and Court Case That Have Affected the Development of the Missouri River Basin*. March 17.

¹⁹ 33 U.S.C. § 701-1(b)

²⁰ *Ibid.*

²¹ U.S. Department of the Interior, Bureau of Reclamation, Great Plains Region. 1998. *An Overview of the Pick-Sloan Missouri River Basin Program*.

²² U.S. Army Corps of Engineers. 2006. *Missouri River Master Water Control Manual*. <http://www.nwd-mr.usace.army.mil/rcc/reports/mmanual/MasterManual.pdf>.

²³ *Ibid.*

²⁴ *Ibid.*

²⁵ Leland E. Rolfs. 2009. *Background Report on the Federal Acts and Court Case That Have Affected the Development of the Missouri River Basin*. March 17.

²⁶ *Hinderlider v. La Plata River and Cherry Creek Ditch Co.* 304 U.S. 92 (1938)

- ²⁷ Letter dated November 28, 2012, to President Barack Obama from the Governor of Montana, and letter dated November 30, 2012, to President Obama, et al., from the governors of North Dakota, South Dakota, and Kansas and the congressional delegations of Montana, North Dakota, South Dakota, and Kansas.
- ²⁸ Letter dated November 26, 2012, to Jo-Ellen Darcy, Assistant Secretary of the Army (Civil Works) from Governor Sam Brownback.
- ²⁹ ETSI Pipeline Project v. Missouri et al., 484 U.S. 495 (1988)
- ³⁰ Susan Green. 2000. *Ex-EPA Chief Proud he Killed Two Fork*, Denver Post, October 28.
- ³¹ Red River Valley Water Supply Project. <http://rrvwsp.com>.
- ³² K.S.A. 82a-529
- ³³ Article V. Section 5.4
- ³⁴ K.S.A. 82a-528
- ³⁵ K.S.A. 82a-518
- ³⁶ K.S.A. 82a-520
- ³⁷ K.S.A. 82a-520, Article III (B)
- ³⁸ K.S.A. 82a.701 et seq.
- ³⁹ K.S.A 82a-711
- ⁴⁰ K.S.A. 82a-708a
- ⁴¹ K.S.A. 82a-709 and Kansas Administrative Regulation 5-3-1b
- ⁴² If the proposed appropriation:
- a) will not impair a use under an existing water right,
 - b) will not prejudicially and unreasonably affect the public interest,
 - c) is made in good faith,
 - d) is in proper form, and
 - e) contemplates the use of water for beneficial purposes, the chief engineer **shall** approve all such applications
- ⁴³ U.S. Army Corp of Engineers, Six-State High Plains-Ogallala Aquifer Regional Resources Study, 1982
- ⁴⁴ K.S.A. 82a – 711 (c)
- ⁴⁵ K.S.A. 82a – 703c
- ⁴⁶ K.S.A. 82a-709 and 710; K.A.R. 5-3-1b
- ⁴⁷ K.A.R. 5-3-3a
- ⁴⁸ K.S.A.82a-707(e)
- ⁴⁹ K.S.A. 82a-709 (h)
- ⁵⁰ K.S.A.82a-708a
- ⁵¹ K.S.A. 82a-1301 et seq.
- ⁵² K.A.R. 5-8-6
- ⁵³ K.A.R. 5-1-1(mm)
- ⁵⁴ K.S.A.82a-1301 et seq.
- ⁵⁵ K.S.A. 82a-1303 and 1304.
- ⁵⁶ Peck, John C. 1981. Legal Constraints on Diverting Water from Eastern Kansas to Western Kansas. *Kansas Law Review*.
After the 1982 Study was released, John C. Peck, a water law professor at the University of Kansas, published a paper in the *Kansas Law Review* on “Legal Constraints on Diverting Water from Eastern Kansas to Western Kansas.” Peck reviewed relevant Kansas water law at the time and a series of legal and institutional problems. He focused on two potential sources of water: Tuttle Creek reservoir on the Big Blue River and the Missouri River. While the Peck article serves as a valuable reference and this paper uses the same general format as the Peck article, this paper’s focus is primarily on the Missouri River as a source.
- ⁵⁷ Montana Department of Natural Resources and Conservation, Water Resources Division. 1982. *A Water Protection Strategy for Montana, Missouri River Basin, Summary Report*. September.
- ⁵⁸ http://www.dnrc.mt.gov/wrd/water_mgmt/water_reservations/missouri_riv_basin/default.asp
- ⁵⁹ K.S.A. 82a-1501 et seq.
- ⁶⁰ K.A.R. 5-50-1 et seq.

⁶¹ K.S.A. 82a-1502

⁶² K.S.A. 82a-1505(a); Kansas Judicial Review Act at K.S.A. 77-601 et seq.

⁶³ 33 U.S.C. Section 1251 et seq.

⁶⁴ 33 U.S.C. 403

⁶⁵ Kaiser Aetna v. United States, 444 U.S. 164, 177 (1979)

⁶⁶ 33 U.S.C. § 701-1(b)

⁶⁷ 42 U.S.C. Section 4321 et seq.

⁶⁸ Obstructions in Streams Act, KSA 82a – 301 through 328.

⁶⁹ K.S.A 24-126

⁷⁰ K.S.A. 82a-301 et seq.

⁷¹ K.S.A. 82a-302

⁷² See K.S.A. 82a – 301 et seq. and KAR 5 – 40 – 1 et seq.

⁷³ K.S.A. 82a-325 et seq.

⁷⁴ K.S.A. 82a-326

⁷⁵ K.S.A. 82a-327(b)(1)

⁷⁶ See State v. Akers, 92 Kan. 169, 140 P.637, 649 (1914): “... the Mississippi river and its navigable tributaries were constituted public highways, and recognized as navigable streams in the fullest and broadest sense” (emphasis supplied). “The Kansas river being a navigable stream within this state its bed and banks to **ordinary high-water mark** belong to the state and the title of the riparian proprietor extends only to that line” (emphasis supplied). Siler v. Dreyer, 183 Kan. 419 (1958).

⁷⁷ State ex rel. Meek v. Hays, 246 Kan. 99, 103 (1990)

⁷⁸ K.S.A. 82a-711

82a-215. Easement for construction of diversion works along Kansas river for city of Topeka; conditions; authorization.

(a) The secretary of state is hereby authorized and directed to grant an easement to the city of Topeka, Kansas, on a tract of land owned by the state of Kansas along the south and north banks of the Kansas river described as follows....

(c) The city of Topeka, Kansas, is hereby authorized to acquire the easement described in subsection (a) and to use such easement for the purpose of locating, constructing, maintaining and operating diversion works for the appropriation of water and to assume full responsibility for such use and hold the state of Kansas harmless therefor.

History: L. 1987, ch. 399, § 1; L. 1987, ch. 329, § 1; May 28

⁷⁹ K.S.A. 82a-521 through 524

⁸⁰ K.S.A. 42-303 "**Right to conduct water along natural channels and withdraw same.** Any person may conduct water into and along any of the natural streams or channels of the state. And may withdraw all such waters so by him turned into such channel at any point desired, without regard to prior appropriations of water from said stream. Due allowance being made for evaporation and seepage. History: L. 1891, ch. 133, art. 1 section 3; May 20; R.S.1923, 42-303.

⁸¹ K.S.A. 82a-1036 through 1040

⁸² An order was issued by the Chief Engineer on January 29, 1992, designating this area as an Intensive Groundwater Use Control Area.

⁸³ <http://water.epa.gov/polwaste/npdes/>

⁸⁴ K.A.R. 5-12-1 et seq.

⁸⁵ The following table shows that there are still significant distances and elevations to be overcome:

City	Elevation	El. above Utica	Miles from Utica
Colby	3160	542	95
Elkhart	3500	882	181
Garden City	2850	232	103
Goodland	3683	1065	130
Liberal	2835	217	144
Leota	3310	692	73
Sublette	2920	302	114
Mt Sunflower	4039	1421	153
Tribune	3543	925	95
Ulysses	3071	453	134
Utica	2618	0	0

Just taking an average elevation of these cities, for water to be delivered in this general area, it would have to be pumped uphill approximately another 653 feet. The range in these elevations above Utica is from a low of 217 at Liberal to a high of 1421 feet at the top of Mount Sunflower.

There are also significant delivery distances from Utica, Kansas to the cities listed above. Those distances range from a minimum distance to Leota of 73 miles to a maximum distance of 153 miles to the top of Mount Sunflower. The average distance is 122 miles.

⁸⁶ Peck at 164

⁸⁷ Kansas Constitution, Article 11, Section 9

⁸⁸ K.S.A. 82a-910

⁸⁹ K.S.A. 82a-927

⁹⁰ K.S.A. 68-2001 et seq.

⁹¹ KTA website

⁹² K.S.A. 68-2095

⁹³ K.S.A. 68-2097; 68-2098; 68-20,104; 68-20,110

⁹⁴ Peck at 203

⁹⁵ Peck at 211

Update of 1982 Six State High Plains Aquifer Study

Chapter 6: Environmental Considerations

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A large-scale infrastructure construction project such as the aqueduct would require a comprehensive environmental review and extensive permitting process and mitigation. The following is not intended to identify all environmental laws and regulations that may be triggered during the construction of the aqueduct. However, major federal and state environmental laws and regulations were evaluated to determine the constraints that would be encountered if a project of this scope is ever undertaken. Other potentially relevant environmental laws and regulations can be found in Table 6 (a).

6.1 Clean Water Act (CWA)

6.1.1 Permits to Discharge Dredged or Fill Material

Section 404 of the Clean Water Act (CWA) establishes a program to regulate the discharge of dredged or fill material into waters of the United States, including wetlands. The basic premise of the program is to ensure that no discharge of dredged or fill material may be permitted if: (1) a practicable alternative exists that is less damaging to the aquatic environment or (2) the nation's waters would be significantly degraded.

Proposed activities, such as fill for development or infrastructure projects, are regulated through a permit review process which is jointly administered by the U.S. Army Corps of Engineers (Corps) and the Environmental Protection Agency (EPA). The Corps is responsible for the day-to-day administration and permit review and EPA provides program oversight. The permit review process includes a public interest review in which the benefits of the project are weighed against reasonably foreseeable detriments. Impacts to wetlands, fish and wildlife, water quality, historic and cultural resources, property ownership, public safety and floodplain management are all considered during the permit review.¹

A 404 permit would be required for an aqueduct lock and dam and intake facilities on the Missouri River, the Kansas River crossing, impacts to other streams and wetlands along the route and construction of the source and terminal reservoirs.

6.1.2 Compensatory Mitigation

For every authorized discharge of dredged or fill material, the adverse impacts to streams, wetlands and other aquatic resources must be avoided and minimized to the extent practicable. If there are unavoidable impacts, compensatory mitigation is required to offset the loss of habitat and aquatic resource functions. The Corps is responsible for determining the appropriate form and amount of mitigation required.²

There are three mechanisms by which mitigation can be accomplished. The first is permittee-responsible mitigation in which the permittee performs the mitigation after the permit is issued and is responsible for the implementation and success of the project. Second, mitigation banking allows permittees to purchase credits from a mitigation bank, which has projects that have been set aside to compensate for future impacts. The value of the banking credits is determined by quantifying the aquatic functions or acres restored. With this mechanism, the bank sponsor is ultimately responsible for the success of the project. Finally, there is in-lieu fee mitigation in which a permittee provides funds to an in-lieu-fee sponsor much like mitigation banking. In-lieu fee sponsors typically pool funds from multiple projects and are responsible for the implementation and success of the mitigation project.

Compensatory mitigation for impacts to streams in Kansas is evaluated under the Stream Mitigation Guidance (SMG). The guidance document, which was developed jointly with multiple federal and state agencies, outlines the methods by which the aquatic functions of streams are quantified and entered into the "Mitigation Equation." The mitigation equation establishes that the proposed mitigation credits must be equal to or greater than the mitigation debits. Debits are quantified based on existing quality of the stream, as well as the length and nature of the impact.

Stream and wetland mitigation costs for a water transfer system such as this would be substantial. While it is difficult to compare such a project to other projects that have been completed recently in Kansas due to sheer difference in scale, recent projects were evaluated to determine the relative cost of mitigation to the total project cost. The Kansas Water Office and the City of Horton, Kansas completed a project as part of the mitigation required for dredging disposal near Mission Lake in 2010. The project impacted 2,220 linear feet of stream habitat and required 11,100 mitigation credits.

The credits were purchased using an in-lie fee sponsor, at the cost of \$29 per credit. The total cost for mitigation was \$334,776 and the total project construction cost was \$612,000. In this case, mitigation represented just over half of the cost of construction. Recent flood detention projects that were completed in Kansas used in-lie fee mitigation and credits were purchased for \$40 per credit for stream impacts and \$75,000 per acre of wetland impacted. In the case of the flood detention projects, total mitigation costs actually exceeded the cost of construction.

To fulfill the compensatory mitigation requirements for a project this size would require considerable financial resources. One possible way to reduce the cost and maximize the efficiency of completing mitigation requirements would be to manage the projects through an entity developed to oversee the construction and operation of the aqueduct.

6.1.3 State Water Quality Regulations and Environmental Coordination

Under Section 401 of the CWA, prior to issuance of a 404 permit a statement certifying the activity is not likely to violate State Water Quality Standards must be obtained. Section 401 Water Quality Certifications are issued by the Kansas Department of Health and Environment (KDHE) as part of the 404 permit process and the state stream modification and floodplain fill permitting process.

Permits for stream obstructions, floodplain fills and dam or levee construction must be obtained from the Kansas Department of Agriculture, Division of Water Resources (DWR). The Water Projects Coordination Act (K.S.A. 82a-325 to 327) requires an environmental review of Kansas water projects to ensure that the project is in compliance with other state regulations. Other permits that may be required prior to issuance of a permit by DWR, include but are not limited to, a permit to appropriate water from the DWR Water Appropriation Program, construction permits from county and local government, Kansas Department of Health and Environment (KDHE) permits for storm water run-off and threatened and endangered species permits from the Department of Kansas Wildlife Parks and Tourism (KDWPT).

6.1.4 National Pollutant Discharge Elimination System (NPDES) Water Transfer Rule

Section 402 of the CWA establishes the National Pollutant Discharge Elimination System (NPDES) program to regulate point source discharges of pollutants into waters of the United States. An NPDES permit sets specific discharge limits for point sources discharging pollutants into waters of the United States and establishes monitoring and reporting requirements, as well as special conditions.³ NPDES permits would be required for the construction activities associated with building the water transfer system; however, it is unclear whether or not an NPDES permit would be required for the actual transfer of water.

In 2008, EPA enacted the National Pollutant Discharge Elimination System (NPDES) Water Transfer Rule. The rule was issued to clarify that water transfers are not subject to regulation under the NPDES program. The rule defined water transfers as activities that convey or connect waters of the U.S. without subjecting the water to intervening industrial, municipal, or commercial use. EPA's legal interpretation of the CWA concluded that, "Congress generally did not intend to subject water transfers to the NPDES program and that there is no 'addition' of a pollutant which would trigger the requirement to obtain an NPDES permit because the pollutants are already in the waters being transferred and are not being added from the outside world."⁴

The Water Transfer Rule was remanded to EPA for reevaluation in March of 2014. A ruling by the U.S. District Court for the Southern District of New York found that transferring water into a different water body risks introducing foreign species into non-native waters and disturbing the natural sediment, nutrient and other balances in the recipient water body. A blanket exemption from NPDES permitting requirements therefore runs afoul of the prohibition in the CWA against the discharge of pollutants without a permit.⁵ EPA, 11 western states and the South Florida Water Management District announced in May of 2014 that they plan to appeal the district court ruling.⁶

At the time of this study update, it is uncertain what the regulatory requirements would be for addressing water quality criteria for a water transfer. If the EPA appeals the ruling of the District Court and the Water Transfer Rule is revalidated, it would exempt the aqueduct from the NPDES regulations. This would leave water quality regulation authority to the state. If the Water Transfer Rule remains invalidated, then NPDES permits may be required for the transfer.

6.2 Rivers and Harbors Appropriation Act of 1899

Obstructions to navigable waters of the U.S are regulated under Sections 9 and 10 of the Rivers and Harbors Appropriation Act of 1899. Section 9 requires Congressional approval to construct dams, dikes, bridges, or causeways in a navigable waterway. In waterways that are only navigable within a state's boundary, the state legislature has authority to approve such projects, although plans must be submitted to and be approved by the Corps Chief of Engineers and by the Secretary of the Army before construction begins. If the waterway is navigable in more than one state, Congress must approve such projects.⁷ Section 10 gives the Corps exclusive authority to approve dredge and filling operations and smaller structures such as wharves, booms and bulkheads.⁸

For an aqueduct intake, Section 9 will require Congressional approval for construction of the lock and dam structure on the Missouri River, and will also require state legislation for the Kansas River crossing. Permits will need to be obtained under Section 10 of the Rivers and Harbors Act for all activities affecting the Missouri River, Kansas River and the Arkansas River.

Section 14 of the Rivers and Harbors Act (commonly referred to as "Section 408") requires a permit from the Corps for the alteration, occupation or use of a Corps civil works project. The 408 permit also requires a review to ensure that the activity will not be injurious to the public interest and will not impair the usefulness of the Corps project.

6.3 National Environmental Policy Act

The National Environmental Policy Act (NEPA) was signed into law in 1970 and requires federal agencies to prepare detailed statements assessing the environmental impact of and alternatives to major federal actions significantly affecting the environment. The NEPA requirements would be triggered at the time a permit application was made under Section 404 of the CWA and if any federal funds were used to construct the project.

The NEPA process consists of an evaluation of the environmental effects of a federal action including its alternatives. There are three levels of analysis: categorical exclusion (CATEX) determination; preparation of an environmental assessment/finding of no significant impact (EA/FONSI); and preparation of an environmental impact statement (EIS).⁹ A large project such as the aqueduct would require an EIS and the project in its entirety would be reviewed to assess the cumulative impacts.

An EIS is a full disclosure document that includes consideration of a range of reasonable alternatives, analyzes the potential impacts resulting from the alternatives, and demonstrates compliance with other applicable environmental laws and executive orders. The EIS process is completed in the following ordered steps: Notice of Intent (NOI), public scoping, draft EIS, final EIS and record of decision (ROD).

The NEPA process incorporates the requirements of other major environmental and historic preservation laws. The process provides the vehicle for multi-agency coordination and public participation.

6.4 Endangered Species Act

The Endangered Species Act of 1973 (ESA) was passed to protect and recover imperiled species and the ecosystems they inhabit. The U.S. Fish and Wildlife Service (USFWS) administers the program at the federal level. Under federal law, species are listed as either endangered or threatened. Endangered species are those that are in danger of extinction throughout all or a significant portion of their range. Threatened species are those that are likely to become endangered in the near future.¹⁰

Federal agencies must cooperate with the USFWS to ensure that actions they authorize, fund, or carry out are not likely to jeopardize the continued existence of listed species. These consultations can result in a biological opinion (BO) issued by the USFWS. The ESA also requires the designation of critical habitat for listed species. Federal agencies are required to avoid destruction or adverse modification of designated critical habitat.

The Kansas Nongame and Endangered Species Conservation Act of 1975 authorized the Kansas Department of Wildlife, Parks and Tourism (KDWPT) to define and list endangered and threatened species. All federally listed species are protected under state law as well as additional species listed as threatened or endangered at the state level. Kansas law defines another classification for Species in Need of Conservation (SINC). SINC species are those that are likely to become threatened or endangered in the future.

In Kansas there are approximately 60 species listed as threatened or endangered. Another 69 species are considered species in need of conservation. Critical habitat designations have been finalized in Kansas for the Whooping Crane (*Grus Americana*) and the Arkansas River shiner (*Notropis girardi*). Critical habitat designations have been proposed for the Rabbitsfoot Mussel (*Quadrula cylindrica*) and the Neosho Mucket Mussel (*Lampsilis rafinesqueana*).

Under state regulations, anytime a project will affect wildlife habitats such as streams, wetlands or other poorly drained areas, riparian areas, native woodland, or native prairie, the project must be reviewed for potential use by threatened or endangered species. Some of the listed species have restricted habitat requirements and are extremely vulnerable to changes at smaller scales. If the project will impact threatened or endangered (T&E) species or their critical habitats, a permit is required from the KDWPT before construction begins. In most cases, it will be necessary to place special conditions on a permit whereby the permit holder will be required to incorporate specific mitigation measures designed to significantly reduce or eliminate a project's adverse impacts to the protected species.¹¹

An initial review of data from the Kansas Biological Survey identified three threatened species known to inhabit areas along the 1982 aqueduct route: the Plains Minnow (*Hybognathus placitus*) near the source reservoir and along the aqueduct route, the Arkansas Darter (*Etheostoma cragini*) near the terminal reservoir and the Lesser Prairie Chicken (*Tympanuchus pallidicinctus*) near the terminal reservoir and along the aqueduct route. Several SINC species are also found in the project area. For example, Greater Prairie Chickens are found in areas along the aqueduct route and near the terminal reservoir. The USFWS is currently considering listing the Northern Long-eared Bat (*Myotis septentrionalis*) as endangered, which would require consideration when clearing trees greater than 3 inches in diameter. The areas that are designated as critical habitat for the Whooping Crane and Arkansas River Shiner are not in the vicinity of the project.¹²

In addition to ESA regulations in Kansas, the construction of a lock and dam structure would require an evaluation of T&E species on the Missouri River. In 2000, the USFWS issued a BO (amended in 2003) that found that actions proposed by the Corps would jeopardize the continued existence of the Pallid Sturgeon. The BO recommended recovery actions that are carried out by the Missouri River Recovery Program, such as creating sandbar habitat and shallow water habitat, as well as propagation efforts.¹³ Any future project on the Missouri River will likely require an extensive review of its impacts on these three federally listed species.

6.5 Invasive Species

Invasive species are nonnative plants or animals that when introduced can cause significant changes to an ecosystem resulting in economic, ecological and human health impacts. For example the zebra mussel (*Dreissena polymorpha*), native to Europe, was introduced to the Great Lakes through the ballast water of ships and has now become widespread throughout the Midwestern U.S. Zebra mussels cause major problems to water quality, public water supply and electric generation, recreation and human health. Executive Order 13112 was signed in 1999 and calls on federal agencies to work to prevent and control the introduction and spread of invasive species.¹⁴

The risk of transporting invasive species from the Missouri River to other receiving water bodies in addition to potential impacts to the infrastructural components of the transfer system must be evaluated if a project is completed in the future.

6.6 Farmland Protection Policy Act

Congress enacted the Farmland Protection Policy Act (FPPA) as a subtitle to the 1981 Farm Bill. The FPPA is intended to minimize the extent to which federal activities contribute to the unnecessary and irreversible conversion of agricultural land to nonagricultural uses. The FPPA requires federal agencies to examine the impact of their programs before they approve an activity that would convert farmland.¹⁵

Prime farmland is defined as land that has the best combination of physical and chemical characteristics for producing food, feed, forage, fiber and oilseed crops and is available for these uses. Unique farmland is defined as land other than prime farmland that is used for the production of specific high value food and fiber crops. Both have the special combination of soil quality, location, growing season and moisture supply needed to economically produce sustained high quality and/or high yields of a specific crop when treated and managed according to acceptable farming methods.¹⁶

The 1982 Study evaluated a source reservoir of 13,000 acres and a terminal reservoir of 25,000 acres. The canal system would use approximately 37,700 acres of land. An evaluation of the projects impacts on any prime or unique farmlands will be required as part of the EIS.

6.7 Historic Preservation

6.7.1 National Historic Preservation Act

The National Historic Preservation Act was enacted in 1966 for the purpose of protecting the nation's historical and archaeological sites. Section 106 of the act requires federal agencies to identify and assess the effects of its actions on historic properties and cultural resources. The Section 106 review is completed in coordination with State and Tribal Historic Preservation Officers (SHPO/THPO). The Section 106 review is incorporated into the NEPA process in which cultural resources must also be addressed.¹⁷

An initial assessment of known historic sites and buildings on the historic register found approximately 40 sites in the vicinity of the 1982 route.

6.7.2 Native American Historic and Cultural Resources

The Native American Graves Protection and Repatriation Act (NAGPRA) became law in 1990 to provide greater protection for Native American burial sites and more careful control over the removal of Native American human remains, funerary objects, sacred objects and items of cultural patrimony on Federal and tribal lands. NAGPRA requires that Indian tribes or Native Hawaiian organizations be consulted whenever archeological investigations encounter, or are expected to encounter, Native American cultural items or when such items are unexpectedly discovered on Federal or tribal lands. Excavation or removal of any such items also must be done under procedures required by the Archaeological Resources Protection Act.¹⁸

The Iowa Tribe of Kansas and Nebraska, Kickapoo Tribe of Indians in Kansas, Prairie Band Potawatomie Nation and the Sac and Fox Nation all have reserves in northeast Kansas. While the components of the 1982 aqueduct system do not cross present-day tribal lands, they have the potential to impact historic cultural resources of the tribes. The landholdings of each of these tribes was once much larger than the boundaries that exist today. Additionally, many other tribes once lived in Kansas and any disturbance of their cultural resources on would require handling in accordance with relevant federal and state laws.

6.7.3 Kansas Preservation Laws

The Kansas SHPO office reviews approximately 3,000 projects per year for potential effects on the state's historic and archeological resources. The Kansas Preservation Act determines effects on listed historic properties. The Kansas Antiquities Act recognizes the need to conserve significant archeological remains. The Unmarked Burial Sites Preservation Act protects unmarked burials, human remains and associated objects.¹⁹

As part of the development of the EIS, identification of all historic properties, including archeological sites must be identified and adverse impacts resolved through consultation with the SHPO, potentially the Advisory Council on Historic Preservation (ACHP) and appropriate and interested Native American tribes and other interested parties.

6.8 Sedimentation Issues

There are several issues related to sediment that must be addressed with a project such as the aqueduct. First, the Missouri River is sediment deficient as a result of the large dams upstream of the site considered for the lock and dam and intake structure. There are numerous efforts to increase the sediment in the Missouri River to balance the drastic reduction from historic loads that occurred because of the mainstem dams. In addition, the Missouri River Bed Degradation study, which pertains to the area below the site considered for the lock and dam, is looking at the major impacts and implications of lack of sediment in the river. Not only is bed degradation a concern on the river, some areas experience the opposite and have excess sedimentation, or shoaling. Because of the size and dynamic nature of the Missouri River, it is sometimes the case that localized areas of shoaling need excess flushing flows in the same years that other areas experience degradation issues.

Sedimentation issues will also need to be considered in relation to the source and terminal reservoirs. Diverting water from the Missouri River, especially during high flow events, will likely result in sedimentation issues in the reservoirs and may also impact the infrastructure of the transfer system

6.9 Conclusion

Addressing the environmental permitting requirements for a project of this scope will be a monumental task that will incur substantial cost to the project. Some of the largest barriers to overcome from an environmental standpoint will likely be the threatened and endangered species on the Missouri River and the rest of the state and the compensatory mitigation requirements under Section 404 of the Clean Water Act.

Table 6(a). Potentially Relevant Environmental Constraints.	
Environmental Law or Regulation	General Description
National Environmental Policy Act of 1969, as amended (NEPA)	Requires the disclosure of the environmental impacts of any major federal action.
Council on Environmental Quality Regulations, Implementing NEPA	The Council on Environmental Quality was established by NEPA and consists of three members appointed by the president to 1) analyze and interpret environmental trends and information, 2) appraise programs and activities of the federal government under NEPA, 3) be aware of and responsive to the scientific, economic, social, aesthetic, and cultural needs and interests of the nation, and 4) formulate and recommend national policies to promote the improvement of the quality of the environment.
Clean Water Act of 1977, as amended	Provides the principle framework for national, state and local efforts to protect water quality, including protection of wetlands.
Executive Order 11988 of 1977, Flood Plain Management	Federal agencies are directed to consider the proximity of their actions to or within floodplains, to 1) reduce the risk of flood damage, 2) minimize the impacts of floods on human safety, health and welfare, and 3) restore and preserve the natural and beneficial values served by floodplains.
Kansas Administrative Regulations 28-16-28c, Surface Water Quality Standards	General provisions state that no degradation of water quality by artificial sources shall be allowed that would have harmful effects on threatened or endangered aquatic life in a critical habitat.
Executive Order 11990 of 1977, Protection of Wetlands	Requires federal agencies to minimize or avoid wetland destruction, loss, or degradation and to preserve and enhance natural and beneficial wetland values.
Endangered Species Act of 1973, as amended	Requires federal agencies that fund, authorize, or implement actions to avoid jeopardizing the continued existence of federally listed, threatened, or endangered species, or destroying or adversely affecting their critical habitat.
Fish and Wildlife Coordination Act	Requires consultation with the Fish and Wildlife Service and the fish and wildlife agencies of the States where waters of any stream or other water body are proposed or authorized, permitted or licensed to be impounded, diverted or otherwise controlled or modified by any agency under a Federal permit or license. Consultation is to be undertaken for the purposes of preventing loss of and damage to wildlife resources.

Table 6(a). Potentially Relevant Environmental Constraints.	
Environmental Law or Regulation	General Description
Clean Air Act of 1970, as amended	Provides the principle framework for national, state and local efforts to protect air quality.
Kansas Administrative Regulations 28-19-17, Prevention of Significant Deterioration of Air Quality	Applies to the construction of major stationary sources and major modifications of stationary sources in areas of the state designated as attainment areas or unclassified areas for any pollutant under the procedures prescribed under the federal Clean Air Act of 1970, as amended.
Antiquities Act of 1906	Authorizes the scientific investigation of antiquities on federal land and provides penalties for unauthorized removal of objects taken or collected without a permit.
National Historic Preservation Act of 1966, as Amended	Establishes as policy that federal agencies are to provide preservation of the nation's prehistoric and historic resources, and establishes the National Register of Historic Places.
Archaeological Resources Protection Act of 1979, as amended	Protects materials of archaeological interest from unauthorized removal or destruction and requires federal managers to develop plans and schedules to locate them.
Rivers and Harbors Act	States that appropriate Federal and State agencies are to ensure that possible adverse economic, social and environmental effects relating to any proposed action have been fully considered in the development of the project, and that the final decisions on the project are made in the best overall public interest, taking into consideration the need for flood control, navigation and associated purposes, and the cost of eliminating or minimizing such adverse effects to biological and human resources.
Migratory Bird Treaty Act	Prohibits the taking, killing, possession, transportation, and importation of migratory birds, their eggs, parts, and nests. Takings could result from projects in lakes, prairies, wetlands, stream and woodland habitats, and those that occur on bridges and their structures.
Noise Control Act	Initiated a federal program of regulating noise pollution with the intent of protecting human health and minimizing annoyance of noise to the general public. Noise is defined as unwanted sound that interferes with normal activities or in some way reduces the quality of the environment. Response to noise varies according to its type, perceived importance, appropriateness in the setting and time of day, and the sensitivity of the individual receptor.
Executive Order on Invasive Species (EO 13112)	Established the National Invasive Species Council to ensure that Federal programs and activities to prevent and control invasive species are coordinated, effective and efficient.
Water Resources Development Act (WRDA) – 1986, '90, '92, '96 and 2013	Addresses long-term disposal of dredge material and promotes decontamination technologies for the manufacturing of material for beneficial uses.

U.S. Environmental Protection Agency. 2013. Section 404 Permitting.

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Update of 1982 Six State High Plains Aquifer Study

Chapter 7: Preliminary Political Assessment

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A political assessment of a project of this magnitude is subjective by its nature. However, the authors (Pope and Rolf) do have extensive experience dealing with the administration of water law in Kansas, interstate water issues and participation in various organizations related to the Missouri River. Much of this experience involved conflicts and disputes related to water shortages or water allocation issues related to various projects, proposals or compacts. As a result, this experience does provide some capability to assess expected reactions to various issues, projects or proposals. An objective attempt will be made to evaluate the reaction to various components of the Kansas Aqueduct Study involving the potential transfer of water from the Missouri River to Western Kansas and/or other areas along the way. In any event, objective information and public education regarding the project, as well as coordination with various organizations with an interest in water, natural resources, the environment, economic development, public water supply and other interests should help people respond to the project in a more informed way.

7.1 Interstate Coordination

There have been six different organizations with direct state involvement that operated in the Missouri River Basin at different times in the past. These organizations have been involved in differing activities that have included coordination, communications, planning, joint political action, as well as other related issues, such as the identification, discussion and resolution of issues of concern to the participants.

7.1.1 Missouri River States Committee (MRSC)

The first organization was the Missouri River States Committee (MRSC) that was formed May 21, 1943 to institute a basin wide political action group.¹ It functioned as a ten state coalition to lobby Congress for the extensive water resources development programs that became the Pick-Sloan Program.

7.1.2 Missouri Basin Inter-Agency Committee (MBIAC)

During the period 1950 through 1954, the MRSC attempted to negotiate a basin wide compact without success. The Missouri Basin Inter-Agency Committee (MBIAC) was formed by the Federal Inter-Agency River Basin Committee after Congress adopted a comprehensive plan for water resources development for the Missouri River Basin (Pick-Sloan Program)². It operated from 1945 through 1972. Its purpose was to interchange information and coordinate activities of the federal and state agencies in the planning and development of water and related land resources throughout the basin. Membership included the Governors of the ten basin States and representatives of seven Federal Departments.

7.1.3 Missouri River Basin Commission (MRBC)

The Missouri River Basin Commission (MRBC) was established on March 22, 1972 by an executive order issued by President Richard M. Nixon.³ The commission was created under the auspices of the Water Resources Planning Act of 1965. The Commission had a presidentially appointed chairman. The members were representatives of the basin Governors, federal agencies and two of the several interstate river compact commissions on tributaries in the basin. The commission had no regulatory power. MRBC was established to prepare and keep current a comprehensive, coordinated joint plan (CCJP) for resource development and recommend long-range schedules of priorities for data collection and investigation, planning and construction of projects.⁴ The Commission adopted the MBIAC Comprehensive Framework Study plan as the first step in preparing the CCJP, but also established a process to update the existing framework report, initiated "Level B" Basin Planning in various areas and Project Planning. The Commission published its first water management plan for the basin in 1977 and an updated plan was adopted in 1981. It ultimately published numerous documents ranging from planning and technical reports to proceedings of meetings and seminars, annual reports and newsletters.⁵ The Missouri River Basin Commission, along with five other similar commissions was terminated by Executive Order of President Reagan on September 30, 1981.⁶

7.1.4 Missouri Basin States Association (MBSA)

Upon the dissolution of the Missouri River Basin Commission in 1981, the ten state governors formed the Missouri Basin States Association (MBSA) to continue some of the activities of the then defunct Missouri River Basin Commission.

Pursuant to terms of the Executive Order dissolving MRBC, MBSA was able to receive the assets and unexpended funds from MRBC. MBSA representatives were appointed by the Governors. Federal officials were not members, but were encouraged to participate. MBSA was organized to continue regional water resource coordination in the basin, to analyze regional water resources issues and to complete two major ongoing studies begun by MRBC, the hydrology and flood plain studies. It was recognized that the programs of MBSA would be reduced in scope and funding from those conducted by MRBC during the previous decade. The MBSA statement of purpose noted that it serves as a forum for the identification, discussion and possible resolution of issues of concern to the basin states, but would not supplant the states' role of planning and managing water resources within their boundaries.⁷ After the two studies were complete and the federal funds expended, the staff was reduced. After a few years, interest in the organization was not sufficient to support the remaining four staff members through state dues and the office in Omaha, Nebraska, was closed in 1988⁸.

7.1.5 Missouri River Basin Association (MRBA)

Most of these organizations included participation of both States and Federal agencies with water or natural resources responsibilities in the basin, but it was not until the Missouri River Basin Association (MRBA) was created through restructuring of the Missouri Basin States Association in 1993 that a seat on the board was provided for the Mni Sose Intertribal Water Rights Coalition, an organization created in 1993 to represent many of the water interests of the Tribes in the basin.⁹

7.1.6 Missouri River Association of States and Tribes (MoRAST)

After the Revised Master Manual was adopted, it became clear that water management and biological issues were so interrelated that the States needed a more coordinated way to provide advice to the Corps and other Federal agencies and that the Tribes should have more involvement. As a result, with MRBA leadership, the Missouri River Association of States and Tribes (MoRAST), was organized by State and Tribal officials to create a new, more broadly based organization to represent a broad range of interests. Tribes were given representation equal to the number of states involved and both the state water management and fish and wildlife agencies were included as state participants.¹⁰

However, there was not total agreement with this approach. While it participated in the organizational process, the State of Missouri did not join MoRAST. More recently, the States of Iowa and Nebraska have withdrawn as members of MoRAST, leaving it with only five state members. While it is not totally clear what has driven these decisions, developing recommendations to the Corps dealing with the operation of the Mainstem Reservoir System has been a challenge for MoRAST, especially considering the historic upstream/downstream conflict and the complexities associated with water management and the implementation of the Missouri River Recovery Program. The flood of 2011 also focused attention on the importance of flood control along the Missouri River compared to other priorities for some of the states.¹¹

While MoRAST is still active, this recent experience illustrates the different views among the States, Tribes, Federal agencies and various other interests, about how to approach coordination and resolution of issues in the basin. For example, while many people in the basin share an interest in the value of flood control and the need for good quality drinking water supplies, there are more divergent views about various other water issues in the basin, including the differences between uses that consume significant amounts water, including the potential transfer of water out of the Missouri River Basin, even in the same State, versus various uses that do not consume much water, but require large flows for instream uses, such as navigation. There are also differences among various interests in the basin regarding the how to deal with recovery of endangered species, environmental resources and the potential effect on other uses.

7.2 Preliminary Assessment of the Project's Political Acceptability

There are components of an aqueduct project that may generate local or region concern. It is not uncommon for there to be political opposition to the transfer of a large amount of water out of the area of origin, as people are often concerned about the potential loss of water as a critical resource for current and future uses of all kinds. Under Kansas law, these issues can be considered pursuant to the Kansas WTA as noted earlier in this report. Based on the 1982 Study, the combination of source and terminal reservoirs, canal and conduit and pumping plants would require between 68,000 and 92,000 acres of land for an aqueduct project, depending on the design capacity. There is often concern or opposition to the

taking of land for public projects, especially if done by condemnation. Issues concerning condemnation were discussed by Peck in his article.¹² The aqueduct is also a large project that would be expensive. A determination of how it would be financed, the costs and benefits and who would pay any new taxes or fees, versus who is expected to receive the benefits, would likely generate a lot of political consideration. However, given the potential to meet important water needs in a broad area of the state, provide a sustainable supply of water to maintain the local, regional and state economy generated by the productive irrigated agricultural and related agri-business in High Plains – Ogallala aquifer area of western Kansas, as well as to provide water for economic development and stability in Kansas, the project may also receive a large amount of support.

7.3 Preliminary Assessment of Secondary Uses of Transferred Water

A number of possible uses have been discussed in this report, including potential uses for wildlife water supply at refuges and municipal and industrial uses, although there may be water quality or environmental constraints, especially at wildlife refuges, that could otherwise directly benefit from additional water from an aqueduct project. Nevertheless, the possibility of water being available for such uses may increase political support, or at least mitigate other concerns that may exist related to the project.

¹ Ferrell, John R. 1993. *Big Dam Era*. U.S. Army Corps of Engineers. http://www.nwd-mr.usace.army.mil/rcc/reports/rcc_publications_reports.html.

² Ibid.

³ Missouri River Basin Commission. 1973. *First Annual Report*. http://library.ndsu.edu/tools/dspace/load/?file=/repository/bitstream/handle/10365/6955/y3m69_1973.pdf?sequence=3.

⁴ Ibid.

⁵ Ibid.

⁶ Executive Order 12319. 1981. <http://www.archives.gov/federal-register/codification/executive-order/12319.html>

⁷ Missouri Basin States Association. 1983. *MBSA Basin Bulletin No. 1*. June 4. <http://library.ndsu.edu/repository/handle/10365/6362/browse>.

⁸ Ferrell, John R. 1993. *Big Dam Era*. U.S. Army Corps of Engineers. http://www.nwd-mr.usace.army.mil/rcc/reports/rcc_publications_reports.html.

⁹ Ibid.

¹⁰ Pope, David L. 2012. *Missouri River Water Management White Paper*. Prepared for the Kansas Water Office. August.

¹¹ Office of Governor Terry Branstad, letter of November 3, 2011.

¹² Peck at 205 (see endnote 56 in Chapter 5)

Update of 1982 Six State High Plains Aquifer Study

Appendix 1: Reconnaissance Study, Alternate
Route B, Water Transfer from Missouri River to
Western Kansas, 1982



**US Army Corps
of Engineers**
Kansas City District

Six-State High Plains Ogallala Aquifer Regional Resources Study

Water Transfer Element

Reconnaissance Study Alternate Route B

Water Transfer From Missouri River To Western Kansas

September 1982

Appendix B

SIX-STATE HIGH PLAINS -
OGALLALA AQUIFER
REGIONAL RESOURCES STUDY

WATER TRANSFER ELEMENTS

ROUTE B STUDY
BY
KANSAS CITY DISTRICT OFFICE

SEPTEMBER 1982

MISSOURI RIVER DIVISION
US ARMY CORPS OF ENGINEERS

SIX-STATE HIGH PLAINS-OGALLALA AQUIFER
REGIONAL RESOURCES STUDY/WATER TRANSFER ELEMENT

ALTERNATE ROUTE B

(MISSOURI RIVER TO WESTERN KANSAS)

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SIX-STATE HIGH PLAINS-OGALLALA AQUIFER
REGIONAL RESOURCES STUDY/WATER TRANSFER ELEMENT
WATER TRANSFER FROM THE MISSOURI
TO WESTERN KANSAS

ALTERNATE ROUTE B

RECONNAISSANCE STUDY

Introduction

This is a reconnaissance study of one of four alternative water transfer routes being evaluated by the Corps of Engineers in conjunction with the High Plains-Ogallala Aquifer Study. This route begins at the Missouri River upstream of St. Joseph, Missouri, and terminates in western Kansas (Fig. 1 Vicinity Map and Fig. 2 Layout of Transfer Route).

Study Authorization

Section 193 of the 1976 Water Resource Development Act (Public Law (PL) 94-587) authorizes and directs the Secretary of Commerce to study the depletion of water resources of the Ogallala-Aquifer and to develop plans to increase water supplies in the area. The High Plains Study Council (representatives from Colorado, Kansas, Nebraska, New Mexico, Oklahoma, Texas, and Department of Commerce), was established to direct and control the studies.

Role of the Corps of Engineers

The Corps was directed by Congress to examine the engineering feasibility of transferring water from adjacent areas to provide future water supplies for the high plains, "...the Secretary of Commerce, acting through the Economic Development Administration in cooperation with the Secretary of the Army, acting through the Chief of Engineers,..." The responsibility for managing and coordinating the Corps of Engineers study was assigned to the Southwestern Division (SWD). Accomplishing the study involved the Tulsa, Fort Worth, Omaha, and Kansas City Districts. A general contracting team composed of Camp, Dresser & McKee, Inc., as prime contractor; Arthur D. Little, Inc.; and Black & Veatch, Consulting Engineers, acting as the High Plains Associates, was hired by the Department of Commerce and the High Plains Study Council to undertake the entire High Plains study and to coordinate the Corps of Engineers' findings with the rest of the study.

Study Objectives

The objectives of this study are to (1) determine the engineering feasibility of water transfer; (2) estimate the costs of constructing, operating, and maintaining a water transfer system; and (3) identify the general environmental effects associated with the action. The findings of this reconnaissance level study will be incorporated into the overall High Plains Study and will help determine if further water transfer study is warranted.

Water Needs

Economic studies performed by the individual states determined the water supply necessary to restore and maintain irrigated acres in the High Plains member states region by the year 2020. Otherwise the lands would go out of production or revert to dryland farming. No new irrigated areas would be served. The SWD adjusted the demand figures to make them pertinent to the Kansas City District's alternative transfer route as follows:

<u>State</u>	<u>Annual Water Requirement (2020)</u> <u>for Alternative Route B</u> <u>(1,000 Acre-Feet)</u>	
Colorado	250	
Kansas	862	
Nebraska	1,783	
Oklahoma	334	
Texas	175	(1/3 total demand)
Total A-F Demand	3,404	

The water demands of New Mexico and two-thirds of Texas (area south of Canadian River), were excluded from the KCD supply area because of the distance from the source. The total of 3,404,000 acre-foot demand is required at the farm headgate and is used in this study as the upper limit of water to be transferred. This amount is increased for enroute losses as follows to determine the actual water demand at the source point as follows: 10 percent seepage and evaporation from the source reservoir to the terminal storage; 5 percent evaporation at the terminal storage; and 10 percent seepage and evaporation from the terminal storage to the farm headgate. Compounding these percentage results, a factor of 1.3 is applied to the projected demand at the headgate to arrive at a 4,425,200 acre-foot of water requirement at the source point.

Water Availability

According to Resolution No. 6 of the High Plains Study Council, only waters surplus to in-basin needs are to be considered for export. Lacking data on in-basin needs of the Missouri River Basin states and the effect of water diversions on the Mississippi River navigation, certain assumptions and conditions were established in order to complete this study. Withdrawals from the Missouri River would not be taken when the streamflow was equal to or less than an established navigation base flow. Water to be transferred would be withdrawn from amounts exceeding the base flow and stored in a nearby source reservoir to be transferred to the High Plains at a constant rate of flow. With these criteria as a base, the Missouri River Division (MRD), Corps of Engineers, made a preliminary evaluation using a computer model to estimate the potential amount of water available for transfer from the Missouri River at St. Joseph, Missouri. Assumptions for the model study were: (1) target river flow of 41,000 cubic feet per second (c.f.s.) during navigation season (8 months) maintained at Kansas City; (2) nonnavigation season base flow of 15,000 c.f.s.; and (3) Bureau of Reclamation future depletions. Using these criteria, the following diversion amounts were projected:

<u>Study Level</u>	<u>Pump Capacity From River (1,000 c.f.s.)</u>	<u>Average Annual Volume of Water Available (million acre-feet)</u>
1975	10	2.9
	20	3.8
	30	4.1
2000	10	2.1
	20	2.7
	30	2.9
2020	10	1.6
	20	2.1
	30	2.2

Recognizing existing navigation demands and projected future depletions, water would not be available from the Missouri River source point to supply the total projected demand of 4,425,200 acre-feet. If the year 2020 is selected as the design demand year, and a pumping capacity of 20,000 c.f.s. is used, a projected diversion amount of 2,100,000 acre-feet is available. This amount was used to design the lower limit of water transfer, recognizing that the average annual amount would be available only fifty percent of the years (according to the period of record examined - 1889 to 1979). Further, the MRD study indicates that in many years, especially during the drought of the 1930's and 1950's, virtually no diversions could have been made. Allowing for enroute losses as described above, the amount of water delivered to the farm headgate amounts to 1,615,000 acre-feet. From these preliminary findings it is apparent that water supply from the Missouri River is questionable and that additional water availability studies are required if higher level planning is directed. Navigation on the Missouri River is the water use feature most affected by flow depletions. The full service navigation flow and the 8 month navigation season severely limit surplus water availability. Reduced flows and shortened navigation season were not evaluated at this level of study due to Resolution No. 6 guidance. Navigation on the lower Mississippi River would also be affected by diversion of water from the Missouri River which is a substantial source of Mississippi River flows during certain periods. The Mississippi impacts have not been evaluated in this study.

Source Point

The diversion point for the Kansas City District water transfer study is on the Missouri River about 35 miles upstream of St. Joseph, Missouri. This site was chosen because of an adjacent favorable location for a large source reservoir. Major withdrawal periods could be coordinated with flood-flows and the nonnavigation season. A lock and dam would be required to accommodate Missouri River navigation coincident with withdrawal rates above 6,000 c.f.s. because of the resultant water elevation drop (Fig. 3). The effects of the lock and dam on floodflows and navigation could have an impact on operation of the mainstem reservoir system. The dam could also increase upstream flood stages and could modify the downstream stages. There would also be a change to the existing sediment transport situation. Full analysis of flood stages, sedimentation, and navigational impacts would be a requirement of any higher level study.

Source Reservoir

The system's source reservoir, referred to as White Cloud, is sited 2.5 miles southeast of the town of White Cloud, Kansas. The design capacity of the lake is 700,000 acre-foot. The surface area would be about 13,000 acres when full, and would require about 19,000 acres of land for the entire feature. Lake storage enables pumping from the river at rates greater than the canal system capacity, when excess water is available, i.e., during flood conditions and the nonnavigation season. Sediment would be deposited in the reservoir, thereby reducing sediment deposition in the canal system. In addition, the water stored in the source reservoir would increase the dependability of the system.

The source lake and its intake structure, while necessary for the storage of excess flows from the Missouri River, will negatively impact terrestrial wildlife habitat. Although no Federal or state designated fish and wildlife area, refuge, or public hunting area would be directly affected, the construction and operation of an intake structure may result in the entrainment and impingement of fish by intake velocities. These velocities could affect the mobility, life stages, and impart certain physiological stress on the life stage of fish.

Construction of White Cloud Lake would impact an area containing scenic high loess bluffs, and heavily dissected drainage valleys mantled with an oak-hickory forest. Except for a few narrow ridgetops and terraces bordering the Missouri River, most of the area is too rough to be successfully farmed. Because of this topographical constraint the area contains valuable terrestrial wildlife habitat.

The environmental effects of this feature are further discussed in more detail in the attached Corps of Engineer's environmental assessment (Appendix B). An assessment of potential environmental impacts by the U.S. Fish and Wildlife Service was used in preparing the assessment. That report is on file for reference.

Transfer Facilities

The primary means of transferring the water is by open, trapezoidal, concrete-lined canal. Routes were selected based on the concept of a series of ridgeline canals connected by pumping plants. The pumping plants would be needed to lift the water approximately two thousand feet to the terminal points. The individual routes, elevation differences, miles of canal, and the number of pumping plants are shown in Figure 4.

Gravity flow would transfer the water between pumping plants, with siphons used to cross major streams and some highways and railroads. Other roads and railroads would be relocated to cross the canal by bridge. The pumping plants would utilize up to ten turbine type centrifugal pumps driven by electric motors. The pumps would discharge into prestressed, precast concrete pipe for delivery to higher elevations where the water would again flow by gravity to the next pump station. The canals would be designed for flow velocities of less than five feet per second with four to five feet of freeboard and check gates at approximately four mile intervals.

Canal dimensions are defined in the Cost and Design Manual (Appendix E) prepared by the Corps of Engineers for this study. Figure 5 shows a cross section of an 6,830 c.f.s. canal which is the largest required for the quantities under consideration.

The canal system is designed to operate at a constant discharge. For design purposes it was assumed that breakdowns, weather, etc. would limit the system to 85% of capacity. The canals therefore are oversized to provide a flow capacity of 1.18 times the design flow. Losses of water in transit because of evaporation, seepage, etc., were assumed to be 10 percent of the flow.

The tentative alignment of the canals is shown on Figure 2. Although the alignments have been selected to follow ridge lines, avoid rough terrain and environmentally sensitive areas, and to minimize pumping plants and siphons, they remain tentative and should not be assumed to be final. Further detailed study would be required to define the most feasible route alignment.

Appropriate cost curves from the Cost and Design Manual were used to estimate the transfer facilities costs. Cost items considered include (1) length, and size of canal, (2) percent of rock excavation expected during canal construction, (3) the number, size and total head lift for pump stations, and (4) the length and size of conduits. Land costs and relocation expenses are also determined from curves presented in the manual. The operation and maintenance costs are dependent upon transfer length, number of pumping stations, and total head of the system. The pertinent data sheet (Appendix A) itemizes these features.

Canal Alignment

The canal would be routed along ridge lines to minimize conflicts with prime farmland, transportation routes, cities, and wildlife habitat. Such an alignment is less expensive to build because of more constant elevations and fewer drainage intersections. As part of the study effort, all major ridge line routes to western Kansas were examined, resulting in selection of two routes (Figure 2); a north route along the northern tier of counties terminating at a proposed reservoir site, Sappa Lake, in the northwest corner of Kansas; and a south route crossing the Kansas River east of Manhattan, Kansas, following the ridge line between the Kansas and Arkansas Rivers, and terminating at a proposed reservoir site, Utica Lake, in west central Kansas in Ness County. The major differences in the two routes are the location of terminal points, head and length of canals. The north route would more readily serve the northwest region of Kansas, the northeast corner of Colorado, and the southwest corner of Nebraska. The south route would better serve central and southwestern Kansas, the panhandle of Oklahoma, north panhandle of Texas, and southeastern Colorado. The south route is less expensive to construct because of its ability to follow a more pronounced ridge line than the northern route, fewer major valley crossings (one on the south versus five on the north route), and the lower terminal reservoir site for the south route, which results in less pumping head. As a result of these differences, the south route has 16 pump stations versus 29 pump stations on the north route. Fewer pumps on the south route result in less first cost as well as less annual operations and maintenance costs.

Either water transfer route would have a negative impact on agriculture throughout its length. The south route, 360 miles long, would remove between 20,880 and 38,880 acres of private land from production, depending upon which canal size is selected. The north route, 295 miles long, would remove between 17,110 and 31,860 acres from production.

The south route would traverse and adversely impact the unique vegetative community called the Flint Hills Prairie.

The environmental effects of this feature are further discussed in more detail in the attached Corps of Engineer's environmental assessment (Appendix B).

Hydropower Opportunity

To cross broad river valleys by canal/drop inlets or pipeline results in significant head losses. A reconnaissance level analysis of alternative means to cross the valleys resulted in adding hydropower generation to the system to reduce the net head loss. The power generated while dropping the water down the side of the valley would be used to pump the water up the other side. Three hydropower sites are proposed on the north route, and one site is proposed on the south route. Because of the preliminary nature of this study, the cost effectiveness of these systems has not been verified in detail.

Terminal Reservoirs

The terminal reservoir would store water at the end of the water transfer system until it is needed at the farm headgate. The cost estimate in this study does not include the distribution canals leading from the terminal reservoir to the use areas. Since the terminal storage is located at a relatively low elevation in the High Plains, additional pumping facilities would be required in the distribution system. The size of the reservoir is determined by the amount of water transferred and the distribution of the water during the year. Camp, Dresser & McKee, Inc., provided typical seasonal irrigation water needs for the northern High Plains as follows:

<u>Month</u>	<u>Percent Total Year Demand</u>	<u>Month</u>	<u>Percent Total Year Demand</u>
January	0.5	July	19.0
February	1.0	August	25.0
March	5.0	September	7.0
April	10.0	October	1.0
May	18.0	November	1.0
June	12.0	December	0.5

The terminal reservoir is designed to dampen seasonal fluctuation in demand at the headgate by storing sufficient water to supplement the constant flow available from the canal. The canal is assumed to provide 1/12th (8.33 percent) of the annual delivery per month operating at 85 percent capacity (allowing for 15 percent annual downtime). The terminal reservoir must be capable of holding the difference between demand and supply rates over the period that demand exceeds the 8.33 percent per month supply rate; in this case April through August. Those 5 months account for 84 percent of the annual water demand. The total storage requirement is increased by 10 percent to accommodate evaporation and seepage losses from terminal storage to farm headgate. A 5 percent evaporation loss in the terminal storage facility was also assumed. Thus, the percentage of yearly water delivery to the farm headgate which must be stored in the terminal reservoir is 84 percent of annual demand less canal capacity for the 5 months, or 41.66 percent of the annual demand plus 10 percent evaporation and seepage loss from reservoir to the field. The resultant factor is 46.6 percent (1.1 x (84-41.66)). When applied to this study's maximum demand of water at the farm headgate, 3,404,000 acre-feet, the factor produces an annual required terminal storage of 1,586,000 acre-feet. For the lower limits of water availability selected for this study, 1,615,000 acre-feet, an annual terminal storage of 753,000 acre-feet is needed.

The original terminal storage site for Water Transfer Alternative B was the Arkansas River near Dodge City, Kansas. However, a reservoir on the Arkansas River was determined unsuitable because the resulting inundation of the broad, flat river valley would eliminate many acres of prime farmland, railroads, and highways. Two other potential reservoir sites in western Kansas were evaluated: Utica Lake, about 50 miles north of Dodge City; and Sappa Lake in the northwest corner of the State. Both sites are within the Ogallala Aquifer region and will accommodate the maximum storage requirements. The design and cost of the reservoirs were developed using the reconnaissance-level study data in the Cost and Design Manual. The probable maximum flood and the standard project flood curves were used in conjunction with drainage areas to design spillway, sediment storage, surcharge, and freeboard elements. The size of lakes and acres of land required are as follows:

	<u>Max System (3.404 MAFA)</u>		<u>Min System (1.615 MAFA)</u>	
	<u>Lake Size AC.</u>	<u>Land Req'd AC.</u>	<u>Lake Size AC.</u>	<u>Land Req'd AC.</u>
Sappa Lake	27,600	39,200	16,500	23,800
Utica Lake	25,000	35,500	15,800	23,000

Due to site characteristics (drainage area, valley shape etc.) the Utica Lake is more efficient in storing water. Specifics of each lake are shown on the pertinent data sheet (Appendix A).

In a region of western Kansas where terrestrial wildlife habitat is at a premium, and primarily relegated to the narrow stream borders, removal of between 16,500 to 27,600 acres (Sappa Lake) or 15,800 to 25,000 acres (Utica Lake) would have a major negative impact on terrestrial wildlife species. These negative impacts of the terminal reservoirs could be ameliorated by the development and management of wildlife areas adjacent to the lake shore.

The environmental effects of this feature are further discussed in more detail in the attached Corps of Engineer's environmental assessment (Appendix B) and the US Fish and Wildlife Service Report which is on file in the Kansas City District office.

Cost Estimating Procedures

a. First Costs. The first costs are derived from applying appropriate cost curves (1979 level) of the High Plains Cost and Design Manual to the component parts of the study. The components as listed below correspond to systems designed to transfer 1 to 5 million acre-feet of water annually, which was the initial range of pumping capacities as directed by the High Plains Council. The first costs were then backdated by the average ENR index for 1977 to be consistent with the base year used by the general contractor of the High Plains Study. A factor of .8957558 was used to index the 1979 figures to 1977 level. Three construction periods (10, 15, and 20 years) were used to demonstrate the impact of the length of construction to the costs. Interest during construction (IDC) factors of 1.406361 (10 year), 1.724463 (15 year), and 2.135693 (20 year) were applied to the first cost to arrive at investment costs.

Table 1 Investment Costs for Establishing Curves

ITEM	(COSTS IN \$ MILLIONS)							
	SOUTH ROUTE (CFS)			NORTH ROUTE (CFS)				
	2000	6000	10000	2000	5000	8000	10000	
Canal	709	1,191	1,523	582	901	1,091	1,236	
Conduit	168	421	690	329	821	1,314	1,642	
Route Relocations	107	114	120	95	106	112	116	
Pump & Power Plants	325	1,300	2,489	716	1,790	2,864	3,581	
Automation & Communication	23	23	23	41	41	41	41	
Source Reservoir	90	90	90	90	90	90	90	
Terminal Reservoir	55	140	257	81	241	379	449	
Lock and Dam	-	-	82	-	-	82	82	
Total	1,477	3,279	5,274	1,934	3,990	5,973	7,237	
11% EDSA	162	361	580	213	439	657	796	
First Costs (1979 Level)	1,639	3,640	5,854	2,147	4,329	6,630	8,033	
Backdate to 1977 level	1,468	3,260	5,243	1,923	3,878	5,939	7,195	
IDC								
10 YEAR CONSTR.	597	1,325	2,131	782	1,576	2,413	2,924	
15 YEAR CONSTR.	1,064	2,362	3,799	1,393	2,809	4,303	5,213	
20 YEAR CONSTR.	1,667	3,702	5,954	2,183	4,404	6,745	8,171	

Using the first costs and IDC for a range of pumping capacities, the Investment Cost Curves, Figure 6, were compiled.

b. Annual Costs

(1) Interest Rate and Amortization. A factor of .07381 for the interest rate of 7 3/8 percent and 100-year project life were used to determine the interest and amortization (I & A) costs.

(2) Operations, Maintenance and Replacement. The operations, maintenance, and replacement components are shown in the initial range of pumping capacities using the 1979 level costs from the Cost and Design Manual:

Table 2 Operations, Maintenance, and Replacement Costs

Annual OM&R Costs	ITEM	(COSTS IN \$ THOUSANDS)							
		SOUTH ROUTE (CFS)			NORTH ROUTE (CFS)				
		2000	6000	10000	2000	5000	8000	10000	
Canal O&M		3,115	3,221	3,322	2,560	2,640	2,700	2,730	
Conduit O&M		148	151	156	371	383	392	396	
Plant O&M		2,582	3,945	5,245	2,934	4,432	5,196	5,960	
Plant Repl.		1,348	2,059	2,739	1,532	2,315	2,714	3,113	
Automation & Communi- cation		48	48	48	91	91	91	91	
Source Reservoir O&M		510	510	510	510	510	510	510	
Terminal Reservoir O&M		370	700	930	370	610	890	930	
Lock and Dam O&M		-	-	700	-	-	700	700	
TOTALS (1979 Level)		8,121	10,634	13,650	8,368	10,981	13,293	14,430	
Backdated to 1977 and rounded (MILLION)		7	10	12	7	10	12	13	

(3) Pumping costs. Electrical power costs (22.69 mills/kWh) used in this report were furnished by Black & Veatch Consulting Engineers. The energy prices reflect 1977 dollar values. This power cost was applied at the rate of 1.333 kWh/1 ACRE-Foot/1 foot of head (from the Cost and Design Manual). The equivalent head in each pumping system is derived from:

- (a) Actual elevation difference between Missouri River and terminal storage,
- (b) 15 feet of head loss through each pump and power plant,
- (c) Friction losses in canals and siphons,
- (d) 18 percent head lost during power generation (turbines at 82 percent efficiency contribute their power to the system).

Table 3 Equivalent Head & Energy Costs

	Acre-Feet Demand	Acre-Feet In System	System Equivalent Head	kWh Per AF Per Foot Head	Energy Cost (\$/kWh)	Energy Cost (Millions)
<u>South Route</u>						
2000 CFS	972,000	x 1.235	x 2377	x 1.333	x .02269	= 86
6000 CFS	2,915,000	x 1.235	x 2223	x 1.333	x .02269	= 242
10000 CFS	4,858,000	x 1.235	x 2204	x 1.333	x .02269	= 400
<u>North Route</u>						
2000 CFS	972,000	x 1.235	x 2923	x 1.333	x .02269	= 106
5000 CFS	2,429,000	x 1.235	x 2912	x 1.333	x .02269	= 265
8000 CFS	3,887,000	x 1.235	x 2784	x 1.333	x .02269	= 404
10000 CFS	4,858,000	x 1.235	x 2780	x 1.333	x .02269	= 505

(4) Summary of Annual Costs and Costs Per Acre Foot. The three items that make up the annual cost (I&A, OM&R, and annual power cost) were totaled, then divided by the acre-feet delivered to the farm headgate to yield cost per acre-foot (Figure 7, Cost Curve of Water Delivered to Terminal Storage). The initial amounts of water transfer ranges and the 10, 15 and 20-year construction periods were used to establish a range costs for each acre-foot delivered to the terminal storage reservoir.

Table 4 Costs Per Acre Foot to Establish Curves

ITEM	(COSTS IN \$ MILLIONS)							
	SOUTH ROUTE (CFS)				NORTH ROUTE (CFS)			
	.972 MAFA 2,000 CFS	2.915 MAFA 6,000 CFS	4.858 MAFA 10,000 CFS	.972 MAFA 2,000 CFS	2.429 MAFA 5,000 CFS	3.887 MAFA 8,000 CFS	4.858 MAFA 10,000 CFS	
<u>10 YEAR CONSTR.</u>								
I&A	152	338	545	200	402	617	747	
OM&R	7	10	12	7	10	12	13	
POWER	<u>86</u>	<u>242</u>	<u>400</u>	<u>106</u>	<u>265</u>	<u>404</u>	<u>505</u>	
	245	590	957	313	687	1033	1265	
DIVIDED BY A-F								
DELIVERED	252	202	197	322	283	266	260	
<u>15 YEAR CONSTR.</u>								
I&A	187	415	667	244	494	756	916	
OM&R	7	10	12	7	10	12	13	
POWER	<u>86</u>	<u>242</u>	<u>400</u>	<u>106</u>	<u>265</u>	<u>404</u>	<u>505</u>	
	280	667	1079	357	780	1172	1434	
DIVIDED BY A-F								
DELIVERED	288	229	222	367	321	302	295	
<u>20 YEAR CONSTR.</u>								
I&A	232	514	827	303	611	936	1134	
OM&R	7	10	12	7	10	12	13	
POWER	<u>86</u>	<u>242</u>	<u>400</u>	<u>106</u>	<u>265</u>	<u>404</u>	<u>505</u>	
	325	766	1239	416	901	1352	1652	
DIVIDED BY A-F								
DELIVERED	334	263	255	428	371	348	340	

Cost Curve Utilization

The cost curves (Figures 6 and 7) as derived above were used to determine the investment costs and cost per acre-foot of water transfer systems to accommodate the maximum demand (3,404,000 acre-feet) and projected supply (1,615,000 acre-feet) of this study. The following are the investment costs (including IDC) and the annual costs for the selected water transfer systems:

Table 5 Annual Costs

TRANSFER SYSTEM ITEM	(COSTS IN \$ MILLIONS)			
	SOUTH ROUTE (CFS)		NORTH ROUTE (CFS)	
	1.615 MAFA 3,240 CFS	3.404 MAFA 6,830 CFS	1.615 MAFA 3,240 CFS	3.404 MAFA 6,830 CFS
<u>10 YEAR CONSTR.</u>				
<u>INVESTMENT COST (INCL IDC)</u>	2,910	5,380	3,980	7,350
<u>ANNUAL COSTS</u>				
I&A (.07381)	215	397	294	542
OM&R	8	11	8	12
POWER	<u>142</u>	<u>281</u>	<u>175</u>	<u>354</u>
TOTAL ANNUAL COST	365	689	477	908
<u>15 YEAR CONSTR.</u>				
<u>INVESTMENT COST (INCL IDC)</u>	3,570	6,520	4,870	9,050
<u>ANNUAL COSTS</u>				
I&A	263	481	359	668
OM&R	8	11	8	12
POWER	<u>142</u>	<u>281</u>	<u>175</u>	<u>354</u>
TOTAL ANNUAL COST	413	773	542	1,034
<u>20 YEAR CONSTR.</u>				
<u>INVESTMENT COST (INCL IDC)</u>	4,400	8,050	5,990	11,200
<u>ANNUAL COSTS</u>				
I&A	325	594	442	827
OM&R	8	11	8	12
POWER	<u>142</u>	<u>281</u>	<u>175</u>	<u>354</u>
TOTAL ANNUAL COST	475	886	625	1,193

The investment costs, annual costs (with and without energy) and the cost per acre-foot of water delivered to the terminal storage is itemized in the pertinent data sheet (Appendix A). The annual costs with projected energy costs (Year 2005-29.72 mils, Year 2105-49.17 mils) are shown in Figure 8.

Multipurpose Opportunities

This reconnaissance level report addresses only the water transfer costs. Opportunities exist throughout the system to incorporate related benefits which could help justify the systems costs. Flood control could be included in conjunction with the source and terminal reservoirs. Recreation and fish and wildlife benefits at the reservoirs and trail systems along the canals could also be considered. Municipal and industrial water supply as well as supplemental wildlife water supply (Cheyenne Bottoms) are very probable opportunities along the transfer route.

Other Water Source Options

For the purpose of this report, only the Missouri River was considered as a source for water transfer. The opportunity exists to obtain a part of the water supply from existing reservoirs, other rivers encountered along the way, drainage area runoff into the source and terminal reservoirs, and the possibility of constructing water supply reservoirs along the transfer route. Any water supply obtained along the route would lessen the demand from the Missouri River and reduce the pumping costs.

Technological Advances

Power for the pumping plants for this study is expected to be fossil fuel generated electricity. The high plains region has an abundance of wind and sunshine, both of which are currently experiencing concentrated research as potential competing energy sources. Future costs of water transfer in this region could be greatly affected by significant breakthroughs in these fields.

Conclusions

This reconnaissance level study shows the estimated cost of transferring water from the Missouri River to western Kansas. Two possible routes for Alternative B are designed and estimated, with the south route being less expensive to build and operate. The area of water need will enter into the decision of terminal site location. The current criteria of water use and projected depletions of the Missouri River limit the amount of water available for transfer: 3,404,000 acre-feet demand at the farm headgate with the projected capability by 2020 of providing only 1,615,000 acre-feet in 50 percent of the years.

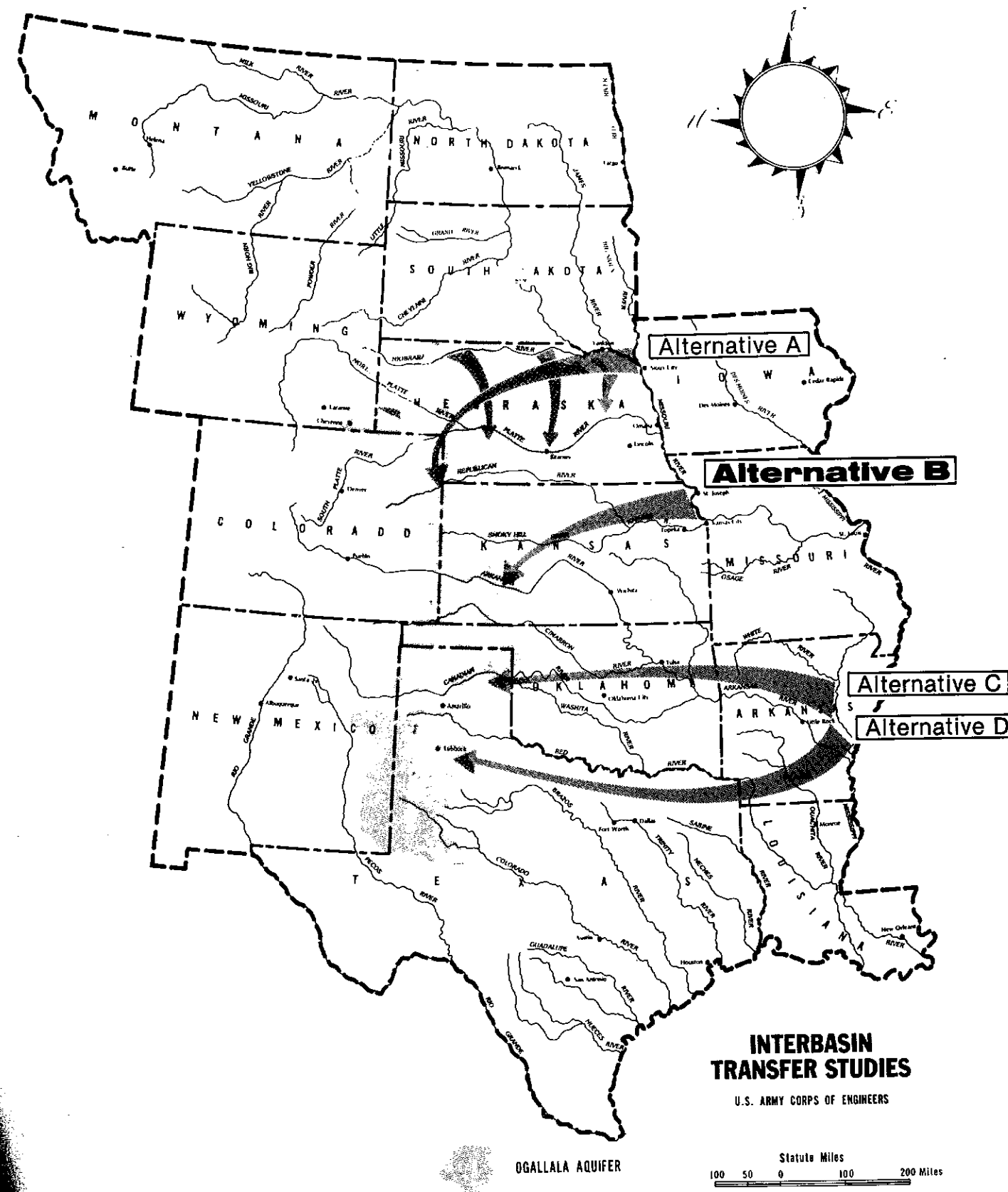


Figure 1. VICINITY MAP

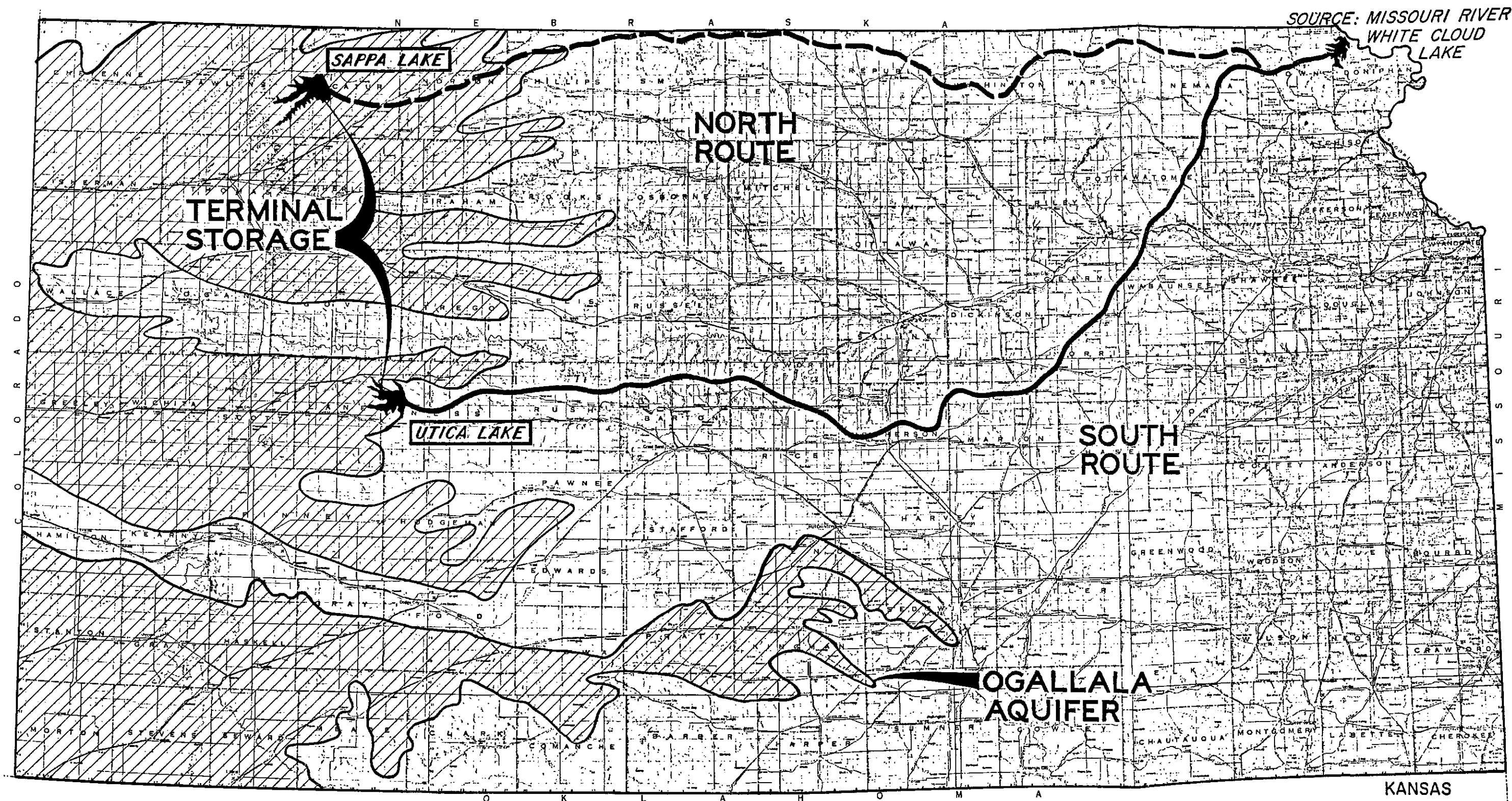
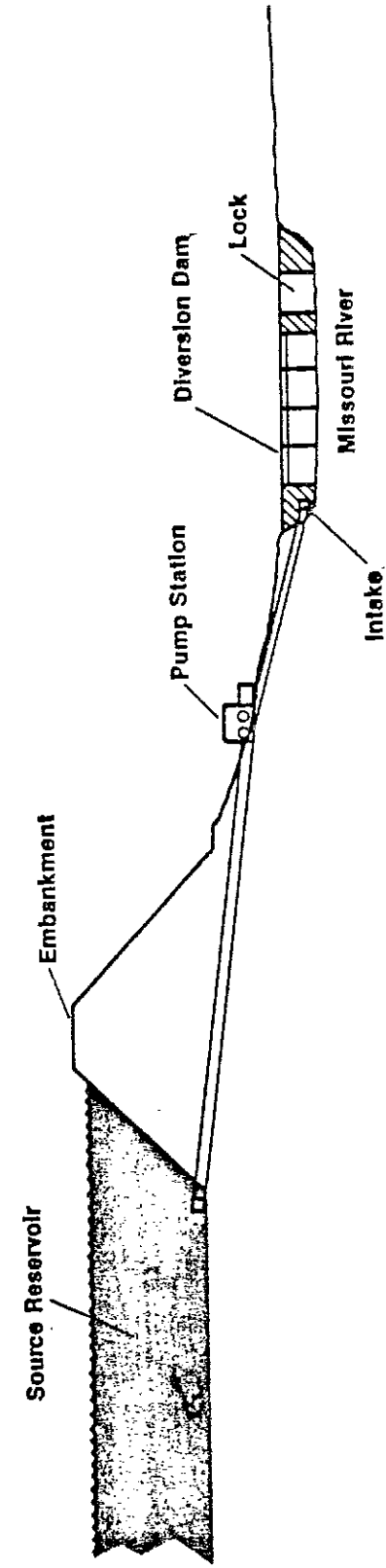
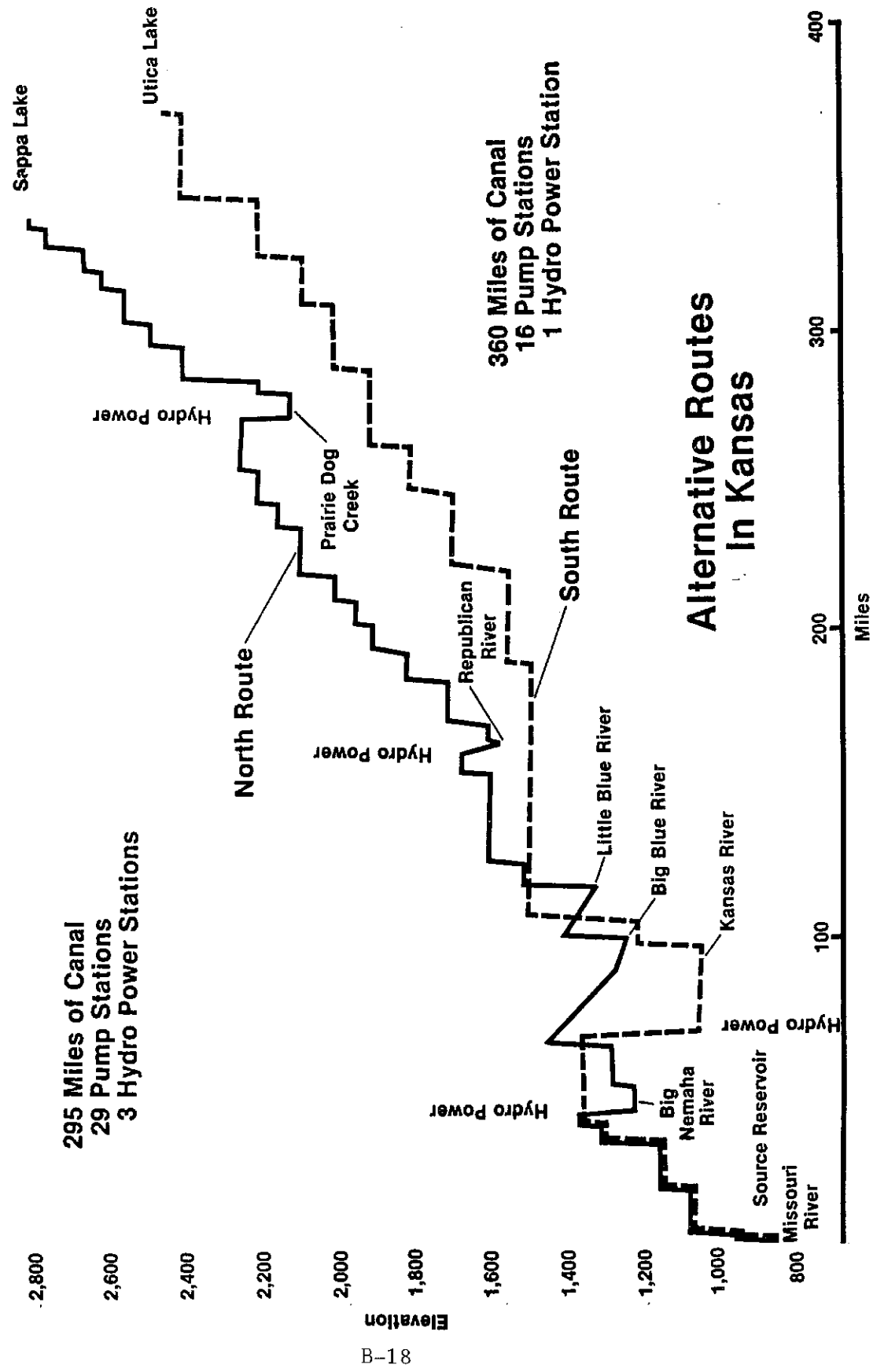


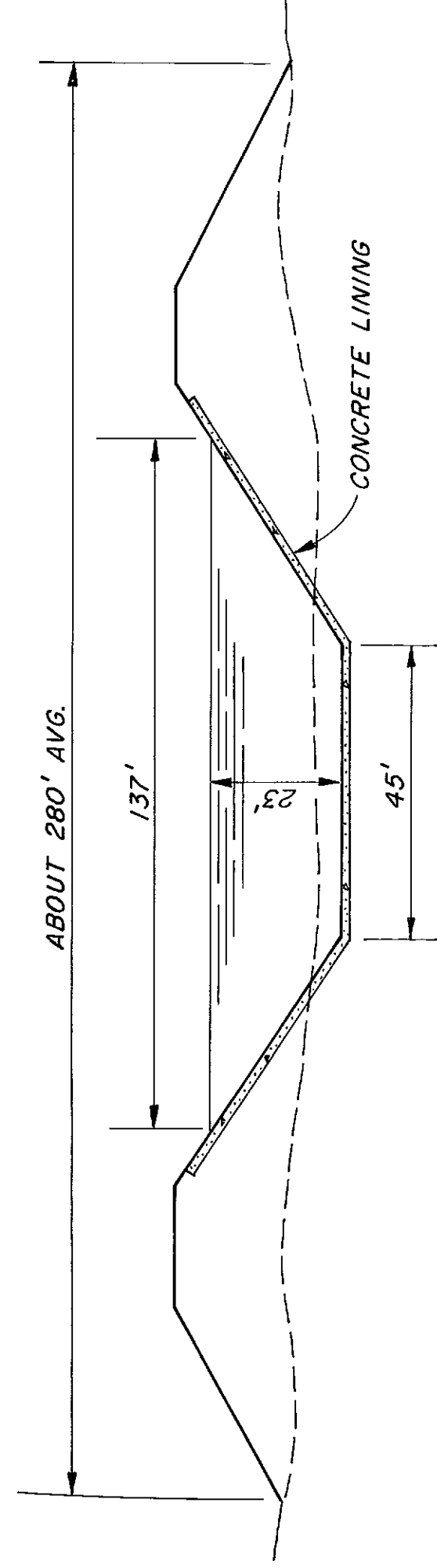
Figure 2
LAYOUT OF TRANSFER ROUTE
ALTERNATIVE B--HIGH PLAINS STUDY



Source Features



B-18



B-19

6,830 C.F.S. CANAL

FIGURE 5 - TYPICAL CANAL DESIGN

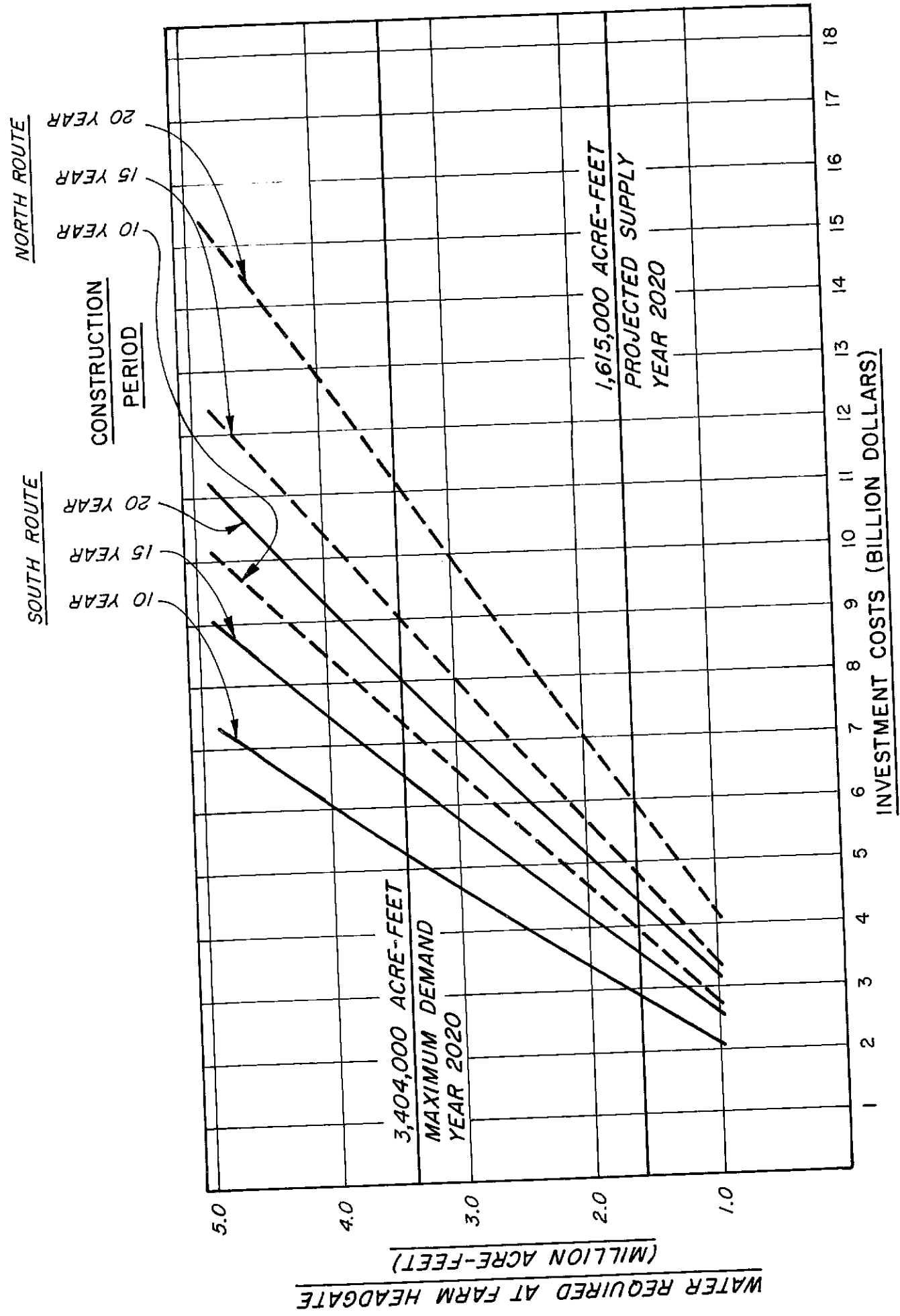


FIGURE 6

WATER TRANSFER SYSTEMS COST

1977 PRICE LEVEL - KANSAS CITY DISTRICT - CORPS OF ENGINEERS

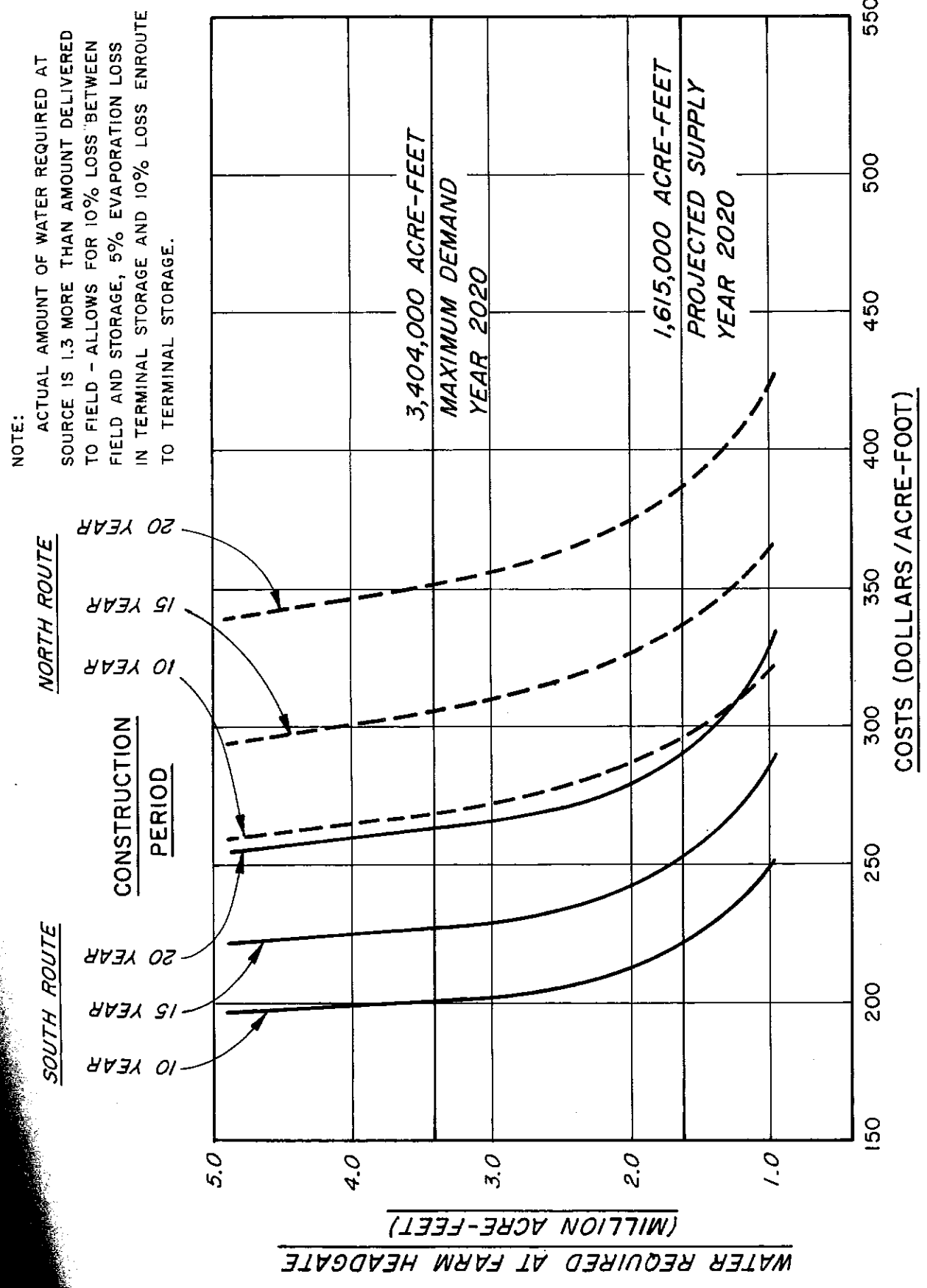
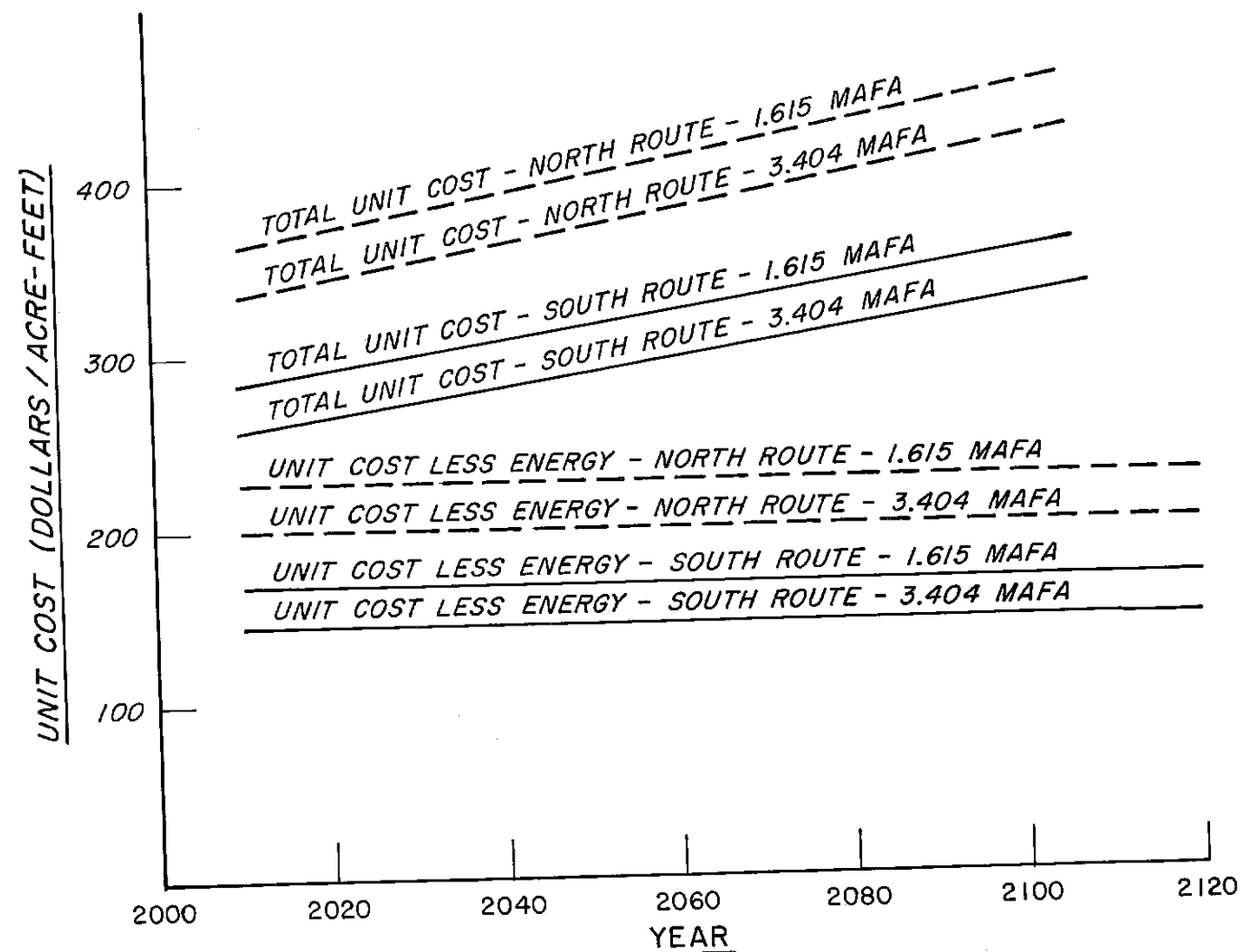


FIGURE 7

COST OF WATER DELIVERED TO TERMINAL STORAGE

1977 PRICE LEVEL - KANSAS CITY DISTRICT - CORPS OF ENGINEERS



NOTE:
COSTS REFLECT 15-YEAR
CONSTRUCTION PERIOD.

ANNUAL COSTS WITH PROJECTED ENERGY COSTS
KANSAS CITY DISTRICT - CORPS OF ENGINEERS

APPENDIX A

PERTINENT DATA SHEET

HIGH PLAINS OGALLALA AQUIFER

ROUTE B

Route B transfers water from the Missouri River North of St. Joseph, Missouri to the Ogallala Aquifer in western Kansas. Two routes were studied to accomplish this task--a North Route and South Route. A maximum annual demand (3,404,000 acre-foot) and a projected annual supply (1,615,000 acre-foot) provide a range of cost.

A. Source

Missouri River near White Cloud, Kansas

B. Quantity

1. 1.615 MAFA (Projected available supply)
2. 3.404 MAFA (Maximum demand)

C. Canal

1. Length
 - a. North Route - 293.71 Miles
 - b. South Route - 359.28 Miles
2. Lined (Concrete)
3. Slope
 - a. .58 Ft/Mile (3240 CFS Canal)
 - b. .20 Ft/Mile (6830 CFS Canal)

4. Freeboard

- a. 4.5 Feet (3240 CFS Canal)
- b. 5.0 Feet (6830 CFS Canal)

5. Shape (Trapezoidal)

6. Width (Toe to Toe)

- a. 175 Feet (3240 CFS Canal)
- b. 280 Feet (6830 CFS Canal)

7. Depth

- a. 14 Feet (3240 CFS Canal)
- b. 23 Feet (6830 CFS Canal)

D. Pumping/Hydro Plants

1. Number

- a. 29/3 (North Route)
- b. 16/1 (South Route)

2. Lift/Drop (Feet)

- a. 1965/309 (North Route)
- b. 1745/293 (South Route)

3. Design Pumping/Generation Capacity

- a. 3240 CFS (1.615 MAFA Transfer)
- b. 6830 CFS (3.404 MAFA Transfer)

E. Dams

1. Source (1)

- a. Proposed White Cloud Reservoir
 - (1) Storage (700,000 AF)
 - (2) Base flow of Missouri River

Navigation Season - 40,000 CFS

Non-Navigation Season 15,000 CFS

(3) Land (18,850 Acres)

(4) Elevation (Full Pool) 1000 MSL

2. Terminal

a. North Route

(1) Sappa Creek Reservoir

(a) Storage

For 1.615 MAFA Transfer - 759,650 AF

For 3.404 MAFA Transfer - 1,586,000 AF

(b) Land

For 1.615 MAFA Transfer - 23,800 Acres

For 3.404 MAFA Transfer - 39,200 Acres

(c) Elevation (Full Pool) 2750 MSL

b. South Route

(1) Utica Lake Reservoir

(a) Storage

For 1.615 MAFA Transfer - 759,650 AF

For 3.404 MAFA Transfer - 1,586,000 AF

(b) Land

For 1.615 MAFA Transfer - 23,000 Acres

For 3.404 MAFA Transfer - 35,500 Acres

(c) Elevation (Full Pool) 2610 MSL

F. Siphons

1. North Route(5)

- a. Big Nemaha River
- b. Big Blue River
- c. Little Blue River
- d. Republican River
- e. Prairie Dog Creek
- 2. South Route (1)
 - a. Kansas River
- 3. Total Lengths
 - North Route - 42.94 Miles
 - South Route - 16.50 Miles

G. Lands

1. North Route

- a. 1.615 MAFA Transfer (66,360 Acres)
 - (1) Reservoirs 42,650 Acres
 - (2) Canal/Conduit 23,565 Acres
 - (3) Pumping Plants 145 Acres
- b. 3.404 MAFA Transfer (91,860 Acres)
 - (1) Reservoirs 58,050 Acres
 - (2) Canal/Conduit 33,665 Acres
 - (3) Pumping Plants 145 Acres

2. South Route

- a. 1.615 MAFA Transfer (68,235 Acres)
 - (1) Reservoirs 41,850 Acres
 - (2) Canal/Conduit 26,305 Acres
 - (3) Pumping Plants 80 Acres

- b. 3,404 MAFA Transfer (92,010 Acres)
 - (1) Reservoirs 54,350 Acres
 - (2) Canal/Conduit 37,580 Acres
 - (3) Pumping Plants 80 Acres

H. First Cost + IDC (7 3/8 % Interest, 1977 Prices)

	1.615 MAFA	3.404 MAFA
1. North Route		
a. 10 Year Construction Period	\$3,980,000,000	\$7,350,000,000
b. 15 Year Construction Period	\$4,870,000,000	\$9,050,000,000
c. 20 Year Construction Period	\$5,980,000,000	\$11,200,000,000
2. South Route		
a. 10 Year Construction Period	\$2,910,000,000	\$5,380,000,000
b. 15 Year Construction Period	\$3,570,000,000	\$6,520,000,000
c. 20 Year Construction Period	\$4,400,000,000	\$8,050,000,000

I. Annual Cost w/o Energy (I&A, O&M&R - 1977 Prices)

	AMOUNT TRANSFERED	
	1.615 MAFA	3.404 MAFA
1. North Route		
a. 10 Year Construction Period	\$302,000,000	\$554,000,000
b. 15 Year Construction Period	\$365,000,000	\$680,000,000
c. 20 Year Construction Period	\$454,000,000	\$839,000,000
2. South Route		
a. 10 Year Construction Period	\$223,000,000	\$408,000,000
b. 15 Year Construction Period	\$271,000,000	\$492,000,000
c. 20 Year Construction Period	\$333,000,000	\$605,000,000

J. Annual Energy Cost (.02269 \$/kWh - 1977 Dollar Value)

	<u>TOTAL COST</u>	<u>COST/AF</u>	<u>TOTAL HEAD(FT)</u>
1. North Route			
1.615 MAFA Delivered	\$174,800,000	\$106	2918
3.404 MAFA Delivered	\$354,200,000	\$104	2786
2. South Route			
1.615 MAFA Delivery	\$141,600,000	\$88	2326
3.404 MAFA Delivery	\$281,800,000	\$83	2210

K. Cost per Acre-Foot Water Delivered to Terminal Storage.

1. North Route

a. With Out Energy	1.615 MAFA Del.	3.404 MAFA Del.
(1) 10 Year Construction Period	\$187	\$163
(2) 15 Year Construction Period	\$227	\$200
(3) 20 Year Construction Period	\$281	\$246
b. With Energy (Total Cost)		
(1) 10 Year Construction Period	\$295	\$267
(2) 15 Year Construction Period	\$335	\$304
(3) 20 Year Construction Period	\$389	\$350

2. South Route

a. With Out Energy		
(1) 10 Year Construction Period	\$138	\$120
(2) 15 Year Construction Period	\$168	\$145
(3) 20 Year Construction Period	\$206	\$178

b. With Energy (Total Cost)

(1) 10 Year Construction Period	\$226	\$202
(2) 15 Year Construction Period	\$255	\$227
(3) 20 Year Construction Period	\$294	\$260

APPENDIX B
ENVIRONMENT ASSESSMENT
HIGH PLAINS OGALLALA AQUIFER STUDY

Introduction

The High Plains Ogallala Aquifer Study is a program directed by the Department of Commerce to study the depletion of the Ogallala Aquifer and develop plans to increase water supplies in that area. As part of this program, the Corps of Engineers has been directed to conduct reconnaissance studies involving the transfer of water to the High Plains regions. The Kansas City District is charged with investigating two routes to divert water from the Missouri River to an interbasin transfer lake in western Kansas. The US Fish and Wildlife Service assisted in determining the environmental impacts.

The south route covered in this assessment follows westerly from the Missouri River in Doniphan County to eastern Nemaha County, southwesterly to the town of Canton in McPherson County, then westerly across northern Barton, Rush, Ness, and Lane County where it terminates at Utica Lake, a reservoir to be constructed (Figure B-1).

The north route follows a more direct westerly course; with its position remaining solely in the most northern tier of Kansas counties. This route utilizes a portion of the south route and diverts westerly in Nemaha, Marshall, Washington, Republic, Jewell, Smith, Phillips, Norton, and terminating in Decatur County at a yet to be constructed reservoir called Sappa Lake.

BOTANICAL ELEMENTS

A. South Route - Major Plant Communities

General. The names of the plant communities addressed in this section basically follow those of Owensby (Launchbaugh, J.L., and C.E. Owensby, 1978, "Kansas Rangelands: Their Management Based on a Half Century of Research." Kansas Agr. Exp. Sta. Bul. 622. 52p.). These plant communities are a composite of the natural vegetation that once existed in Kansas prior to the introduction of agricultural and industrial technology. The only plant community in this region which remains essentially unaltered from earlier times is the Flint Hills Prairie located in the eastern third of the state. All other vegetative communities have been drastically altered by land-use changes, some so significantly that they can only be distinguished by careful analysis of subsoils.

Northeast Deciduous Forest. This plant zone is heavily wooded with oak (Quercus sp.) and other hardwoods such as hickory (Carya sp.). Agricultural use of this area is limited to those sites where trees have been removed and grasses or legumes introduced. The soils in this zone suitable for cultivation are fairly deep, cherty silt loams over silty clay loam subsoils. An impervious clay layer underlies the above mentioned layers.

Northern Floodplain Forest. This plant community is found along all the large and medium sized rivers in the eastern half of the state. Cottonwood (Populus sp.), willow (Salix sp.), and elm (Ulmus sp.), typify the vegetation found in this habitat. The soils within these areas consist of alluvial material. Cultivation is restricted to the narrow flood plains where grain sorghum (Sorghum sp.), wheat (Triticum aestivum), and hay are the prevalent agricultural crops.

Eastern Subhumid Prairie. A major component of this plant community is the Flint Hills Prairie (see Unique Areas). The majority of this land is native prairie and used for livestock grazing. Area subsoils contain massive limestones, interbedded gray to dark shales and highly flinty and cherty limestones (Lugan, H.D. and T.D. Galloway, 1975. "The Future of Kansas: A Working Document." The University of Kansas, Lawrence, Kansas). The upland soils are less than 10 inches deep and composed of a silty clay loam over a claypan-like subsoil.

Central Dissected Prairie. Three-fifths of this vegetative community is in cultivation with the balance in pasture. The typical native grasses in this region are grama (Bouteloua sp.) and bluestem (Andropogon sp.). The topography of this dissected prairie varies considerably with large areas of land containing rolling ridge tops and sharply sloping sides.

Dakota Sandstone Prairie. Bluestem and grama are typical of the native grasses in this vegetative community. Because of steep, rough, and broken terrain, agriculture is also limited. Most of the rivers and valleys of this region are deeply entrenched. The area is a strongly dissected plain with large areas of rough broken hilly land.

Marsh Prairie. The characteristic vegetation in this plant community is saltgrass (Distichlis sp.), bulrush (Scirpus sp.), and sacaton (Sporobolus sp.). This unique community is found in a number of areas in Kansas, although its presence is rapidly disappearing as a result of various land-use practices. Invariably, this community has resulted from a low-lying area which collected water and later exhibited wetland characteristics. Many of the areas in this community have no special significance, however, some are unique and contain the appropriate water quality and soils to support plant and animals which are becoming less common in Kansas.

High Plains Prairie. The native vegetation in this area is characterized by blue grama (Bouteloua gracilis) and buffalograss (Buchloe dactyloides). Three-fifths of these lands are in ranches and farms. The soils of this region are deep loess sands or silts.

Xeric Sandhills Prairie. A thin stand of vegetation typified by bluestem, sandsage (Artemisia filifolia), and sandreed (Calamovilfa sp.) occupies the sandhills prairie. This area encompasses a strip of land south of the Arkansas River containing many hummocks and dunes, with little or no surface drainage. Numerous "blowouts" and bare shifting dunes occur in the area.

B. North Route - Major Plant Communities

General. The north route contains the same plant communities as described for the south route with one addition, the Loess Breaks Prairie. This area supports such native plants as blue grama, western wheatgrass (Agropyron smithii), and bluestem. Winter wheat is the main crop under dry land conditions. Like the High Plains Prairie, the Loess Breaks Prairie is an area containing deep wind-deposited sands or silts.

THREATENED AND ENDANGERED SPECIES

A. Plants

No plants in Kansas are on the current (20 May 1980) Federal Listing of Threatened and Endangered Plants. The followings, however, are plants which are considered rare in Kansas (McGregor, R.L. 1977. "Rare Native Vascular Plants of Kansas." State Biological Survey, Technical Publication No. 5, 44 p.) and which have been collected in counties traversed by the channel alignment(s) (Table 1). While the exact location of the extant populations and channel may not overlap in the final analysis, those "affected" counties are also listed in Table 1.

Table 1. Rare Native Vascular Plants of Kansas

Common Name	Scientific Name	County	Route
Fern	<u>Woodsia oregana</u>	Doniphan	Both
White Baneberry	<u>Actaea alba</u>	Doniphan	Both
Red Baneberry	<u>Actaea ruba</u>	Doniphan	Both
Early Meadow Rue	<u>Thalictrum dioicum</u>	Doniphan	Both
Blue Cohosh	<u>Caulophyllum thalictroides</u>	Doniphan	Both
Rock Elm	<u>Ulmus thomasi</u>	Doniphan	Both
Terrestrial Star-wort	<u>Callitriche terrestris</u>	Doniphan	Both
Broadleaf Goldenrod	<u>Solidago flexicaulis</u>	Doniphan	Both
Southern Blue Flag	<u>Iris shrevei</u>	Doniphan	Both
Cow Parsnip	<u>Heracleum sphondylium</u> var. <u>montanum</u>	Brown	Both
Jacob's Ladder	<u>Polemonium reptans</u>	Brown, Doniphan	Both
Agrimony	<u>Agrimonia gryposepala</u>	Marshall	North
Eriogonum	<u>Eriogonum effusum</u> var. <u>rosmarinoides</u>	Lane	South

B. Fish

Though no threatened or endangered fish species are known within the project area, the State of Kansas lists two threatened species which may be affected by the project construction. These species are: the Topeka shiner (Notropis topeka) and blue sucker (Cycoreptus elongatus).

The planned intake structure including a lock and dam system could have a negative impact on the blue sucker. Specimens of this species have been taken from the mainstem of the Missouri River within the last 10 years. Intake velocities could result in the entrainment and impingement of adult fish or adversely affect its general life history.

The Topeka shiner (Notropis topeka), classified by the State of Kansas as threatened, is the only threatened fish species within the area of the south route channel alignment. This species is gone from Shunganunga Creek near Topeka, and from much of its former range in the Kansas River System west of the Flint Hills Prairie. The only place in the entire Arkansas River system where this species can be found is in the headwaters of the South Fork of the Cottonwood River. Construction of the south route channel, located on the ridgetops, may affect this species if soil erosion from the construction reached the South Fork. The north route of the transfer study does not appear to impact any currently known threatened or endangered fish species on either the Federal or state listing.

C. Birds

Federal List

The bald eagle (Haliaeetus leucocephalus) winters in substantial numbers in Kansas, predominantly around rivers, lakes and reservoirs, usually in association with large waterfowl concentrations. It is anticipated that construction of either the north or south diversion alignments would not adversely affect the bald eagle.

The peregrine falcon (Falco peregrinus) occasionally winters in Kansas. A few sightings of this falcon are reported each year during their spring and fall migrations, but data are insufficient to estimate population status in the state. It is anticipated that construction of either diversion alignment would not adversely affect these birds during their migratory period.

Whooping cranes (Grus americana) annually migrate through Kansas during the spring and fall, but do not remain. Usually the large marshy areas in the western two-thirds of the state are used by those cranes during migration. Diversion channel construction could have a minor effect on these birds during their migration if active construction were occurring close to their rest stops along the south route alignment at Cheyenne Bottoms. The planned south route at its closest location, is 10-15 miles from Cheyenne Bottoms.

State List

Prairie falcon (Falco mexicanus). This migratory falcon comes to Kansas in the fall and remains until the following spring. There is some indication based upon summer sightings, that these birds may nest in Kansas. Neither route alignment would significantly affect these birds during their winter stay.

Least tern (Sterna albifrons). This tern nests in Kansas on river sandbars, soft flats, and exposed sandy areas. Least terns arrive in the state in the spring and leave between August and September. The diversion channel routes could affect these birds in areas where the construction crosses rivers.

D. Mammals

The only mammal of concern in the project area, is the black-footed ferret (Mustela nigripes). Though a federally-listed endangered species, the most recent Kansas record was a sighting in 1957. Either planned canal route will not impact this species.

WETLANDS

Although both south and north routes may not affect any major wetlands, these unique ecosystems in Kansas are steadily declining in number and size. Reduction of state wetlands has increased rapidly during the past 30 years with most losses attributed to the draining of private lands. State and Federal wildlife agencies have preserved some excellent wetlands in Kansas. Examples of these areas include Cheyenne Bottoms in Barton County and the Republican Waterfowl Management Unit in Republic County.

CULTURAL RESOURCES - (Both Routes Discussed)

A review of archeological and historical sites listed in the National Register of Historic Places, and supplements thereto, indicated that no listed or eligible sites would be disturbed by either route alignment.

No specific cultural resources investigations have been conducted to date along the diversion alignments; therefore, some as yet undiscovered sites or properties could be impacted by either route. It will be necessary to conduct cultural resources investigations to locate any sites that may be impacted if, and when an alignment is selected.

ENVIRONMENTAL CONSEQUENCES

A. Intake Area

Although no Federal or state designated fish and wildlife area, refuge, or public hunting area would be directly affected, the construction and operation of an intake structure may result in the entrainment and impingement of fish by intake velocities, which could vary between 4,000 cubic feet per second (c.f.s.) and 20,000 c.f.s. This velocity would affect the mobility, life stages, and impart certain physiological stress (e.g. oxygen concentration, temperature differences, currents, etc.) on the life stage of fish. Other environmental effects would result from the presently unconstructed intake storage facility known as White Cloud Lake. This lake would require approximately 19,000 acres to be purchased in fee, i.e. 13,000 acres of water; 6,000 acres of land, and would be located in northeast Doniphan County near White Cloud, Kansas. Construction of White Cloud Lake would inundate an area containing scenic high loess bluffs and heavily dissected drainage valleys mantled with an oak-hickory forest. Except for a few narrow ridgetops and terraces bordering the Missouri River, the topographical features of most of the area are too rough to be successfully farmed; therefore, the area contains significant terrestrial wildlife habitat.

Although 13,000 acres of terrestrial habitat would be eliminated, these acres would be supplanted by a equivalent number of aquatic acres. This ecosystem change would result in a large reduction of faunal and floral diversity.

B. Terminal Storage Area

Sappa Lake is the proposed terminal storage facility for the north route while Utica Lake would receive storage from the south route. Each of these lakes would be sized according to the annual amount of water for which the delivery system is designed. The range in size of the terminal storage lakes would require fee acquisition of from 23,000 acres (15,800 surface acres; 7,200 land area) to 39,200 acres (27,600 surface acres; 13,200 land area) of predominantly private land.

In a region of western Kansas where terrestrial wildlife habitat is at a premium, and primarily relegated to the narrow stream borders, removal of between 15,800 and 33,000 acres would have a major negative impact on terrestrial wildlife species such as mule deer (Odocoileus hemionus) and white-tailed deer (O. virginianus). The negative impacts of the western storage reservoirs could be ameliorated by development and management of wildlife areas adjacent to the lake shore. Management of the upper reaches of most Kansas impoundments has provided excellent wildlife cover, increasing the carrying capacity of many wildlife species in the drainage when compared to preproject conditions. In the midst of an agricultural "desert" in western Kansas, reservoir associated terrestrial wildlife cover is an "oasis" for fauna.

C. Canal Right-of Way

Either canal would have an adverse environmental impact on the mammal movements in the area. The fenced canal would effectively be an impregnable barrier along its entire length, the exceptions being small areas adjacent to the canal's siphons and lift pumps. Random population movements of such mammals as furbearers (raccoon, coyote), small game (rabbits, squirrels), and big game (mule and white-tailed deer) would be restricted once the canal was constructed.

Either water transfer route, with the inclusion of the storage lakes, would also have a negative impact on agriculture throughout its entire length. The south route, 376 miles long, would remove between 26,300 and 37,600 acres of private land from production, depending upon which channel size is selected. The north route, 337 miles long, would remove between 23,600 and 33,700 acres from agricultural production.

UNIQUE AND/OR SENSITIVE AREAS

A. South Route

There is little doubt that during and long before Spanish explorations into Kansas took place, the tall grass prairie covered vast areas that stretched from Texas to Canada. Presently only small tracts of this unique plant community remain. The only one Kansas remnant that is still of relatively good size is called the Flint Hills Prairie, a 30-mile wide band of native grassland which extends along a north-south line in the eastern part of the state.

The Flint Hills Prairie is an important and unique resource supporting numerous species of grasses and forbs which are important to the livestock industry. Forbs add much to this prairie community by providing an extraordinary number and variety of wildflowers. In addition to the plants within this community there are a wide variety of faunal species present, some of which are principally found only in grasslands (e.g. grasshopper sparrow - Ammodramus savannarum).

The Flint Hills Prairie remains essentially intact because much of the area contains a shallow topsoil underlain by a limestone which makes plowing difficult. This geological preservation is of special significance since nowhere in the United States is there an area of tall grass prairie comparable in size and character to the native Flint Hills Prairie.

This prairie is more than a landscape with grasses and forbs; it is a unique area which has evolved as an area that requires no irrigation or fertilization, yet is productive and contains some of the best livestock grazing range in the United States.

AREAS OF INTEREST

A 10-mile wide belt (5 miles on each side of the channel) was superimposed over each of the channel routes. This "area of influence" was used to determine the possible effects the channel routes could have on the adjacent refuges, preserves, and management area.

A. Large Mammal Preserve

The Maxwell Game Refuge, a 2,254-acre refuge located in east-central McPherson County, would be approached within 2 to 3 miles by the south route channel alignment. The predominant animals protected on this refuge are bison (Bison bison) and elk (Cervus canadensis). The north route does not contain such a large mammal refuge.

B. Other Wildlife Refuges, Preserves, Management Areas

The following management areas may be affected by the north route: Norton Game Management Area (Norton County) and Lovewell Game Management Area (Jewell County). These areas are located adjacent to large Federal lakes and are managed for a variety of wildlife.

The south route will not approach any management area within the predetermined 10-mile width.

The first few miles of the channel could affect Brown County State Lake. This 189-acre lake, located in eastern Brown County, is an important waterfowl staging area during the fall migration. Thousands of geese and ducks use this lake during this period.

C. Scenic Drives

A National Scenic Roads and Parkway Study conducted in 1965 identified 28 scenic drives in the United States. In 1974, the National Scenic Highway Study was undertaken to determine the feasibility of establishing a national system using the above scenic drives. Within Kansas, the following designated scenic drives would be directly affected by channel construction.

Both Routes. Northwest Doniphan County contains a scenic drive which begins at the west juncture of US-36 a K-7 at the town of Sparks. This scenic drive is generally adjacent to the banks of the Missouri River following K-7 northwest to the city of White Cloud. West and south of White Cloud lies a rolling, tree-covered glaciated landscape often referred to as the "Kansas Switzerland."

South Route. There are one scenic drive and one Prairie Parkway Drive which together traverse portions of eastern Kansas. The Prairie Parkway Drive, the longest scenic drive in the state, begins on the Kansas-Oklahoma border (Chautauqua Co.) and terminates near Hanover, Kansas (Washington Co.). The drives traverse the rolling, native bluestem hills which are almost entirely devoted to livestock grazing.

The scenic drive, locally called the Mill Creek Skyline Drive, originates in southeast Riley County on highway K-177, meanders in a southeast direction through Alma, and terminates as it intersects highway K-4 near the Shawnee County line.

D. Areas of Subsidence or Collapse

South Route. Large areas in central and western Kansas are underlain with easily dissolved salt (sodium chloride) and gypsum (calcium sulfate) beds which can develop into sink holes. These sink holes usually slowly subside within a circular area and have been known to cause structural damage to bridges, buildings, roads, and pipelines. Except by extensive use of grout, little can be done to stop or slow the development of these unstable areas and their presence could adversely impact on a south route diversion channel.

North Route. There are no major areas of collapse located in the northern tier of Kansas counties.

E. River and Creek Crossings

South Route. The Kansas River is the only river valley that would be crossed by diversion channel construction. If this were the selected route, a large pipe or siphon would need to be provided which would carry water under or over the river. Creek valleys, such as Cedar Creek and Vermillion Creek would also need to be crossed by these methods.

North Route. River valleys crossed by this route includes the Big Nemaha River (South Fork), Little and Big Blue, and the Republican. Prairie Dog Creek and Cedar Creek presents additional crossings.

F. Fault Zones

Both Routes. Earthquakes have been reported in nearly every part of Kansas over the past century. Such disturbances have been rare and minor in nature although there is a likelihood of moderate intensity earthquakes in a broad north-south zone in east-central Kansas which includes the Manhattan area. Since there is a possibility of future earthquakes in these areas seismic studies should be conducted on the selected route alignment to determine the potential for damage to the diversion channel.

US FISH & WILDLIFE SERVICE REPORT

The US Fish and Wildlife Service provided an analysis of both the beneficial and adverse impacts to fish and wildlife resources based upon the two alternative canal/reservoir systems proposed by the Kansas City District Corps of Engineers. The USFWS report is on file in the Kansas City District office. The major findings of the report were that the south route and reservoir would involve a lower overall loss of habitat units and that the south route, while impacting the native prairie of the Flint Hills region to a greater extent, offers a positive feature of supplying additional water to Cheyenne Bottoms

for migrating waterfowl management and preservation of the critical habitat for the whooping crane. The report provides a narrative analysis of various components of the alternative canal/reservoir-proposals and a comparative matrix which numerically displays the magnitude of beneficial and adverse impacts of each resource evaluated.

SUMMARY OF IMPACTS

<u>Botanical Elements</u>	<u>South Only</u>	<u>North Only</u>
Threatened and Endangered Plants (State)	(1) Eriogonum (See Table 1)	(1) Agrimony
<u>Biological Elements</u>		
Threatened and Endangered Fish (State)	(1) Topeka shiner	0
Terrestrial Wildlife		
Habitat Decrease		
Length of Canal/conduit	376 miles	337 miles
Length of Canal	Restricts mammal movement	Restricts mammal movement
Canal/conduit Right of way	26,300--37,600 ac	23,600--33,700 ac
Lakes Total land required	41,850--54,350 ac	42,650--58,050 ac
Lakes - Inundated	28,800--38,000 ac	29,500--40,600 ac
Aquatic Habitat Increase	28,800--38,000 ac	29,500--40,600 ac
<u>Unique and/or Sensitive Areas</u>	(1) Flint Hills Prairie	0
<u>Areas of Interest</u>		
Game Refuges, etc.	(1) Maxwell Game Refuge	(2) Norton Game Mngt Area - Lovewell Game Mngt Area
Scenic Drives	(3) See VII. B. Scenic Drives	
River Crossings	(1) Kansas River	(4) Big/Little Blue, Repub- lican, Big Nemaha River (South Fork)
Creek Crossings	(1) Cedar Vermillion	(2) Cedar Prairie Dog
Areas of Subsidence	Yes	No

Update of 1982 Six State High Plains Aquifer Study

Appendix 2: Scope of Study for Kansas Aqueduct
Study. January, 2014

APPENDIX A
SCOPE OF STUDY FOR
KANSAS AQUEDUCT STUDY

11152013

INTRODUCTION

The U.S. Department of Commerce conducted the Six-State High Plains-Ogallala Aquifer Regional Resources Study (also known as the “Six State” or “1982 High Plains Study”) which included an examination of a Missouri River water diversion and an aqueduct to western Kansas. Under the 1982 concept water would be diverted during Missouri River flows occurring over and above the navigation requirement, then be stored and transferred to western Kansas (and/or other western states) and eventually be used to help offset the rate of depletion occurring in the Ogallala Aquifer. The U.S. Army Corps of Engineers (USACE) Kansas City District assisted in the 1982 High Plains Study, as authorized by the Water Resources Development Act of 1976, by preparing the Reconnaissance Study for Water Transfer from the Missouri River to Western Kansas in September, 1982.

Under the Corps 1982 Reconnaissance Study, quantification of water availability was simplified through assumptions. Availability would occur when Missouri River flows exceeded the base flow established for navigation, i.e. “Withdrawals from the Missouri River would not be taken when the stream flow was equal to or less than an established navigation base flow.” Storage of the diverted water would take place in a source reservoir 35 miles upstream of St Joseph, Missouri, and would then eventually undergo aqueduct transfer 360 miles westward to a terminal reservoir in western Kansas to support aquifer recharge, crop irrigation and other beneficial water uses.

PURPOSE AND SCOPE OF STUDY

This PAS Study will be known as the “Kansas Aqueduct Study.” This PAS study will update certain components of the 1982 High Plains Study, especially those which directly relate to the water transfer routing plan in the original USACE-developed Water Transfer Element of the High Plains Study; and will specifically focus on the “Kansas Alternative B South Route” plan as described in that 1982 documentation. At that time, the “Kansas Alternative B South Route” had one of the lowest investment costs, the least expensive energy cost, the lowest unit cost (dollars per acre-foot) for water transfer, and the shortest transfer distance at 360 miles. The PAS study will evaluate a baseline condition and future conditions including, but not limited to, technical, legal, political, environmental, economic, and related planning characteristics of the “Kansas Alternative B South Route.” It is conceivable that this PAS study may proffer recommendations for additional study, if warranted, in order to better understand the risks, costs, and benefits of constructing the Kansas aqueduct.

The study is generally arranged into two groups of tasks: a) State of Kansas led tasks and b) Corps of Engineers led tasks. Schedules for the two task groups will overlap and selected tasks will be conducted concurrently.

- The State of Kansas will generally lead tasks related to the formation of a Stakeholder Advisory Committee and a legislative/political review and analysis of project feasibility. The State will oversee evaluation of the “Kansas Alternative B South Route” plan in terms of political acceptance at the local, state, and Federal level and the potential implications from a perspective of interstate and other water rights issues. The State will also lead analysis of potential project financing, water demand, environmental clearances (tasks 1, 2, 3, and 4) and provide support in the data collection and report preparation (tasks 8 and 9) .
- The Corps of Engineers will generally lead the tasks and supporting studies related to the technical and engineering aspects, economic benefits, and estimated project cost. The Corps will produce the documentation necessary to capture study findings, conclusions, and any forthcoming recommendations (tasks 5, 6,7 ,8, and 9).

Task 1 – Legislative Review

This task would provide a preliminary review to determine whether a Kansas Aqueduct concept conflicts with existing legislation such as the State Appropriation Act, as well as, interstate water compacts. This preliminary review may identify areas of potential conflict regarding the aqueduct that could warrant a more comprehensive review. The 1982 study did not address these water compact issues.

There may also be a need to investigate legislation that would be required for storing water in existing lakes and reservoirs along the aqueduct route. Legislation in the Pick Sloan Act and flood control will also need to be identified with relation to plans for aqueduct water transfer. Legislation related to water quality and potential impacts to streams along the aqueduct corridor will also be addressed here at a general level and in more detail in Task 4 Environmental Constraints.

Investigations will also be needed to determine the institutional options available to construct, operate, and maintain an aqueduct that has taxing and eminent domain authority.

Task 2 – Political Assessment and Stakeholder Coordination

A Stakeholder Advisory Committee would be formed comprised of individuals from communities located geographically within the Ogallala Aquifer study area and in areas along the proposed project route. Stakeholders selected would represent various use and interest categories such as city and county government, public utilities, industries, agriculture, and financial institutions. In addition to being involved in reviewing the findings from the technical, environmental, financial, and legal reviews, the committee would assist in identifying the other issues impacting the feasibility of the Kansas Aqueduct project. This task would also include interstate coordination regarding any water transfer plans developed under this study.

The Stakeholder Advisory Committee would be directly involved in the assessment of the project’s political acceptability and the potential project financing sources across the local, state

and federal levels. Examination of secondary uses of the transferred water to include wildlife water supply and other industrial and municipal purposes maybe be explored.

Landowners along the aqueduct corridor and in proximity to support infrastructure would be identified in the initial stages of this study and a database and communication plan will be developed to ensure communication of the status of the aqueduct planning process to this stakeholder group. This task will also address a methodology and develop an initial approach for identifying benefits and costs that would accrue to areas within the aqueduct corridor and the Kansas Ogallala Aquifer Region.

Task 3 – Water Demand Analysis

Water demand for both existing as well as new irrigation and other purposes in the region will be updated and forecasted to determine overall potential demand. Current water demand at all levels of industrial, residential, and in the agricultural sector would need to be identified and forecasted. Demand for agriculture use in addition to irrigation including dairies, swine, beef cattle production and other agricultural industries will also be identified. Existing and forecasted water demand from communities, i.e. Wichita, Hays, etc., located along the aqueduct corridor would also be determined in terms of future water needs for these communities.

A gap analysis would be developed based on the water availability and water demand forecast for all sectors along the Ogallala Aqueduct service area.

Task 4 – Environmental Constraints

Based on the study area configuration boundaries identified and facility characteristics developed in prior task, a broad-brush assessment will be made of the potential environmental concerns associated with the construction of the facility. National Environmental Policy Act, Section 404, jurisdictional waters determination, Historic Preservation Act Section 106 concurrence, and other environmental compliance will be addressed in terms of identifying initial regulatory requirements for the overall water transfer system.

The 1982 Ogallala Aquifer Study conducted an inventory of environmental constraints that can be updated in this current study. These updates may identify a need to modify the existing southern route alignment in order to avoid sensitive environmental resources.

Task 5 – Water Availability

This task will make estimates and projections of the amount of water available at flow levels over and above the Missouri River's navigation requirements. This would require analysis of USGS gages along the Missouri River. This analysis will estimate the potential amount of water available from the Missouri River at a water transfer diversion site upstream of St Joseph, Missouri (on the right bank near White Cloud, Kansas).

Estimates made in the 1982 study will be revised to reflect current conditions. The 1982 study estimated a range of potential transfer quantities from 1.615 million acre-feet annually (MAFA)

(projected available supply) to 3.404 MAFA (maximum demand) for the Kansas Alternative B South Route aqueduct system. New baseline data will require updating such factors as the holding capacity of system source reservoirs, size of the transfer feature (canal or aqueduct) and the capacity of the pumping system.

Task 6 – Water Transfer System and Alternative Features

The “water transfer system” is defined as source and terminal reservoirs and the actual conveyance aqueduct and any associated conveyance facilities. This task will be closely coordinated with task 4 and task 7 using an iterative review process.

Source Reservoir: The 1982 plan called for a lake 2.5 miles southeast of White Cloud, Kansas, with a design capacity of 700,000 acre-feet requiring a surface area of 13,000 acres and a land requirement of 19,000 acres for the entire feature. Required intake structures and all aspects of the operation of the lake will be taken into consideration for an analysis of alternative approaches to the 1982 report recommendation. Updated computer modeling in terms of water availability and water demand may require resizing and modifications to the design of the source reservoir. Alternatives to use of a reservoir will be evaluated.

Aqueduct and Associated Conveyance Facilities: The primary water transfer means proposed in the 1982 Kansas Alternative B South Route plan is an open aqueduct/canal with a trapezoidal, concrete -lined structure 137 feet across and 23 feet deep providing a capacity of 6,830 CFS and running for 360 miles westward with 16 pump stations and one hydropower station. A review will be made of the canal alignment and all features of that 1982 plan to determine impacts to farm land, transportation routes, cities, and wildlife habitat. Alternatives to a canal such as pipelines will be evaluated.

Terminal Reservoir: The terminal reservoir would store water at the end of the water transfer system until it is needed. The land requirements for the reservoir was based on typical seasonal irrigation water needs for the high plains region and would range between 23,000 to 35,500 acres of land to store water to meet seasonal demand.

Task 7 – Cost Estimates

Based on current study updates and the 1982 Kansas Alternative B South Route plan and any current modifications thereto, a new baseline cost estimate for the entire water transfer system will be developed. The cost estimate will include a breakout of all construction related costs, anticipated annual recurring costs for maintenance and repair of the overall system, and energy costs. A resulting cost per acre foot of water delivered will be calculated using appropriate availability and delivery factors. The cost estimate is considered a critical product for effective governmental decisions.

Estimate costs associated with potential environmental mitigation requirements will be developed. These mitigation requirements are developed under a separate environmental task item below. This will involve a variety of discussions at the local, state and federal level so as to

adequately identify these costs. Development of appropriate simplifying assumptions may be necessary.

Included within this overall task is the development of a cost estimate risk analysis which identifies those areas of significant project risk and the associated affects on projects cost uncertainty. Also develop risk mitigation strategies that may help reduce cost estimate uncertainties in the longer-term.

Task 8 – Field Data Collection, GIS Development and Base Mapping

This task would include any field data collection necessary to support the overall Kansas Aqueduct analysis and the mapping efforts needed for this PAS study. Available GIS information would be used to the extent available and practical during the development of base mapping for the identified study areas and the water transfer corridor. A GIS map will be prepared for the alignment and support facilities for the water transfer system to include existing topographical and man-made features which must be considered in the aqueduct routing analysis. User-friendly maps and associated geographically-based illustrations of key study concepts and findings are a critical product.

Task 9 Study Documentation, Reports and Support for Meetings

The results of this PAS study will be submitted in technical memorandums and a draft and final report. Technical memorandums and PowerPoint formatted slides will be used to present the study findings for individual tasks as they are completed in order to provide review and input as the study progresses through completion of tasks.

This task includes the necessary personnel and logistical support to accomplish effective in-progress and final presentations to the Kansas Water Authority, the stakeholder group, and various other presentation forums for interested parties. The Corps will work closely with the State of Kansas to set study meeting agendas.

LIMITATIONS

The current study will **not** address: hydropower potential, examination of water distribution systems supplying end-users from the terminal reservoir, multi-purpose benefit trade-off evaluation, NEPA-compliance documentation, nor detailed federal NED feasibility analysis.

PROJECT MANAGEMENT AND QUALITY CONTROL.

The Corps will manage this study in accordance with requirements for the Planning Assistance to States Program. The Corps will hold meetings with participants and technical elements to review progress, prepare budget information, and report on or discuss the progress of the study. The Corps will develop appropriate quality control plans and project management information and reports as required by Corps guidance for effective product development, scheduling, and project programming actions. This task includes Corps technical contract oversight and administration if and when contract support is needed.

STUDY BUDGET AND SCHEDULE ESTIMATES.

As required by Federal law, a non-Federal Sponsor must bear an equal share of the cost of this PAS study. It is estimated that the study would require 12 to 18 months to complete. The total cost of the study will not be increased without the mutual approval of the Sponsor and the Corps of Engineers. The budget estimates for study tasks are estimates subject to further adjustment after development of detailed labor and any architect-engineer contract cost requirements pursuant to the Agreement. The study cost estimate and matrix of task responsibilities is shown in Appendix B.

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**APPENDIX B
COST ESTIMATE**

**COST SHARING AGREEMENT FOR PLANNING ASSISTANCE
BETWEEN THE U.S. ARMY CORPS OF ENGINEERS
AND THE KANSAS WATER OFFICE
FOR
KANSAS AQUEDUCT STUDY**

	COST
STATE OF KANSAS - Tasks 1-4	\$75,000
Task 1 – Legislative Review	
Task 2 - Political Assessment and Stakeholder Coordination	
Task 3 – Water Demand Analysis	
Task 4 - Environmental Constraints	
CORPS OF ENGINEERS AND AE FIRM Tasks 5-9	\$205,000
Task 5 - Water Availability	
Task 6 - Water Transfer System and Alternative Features	
Task 7 - Cost Estimates	
Task 8 - Field Data Collection, GIS Development and Base Mapping	
Task 9 - Study Documentation, Reports and Support for Meetings	
Project Management	\$20,000
TOTAL ESTIMATED PROJECT COSTS	\$300,000
TOTAL ESTIMATED FEDERAL COSTS (50%)	\$150,000
TOTAL ESTIMATED NON-FEDERAL COSTS (50%)	\$150,000
Cash	\$75,000
Work in Kind	\$75,000

Update of 1982 Six State High Plains Aquifer Study

Appendix 3: Members of the Aqueduct Study Stakeholder Committee and Notes from Meetings

Aqueduct Advisory Committee

Steve Cadue, Horton, KS

Raymond Flickner, Wichita, KS*

Greg Graff, Leoti, KS *

Jeffery Grossenbacher, Bern, KS

Randy Hayzlett, Lakin, KS *

Lou Hines, Colby, KS

John Kaufman, Shawnee, KS

Brad Loveless, Lyndon, KS *

Darci Meese, Lenexa, KS

Joe Pajor, Wichita, KS

Tim Rhodd, White Cloud, KS

Mark Rude, Garden City, KS

Clark Rusco, Great Bend, KS

Clay Scott, Ulysses, KS

Judy Wegener-Stevens, White Cloud, KS

* Kansas Water Authority Members

Meeting Notes
Kansas Aqueduct Study Stakeholder Committee Meeting
NRCS Training Center, Salina
January 21, 2015
10:00 am

Attendance: Raymond Flickner, Gregg Graff, Jeffery Grossenbacher, Brad Loveless, Joe Pajor, Mark Rude, Clark Rusco, Clay Scott, Judy Wegener-Stevens, Darci Meese, Tim Rhodd, Randy Hayzlett,

Staff:

Tracy Streeter, Earl Lewis, Diane Knowles, Margaret Fast, Erika Stanley, Katie Ingles - Kansas Water Office

Others: Alan Kelley, Iowa Tribe; Ken McCauley, Iowa Township, Doniphan County; Frank Taggart, landowner; Duane Schrag, citizen; Ken Lewis; Darrell Ditting, farmer; Donna Sullivan, Grass & Grain; Barth Crouch, PLJV; Dan Baffa; Kent Askren, Kansas Farm Bureau; Tim Boese, GMD 2; Orrin Ferril, GMD 5; Jason Norquist, GMD3; Bob Bacon and Harry Bozoian, Mo DNR; David Brenn, Ks Water Congress; Fred Jones, Garden City; Mike Corn, Hays Daily News

Introductions – Tracy called the meeting to order. Self-introductions of the committee were made. There were about 33 people in attendance.

Review of Executive Summary – Margaret Fast walked the committee through each section of the Executive Summary.

Introduction – no comments

Study Purpose and Authority

- Highlight more directly that this is not meant to be a prelude to design of a project
- Include David Pope Consulting, and his subcontractor Lee Rolfs, as contributor

Stakeholder Coordination

- Highlight GMDs

Missouri River Background – no comments

Water Demand – no comments

Water Availability

- Emphasize it is a very high level analysis
- Discussion of comparison with CAP actual down time record; assumptions in this study are higher, but consistency the 1982 parameters is the approach throughout this update

Water Transfer System – no comments

Preliminary Opinion of Probable Costs

- Elaborate on, or better explain the use of indices to update the costs from 1982
- Elaborate on interest over 20 year period change during the course of the study
- Discussion about concern that land costs we know are now higher; again, using consistent index
- Focus on the assumptions
- Be consistent on use of factors
- No costs included for legal or environmental
- Emphasize this is not planning a project

Review of Legal and Legislative Issues

- Question about the use of a legislative claim option such as used by California on the Colorado River Basin

Environmental Considerations

- Benefits possible for wildlife, wetlands

Preliminary Political Assessment

- Is there any discussion of possible positive benefits and supporters
- As is, project would put NE Kansas in position similar to SW
- Effect on county budgets

Conclusions and Recommendation for Future Study

- What is the path forward
- Create space to discuss the Missouri River with the other states

Advisory Committee Discussion:

- Concern expressed by tribal reps that the source reservoir would be a taking of homes, land and livelihoods; and impact on their water supplies. They have tried to operate sustainably and this could potential be harmful
- This led to discussion of what is the greater good, due compensation and trying to find win-wins
- Can we agree that we should move forward with a discussion on a compact with the other Missouri River state and discussion of Indian reserved water rights
- The Tribe is not comfortable being forced into having to quantify rights
- The ecosystem gets changed
- This whole study was a sneak attack because no one from Doniphan County was represented originally; no one from Ness county is on the committee
- This is the last meeting of the committee; the committee role now is to track, and follow, talk to reps as they see fit
- There was not a comprehensive legal or political review in the 1982 study

Other Public Comments

- Ken McCauley statement is attached to these notes
- Recharge is not quantified in this study as a source of supply
- How much energy will this take, where does it come from, how much is it
- This is a sneak attack
- Is there a matrix of benefits
- Do a better job with assumptions
- Impacts to local units is not included
- Vision does not recommend use of recharge only to be sustainable
- Back off corn; cost to produce, market and the inputs too high
- Corn can be grown at 6-8" but there is less yield
- Inputs – maximum yield may not be maximum efficiency
- What would it cost not to do a project
- We are in a natural transition; the technical part of the study update is done; will switch more into policy
- This committee was ad hoc to oversee the study. The study is now done.
- Stress this is only update of 1982 study, not a project for construction
- Identify challenges and factors for transfer of water around Kansas
- Take out demand along the way

What Happens Now?

- KWA meets on Jan 29. Will ask they accept the report
- We will not ask for adoption or agreement.
- We assume no consensus to go forward with THIS study
- We will provide copies, or notify key legislative committees the report is available; will overview with them if they want a hearing
- Tracy thanked the committee for their time and effort. The committee has completed their work.
- If needed the committee could be called on again.

Remaining Actions and Meetings

- January 29th KWA meeting
- Unknown if there will be any legislative hearings

Meeting Notes
Aqueduct Stakeholder Committee
November 14, 2013

Note: The Planning Assistance to State's contract had not yet been signed by the KWO and Corps. This meeting was to get input on the scope of work.

Attendance: Jeff Grossenbacher, Producer, Vice Chair, Missouri BAC ; Darci Meese, Water One of Johnson County (participated by phone); Brad Loveless, Westar Representative, KWA (participated by phone) ; Curtis Tobias, Kansas Water Authority, GMD 2 & 5 Representative; Joe Pajor, Wichita Representative ; Gregg Graff, Kansas Water Authority, GMD 1, 3 & 4 Representative; Mark Rude, Executive Director, GMD 3; Clay Scott, Producer, GMD 3 Board Member ; Lou Hines, Farmers and Merchants Bank, Colby; Randy Hayzlett, Kansas Water Authority, Representative of President of the Senate

Not in Attendance: Clark Rusco, Chair, Upper Arkansas BAC, Barton County Engineer; Steve Cadue, Chairman, Kickapoo Tribe in Kansas, Horton; John Kaufman, Leavenworth Water Department General Manager

Others in Attendance: Kate Wilkins-Wells, GMD 4; Jan King, GMD 1; Tim Boese, GMD 2; Jason Norquist, GMD3; David Brenn, Kansas Water Congress

Staff:

Earl Lewis, Diane Coe, Margaret Fast, Erika Stanley, Tracy Streeter - Kansas Water Office
Scott Gard - Kansas City District Corps of Engineers

1. Introductions – Self Introductions
2. Review Purpose of Committee – Earl reviewed the overall purpose and highlighted the update of the southern Kansas aqueduct route portion of the 1982 Corps of Engineers study, part of the larger Six State High Plains Aquifer Study.
3. Review 1982 study – Scott Gard overviewed the Planning Assistance to State study which is being used to support a state interest. The Corps had hired CDM to develop the water transfer component of the 1982 study. The study had looked at 4 routes; the south route is the only one being reevaluated in the current PAS. It should be noted that the Kansas south route is the shortest, cheapest, lowest energy and most efficient of the ones studied at the time.

Items of discussion:

- Variations on the original scope are covered in the SOW; i.e. alternates on route to small degree, orientation and terminal reservoir
 - Original did not consider dropping off water along the way
 - In response to a question, the study will identify the obstacles that will be encountered, social, environmental, and political.
 - This discussion segued into the next agenda item.
4. Review Scope of Work – in working through each task, each task was discussed and the following comments were captured.

Task 1

- Consider existing legislation aspect that may relate to dropping water off into existing water bodies – water quality, appropriations.
- Consider stream obstructions issues

- Consider institutional options to construct, operate, maintain an aqueduct that has taxing and eminent domain authority
- consider flood control aspects of Pick Sloan

Task 2

- Add clear statement about interstate coordination
- consider proactive engagement of landowners along the route, pr, etc

Task 3

- Pull numbers out of the scope
- Demand for other needs should be captured – i.e. dairies, swine, etc.
- expand demand to other areas, i.e. Wichita, Hays, etc
- look at “order of magnitude demands along the way
- consider whether to address “new” irrigation as it could help with costs

Task 4

- Add language that alternative route may raise different issues.
- Issues may show routes to avoid.
- Add time frame for environmental clearances as some may be lengthy

Task 5

- ok

Task 6

- Add in the italic statement that this task will be closely coordinated with task 4 and task 7; somewhat iterative

Task 7

- Scott has copy of the cost methodology used in the 1982 study; will provide.

Task 8

- This task should move to be a state task (will need to modify language under Purpose and Scope).
- This task will also be suspended temporarily. The direct impact area will be defined iteratively by alternatives that are evaluated.

Tasks 9

- There will be components of this that are state tasks as well

Task 10

- Primary report will be generated by Corps, but components may also be produced as state task.

These comments will be incorporated into a revised scope of work that will be shared with the committee.

There was a discussion of how information will be managed. How much detail will be available when? How detailed maps will be. Who will handle PR.? The KWO will have an Aqueduct page on kwo.org and will be the main media point of contact.

5. Overview WIK agreements – Margaret handed out a form but stressed we will make it easy to track time; anyone involved in a meeting that is not counting time or being paid by a federal source can be counted in our work in kind total.

6. Identify additional members as necessary – All the GMD managers want to be kept involved and informed. Water Assurance district manager should be represented. Livestock should be represented.
7. Review Draft Schedule – This was passed out. Committee meetings will be held periodically, some by teleconference. Regular updates will be provided to the KWA and BACs.

Kansas Aqueduct Study Stakeholder Committee Meeting
315 E. Main Street
Assaria, Kansas
April 21, 2014
10:00 am

Attendance: Raymond Flickner, Gregg Graff, Jeff Grossenbacher, Randy Hayzlett, Lou Hines, John Kaufman, Darci Meese, Joe Pajor, Tim Rhodd, Mark Rude, Clark Rusco, Clay Scott, Judy Wegener-Stevens

Not in Attendance: Steve Cadue, Brad Loveless

Others in Attendance: Orrin Feril, GMD#5; Chris Howell, Kansas Native American Affairs; Kate Wilkins-Wells, GMD 4; Tim Boese, GMD 2; Jason Norquist, GMD3; Bob Bacon, State Hydrologist, Missouri Department of Natural Resources

Staff:

Earl Lewis, Diane Coe, Margaret Fast, Erika Stanley, Tracy Streeter - Kansas Water Office
Scott Gard, Ed Parker, Thomas Topi, Phillip Alig - Kansas City District Corps of Engineers
John Denlinger, Eric Dove – HDR

Introductions - Tracy Streeter called the meeting to order. Self-introductions were made.

Overview Agenda – The agenda is organized with the items from the Scope of Work.

Water Availability

Ed Parker overviewed information he has developed. The 1982 study considered all flow above navigation targets – 41,000 cfs during nav season; 15,000 cfs winter. The data period of record was 1889 – 1979. Methodology and assumptions outlined in Power Point.

- Uses same nav targets
- Ed built an EXCEL spreadsheet model
 - Gage at St Jo
 - Daily values 1930 – 2010
 - 2010 level of development
 - Provided by Omaha division office
- Model shows the optimal storage depends on the diversion and transfer rates
- Mississippi navigation is a consideration
- The spreadsheet can review the assumption of size of source reservoir and diversion rate

Questions and Comments

- Can 2011 – 2012 data be added? This is not in the dataset that Omaha division is using currently
- What is the impact of the streambed degradation
- Can the model be run in a way to show yield
- If use the KC gage, the Kansas River flows are included
- Look at by year, graph amount available each year
- Put the excel model on our website so the stakeholders can do what ifs
- HDR will use the model for sizing of structures

Water Demand Analysis

Methodology, Questions and Comments

Earl presented some slides to lead the discussion on how demand should be estimated

- How far out from aqueduct is it feasible to look? We have 5, 10 and 20 mile buffers.
- Should irrigation be only the currently irrigated? How and where should this be quantified
- Should all possible municipal be considered
- Look at places where use is possible by gravity and/or using existing channels
- Use natural stream courses as much as possible
- Maybe the terminal reservoir location is too limited. Assume limited supplemental irrigation in DP County.
- Consider assurance supply
- Have to have industrial and municipal to pay for the system
- The demand is greater than the supply, so demand is determine by who will pay
- Use existing data – have annual water use reports for all use except domestic
- Why break up the demand by use now? Leave options open, what is the cost/ac-ft. breaking point.(cost will affect demand)
- Consider 50% of the demand used to point of diversion to Wichita; 50% after muni diversion to irrigation
- Consider Kansas and Neosho basins
-

Water Transfer System and Alternative Features

(Source Reservoir, Aqueduct and Associated Conveyance Facilities, Terminal Reservoir)

- John Denlinger, HDR reviewed what they will be doing with sizing and costing the key features
- This task will be coordinated with the demands and the supply; alternatives will be considered
- High level cost will be determined

Comments and Questions

- Northern flint Hills, and others? liked the idea of adding recreation to add value and opportunities
- Consider flexibility in source reservoir, i.e. bank storage wells and Wolf river reservoir
- Amount of resources in the study is limited, so alternatives may be limited
- Suggestion of bring water to the SW without a terminal storage – take directly to irrigators or to aquifer storage (recharge) when not irrigating
- Would a pipeline be cheaper? More direct route, no evap
- Can costs be saved if natural gas pipeline located in conjunction with aqueduct? HDR will consider energy options
- Just update the costs and see if anyone is interested.
- Do cost of total and then drop off along the way.
- HDR will develop a spreadsheet type model for reservoir size, conveyance, multiple sources, adding dump off location, consider multiple buckets
- This prompted a comment – focus on the corridor
- Comment on the amount of non-irrigated dryland between here and there.
- Consider using existing reservoirs for storage

Legislative Review

Methodology – expect to hire this out

Questions. Basic considerations are in the scope.

- Appropriation act considerations

- Quantify the amount of water coming out of the S. Platt. In Co state law this is nonnative water and can be used to extinction.
- The legislature should be asked to set aside of 4 MAF. Not allowed to be appropriated. This puts it on the table for interstate discussions
- Define what is in it for Missouri
- Consideration of degradation, need enough in the river for navigation.
- Where is the state boundary in the river
- Can this serve Missouri cities
- Top off reservoirs consideration
- What about reserved water rights of the tribes
- Consultation policies with tribes have been updated since the 1982 study.
- Some legal issues come under environmental constraints.

Schedule and Location of Meetings

There will be 3 more planned meetings of the stakeholder group. It was determined to hold the next meeting in June/July in the east and a September/October meeting in the west. The KWO will send out a doodle poll for both dates to get them set.

A final meeting will be held late year or early January to review drafts. A draft of the report at least will be ready for the legislative session.

Kansas Aqueduct Stakeholder Committee

Steve Cadue, Chairman, Kickapoo Tribe in Kansas, Horton
 Ray Flickner, Kansas Water Authority, GMD 2 & 5 Representative
 Gregg Graff, Kansas Water Authority, GMD 1, 3 & 4 Representative
 Jeff Grossenbacher, Producer, Vice Chair, Missouri BAC
 Randy Hayzlett, Kansas Water Authority, Representative of President of the Senate
 Lou Hines, Farmers and Merchants Bank, Colby
 John Kaufman, Shawnee
 Brad Loveless, Westar Representative, KWA
 Darci Meese, WaterOne of Johnson County
 Joe Pajor, Wichita Representative
 Tim Rhodd, chairman, Iowa Tribe in Kansas, White Cloud
 Mark Rude, Executive Director, GMD 3
 Clark Rusco, Chair, Upper Arkansas BAC, Barton County Engineer
 Clay Scott, Producer, GMD 3 Board Member
 Judy Wegener-Stevens, Doniphan County Conservation District, White Cloud

Staff:

Earl Lewis, Margaret Fast, Diane Knowles, Erika Stanley - Kansas Water Office
 Scott Gard - Kansas City District Corps of Engineers

Meeting Notes
Kansas Aqueduct Study Stakeholder Committee Meeting
Community Building
Iowa Tribe of Kansas and Nebraska Reservation
August 20, 2014
1:30 pm

Attendance: Raymond Flickner, Gregg Graff, Jeff Grossenbacher, Randy Hayzlett, Lou Hines, Darci Meese, Joe Pajor, Tim Rhodd, Mark Rude, Clark Rusco, Clay Scott, Brad Loveless, Judy Wegener-Stevens

Not in Attendance: Steve Cadue

Staff:

Earl Lewis, Diane Knowles, Margaret Fast, Erika Stanley, Tracy Streeter - Kansas Water Office
Scott Gard, Ed Parker - Kansas City District Corps of Engineers
John Denlinger, Eric Dove, Terry McArthur – HDR

Introductions – Tracy Streeter called the meeting to order. Self-introductions of the committee were made. There were over 50 people in attendance.

Introductory Comments – Tracy thanked the Tribe for hosting the meeting and tour and turned the comments over to Lance Foster, Tribal Historic Preservation Officer, who made comments about the significance of the River to the tribe and introduced tribal elders in attendance.

Legislative Review

Tracy introduced Margaret Fast who overviewed the approach to the legal review. The “legal team” work is being conducted by Brian Huston, recent graduate from KU School of Law, and Pope Consulting, LLC. David Pope and Leland Rolfs will be conducting the majority of the work. A preliminary draft should be available by late October, with a final of this report due in December.

The question was raised by one of the Iowa tribal elders why the Indian reserve water rights were not mentioned in the legal issues overview. David Pope had some experience in this area during his time with MORAST.

Water Demand Analysis

Earl Lewis went through a power point that had a focus on demand projections examined for both existing as well as new irrigation. The municipal demand is just getting underway.

Water Transfer System and Alternative Features

John Denlinger, Eric Dove and Terry McArthur, HDR, reviewed various aspects of the aqueduct components, alternatives examined and the preliminary estimated costs. They figure they are about half way done with their analysis.

Discussion of Methodologies and Time Frames

Much discussion ensued. Comments:

- Should we look at replacement water or just meet demands.
- The impact of cost – who will buy at the price
- What is the effective demand? If users can’t pay, is there a demand.
- This is like an assurance program, use whenever i might be needed
- The preliminary numbers are probably not affordable for irrigator, cities may be more able to pay

- Cities, feedlots, dairy have all offered to buy water
- We know we are going to have to adapt in western Kansas
- This study is not being done at a feasibility level
- There were lots of problems with the 1982 study; it used a huge reservoir. Western Kansas will take whatever it can get.
- There has been interaction with the Mississippi river commission
- Check into the question of whether counties tax water delivered as a commodity or would it be infrastructure that could be taxed locally?
- What is the cost of the Central Arizona Project (CAP) delivered water?
- The demand in Kansas is currently unmet.
- The first 6" of water is the most valuable on dryland. Looking at demand – in the western third, 10" on dryland; on all 6"
- Why aren't other options like reducing irrigation, conservation, etc. being evaluated?
- A question was asked why GMD3 does not have a LEMA. Mark indicated they are not done with the conversation.
- Greg made a few comments about why the GMD 1 LEMA was voted down. They are trying again.
- The Vision included water conservation. Everyone has to be cut
- Consider no source reservoir
- Consider using existing lakes, and other storage options.

Next Meetings

It is anticipated that next meeting will be in mid to late October and will be held in the western part of the study area. Another meeting may be held via teleconference in December to review the draft report. The final report is expected to be available for review by the committee and the KWA at the January KWA meeting, late January, 2015.

Meeting Notes
Kansas Aqueduct Study Stakeholder Committee Meeting
Grant County Civic Center
October 29, 2014
1:00 pm

Attendance: Raymond Flickner, Gregg Graff, Randy Hayzlett, Lou Hines, Darci Meese, Joe Pajor, Tim Rhodd, Mark Rude, Clark Rusco, Clay Scott, Judy Wegener-Stevens

Staff:

Earl Lewis, Diane Knowles, Margaret Fast, Erika Stanley, Tracy Streeter, Katie Ingles - Kansas Water Office
Scott Gard - Kansas City District Corps of Engineers
John Denlinger, Eric Dove – HDR

NOTE: The Power Point for this meeting has been posted on the KWO web site. These notes will not attempt to review the presentation, only key points and discussion.

Introductions – Tracy Streeter called the meeting to order. Self-introductions of the committee were made. There were over 50 people in attendance.

Introductory Comments – Tracy thanked the Clay Scott for arranging the tour and lunch and meeting facilities.

Legislative Review

Due to a death in the family, the contractors working on this task, David Pope and Lee Rolfs were not able to attend. Earl Lewis reviewed the key points identified to date covering key issues on each component of the proposal – obtaining, transporting and using Missouri River water.

Comments on the presentation:

- This committee will not address all the options. Mark identified 3 options of accessing large amount of water on the river – Congressional, compact, or the Supreme Court.
- Mark suggested reserving a portion of water now while we work through the issues, some kind of non-binding statement of intent
- Tribal reserved water rights were settled as a part of the Central Arizona Project.

Water Supply and Demand Analysis

Earl Lewis reviewed some background covered in previous meetings – the availability of supply over the 41,000 cfs navigation target at KC and the determination of irrigation demand. The summary of total projected new demand ranges from 4.2-6.5 Million acre feet.

Three local presenters gave perspectives on efforts to increase irrigation efficiencies. Monte Teeter of Teeter Irrigation discussed the changes in irrigation technologies over time. Jeff Schaef of Monsanto discussed the development of drought resistant crop varieties. Mitch Baalman of GMD #4 gave an overview of the process and education that took place to develop the Sheridan 6 Local Enhanced Management Area (LEMA).

Margaret Fast then reviewed the current and projected municipal demands. The quantity is significantly less than irrigation, total demand along the route, in the I-35 corridor, and the drought impacted area around Hays only amounting to a total of about 145,000 ac-ft. There is also a possibility of using the planned route to look at dropping off into the Neosho basin where projected supply and demand curves cross in 2023 and the Kansas River basin, where supply and demand line curves cross in 2064.

Environmental Constraints

Earl reviewed the work done so far to assess the environmental review issues that would be required for this type of project. There was some discussion on the stream mitigation guidelines.

Water Transfer System and Alternative Features

Eric Dove, HDR, gave a quick review of the components and updated costs that had been presented at the last stakeholder meeting. They also made a comparison with costs to the Central Arizona Project (CAP) which prompted most of the discussion. The CAP was federally subsidized.

Next Steps

- More in-depth financial review was suggested. What would CAP have been if no subsidies were granted. What if the project was bonded?
- The next meeting of the committee should be after a review of the draft report.
- Committee should review toward an eye of what is missing.
- What is the legislature supposed to do with the report, should the report line out other legal strategies.
- Tracy challenged the committee to review the report and each of the interests represented should write a report on what the project means to them.
- What is the cost of bringing the project farther west, beyond the 1982 proposed Utica site.
- What would it cost if there was more than a 10 year payback?
- Should there be guidelines developed for how end users could use the water, how would that be governed.

Meeting Notes
Kansas Aqueduct Study Stakeholder Committee Meeting
Assaria Safety Bldg.
December 15, 2014
10:30 am

Attendance: Raymond Flickner, Gregg Graff, Jeffery Grossenbacher, Brad Loveless, Joe Pajor, Mark Rude, Clark Rusco, Clay Scott, Judy Wegener-Stevens

Staff:

Earl Lewis, Diane Knowles, Margaret Fast, Erika Stanley - Kansas Water Office
Scott Gard - Kansas City District Corps of Engineers
John Denlinger– HDR

Others: Bryan Thompson, KPR, Salina; Rep. Steve Johnson, Assaria; Kent Askren, Kansas Farm Bureau; Tim Boese, GMD 2; Orrin Ferril, GMD 5; Jason Norquist, GMD3; Bob Bacon, Mo DNR; David Brenn, Ks Water Congress; Fred Jones, Garden City; Greg Krissek, Kansas Corn Growers

Introductions – Earl Lewis called the meeting to order. Self-introductions of the committee were made. There were about 25 people in attendance.

Review of Major Findings – Margaret Fast provided a quick review of findings with discussion occurring to clarify some items. Irrigation is the major use in Kansas and in SW Kansas with demand estimated for present use there as well as some new use along the way.

Municipal demand did not include southwest Kansas as it is a minor amount compared to irrigation. The question was raised if large industrial use (those with their own water rights) should be included. It was decided that that went beyond the scope of updating the 1982 study but it would be important to be clear in the description that it was not included.

Discussion of water availability emphasized that this depends on the assumptions.

Cost estimates depend on many factors, including the size of each component. John Denlinger explained the revisions on construction costs due to changes in interest rates / federal discount rates since 1982. This adjustment decreased the estimated cost of water to \$500/acre-foot. The costs of the major components will be in the final report.

A comparison to the CAP project was also requested, what would it cost now?

It was noted that realistic costs depend directly on demand which depends on cost. This would be in a future step. A range of cost was suggested for now.

Advisory Committee Development of Comments and Recommendations: Some of the overarching themes discussed by this committee, representing diverse areas and interests were:

1. Missouri River water is flowing by Kansas and should be claimed;
2. The transfer of water around the state can be difficult so the laws need to be reviewed and fixed;
3. Provide a list of issues related to this proposal.

The planning of any project will come later not out of this study, an update of the 1982 study. A list of alternatives could be developed.

The committee provided staff with input on the following questions:

What do individual members and/the committee as a whole want to tell the KWA and legislature?

- Saw in western the value of water in aspect of agriculture; in NE saw the cultural value. The economic value of water in the area was not highlighted during the tour.
- Political and environmental issues need to be identified
- This study was 30,000 feet. When continue, bring in feds, regionalize – CO, AZ NE
- Need to bring in more people if a project is moving forward
- Statement was made that water use in western KS is not selfish
- Part of answer has to be conservation

What is an aspect of this study you like?

- The representatives from different parts of the state valued seeing and learning about the other parts of Kansas.
- They welcomed the willingness of others to talk about issue in their areas.
- Study did go beyond the 1982 study for legal and political
- Identified a new untapped resource in the state
- Starting a process for long term solution
- Preparing to be able to tap into a regional (beyond Kansas) supply
- Good stating place to refine
- Strength was quality of Input – Pope, Rolfs, HDR

What is an aspect of this study you dislike?

- Disliked public perception (press included) that this is a project, not a study
- Preconceived opinions mostly that the project is too expensive.
- Does not like the 1982 route.
- Concern that Ness County wasn't represented on committee.
- Many changes have occurred since 1982. Dislike limitation of "updating" 1982 study.
- Doesn't look at opportunities along the way
- Doesn't indicate what is limit of willingness to pay
- Doesn't provide a path forward
- Haven't moved on "reserving" water in the Missouri River
- Inconsistency in how study/project was being portrayed in different meetings
- Uncertainty of what is meant - We can get water off the Missouri River – it's a perennial issue -
- Terminology inconsistency – high flow, flood flow, surplus water, etc
- Potential impact on private property rights

What aspects of the study require more attention at this time or what is an aspect, component, or issue that is missing?

- Tribal issues and concerns
- Determine willingness to pay and demand along the way.
- Range of costs
- Environmental challenges.
- Future steps- what happens next.
- There's no water right yet
- Need a better idea/costs of distribution network
- Willingness to pay
- Costs to store and distribute water in SW Kansas.
- Economic impacts of northeast Kansas have not been considered

- What is needed to make the project economically feasible?
- Settle question of what property/water right with sister state level
- Position of the State of Kansas.
- How does water bring value to the state
- Federal involvement/lack of involvement; need some federal assistance
- Private money is concerning – what could this mean
- Regional interest – Colorado, SW US
- Access to water as first step
- Compact on River
- Assure Kansas Law will allow water transfer

Are there alternatives that you would suggest exploring further?

- Water use along the way
- Small reservoirs - value added benefits – distributed storage
 - Use LIDAR to id where smaller lakes could be built
- Kansas River structure to take and give water.
- Terminal reservoir at Kendell or Hartland.
- Distribution down to Cimarron
- Legislative intent/interest to develop an authority dedicated to a project “interbasin transfer authority for surplus water (e.g.KTA)
- Utilize existing storage for interbasin transfer
 - Tie in with need to dredge
 - Maximize existing infrastructure
- Financing options

Remaining Actions and Meetings

- Draft report to committee by early January
- Mid-January committee meeting
- January 29th KWA meeting

Update of 1982 Six State High Plains Aquifer Study

Appendix 4: 1982 Study, Appendix E. Cost and
Design Manual, August 1980

COST AND DESIGN

MANUAL

Prepared by Southwestern Division
Corps of Engineers for the water
transfer element of the High Plains
Ogallala Aquifer Study

August 1980

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SECTION I - OVERVIEW

A. AUTHORITY. The High Plains Ogallala Aquifer Study was authorized by Section 193 of the 1976 Water Resources Development Act (Public Law 94-587). This act directs the Departments of Commerce and Army to study the depletion of the Ogallala Aquifer, and to develop plans to increase water supplies in the area. The Corps of Engineers is to conduct studies dealing with the transfer of water into the High Plains region from adjacent areas.

B. PURPOSE. The purpose of this guidebook is to provide guidance for the Corps of Engineers in preparing reconnaissance level designs, cost estimates, and environmental assessments for large water transfer facilities. It is intended for use by planners in laying out water transfer systems, developing estimates of project costs, and assessing environmental effects along each alternative transfer route. Use of the document will assure uniformity in the methodologies and procedures among the four Corps district offices preparing preliminary designs and cost estimates for water transfer alternatives. Design, cost estimating and environmental assessment procedures, and data presented here can be used with little reference to other information sources, thereby minimizing time, effort, level of expertise, and costs required for the "finished product."

C. SCOPE. The data presented are applicable to conveyance facilities with capacities up to 30,000 cubic feet per second (cfs). These data were developed from information provided by the Water and Power Resources Service (formerly Bureau of Reclamation) of the Department of the Interior, the State of California, and to a small degree from numerous other state agencies. Cost data were updated to January 1979 price levels and modified as needed to simplify their use. Data "gaps" were filled through interpolation, extrapolation, and approximations based on available information. Therefore, the data and procedures contained

herein should not be used other than for reconnaissance or subreconnaissance level designs and costs. Although parts may be applicable to other studies, this should not be attempted prior to determining whether the underlying assumptions are consistent with the needs of the other studies.

SECTION II - ASSUMPTIONS

A. DESIGN CRITERIA.

1. General. All costs in this manual are indexed to January 1979 price levels using various published cost indexes. The need to adjust price levels for variability of costs throughout the region was investigated. As reflected on Table 1, the construction cost indices at six locations near or in the study area are quite uniform; thus, regional cost adjustment was deemed unnecessary.

Table 1
GEOGRAPHIC COST INDEXES

<u>Index</u>	<u>Date</u>	<u>Value</u>
ERN CCI (1967 = 1.00)	Jan 79	2.53
Minneapolis	Jan 79	2.62
Denver	Jan 79	2.94
Kansas City	Jan 79	2.57
St. Louis	Jan 79	2.64
Dallas	Jan 79	2.81
New Orleans		

Highway bid prices (1967 = 1.00) (from ENR 22 Mar 79)

Montana	4th Q 78	2.84
South Dakota	4th Q 78	2.96
Nebraska	4th Q 78	2.62
Colorado	4th Q 78	2.34
Missouri	4th Q 78	2.82
Texas	4th Q 78	3.85

2. Lands and Damages. The estimated width for a canal is based on the width required for a balanced cut and fill cross section plus 40 feet for

construction area, plus 80 percent to account for topographic characteristics along the route, plus 50 percent of that total for spoil, borrow, and drains. Figure 1 shows canal land requirements for various design flows.

3. Relocations. The relocation components consist of highways, railroads, major pipelines, major powerlines, and a miscellaneous factor for other minor relocations. Relocations for conveyance facilities are handled separately from dam and reservoir relocations in accordance with the following assumptions:

a. Conveyance Facilities.

(1) Highway crossings. Highway relocations include Interstate, US, and state highways. (Federal Aid Secondary (FAS), county, and township roads are included in miscellaneous relocations).

(2) Railroad crossings. The railroad relocation curve is considered applicable to canal crossings at which no more than 10-foot fill will be required for the track approach section.

(3) Pipeline crossings. The predominant factors in the cost of relocating pipelines are the length and depth of the required excavation as dictated by site topography.

(4) Powerlines. Each powerline crossing of the canal assumes the need for a tower on either side of the canal.

(5) Miscellaneous Relocations. Miscellaneous relocations include FAS and secondary county roads, electrical distribution, rural waterlines, and telephone lines. It has been assumed that each alternative route would include a FAS bridge crossing at an average 6-mile interval; 1 mile of secondary county road relocation per mile of canal; no secondary county road bridge crossing; an average interval of 1.5 miles between distribution lines for both electricity and telephone; and an average interval of 2.5 miles between rural waterlines.

b. Dams and Reservoirs. It is assumed the relocations required for construction of dams and reservoirs are of typical midwest design. Without knowing specific topography, it is assumed the relocated roads and railroads will require earthwork, drainage structures, and other design elements similar to past roadwork within the region, and that no major bridge structures (over 500-foot-length) are required.

4. Dams and Reservoirs

a. General. Design assumptions on dams and reservoirs for this guidebook reflect the design of about 75 Corps of Engineers projects recently reported on in survey reports and design memorandums. Some design information was also obtained from Series 150, Appendix A, "Estimating Data" of the Water and Power Resources Service's Reclamation Instructions. Recently developed information for the National Hydropower Study was used for comparison.

(1) The principal function of reservoirs addressed in this manual is conservation storage of diverted water. Therefore, it is assumed that only sediment and conservation storage would be provided.

(2) Design procedures and cost curves have been developed for concrete, rockfill, and earthfill dams. The crest of the emergency spillway, unless a gated spillway is used, would be located at the top of the conservation pool. Flood surcharge capacity would exist above the conservation pool because design flood is assumed to pass through the emergency spillway atop a full conservation pool. This results in additional dam height and land requirements beyond that needed for the conservation pool. In addition, freeboard is required above this flood surcharge elevation to provide a factor of safety against the dam being overtopped during passage of the design flood.

(3) The following sections provide design criteria for dams and reservoirs including typical dam sections, sediment storage requirements, conservation storage requirements, emergency spillway design, land requirements, and

dam freeboard.

b. Types of Dams. Typical cross sections for earth dams, rockfill dams, concrete gravity dams, and concrete arch dams are shown on figure 2. The concrete arch dam section would actually be slightly curved, concave downstream, but is shown in a section convenient for computing the volume of the structure. In plan view, the concrete arch dam should be a circular arc of reasonable proportions from one abutment to the other. The other dam types usually run straight across between abutments.

c. Inactive Storage. Inactive storage is defined as the 100-year sediment storage. Data from a number of Corps dams studies in design memorandums and survey reports were used to determine the range of sediment requirements. These data are shown in table 2 and suggests that 0.6 acre-feet per square mile per year be used for most conditions. A value of 0.2 would be appropriate for areas known to have very low sediment runoff while 1.5 might be used where there is a known sediment runoff.

Table 2
RESERVOIR SEDIMENT STORAGE

<u>Dam</u>	<u>Drainage Area</u> <u>Mi²/</u>	<u>Sediment Yield</u> <u>AF/Mi²/Yr</u>
Chatfield (Colo., Rocky Mts)	3,018	0.07
Pipestem (N. Dakota, dryland agr.)	594	0.08
Bowman-Haley (N. Dakota, rangeland)	446	0.11
Garrison (N. Dakota, Missouri R.,	123,215	0.31
Ft. Randall (S. Dakota, Missouri R., badlands)	14,150	1.17
Papio No. 15 (E. Nebr, dryland agr., loess hills)	15.2	2.16
Sand Creek (Colo., rangeland)	83	0.60
Graybill (W. Iowa, dryland agr., loess hills)	99	2.15
Wolf-Coffee (E. Kansas, urbanizing, loess hills)	45.4	2.00
Flandreau (S. Dakota, dryland agr.)	1,041	0.15
Arcadia (E. Okla. urban-agr.)	105	0.67
Millican (E. Texas, agr.)	2,120	0.44
Seneca (Va., mountains)	8,300	0.11
Bloomington (W. Va., Allegheny Mts.)	287	0.10
Bear Creek (Colo., Rocky Mts.)	236	0.08
Davids Creek (W. Iowa, dryland agr.)	57	0.72
West Bijou (E. Colo., rangeland)	271	0.49
AVERAGE		0.67

d. Conservation Storage. The amount of storage required for a particular reservoir site will depend on the total amount of water to be transferred, other reservoirs in the system, flow characteristics of the source stream area, the pattern of water utilization, the relative location of the reservoir along the diversion route, evaporation rate, and other factors. Individual hydrologic studies will be necessary to determine conservation storage requirements.

e. Spillway Design. The spillway for a dam should pass the PMF (Probable Maximum Flood) atop a full conservation pool. Normally, flood routings are performed to determine the spillway discharge and attendant parameters including the height of the dam and extent of the flooded area resulting from temporary surcharge during passage of the design flood. A much simpler approach involves establishing an approximate relationship between spillway design discharge and PMF discharge. Since the surcharge storage provided while the PMF is passing through the pool reduces or attenuates the flood peak as experienced at the inlet to the reservoir, spillways located at the elevation of the top of the conservation pool should be designed for 65 percent of the PMF peak discharge (the PMF discharge can be obtained from figure 3). Should a case be experienced where the spillway is perched, the design discharge should be reduced linearly until it is zero in the case where the entire PMF is stored without spill. Gated concrete spillways are normally part of the embankment at valley level. In that case, it is suggested that these be designed for 90 percent of the PMF.

f. Land Acquisition. In this study, the reservoirs are expected to be principally designed for irrigation water storage so land acquisition would include the conservation pool plus some allowance to prevent excessively frequent flooding of nonproject lands. It is suggested that land acquisition be sufficient to store no less than half of the SPF (no freeboard) in nonurban areas without encroachment on nonproject lands, and no less than the SPF (no freeboard) in urban areas. The SPF volume may be determined from figure 4. If the spillway

RESERVOIR LAND REQUIREMENTS

The method for determining reservoir land requirements (and dam heights) yields reasonable results in most cases. However, a few circumstances have resulted in land requirements (and dam heights) that appear unreasonably low or high. In order to eliminate these cases, we suggest the following checks be performed.

a. Check for lower limit.

The total land requirements for reservoirs as determined by storage of 1/2 SPF (full SPF for urban areas) atop the conservation pool should not be less than the conservation pool plus the percentage obtained from the upper curve of figure 4a.

b. Check for upper limit.

Land should not be acquired more than 20 feet above the top of the conservation pool. If storage of 1/2 SPF (full SPF for urban areas) results in a depth increment greater than 20 feet, the depth increment should be reduced to 20 feet. A corresponding reduction should also be made in the dam height.

is perched above the reservoir design flood storage level, land would be acquired to the spillway crest, or the top of gates in the case of a gated spillway.

g. Freeboard, A number of constructed Corps dams were studied to determine freeboard requirements. Freeboards ranged from 3 feet for very small dams to about 15 feet for the main stem Missouri River dams. Table 3 lists suggested freeboard criteria. To determine the top of a dam, the freeboard is added to the maximum water surface for the design flood which was approximated in the previous step by providing for storage of 1/2 SPF or SPF atop the conservation pool as the location warrants.

Table 3
FREEBOARD CRITERIA

<u>Pool Volume</u>	<u>Freeboard</u>
0-300,000 AF	5 ft.
300,000-1,000,000 AF	8 ft.
1,000,000-10,000,000 AF	10 ft.
over 10,000,000 AF	15 ft.

h. Diversion Dams.

(1) To make streamflow available for irrigation use, it must be diverted by a diversion dam and headworks, a diversion headworks alone, or a pumping plant. Diversion dams and headworks are addressed in this section. A diversion dam takes the form of a low dam or overflow weir, usually of concrete. The purpose is to raise or control the water surface so a desired flow may be diverted into a canal and yet function as a spillway for flood flows. The only design parameters required to estimate the costs of diversion dams are the height and width. In general, diversion dams are on the order of 10 feet high and within the streambed channel or lowest level terrace if the additional depth is needed. Corresponding widths can be obtained from topographic maps. The weir portion of the diversion

dam may be uncontrolled or may be gated. Gates are used where the value of property requires control of the upstream water surface during flood flows. Detailed design guidelines for diversion dams and headworks are found in the WPRS's Design Standards No. 3 "Canals and Related Structures."

(2) Canal headworks are usually located alongside of and at an angle to a diversion dam. The headworks usually takes the form of a short, concrete channel with a gate or gates. In some cases, the headworks consists of a buried conduit similar to a outlet works for a Corps dam. The only parameter necessary to estimate the cost of headworks is the diversion capacity. This is obtained from separate hydrologic studies.

5. Pumping Plants.

a. Pumping plants will be required at the source point for each transfer alternative and at intermediate lift stations along the conveyance route. Plants at sources such as streams and reservoirs would be designed to accomodate fluctuations in water surface elevation at their intakes.

b. All pumping plants would be semiattended indoor plants equipped with turbine-type centrifugal pumps driven by electric motors. The number of units at each plant would vary with plant capacity from 3 units at plants with lower capacities to 9 units at the largest plants. The pumping units include one operational standby. A typical pumping plant is illustrated on figure 5.

6. Pipelines (discharge conduits) would be required to convey water from the pumping plants to higher elevations. The pipelines are assumed to be constructed of precast, prestressed concrete cylinder pipe with a minimum of 3 feet of cover and maximum diameter of 20 feet. Pipe diameter (in feet) is estimated by the formula $D = (0.981Q)^{0.375}$ where, Q is the discharge, in cubic feet per second. Where the diameter from the formula would exceed 20 feet, more than one conduit would be utilized.

7. Canals. In developing a means for transferring water to the Ogallala Aquifer, it was assumed that an open trapezoidal concrete-lined canal would be the best overall solution. The canal would be as straight as possible with the side slopes, bottom slope, and bottom width to stay constant for an entire reach. It is assumed that the velocities would not exceed 5 feet per second, there would be a check gate every 4 miles, and freeboard of 3-6 feet be included. Assumed canal properties and typical shape are shown on the table 4 and figure 6, respectively. Small natural drainages crossed by the canal would be piped under the canal.

8. Inverted siphons would be required where the canal crosses major streams. Siphons may also be required where the canal crosses certain major highways and/or railroads, and where bridges would not be practical to provide grade separation. Maximum siphon barrel diameter is assumed to be 20 feet. Therefore, multiple siphon barrels may be required, depending upon the design discharge. Siphon barrels are assumed to be constructed of precast, prestressed concrete cylinder pipe with a minimum of 3 feet of cover. Siphon structures include intake and outlet transitions.

9. Tunnels may be required where they would result in a saving in cost over other alternatives such as a longer conveyance route and/or an additional pumping plant. The maximum practical tunnel diameter is assumed to be 50 feet. Sizes and numbers of tunnels necessary to carry capacities ranging from 1,000-30,000 cfs are listed below:

<u>Total Capacity cfs</u>	<u>Diameter (ft)</u>	<u>Number</u>
1,000	18.4	1
5,000	37.6	1
10,000	47.6	1
15,000	40.0	2
22,500	40.0	3
30,000	40.0	4

10. Automation and communication. The control system is assumed to be a single control point with all necessary control for pumps and water flows with all necessary data feedback and alarm systems.

11. Cultural Resources. Few comprehensive cultural resources surveys have been conducted in the vicinity of the transfer routes. Those surveys that have been conducted indicate that the area is rich in cultural resources. There appears to be a high density of early man sites. Earthlodge village sites are associated with most of the major stream drainages in the northern portion of the study area.

B. MAJOR COST ELEMENTS

1. Lands and Damages. Lands required for canal and reservoir construction constitute most of the project lands. Some additional lands may be needed for pumping station areas, special drainage accommodations, etc.; however, these areas are insignificant to the total land requirements and are not to be delineated. Unit values of land and damages are shown below for different regions. These unit values include the unimproved land value, severance, improvements, relocation assistance under PL 91-646, administrative expenses, and contingencies.

<u>Region</u>	<u>Unit Value Per Acre</u>
Montana, Wyoming, North Dakota, and South Dakota	\$ 900
Nebraska panhandle, Colorado and Texas	1,550
Nebraska sandhills and Niobrara Basin	1,750
Kansas	1,300
Oklahoma and Arkansas	1,900

Figures 7 through 10 show land costs per mile of canal.

2. Relocations. Relocation costs are divided into those associated with conveyance facilities and those required for construction of a dam and reservoir.

TABLE 4
CANAL PROPERTIES

SIDE SLOPE = 2:1 when $d \geq 14$ ft.
1.5:1 when $d < 14$ ft.

Q cfs	A s.f.	V ft./sec	b ft.	d ft.	b/d	r	n	S ft./foot	f ft.	F ft.	T ft.	I in.	W ft.
25,000	5250	4.76	115	30	3.83	21.07	.016	.000045	3.2	6.4	4	4.5	24.
20,000	4470.1	4.47	89	30	2.97	20.03	.016	.000043	3.1	6.2	4	4.5	24
15,000	3600	4.17	60	30	2.00	18.54	.016	.000041	3.0	6.0	4	4.5	24
11,000	3136	3.51	56	28	2.00	17.30	.016	.000032	2.8	5.6	3	4.5	24
9,000	2601	3.46	51	25.5	2.00	15.76	.016	.000035	2.5	5.0	3	4.5	24
7,500	2256.2	3.32	47.5	23.75	2.00	14.68	.016	.000036	2.5	5.0	3	4.0	24
6,350	1936	3.28	44.	22	2.00	13.60	.016	.000038	2.5	5.0	3	4.0	24
6,000	1764	3.40	42	21	2.00	12.98	.016	.000044	2.5	5.0	3	4.0	24
4,750	1024	4.64	32	16	2.00	9.89	.016	.000118	2.5	5.0	3	4.0	18
4,000	900	4.44	30	15	2.00	9.27	.016	.000118	2.5	5.0	3	4.0	18
3,500	841	4.16	29	14.5	2.00	8.96	.016	.000108	2.5	5.0	3	4.0	18
3,200	784	4.08	28	14.	2.00	8.65	.016	.000109	2.2	4.5	3	4.0	18
2,750	676.2	4.07	27.8	13.9	2.00	8.68	.016	.000108	2.0	4.0	3	4.0	18
2,350	591.5	3.97	26	13.0	2.00	8.12	.016	.000112	2.0	4.0	3	4.0	18
2,000	504.0	3.97	24	12.0	2.00	7.49	.016	.000125	2.0	4.0	3	4.0	18
1,800	462.9	3.89	23	11.5	2.00	7.18	.016	.000127	2.0	4.0	3	3.5	18
1,500	423.5	3.54	22	11	2.00	6.87	.016	.000111	1.8	3.9	3	3.5	18
1,200	350.0	3.43	20	10	2.00	6.24	.016	.000118	1.7	3.7	3	3.0	18
800	224.0	3.57	16	8	2.00	5.00	.015	.000152	1.5	3.4	3	3.0	14
600	171.5	3.50	14	7	2.00	4.37	.015	.000175	1.3	3.1	3	2.5	14
5,000	1089	4.59	33	16.5	2.00	10.20	.016	.000110	2.5	5.0	3	4.0	24
3,750	841	4.46	29	14.5	2.00	8.96	.016	.000124	2.5	5.0	3	4.0	18
2,500	637.9	3.92	27	13.5	2.00	8.43	.016	.000104	2.1	4.2	3	4.0	18
900	252.9	3.56	17	8.5	2.00	5.31	.015	.000139	1.6	3.5	3	3.0	14
700	196.9	3.56	15	7.5	2.00	4.68	.015	.000165	1.4	3.3	3	3.0	14
500	147.9	3.38	13	6.5	2.00	4.06	.015	.000180	1.3	3.0	3	3.0	14
400	126.0	3.17	12	6.0	2.00	3.75	.015	.000176	1.2	2.8	3	2.5	14
300	102.0	2.94	8	6.0	1.33	3.44	.015	.000169	1.0	2.6	3	2.5	14
200	76.1	2.63	6	5.4	1.11	2.99	.015	.000163	1.0	2.4	3	2.5	10

a. Relocation crossings at Conveyance Facilities. Five cost elements are identified as conveyance relocation items: highways, railroads, major pipelines, major powerlines and miscellaneous relocations (FAS and secondary county roads, electrical distribution, rural waterlines, and telephone lines).

(1) Highways. Highway relocations include Interstate, US and state highways. Figure 11 presents cost data on Interstate and state highways. The state highway standard cost curve is applicable to both US and state highways. Both highway cost curves are based on an assumed typical site topography which would require both 12 feet of fill or 10 feet of cut for the highway approach to the canal crossing. More severe site topography could cause some increase in highway approach costs, but such increases would be insignificant in comparison to the bridge costs.

(2) Railroads. The railroad relocations cost curve, Figure 12, is also based on an assumed typical site topography. As with highways, the bridge costs represent the significant portion of the estimated cost. The curve is based on a single track. Additional tracks may be calculated as multiples of the estimated cost from this curve.

(3) Pipelines. Because specific site topography is not known at the preliminary study stage, a single value of \$75,000 has been estimated per single pipeline.

(4) Powerlines. A single value of \$80,000 per powerline has been estimated for all powerlines which are 115 kilovolt or larger. Powerlines less than 115 kilovolt are included in miscellaneous relocations.

(5) Miscellaneous Relocations. Figure 13 which shows Minor Relocations Costs per Mile of Canal is a composite of the estimated costs of FAS and secondary county roads, electrical distribution, rural waterline, and telephone line relocations. This curve represents typical or average miscellaneous relocations that would be required for any of the water transfer alternatives.

b. Relocation Crossings at Dam and Reservoirs. The major relocation cost

elements to consider within a reservoir's influence include highways, railroads, transmission pipelines (natural gas, crude oil, oil products), powerlines (transmission, distribution), telephone lines, and rural waterlines. A cost estimate on each element per mile is provided on Figure 14. The estimates assume a typical midwestern relocation (moderate slopes, adequate soil depths, moderate rock excavations, etc.). A contingency factor of 25 percent is included to account for atypical situations. In general, the costs reflects:

(1) Highways and Railroads. Costs are for typical site topography. Land prices are included in the total. Major bridges (exceeding 500-foot length) are not included.

(2) Pipelines. General costs include easement, clearing, surveying and construction of the pipelines. The estimates are based on similar past construction.

(3) Powerlines. Powerlines are priced as above-ground installation. Estimates include easement, clearing, surveying, drilling and construction.

(4) Telephone Lines. The cost estimate is for underground installation.

3. Dams and Reservoirs.

a. General. This section presents data to develop reconnaissance-level cost estimates for concrete, earth, and rockfill dams; spillways; and outlet works. Land and relocation costs were covered in previous sections. All cost curves, unless stated otherwise, include contingencies and unlisted items and are based on January 1979 prices.

b. Concrete Dam Costs. The cost curve for concrete dams was derived from WPRS information and is shown on figure 15. The cost relationship is based on recent contract costs of constructed concrete dams and includes the dam structure, spillway, outlet works, unlisted items, and contingencies ??? shows the relationship of the cost curve to individual dam data. The upper circled data points are taken from available data on concrete dam costs from Corps reports. The lower short

line segments are costs of mass concrete only from the same reports.

c. Earth Dam Costs. Whereas concrete dam costs include the dam, spillway, and outlet works; the costs of these items must be computed separately for earth dams. The costs for embankment, spillway, and outlet works are presented in the following sections.

(1) Embankment.

(a) The relationship between earth embankment volume and cost is shown on Figure 16. The cost curve is also applicable to rockfill embankments. The cost curve was derived from the WPRS information and is based on bid prices of constructed dams.

(b) Figure 16a compares the WPRS cost curve with one from the Corps of Engineers' National Hydropower Study. The NHS curve is based on results of a questionnaire distributed to many Corps' districts regarding dams constructed or studies in detail. The individual data points shown were taken from about 65 dams in Corps design memorandums and survey reports. About half of these dams were from the Omaha District, with most of the remainder from the Kansas City, Tulsa, and Fort Worth Districts. The WPRS curve follows a logical track through the center of the points. The available data points for rockfill dams fall in the same range as earth dams.

(2) Spillways.

(a) The spillway cost curve is presented on Figure 17. The cost curve is derived from Corps and WPRS data. Data on the head from dam crest to streambed (less 5 feet) and capacity of the spillway (normally 65 percent of PMF) are needed to obtain the spillway cost. A separate curve has been provided for gated spillways because of the significantly greater costs. Although the gated spillway, itself, is more expensive, gated spillways can reduce the overall cost of the project by allowing a lower maximum pool. Gated spillways are frequently built as part of

the embankment at valley level, while the other types of spillways are high-level in the abutments. The outlet works is generally a gated opening in the gated spillway concrete section below the gates, and its cost in that case would be part of the spillway cost.

(b) Figure 17a shows the derivation of the cost curves on plate 7. The data points include earth-cut spillways, rock-cut spillways, ungated concrete spillways, and gated concrete spillways. The earth, rock, and ungated spillways fall generally along the same path. Gated concrete spillways lie to the right and are more costly for the same design parameters. The WPRS curve lies along the center of the data points.

(3) Outlet Works.

(a) The outlet works cost curve is presented on Figure 18. The cost curve is derived from bid prices of the WPRS. Data on the head from the dam crest to the streambed (less 5 feet) and the required outlet works capacity are needed to determine the cost. The outlet works are typical Corps designs, ranging from a culvert-type outlet for very small dams to a single concrete tube with intake tower and stilling basin for most other dams. For very large dams, the outlet works consist of a large multitunnel structure.

(b) Figure 18a compares the WPRS cost curve and the Corps documents data points for outlet works. The Corps dam used as sample points is essentially the same as that used for the embankment and spillway.

(4) Diversion Dams.

(a) The cost curves for diversion dams with ungated spillways (or weirs) and gated spillways are shown on Figures 19 and 20, respectively. The cost curves in the manual Series 150 - Appendix A "Estimating Data." The cost curves are extrapolated beyond the size parameters of 3,100; 12,000; and 1,800, respectively.

(b) To verify the WPRS curves, cost estimates were computed using parameters

and quantities from typical diversion dams shown in the WPRS Design Manual No. 3. The agreement with the WPRS curve is fairly good. Only basic quantities were used in the cost estimates such as concrete, steel, earthwork, and riprap. The difference could be attributed to unlisted items and foundation treatment.

4. Pumping Plants.

a. The Water and Power Resources Service computer program for pumping plant costs, SW981E, was run for heads of 50, 75, 100, 200, 300, 400, and 500 feet capacities of 1,000, 5,000, 10,000, 15,000, 20,000, and 30,000 cubic feet per second (cfs) for each head to obtain plotting data for various combinations of head and capacity.

b. When costs exceed eight places, stars (*) appear in the output for costs. When this occurred in the total cost but not in the individual items listed in the output, costs of the individual items were added to obtain the total. When stars appeared in any of the individual items, as well as the total, in a computer run, the curve for the individual item contained in Appendix A to the Bureau of Reclamation Series 150, Estimating, Reclamation Instructions was used. The cost taken from the curve was updated to January 1979 price levels by applying the Engineering News Record index. For "manifolds and valves," curves were developed from computer outputs for smaller capacity plants and extrapolated to the larger capacities.

c. Ten percent was added to the pumping plant cost determined as described above to account for miscellaneous items. Finally, 25 percent was added to allow for contingencies prior to plotting the curves shown on Figure 22. Since the curves do not account for reservoir/river intakes, 33 1/3 percent should be added to the cost taken from the curve if the cost of such a pumping plant is required.

5. Pipelines. Pipelines (pumping plant discharge conduit) costs were updated from reconnaissance level cost curves developed for the Oklahoma Water Plan studies by the Water and Power Resources Service. The costs include the costs of excavation,

furnishing and laying pipe, valves, manholes, structures, backfill, restoration of the site, and all items necessary for completion except the pumping plant discharge manifold, rights-of-way, and indirect costs. The costs from the curves on Figure 23 include 10 percent for miscellaneous items and 25 percent for contingencies.

6. Canals.

a. The major cost elements for canals are the canal and waterway. The canal is the concrete used in construction. The waterway is the excavation common and rock, borrow, compacting embankment, and trimming of the canal for the concrete lining.

b. The Water and Power Resources Service preliminary design North Texas canal from Lake Tawakoni, Texas, to Bull Lake, Texas, December 1970 was used in developing the graph of costs per mile vs. flow rate. This canal cost was broken into seven reaches ranging in length from about 36 miles to about 150 miles and five flow rates, 9,000 cfs, 11,000 cfs, 15,000 cfs, 20,000 cfs, and 25,000 cfs. The costs were further broken down for each reach and flow rate to canals, waterways, canal structures, canal protective works, clearing rights-of-way, structures and improvements, and roads and bridges. The definitions of these cost items are as follows:

Clearing rights-of-way:	Clearing the land of vegetation
Structures & Improvements:	Fencing of the canal and replanting grass.
Roads and Bridges:	The maintenance of roads and bridges which are gravel or paved surfaces.
Canals - Waterways:	This is excavation common and rock, borrow, compacting embankment, trimming of canal for concrete lining, and cement.
Canal Structures:	Equipment housing, radial gates and hoists, metal hoists, metal work at checks, concrete in structures, reinforcement, and excavation and backfill.

Canal Protective Works: Toe drains, riprap, concrete in structures,
 excavation, and reinforcement.

c. Major factors that impact on canal costs include the amount of common excavation, rock excavation, compacted fill, cement, canal lining, slope of canal, and length of canal. The cost of the items was updated from July 1970 prices to January 1979 prices.

d. A graph showing canal costs per mile vs. flow rate was developed (figure 24) to reflect the above items plus a 25 percent contingency and a 10 percent added cost for miscellaneous items. Engineering and development are not included in this graph, but the 25 percent contingency would account for some additional sinuosity in the canal alignment over that included by these reconnaissance estimating procedures.

e. The graph gives a cost of constructing concrete-lined canals for flow rates from 500 cfs to 30,000 cfs with different percentages of rock excavation to total excavation. Excavation was found to be a major cost item. Rock excavation to total excavation caused a great variation in cost per mile; therefore, separate curves were drawn with each representing a particular percentage of rock excavation to total excavation. Actual cost could vary by about ± 10 percent due to variations in minor cost items in the Water and Power Resources Service design information. However, since the primary function of this graph is to compare alternatives, this range is acceptable.

7. Siphons.

a. The Water and Power Resources Service computer program for siphon costs, SIPHON, was run for heads of 50, 100, and 150 feet with capacities of 1,000 and 5,000 cubic feet per second (cfs) for each head.

b. Unit costs for the siphon pipes were not output from the computer run. The unit costs were obtained from the Water and Power Resources Service Engineering

and Research Center in Denver, Colorado. These unit costs were multiplied by the pipe quantities from the computer output, then added to the other cost items.

c. Unit costs were applied to quantity estimates for transitions and siphons with capacities of 9,000, 11,000, and 15,000 cfs furnished by the Service. Costs for 10,000 and 20,000 cfs transitions were interpolated and extrapolated, respectively, from those estimates. Other costs for the 10,000 and 20,000 cfs siphons were estimated by multiples of the appropriate cost items from the 5,000 cfs siphon.

d. Ten percent was added to the siphon costs to account for miscellaneous items. Finally, 25 percent was added to allow for contingencies prior to plotting the curves on Figure 25. The curves were then graphically extrapolated to 30,000 cfs.

8. Tunnels. Appendix A to the Bureau of Reclamation Series 150 Estimating Instructions furnishes unit cost data for tunnels with diameters of 10, 20, 30, 40, and 50 feet except that unit costs for steel supports and timber lagging are not given for diameters of 30, 40, and 50 feet. Unit costs for these two items were extrapolated from unit costs for the smaller diameters, and estimates of cost per linear foot were developed for tunnel diameters ranging from 10 to 50 feet. (Diameters greater than 50 feet were not considered.) Sizes and numbers of tunnels necessary to carry capacities of 1,000, 5,000, 10,000, 15,000, 20,000, and 30,000 cfs were estimated based on the tunnels flowing about 75 percent full. The cost per linear foot of tunnel(s) for each capacity was estimated from the cost data discussed above and updated by applying the ENR index. The costs were increased by 10 percent to allow for miscellaneous costs. Finally, 25 percent was added for contingencies, resulting in the curve on Figure 26.

9. Automation and Communication. Automation includes both hardware and software

required for remote monitoring and control of pumping and other canal works from a centrally located command center. It also includes redundant control at each pumping plant. Costs for the High Plains study transfer alternatives are assumed to be similar to those experienced with the California State Water Project.

10. Cultural Resources. Public Law 93-291, "An Act for the Preservation of Historic and Archeological Data," authorized up to 1 percent of the total amount authorized for a project to be spent on the preservation of cultural resources. The limited number of cultural resource surveys conducted in the study area indicate that the area is rich in cultural resources. Based on this and the rapidly rising costs for cultural resources investigations, the entire 1 percent of authorized project costs will be used to estimate costs for the preservation of cultural resources.

SECTION III - ROUTE LAYOUT

A. SCOPE. The following are suggested steps in systematically laying out and establishing an alignment upon which to base reconnaissance-level designs and cost estimates for water conveyance facilities involving open, ridge-lined canals connected by lift stations. The procedure assumes that the general locations of the origin(s) and destination(s) have been established prior to the route layout. Numerous alternative routes are likely to be available. Therefore, considerable judgement will be necessary in laying out an alignment which would best represent design features and costs of a plan developed from more detailed studies.

B. PROCEDURE.

1. Locate origin and destination (source and terminal) on a map showing major drainage systems. The scale should be just large enough to cover the entire area to be traversed.

2. Delineate major watershed divides and streams along the general route from

origin to destination. The delineation need not be exact as it will serve only as a guide in subsequent steps. This map can be used to select maps for use in step 3.

3. Using the map developed in step 2 as a guide, obtain topographic maps with scale 1:250,000 covering the general conveyance route. Transfer the ridgeline route(s) from step 2 onto the larger maps. Using the general route as a guide and with assistance of environmental planners, lay out an approximate alignment from source to terminal following natural contours to the extent practical. Due to the contour interval and scale of these maps, the slope of the canal invert will have little influence on this preliminary alignment. However, the general locations where lift stations (pumping plants with discharge conduits) and siphons will be required can be determined. Each segment of canal between lift stations should begin at a high point on or near the watershed divide delineated in step 2 and end where the canal, due to its slope and the terrain, reaches the minimum practical elevation. At these locations, pumping plants should be located on the alignment at a point high enough to avoid flooding of the plant and canal from natural streamflows and to allow for possible spills from the canal into a natural drainageway in the event of a power failure at the plant. Excessive distances from the pumping plant to the head of the next canal segment should be avoided because of the high cost of discharge conduits. This can be accomplished by extending the canal, by way of a deep cut, into the side of the "hill" below the head of the next canal segment. Because of their high cost, the number of pumping plants should be held to a minimum.

5. Using the rough alignment developed in step 3, obtain USGS quadrangle sheets covering the preliminary route. Transfer the route from step 3 onto the quadrangle sheets. This route will serve as a guide to lay out the alignment in more detail.

5. Select the beginning point of the canal at the highest practical elevation on or near the guide from step 4 and near the point of origin. (Avoid excessive lengths of discharge lines from the intake pumping plant to the head of the canal.) Assume the canal water surface elevation to be the same as the ground elevation at the centerline of the canal at its beginning.

6. Layout an approximate canal alignment taking into account the terrain and canal slope. (Allow for head losses of approximately 1 foot per 1,000 feet through siphons.) Check for excessive short-radius curves and excessive cuts and fills. (This will require judgement.) Adjust the alignment as required. Measure lengths of canal segments, siphons, and discharge conduits. Set the beginning water surface elevation for each canal segment. Then, using the canal length and invert slope, determine the water surface elevation at each subsequent siphon inlet and outlet, tunnel inlet and outlet, drop structure inlet and outlet, and pumping plant intake. Make final adjustments in the canal alignment so that control elevations match ground elevations and water surface elevations are consistent with starting elevation, slopes, distances, and head losses through structures.

7. Tabulate final lengths of canals, siphons, tunnels, and discharge conduits. Check and tabulate elevations.

8. Show final layout on maps with scale 1:250,000 (USGS 2° sheets). Elevations at pumping plant intakes and outlets, siphon and tunnel inlets and outlets, and drop structures should be shown on the maps, along with lengths of canal segments (including drop structures), siphons, tunnels, and discharge lines. Pumping plants, siphons, tunnels, and drop structures should be numbered on the maps for convenience.

SECTION IV - COST ESTIMATING PROCEDURE

A. Lands and Damages

1. Dams and Reservoirs - Covered in Section IV.

2. Conveyance Facilities. Use Figure 1, labeled Canal Land Requirements, to arrive at the number of acres required per mile of canal according to the design flow. Next, use the appropriate Land Costs Curve for the region to arrive at the estimated costs of lands and damages for the given canal alternative.

SAMPLE COMPUTATION FORM
ESTIMATED LANDS AND DAMAGES COST
(ROUTE - FLOW RATE)

Date: _____
District: _____
Prepared by: _____
Checked by: _____

Reach	Length (mi)	Acres	Unit Value (\$/acre)	Total First Cost
Totals				

3. Fish and Wildlife Mitigation. This section provides a simple method for estimating the cost of mitigating wildlife resource directly attributable to water transfer systems.

a. Types of losses considered. Only fish and wildlife habitat losses directly attributable to water transfer features, i.e., reservoirs, canals, pumping plants, and similar facilities, will be considered. No secondary losses are included.

b. Derivation of formula.

(1) Each district will utilize in-house expertise, consult with the US Fish and Wildlife Service, appropriate state fish and wildlife agencies to establish habitat values occurring along their assigned diversion routes. Habitat types will be valued in habitat units (hu) on a scale from 1 to 10 where 10 is the greatest value. Habitat types should be categorized, and for any given region there should be no more than 4 or 5 categories.

(2) Given a specific corridor route, a weighted average hu/acre (A) will be computed. This average hu/acre (A) less an assumed inherent value of 1.0 hu/acre for the water transfer facilities after construction will equal net hu/acre losses (B) per acre of land committed to the project.

(3) Habitat losses will be mitigated by the acquisition and improvement of lands for wildlife. All lands acquired for mitigation along the corridor will have an initial value equal to the average hu value (A) computed above. However, through improvement and management of these acquired lands, this value will increase from the average value (A) to 9.0 hu/acre. This results in (C), a gain in hu for each acre acquired, improved, and managed for wildlife ($C = 9.0 - A$).

(4) The land that must be acquired for mitigation (F) and the cost of acquiring it are proportionate to the number of acres acquired or committed to the water transfer system. Based on the above, this proportion can be expressed as:

$$F = \frac{BDE}{C}$$

where

B = hu losses/acre = $(A - 1.0)$;

C = hu gains/acre through improvement and management = $(9.0 - A)$;

D = acres of land acquired for the water transfer system;

E = cost of land/acre; and

F = total cost of land needed for mitigation

(5) The cost figure derived from this formula, however, would represent only the initial acquisition cost. Experiences in other cases indicate that improvement costs usually range near half again as much as initial acquisition costs. The cost formula for mitigation (G) is derived from the above formula in the following manner:

$$G = 1.5F$$

where

F = total cost of land needed for mitigation

G = mitigation costs

(6) The land cost/acre used in the above formulas should be the same cost as used for the other elements of the water transfer system.

c. Example Calculation. A canal system that crosses the State of Nebraska involved two storage reservoirs, 450 miles of main canal, and three major pumping plants, all of which will require 100,000 acres of land acquisition. Assume for the purpose of this example that the average cost of land per acre in Nebraska is \$1,000/acre. The average habitat value (A) along the water transfer system in Nebraska is estimated at 3.0 hu/acre. Mitigation costs (G) are therefore:

$$\begin{aligned}
 G &= 1.5 \frac{BDE}{C} \\
 &= \frac{(1.5) (3.0 \text{ hu} - 1.0 \text{ hu}) (100,000 \text{ ac}) (\$1,000/\text{ac})}{(9.0 \text{ hu} - 3.0 \text{ hu})} \\
 &= \frac{\$300,000,000}{6} \\
 &= \$50,000,000
 \end{aligned}$$

B. Relocations. Cost estimates for relocation elements fall in two general categories: dams and reservoirs and conveyance facilities. To use the cost estimates, and alignment or reservoir area is to be delineated on an appropriate map. USGS topographic maps having a scale of 1:250,000 may be used for both highway and railroad relocations. For pipelines use the following listed maps: (1) Atlas of Major Gas Transmission Lines of the United States and Canada, (2) Crude Oil Pipeline Atlas, and (3) Products Pipeline Atlas of the United States and Canada. Powerlines can be determined from DOE electric facilities maps.

1. Dams and Reservoirs. Cost estimates are provided as a per-mile unit. After the reservoir limits are determined, the following relocation items are to be assessed: highways (Interstate, US, and state, FAS, county), railroads, transmission pipelines (natural gas, crude oil, oil products), powerlines (transmission, distribution), telephone lines, and rural waterlines. The above listed maps are used for dam and reservoir relocations, with the additional need for consultation with state regulatory bodies to determine power distribution lines, telephone lines, and rural waterlines.

Relocated routes for the effected elements are to be sketched on the appropriate map and measured. By utilizing Figure 14 an overall relocations cost can then be determined.

2. Conveyance Facilities. Cost curves are provided for the following relocation elements: highways, railroads, major pipelines, major powerlines, and miscellaneous relocations (FAS and secondary county roads, electrical distribution, rural waterlines, and telephone lines). Except for the miscellaneous relocations curve, each of the cost curves represents the estimated cost of a single relocation. Therefore, the number of highways, railroad tracks, etc., which would be relocated may be determined from the appropriate maps and applied to the appropriate cost curve, Figure 11, 12 or 13.

C. Dams and Reservoirs. The following is a step-by-step procedure to prepare cost estimates for dams and reservoirs:

1. Select damsite. Determine profile for dam centerline, reservoir area-capacity curve, and uncontrolled and total drainage areas from contour maps.

2. Determine PMF peak flow from plate 1 and SPF volume from Figure 4. If upstream reservoirs are designed for flood control, it may be permissible to use only the uncontrolled drainage area instead of the total drainage area.

3. Select sediment production rate based on 0.2 AF/sq mi, 0.6 AF/sq mi, and 1.5 AF/sq mi for areas with low, moderate, and high erosion potential, respectively. Multiply sediment production rate by the uncontrolled drainage area. Multiply the resultant product by 100 to obtain the total sediment for the life of the project.

4. Determine conservation storage needs from separate hydrologic studies.

5. Determine flood surcharge volume ($1/2 \times$ SPF volume from step 2 for rural areas and total SPF volume for urban areas).

6. Determine total reservoir volume (sum of sediment storage from step 3, water

storage from step 4, and flood surcharge volume from step 5).

7. Refer to area-capacity curve and determine land requirements at top of total storage - multiply by unit land value from previous section to obtain total land cost.

8. Determine total dam height. Total height is distance from stream bed to top of total storage from step 7 plus freeboard. Obtain freeboard from table 3.

9. Determine dam volume using dam profile and typical cross sections shown on Figure 2. Refer to Figure 6 to obtain embankment cost for earth and rock dams. For concrete dams, refer to Figure 15.

10. Determine spillway cost from Figure 17. Use capacity of 0.65 PMF for spillways with crest at top of conservation pool and 0.9 PMF for gated spillways at valley level. Head used in Figure 17 is vertical distance from dam crest to stream bed minus 5 feet. Use the appropriate curve depending upon whether the spillway is gated or ungated. Spillway costs are already included in the costs of concrete dams so they should not be computed separately here.

11. Determine outlet works costs from Figure 18 based on outlet works head and capacity. Head is determined same as step 10. Capacity is selected on basis of downstream release requirements whether for subsequent diversion in connection with this study or for other functions. Outlet works costs are already included in the cost of concrete dams and gated spillways at valley level and should not be computed separately here.

12. Determine relocation costs from Section IV-B.

13. Determine total first cost of dam and reservoir. Total costs includes land cost from step 7, dam earthwork or concrete costs from step 9, spillway cost from step 10, outlet works cost from step 11, and relocation cost from step 12.

D. Pumping Plants. Pumping plant costs are obtained from the curves on Figure 22. These curves are based on an overall plant efficiency of 82 percent, assuming up

to nine pumping units (including one operational standby unit) per plant. The total head is estimated as the sum of the static head, friction losses through the plant of 15 feet, and friction losses through the discharge conduits of 1 foot per thousand feet of length. The user should interpolate to obtain costs for total heads not shown. The costs from the curves include all costs for a complete pumping plant except the costs of rights-of-way, discharge conduits (discharge manifold and valve costs are included in the pumping plant cost curves), access roads, automation, cultural resource preservation, mitigation or compensation of fish and wildlife habitat losses, engineering and design and supervision and administration. The cost obtained from the curves should be increased by 33 1/3 percent if the pumping plant includes a river or reservoir intake where the intake water surface would fluctuate significantly. Example: Estimate the cost of a pumping plant with a total capacity of 15,000 cfs. The plant is to pump from a reservoir with maximum water surface at elevation 500.0 and bottom of active storage at elevation 460.0. The plant is designed to pump to a canal with water surface elevation 650.0. The horizontal distance from the pumping plant to the canal is 2,000 feet.

Procedure:

Determine the maximum total head, H_T .

Static head = 650.0 - 460.0 =	190.0 feet
Head loss thru plant	15.0 feet
Head loss thru discharge conduit = $2,000 \times 1/1000 =$	<u>2.0 feet</u>
H_T	207.0 feet

Enter pumping plant cost curve on vertical axis at 15,000 cfs.

Find intersection of 15,000 cfs and 207-foot Head curve (interpolate between 200-foot and 300-foot head curves). Read \$250,000,000 on horizontal axis. Add 33 1/3 percent for reservoir intake.

Total cost = $1.33 \times 250,000,000 = \$332,500,000$.

E. Pipelines. Pipeline (pumping plant discharge conduit) costs are obtained from the curves on Figure 23. The costs include the costs of excavation, backfill, furnishing and laying the pipe, valves, manholes, structures, restoration of the site, and

all items necessary for completion except the pumping plant discharge manifold, rights-of-way, and indirect costs (engineering and design, supervision and administration, automation, cultural resource preservation, and mitigation or compensation of fish and wildlife habitat losses). The total head is estimated as the static head plus friction losses through the conduit(s) of 1 foot per thousand feet of length. The conduit diameter is estimated by the formula $D = (0.981Q)^{0.375}$ where Q is the discharge, in cubic feet per second, through the conduit. Where the diameter obtained from the formula would exceed 20 feet, more than one conduit would be utilized. Multiple conduits are taken into account on Figure 23. The cost per linear foot of conduit obtained from the curve should be multiplied by the distance from the pumping plant to the discharge outlet in feet.

1. Example: Estimate the cost of the discharge conduits required for the pumping plant in the previous example.

2. Procedure: The total head on the conduits is 192 feet (static head plus friction losses. Enter pumping plant discharge conduit cost curve at 15,000 cfs on the horizontal axis. Find the intersection of 15,000 cfs with the curve for 192-foot head (interpolate between curves for 150-foot and 250-foot heads). Read \$12,000 per linear foot. Total cost = \$12,000/ft. x 2,000 ft. = \$24,000,000.

F. Canals.

1. Three quantities are needed to calculate the cost of the canal: the length of the segment to be estimated, the percent rock excavation, and the flow rate for the segment.

2. Go to the Figure 24 for Canal Cost/Mile vs Flow Rate. On the X axis, locate the flow rate for the segment. Extend a vertical line to the curve which represents the percent rock excavation. Draw a horizontal line to the Y axis and read the cost/mile. Multiply this cost by the length of the segment. This will give the cost of the canal for this segment.

3. Example: 50-mile segment.

30 percent rock, 14,000 cfs.

cost/mile = \$4.4 million

4,400,000 \$/mile x 50 miles = \$220,000,000

G. Siphons. Siphon first costs are obtained from the curves on Figure 25. The curves include costs of concrete, cement, reinforcement, forming, excavation, back-fill, furnishing and laying the siphon pipe, valves, manholes, restoration of the site, miscellaneous costs, and an allowance of 25 percent for contingencies. The costs are for the complete siphon, including transitions, but do not include costs of rights-of-way and indirect costs (engineering and design, supervision and administration, automation, cultural resource preservation and mitigation or compensation of fish and wildlife habitat losses). The user should interpolate for siphon lengths not shown. The siphon costs are based on the use of multiple barrels, where necessary, with a maximum diameter of 20 feet.

1. Example: Estimate the cost of a 3,000-foot siphon with a design discharge of 15,000 cfs.

2. Procedure: Enter the siphon cost curve (Figure 25) on the horizontal axis at 15,000 cfs. Find the intersection of 15,000 cfs with the curve for length = 3,000 feet (interpolate between curves for 1,000-foot and 5,000-foot lengths). Read \$11,500 per linear foot on the vertical axis.

Siphon cost = \$11,500/ft x 3,000 ft = \$34,500,000.

H. Tunnels. Tunnel first costs are obtained from the curves on Figure 26. These costs include costs of excavation, concrete lining, cement, steel supports, timber lagging, and miscellaneous costs, as well as an allowance of 25 percent for contingencies. They do not include rights-of-ways and indirect costs (engineering and design, supervision and administration, cultural resource preservation and mitigation, or compensation of fish and wildlife habitat losses).

1. Example: Estimate the cost of a 5,000-foot tunnel with a design discharge of 15,000 cfs.

2. Procedure: Enter the tunnel cost curve (Figure 26) on the horizontal axis at 15,000 cfs. Find the intersection of 15,000 cfs with the curve. Read \$21,300 on the vertical axis.

Tunnel cost = \$21,300/ft x 5,000 ft = \$106,500,000.

I. Automation and Communication

1. Hardware for the main control center is estimated to cost \$400,000 for the scale of alternatives being considered. An additional cost of \$200,000 plus \$10,000 per pumping plant controlled would be necessary for software at the main control center. Hardware and software at each pumping plant controlled would cost an estimated \$600,000. Communication system costs are estimated to be \$200,000 plus \$10,000 per pumping plant. Total estimated first cost for automation may be taken to be \$700,000 plus \$620,000 per pumping plant. (Hydroelectric power plants may be counted as pumping plants for the purposes of estimating automation costs.)

2. Annual automation costs are estimated at \$0.70 per communication circuit per month per mile. Two circuits would be required for each pumping plant. The length of the circuits would average one-half the total length of the canal. Therefore, annual automation costs may be taken to be \$8.40 per pumping plant times the length of the canal.

J. Cultural Resources. Costs to preserve and enhance cultural resources associated with any alternative transfer route will be equal to 1 percent of the estimated construction costs of the transfer plan.

K. E&D and S&A. Engineering and design (E&D) and supervision and administration (S&A) costs are estimated as a percentage of the direct construction cost of the project (total project cost less costs of lands, E&D and S&A). For direct costs of the magnitude considered in the High Plains study, the E&D and S&A percentages are assumed to be 6 percent and 5 percent, respectively. These percentages are to be added as a last step in estimating total project cost.

1. Example: Estimate E&D, S&A, and total project cost for a project with a total direct cost, including lands, of \$50 billion. The estimated cost of lands is \$150 million.

2. Procedure:

Direct cost	\$50,000,000,000
Less cost of lands	<u>-150,000,000</u>
Subtotal	49,850,000,000
E&D (6%+)	2,990,000,000
S&A (5%+)	2,490,000,000
Lands	<u>150,000,000</u>
Total Project Cost	\$55,480,000,000

L. Operation, Maintenance, and Replacement

1. Dams and Reservoirs.

a. The cost curve for operation, maintenance, and replacement of dams and reservoirs is shown on Figure 27. The costs, which are based on total volume of controlled storage (sediment storage plus conservation storage), were obtained from actual cost experiences for Corps of Engineers projects in the Omaha District.

b. A sample of 13 smaller dams and 6 Missouri River main stem dams was used to develop the cost curve. Figure 12 in the appendix shows the cost curve with data points. The smaller dams are basically flood control reservoirs. The large dams are multipurpose Missouri River main stem dams. Specific operating costs for hydropower and recreation were excluded from the data points. However, overhead costs related to power and recreation were retained since a similar overhead (for planning, engineering, etc.) would be needed if an irrigation function were substituted for the excluded power and recreation functions. The intent is to develop annual operation and maintenance costs that would be necessary due to the basic existence of the reservoir. Operating costs should be added for specific irrigation facilities existing at the reservoir, such as a pumping plant or diversion headworks.

2. Pumping Plants.

a. Operation and maintenance costs used in plotting the O&M cost curves on Figure 28 were obtained from the pumping plant computer runs discussed in Section II, paragraph C4. The costs represent the average annual cost of personnel, materials, supplies, and repairs necessary for operation and maintenance of the pumping plant.

They do not include costs of major replacements or energy. The curves are to be used in a similar manner to that described in the example for pumping plant cost.

b. The curves on Figure 29 represent the average annual cost of replacement of major items of pumping plant equipment over the life of the plant. The curves are based on a rate of \$0.003 annually per dollar of first cost for pumps and prime movers used by the Water and Power Resources Service regional office in Amarillo, Texas, in their appraisal level estimates for the Oklahoma Water Plan studies. The curves are to be used in a similar manner to that described in the example for pumping plant cost.

3. Conveyance Facilities.

a. Two sources were consulted in developing the annual operation and maintenance cost for canals...the Texas Water Development Board report on "Inter-Basin Canals and Pipelines 1967" discussions with personnel of the California Department of Water Resources.

b. The "Inter-Basin Canals and Pipelines 1967" report showed a table of Canal Maintenance - Annual Cost per mile for canals of from 400 cfs to about 9,700 cfs capacity. This range covers the smaller flows under investigation here. However, these costs proved to be much lower than the actual operating costs for the California project even with the adjustment of August 1966 prices to January 1979 prices. Therefore, the Texas costs were not used.

c. The California Department of Water Resources provided actual Operation and Maintenance (O&M) cost per mile for fiscal year 1978 (1 July 1978 to 30 June 1979). The canal capacities on that project range from 300 cfs to 13,100 cfs. The O&M cost includes the following major items: Maintenance of one hard surface road and one gravel road on large canals and a gravel road on each side of the small canals; fixing chain link fence that lines both sides of the canals; mowing the grass on

both sides of the canals; cleaning out the through drainage structures; keeping the canals clean of dirt, rocks, tumbleweeds and anything else that may impede the flow of water; repairs and maintenance of small metal bridges, check gates, operation building; and maintenance of the concrete canal. Power to operate the pumping stations is not included in this cost.

d. Two curves, displayed on Figure 30, were developed for the annual operation and maintenance of a canal based on the California data with an added 5 percent to cover unknown costs. These curves were extrapolated to 30,000 cfs by assuming that O&M costs would approach a constant rate at 20,000 cfs.

e. The higher cost from California project reflects a high concentration of suspended particles from flood waters, large amounts of debris from high winds and an abnormal number of siphons or check gates over the canal. The low cost would reflect a check gate every 8-12 miles with a metal bridge, very few number of siphons, and the through drains can handle the rainwater so not to cause a high amount of sediment in the canal.

f. Major replacements were considered in developing these two curves. The canal structure is considered to last the life of the project (100 years). The check gate structures, metal bridges, and lateral drainage structures are also going to last the life of the project. The cost per mile curves include costs for replacement of a fixed amount of fencing, dirt roads, and paved roads. These curves also have replacement costs of items that are less than \$100,000 such as, radial gates, small motors, and small computers that operate the check gates.

g. In summary, if the canal will have high maintenance, use \$11,800 per mile, and if it will be more on the normal maintenance, use \$9,500 per mile. The difference in O&M costs between low-flow canals and high-flow canals is not significant enough to warrant using a curve.

h. Example:

(1) The canal segment is 50 miles long and normal maintenance is expected to be needed. To find the annual operation and maintenance, two items are needed: length of the segment of canal being evaluated, and if the annual maintenance of this segment will be high or normal. From the discussion in the preceding paragraph, the annual normal maintenance is \$9,500 per mile of canal.

(2) \$9,500/mile x 50 miles = \$450,000 for the annual O&M cost.

4. Automation and Communications. The first costs for automation (including hardware and software) are estimated to be \$700,000 plus \$620,000 per pumping plant. (Hydroelectric power plants may be counted as pumping plants for the purpose of estimating automation costs.) Annual automation costs are estimated at \$8.40 per pumping plant times the length of the canal.

SAMPLE COMPUTATION FORM
ESTIMATED AUTOMATION COSTS
(ROUTE - FLOW RATE)

Date: _____
District: _____
Prepared By: _____
Checked By: _____

Reach	No. of Pumping Plants	First Cost Unit Price (\$/Plant)	First Cost (\$)	Annual Cost Unit Price (\$/plant/mile)	Canal Length (mi)	Annual Cost (\$)
-------	-----------------------------	--	--------------------	--	-------------------------	------------------------

Sub Totals
Base Cost
Totals

\$700,000

N. Energy. Energy requirements for pumping plants shown on Figure 31 are based on an assumed plant efficiency of 82 percent. The pumping plant energy requirements were increased 5 percent, to allow for energy required by miscellaneous equipment associated with the pumping plants, prior to plotting the curve. To estimate the annual cost of energy needed to run the pumps and related equipment, the value obtained from the curve should be multiplied by the appropriate rate per kilowatt-hour

and the annual volume of water pumped in acre-feet.

O. Contingencies. An allowance for contingencies was made in the amount of 25 percent of the estimated construction cost. The 25 percent is included in the cost analysis curves of canals, pumping plants, siphons, relocations, reservoirs, diversion dams, and tunnels. A contingency factor of this magnitude was selected in accordance with the following reasons:

1. A canal of this magnitude has not yet been built.
2. The wide variation in terrain and climatic conditions over which this project will cover (from Montana to Texas).
3. Costs estimates will be of a reconnaissance level.
4. Lack of uniform mapping in study area.
5. The large variation of design discharges (500 cfs to 30,000 cfs).

SECTION V. ENVIRONMENTAL ASSESSMENT

A. General. The purpose of this section of the guidebook is to establish uniform procedures for conducting preliminary environmental assessment for identified alternative water transfer elements. In accordance with the Plan of Study (November 1977), these assessments will be of a broad-based reconnaissance level, will concentrate on significant environmental impacts, will consider only impacts associated with construction of canals or other transfer facilities and the physical effects along the canal routes during operation, and will be based primarily on data found in published sources and available files.

B. Assessment Criteria.

1. Sensitive Areas. Environmental hazard areas/sensitive or significant features along each potential study route will be identified and mapped on USGS (or equivalent) maps of the proposed route. The corridor location and the features required for each water transfer route should be designed as practicable to avoid adverse impacts on State, Federal, and private wildlife refuges, Indian reservations, military reservations, ethnic settlements, management areas, natural areas, parks,

recreation areas, identified archeological and historical sites or districts, and national or state forests. Potentially significant impacts on migration patterns of terrestrial, aquatic or bird species, and significant impacts on prime or unique farmlands, aesthetically rich areas, or critical or otherwise recognized important wildlife habitats or aquatic systems will be identified. If significant adverse impacts are identified and cannot be avoided, mitigating or compensating measures should be reasonably available to lessen impacts and should also be identified.

2. Resource Importance. The general importance of wildlife habitat, aquatic systems, land use, physiographic features, aesthetics, and environmental quality adversely affected along the study routes will be assessed using known base resource data for the region involved. Quantification of land uses affected, vegetation or wildlife habitat lost or modified, and qualification of physiographic features, aesthetic value, and aquatic and terrestrial wildlife values in each study corridor will be done, as possible, based on known feature sizes and channel ROW widths and USGS maps or available aerial photography. The amount and type of resource affected will be compared with the given resource's local, regional, and national importance. The importance values should reflect the scarcity of the resource, the body of national and regional policy concerning the resource, and social perceptions and attitudes toward the resource. Local area will be the direct feature impacts and political boundaries on approximately the county level. Regional area will be defined as appropriate for each study route based on political, watershed, or natural geographic boundaries.

3. Environmental Risk. The degree of unknown environmental risks involved (river crossings, population centers, environmentally sensitive areas) along each water transfer route will be assessed. Based on analysis of the features involved and the study corridor for each water transfer route, an assessment will be made of the degree of unknown factors or need for further detailed study required to predict

significant changes in ecosystems or lessen the risk involved to future environmental quality.

4. Compliance with Environmental Policy. Potential conflicts with environmental laws/regulations for each water transfer route will be assessed. An assessment will be made of each transfer route to determine probable compliance or noncompliance with existing environmental legislation and executive policy. Discussion of compliance with environmental laws and regulations will consist of a brief response to requirements of the listed Act or Executive Order. This will not be a detailed response, but an analysis (based on literature sources and available file date) of the relationship of transfer elements to the specific law or regulation, and a statement of probable compliance/noncompliance under current standards. The requirements to be considered should approximate those for Level A studies and should include: agency (Department of Commerce) responsibility.

a. Endangered Species Act of 1973, PL 93-205, as amended. An analysis of listed endangered or threatened species of flora and fauna, proposed species, and designated or potentially designated critical habitats will be made to determine potential Section 7 conflicts along each study route. State listed endangered/threatened species may also be included in the analysis if more extensive than the federal list. The most recently published federal list will be used (currently 17 January 1979 for fauna and 16 June 1976 for proposed flora).

b. Wild and Scenic Rivers Act, PL 90-542, as amended. Rivers designated in the Act or amendments for inclusion in the Wild and Scenic River System, under study for inclusion, or listed or under study for a state wild, scenic, or recreational river system will be identified if potential impacts are expected. An analysis of any river crossed by the transfer route will include a brief discussion of the river's existing or future potential for inclusion in such a system.

c. Preservation of Archeological and Historical Data Act (PL 93-291), Historic Preservation Act of 1966 (PL 89-655), and Executive Order 11593. Based on available data, an analysis will be made of the transfer route's impacts on cultural resources (historic, archeological, architectural). The analysis will be limited to listed National Register sites, state historic sites, and available literature sources on potentially significant areas requiring more detailed reconnaissance survey work. The degree of unknown information of the cultural resource record along the study route should be noted.

d. Clean Water Act, PL 95-217 (Section 404). A brief analysis of the features included in each water transfer system will be made in relation to requirements of Section 404 and EPA's guidelines for evaluating the discharge of dredged or fill material in waters of the United States (40 CFR 230).

e. Executive Order 11988, Flood Plain Management. If applicable to a water transfer route or features included in the water transfer route, a brief analysis of the relationship to this executive order will be made.

f. Executive Order 11990, Protection of Wetlands. An analysis of each transfer route's potential effects on wetlands will be made. Avoidance of wetlands or avoidance of adverse impacts on wetland areas will be an environmental goal in accordance with the Executive Order.

g. Fish and Wildlife Coordination Act (PL 85-624), as amended. A brief analysis of past or present coordination with the USF&WS regarding previously studies transfer routes or elements, and an analysis of probable impacts to fish and wildlife with currently identified water transfer routes will be conducted. Coordination with USF&WS field offices will be limited to obtaining or utilizing file data and available biological expertise.

C. Environmental Checklist. To assure that all significant parameters are identified in assessing the impacts of an identified water transfer element and to assure

that a comparable level of detail is achieved by each working element involved,
an environmental checklist follows in Table .

TABLE

I. PHYSIOGRAPHIC ELEMENTS

A. Geologic Landforms

- Canyons, gorges
- Distinctive mountain features (peaks, hills, buttes)
- Distinctive rock formations
- Soils
- Unusual exposed minerals
- Caverns, caves
- Salt flats or beds
- Water-land interfaces
- Oil and gas fields lignite

B. Hydrologic

- Climatology
- Surface drainage
- Groundwater, aquifer recharge areas
- Lakes, ponds, lagoons
- Free-flowing rivers, streams, tributaries
- Wetlands
- Springs
- Waterfalls
- Water quality

II. BIOLOGICAL ELEMENTS

A. Botanical

- Land Cover
- Rare, endangered, threatened, remnant or unique species, specimens, stands, or communities, champion trees
- Climax communities
- Vegetative types unusual to a region, Endemic species
- Aquatic weeds (troublesome, beneficial species)

B. Zoological

1. Terrestrial Animals

- Threatened or endangered species
- Habitats (critical and otherwise), migratory routes, breeding, resting, wintering grounds of threatened, endangered, unique, or otherwise significant species or communities

2. Ornithological

- Threatened or endangered species, habitats (critical and otherwise), migratory routes, breeding grounds, roosting sites, feeding-nesting areas of threatened, endangered, unique, or otherwise significant species or communities.

3. Aquatic

Threatened or endangered species.

Marine, estuarine, and freshwater habitats (critical and Otherwise), anadromous routes, spawning grounds, feeding areas, nursery areas, and other features relating to significant species of fin and shell fish. Introduced and troublesome species.

- C. Life Zones/Biomes, Wetland Communities, and Other Ecologically Significant Areas Not Identified Above

III. CULTURAL ELEMENTS

A. Archeological

Pictographs, petroglyphs

Burial grounds, mounds

Village sites, ruins, artifact scatters

All sites listed in the National Register of Historic Places

B. Historical

Historical sites and districts, monuments, structures, and buildings

Transportation features; trails, canals, and bridges

Old communities or areas retaining character of historical background

All sites listed in the National Register of Historic Places

C. Paleontological

Fossil remains

Petrified wood

Pollen analysis

Human cultural associations

D. Contemporary

(Those features which reflect man's current values, activities, styles of life, social events)

Architectural and engineering works

Sites of fairs, festivals, art and musical events, and other cultural activities

Ethnic colonies; i.e., creole, amish, etc.

Employment

Educational opportunities

IV. LAND USE

A. Urban and Built-up Land

Residential

Commercial and services

Industrial

Extractive

Industrial
Extractive
Transportation, communications, and utilities
Open space

B. Rural Land

Prime or unique farmland
Cropland and pasture - General
Forest Land - General

C. Environmental Use or Management Areas

1. Federal, state, local, or private land or water areas which have been formally and/or legally designated for some conservation or environment-related purpose.

Parks
Forests
Seashores
Scenic roads and trails
Wild and scenic rivers
Wildlife preserves and refuges
Nature trails, arboretums
Open and green space
Research or educational areas
Outdoor recreation areas
Historical parks
Wilderness areas

2. Land and water areas, as above, which have been identified but have not been formally or legally designated or developed.

D. Assessment Procedure

1. Introduction. Purpose, scope of assessment (identify assumptions). SWD will prepare a general introduction to be used in any report compiled for transfer routes assessed.

2. Water transfer element. Briefly identify and describe study area or corridor (define canal route, features, storage reservoirs, pumping facilities, sizes, design criteria). The description should only include sufficient detail to delineate the element assessed, and should not repeat detailed data also presented in reports compiled by SWD.

3. Affected environment. Based on broad checklist and available literature sources, develop brief overall base environmental setting or profile (narrative) of study area. This will be concise and general, provide an easy to read overview, and be divided into paragraphs on physical, environmental quality, biological and cultural settings. Locate all significant sensitive areas, major cultural resource features, critical habitats, and environmental problem or hazard areas, based on checklist and source data. These should be displayed on a base map (or maps) with the element or route under study.

4. Environmental consequences.

a. Develop tabular display of all general transfer route impacts (quantified as possible) by major environmental category from source data and aerial photos.

(1) Physical

- (a) Lands required
- (b) Geological
- (c) Hydrological
- (d) Groundwater

(2) Environmental quality

- (a) Water Quality
- (b) Air quality
- (c) Noise pollution
- (d) Aesthetic values

(3) Biological

- (a) Terrestrial vegetation/wildlife habitat

- (b) Wetlands
- (c) Aquatic ecosystem/fisheries
- (d) Wildlife
- (e) Endangered and threatened species
- (f) Vector populations

(4) Cultural

- (a) Relocations (transportation, pipelines, people)
- (b) Land use

SECTION VI - PROJECT COST ESTIMATES

A. Definitions

1. First Cost. The expenditure, subsequent to the authorization of the project, of labor, materials, and equipment necessary to design and construct the project, including those needed to minimize or eliminate adverse economic, social, and environmental effects required by Section 122 of the 1970 Rivers Harbor Act. This includes the cost of land and rights-of-way on which the project is located or which is required for its construction and operation and compensation for damages, relocations of structures and facilities, any remedial measures, and all other adjustments expected to be made in connection with the project.

2. Average Annual Cost

a. Interest rate. The interest rate (discount rate) to be used in project evaluation is the federal rate established for each fiscal year by the Water Resources Council. It will be used to present worth costs to the base year then to spread (amortize) them over the life of the project.

b. Period of analysis. The period beginning at the end of the installation period over which benefits (and cost) will accrue. This will never exceed 100 years and is limited to the less of (1) the period of time over which the project would serve a useful purpose, or (2) the period of time after which further discounting of benefits and adverse effects would have no appreciable impact. A 100-year period is appropriate for studies such as the High Plains Ogallala Aquifer Study.

c. Interest during construction. Actual interest during construction is computed based on the actual expenditures in construction of the project. The federal interest rate is applied to the expenditures in the year in which they are made. For planning purposes the mid-point of the anticipated construction period is assumed to be the mid-point for expenditures.

d. Investment cost. Includes first costs and interest during construction.

e. Interest and amortization. The periodic (annual) payment necessary to pay off the project costs at the specified federal interest rate. Used to spread costs uniformly over the life of the project.

f. Operation, maintenance, and replacement costs. These costs represent the current value of materials, the current value of materials, equipment, services, and facilities needed to operate the project and make repairs and replacements necessary to maintain project measures in sound operating condition during the period of analysis.

g. Energy cost. Prescribed by others.

h. Total average annual cost (average annual costs). The average annual cost includes the amortized value of all costs which are to be included in the benefit-cost analysis. These costs include investments costs, operation and maintenance, energy and major replacements.

B. Cost Estimating Procedure

Find first costs (exclusive of housing or highway betterments).

Add interest during construction.¹

Add (1) & (2) to get investment cost

Multiply investment cost x interest and amortization factor for period of analysis.

¹ Interest during construction may be estimated by applying the federal interest rate to the estimated annual expenditures and compounding to the end of the construction period.

To the interest and amortization add annual operation and maintenance charges.
To (5) add the annualized present value of major replacements, i.e., find the present of future major replacements and multiply it by the interest and amortization factor for the appropriate rate of interest for the period analysis.

This result in total annual charges.

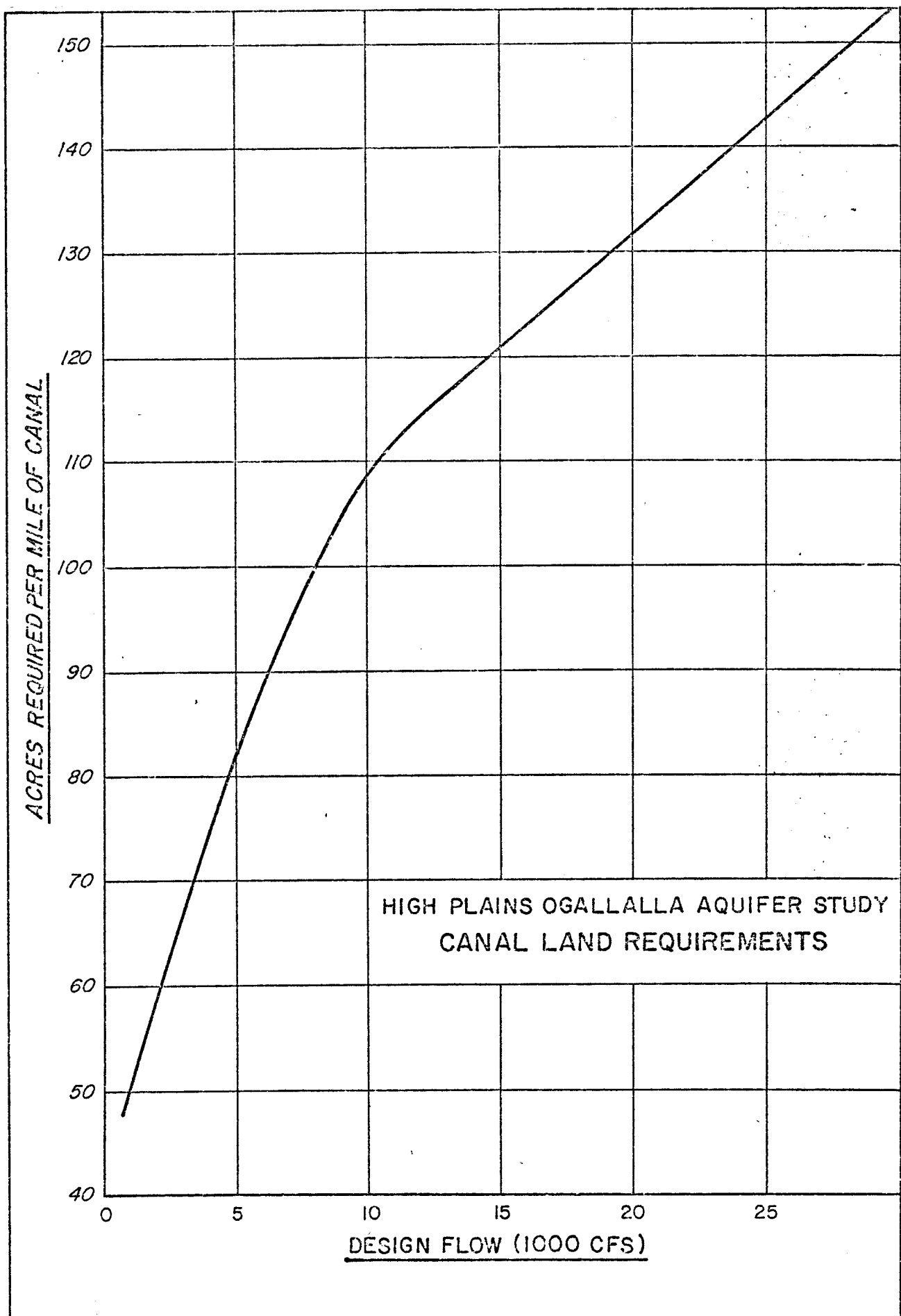
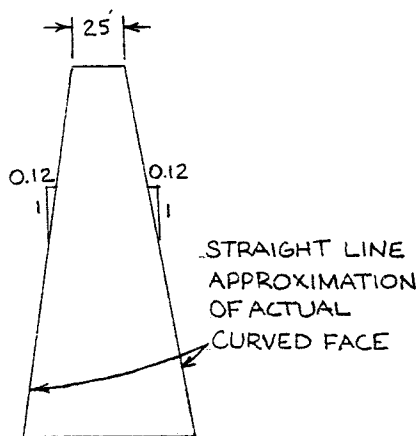
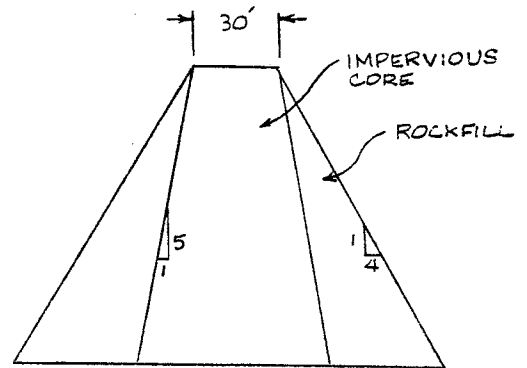


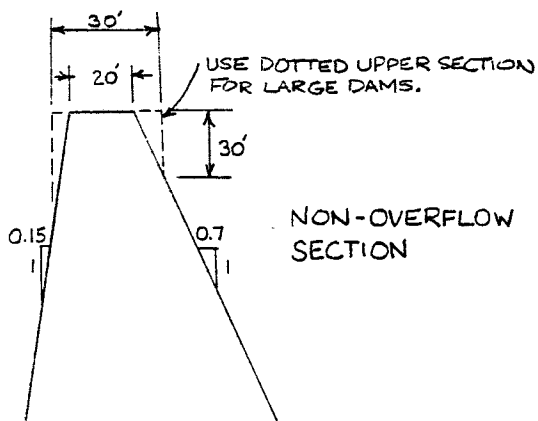
Figure 1



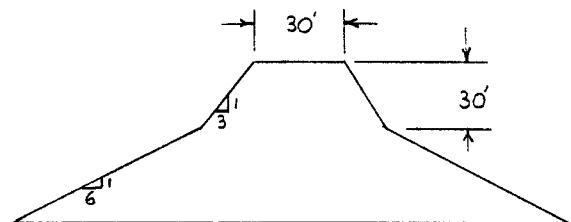
CONCRETE ARCH
DAM



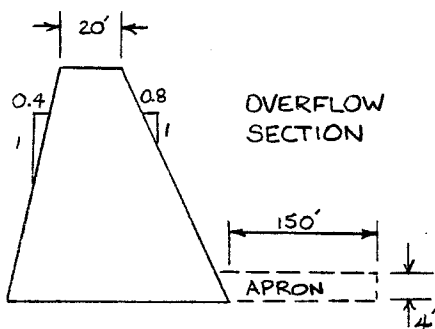
ROCKFILL DAM



NON-OVERFLOW
SECTION



EARTH DAM



CONCRETE GRAVITY DAM

HIGH PLAINS OGALLALA
AQUIFER STUDY

FIGURE 2

TYPICAL DAM SECTIONS

NOT TO SCALE

Figure 2

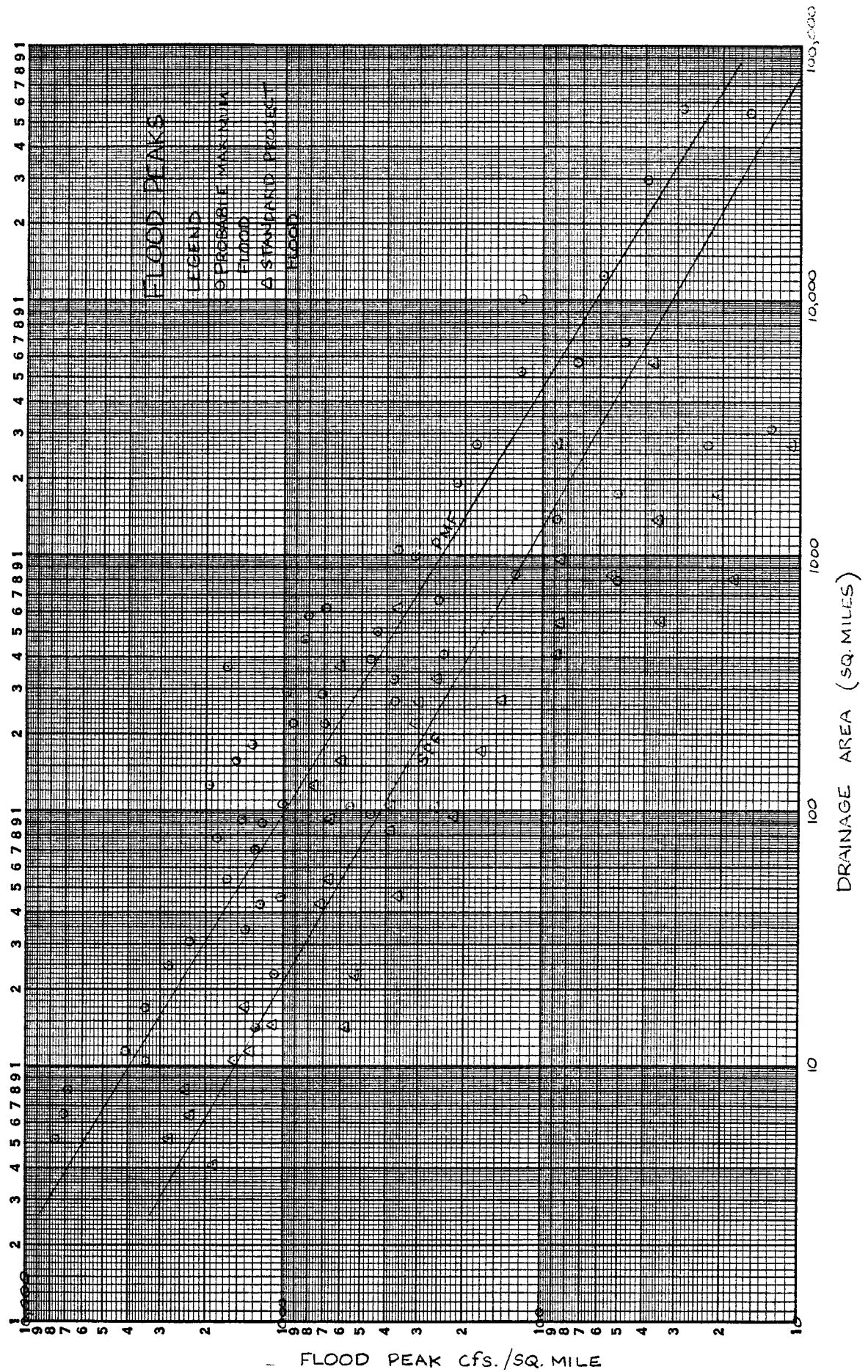
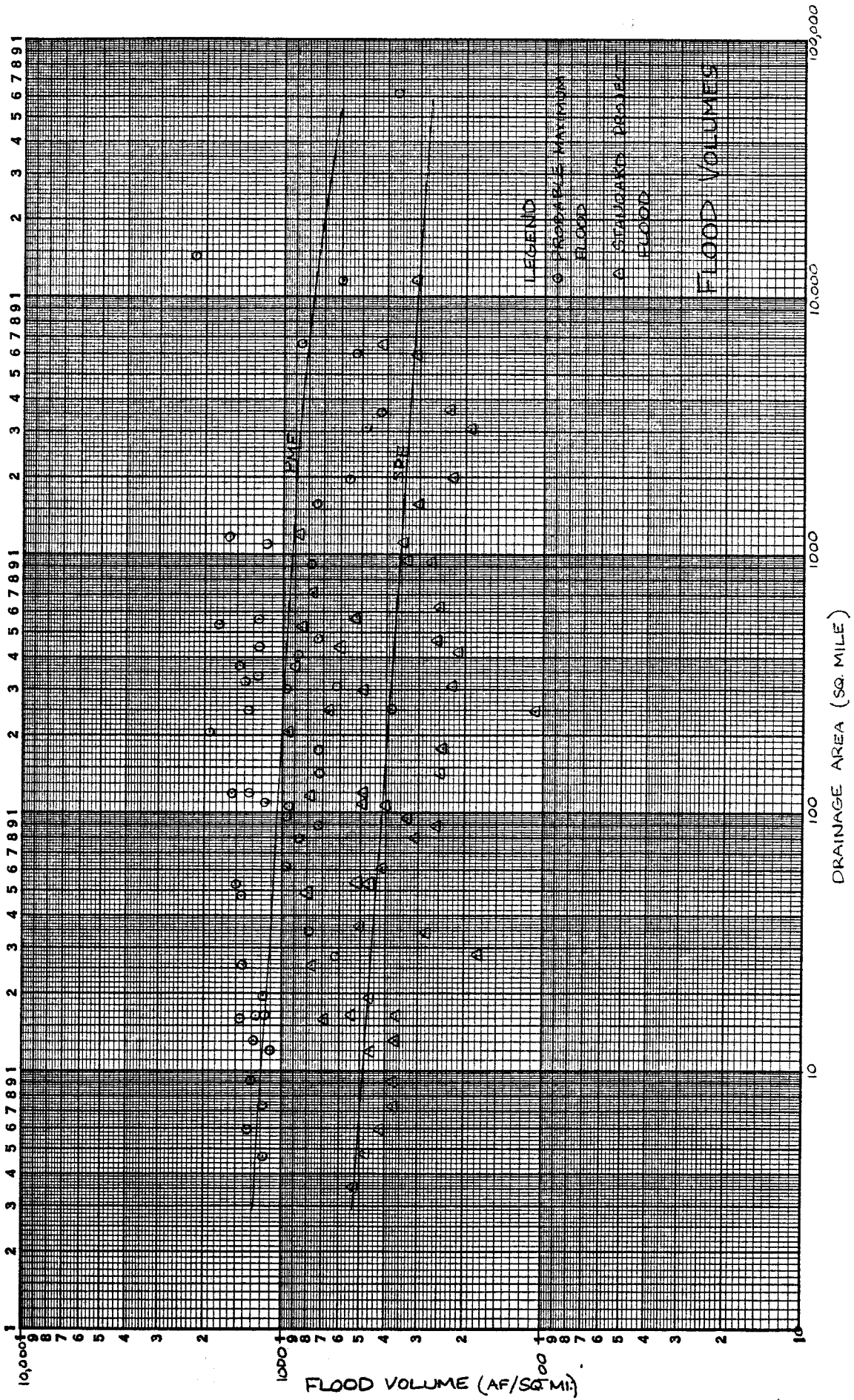


Figure 3



FLOOD VOLUMES

Figure 4

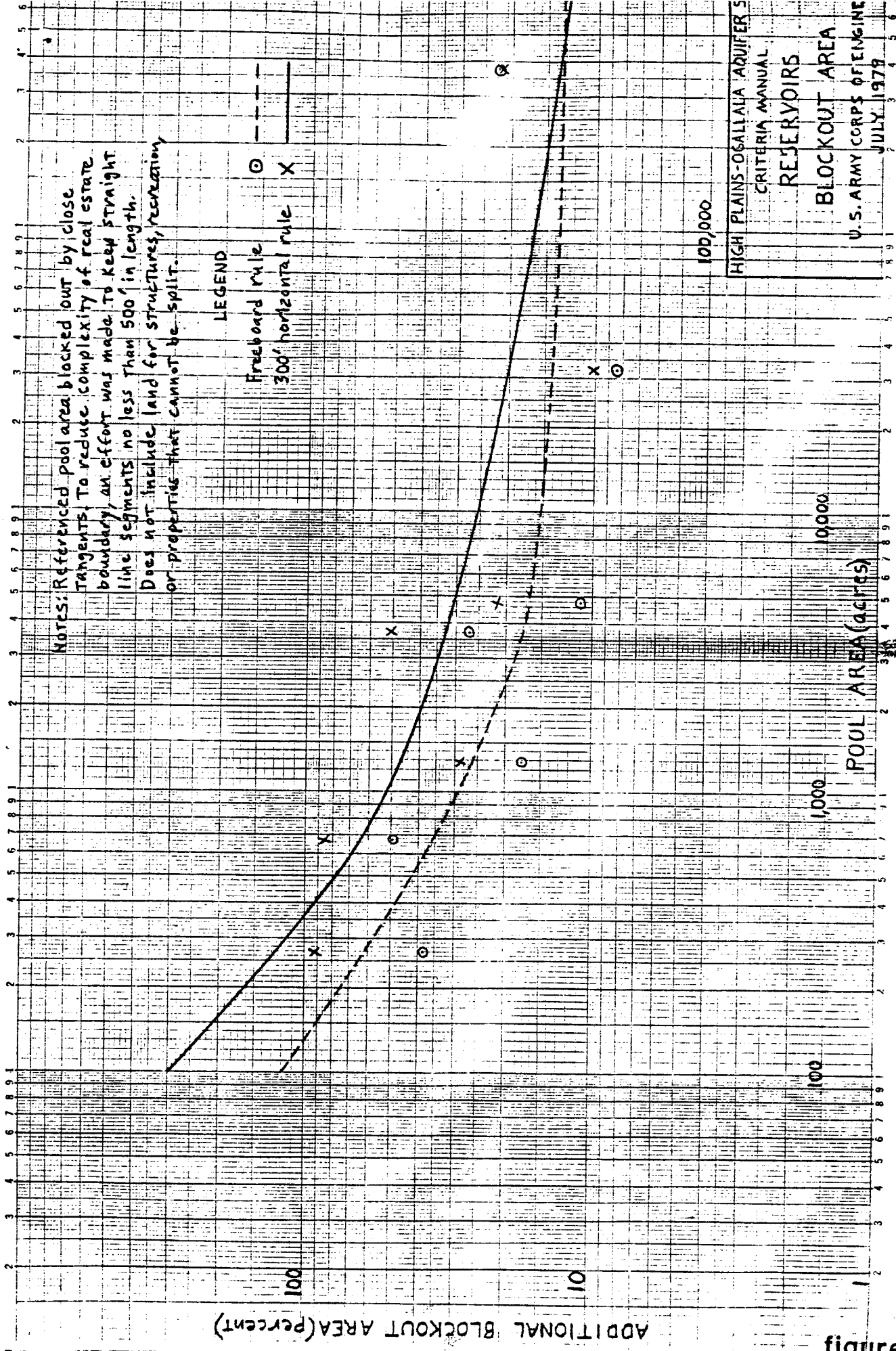


figure 4a

HIGH PLAINS-OSALLALA AQUIFER 5
 CRITERIA MANUAL
 RESERVOIRS
 BLOCKOUT AREA
 U.S. ARMY CORPS OF ENGINEERING
 JULY 1979

TYPICAL PUMPING PLANT

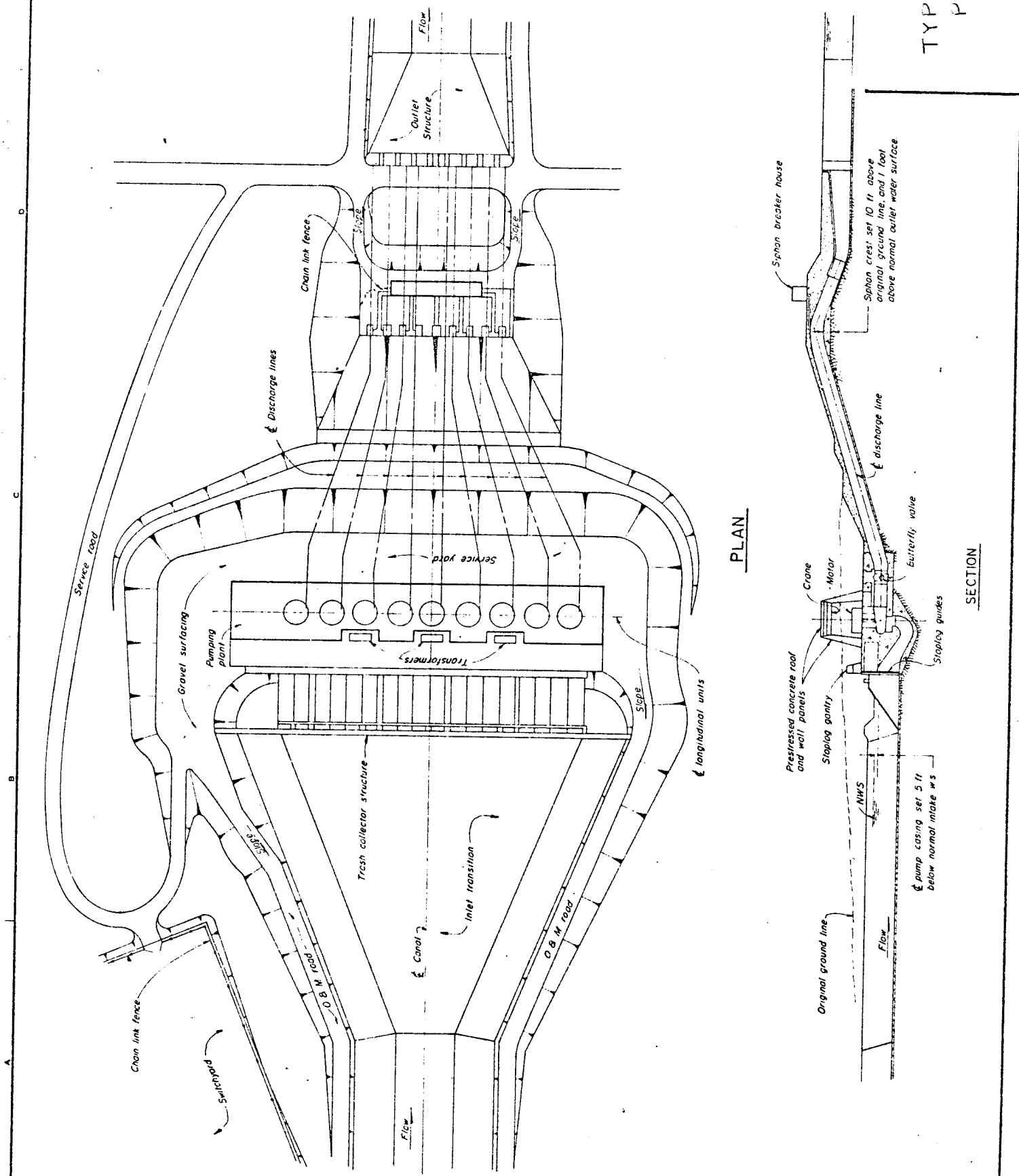
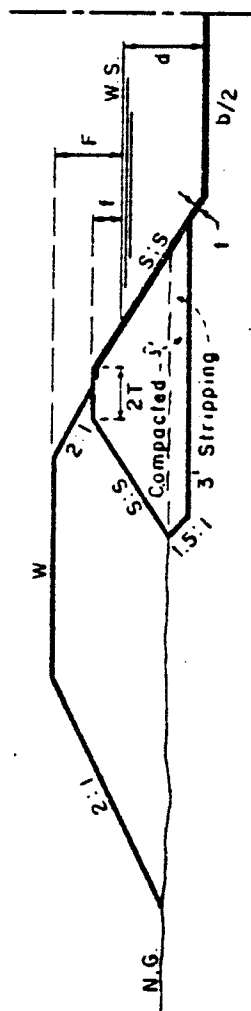
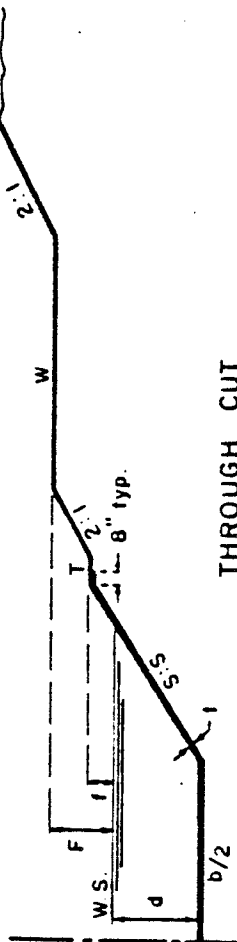


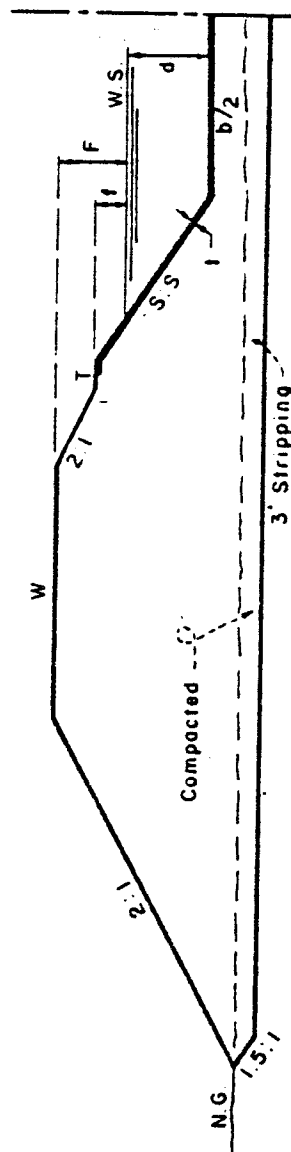
Figure 5



CUT AND FILL



THROUGH CUT



THROUGH FILL

SIDE SLOPE = 2:1 when $d \geq 14$ ft.
1.5:1 when $d < 14$ ft.

FIGURE 6
CANAL SECTIONS

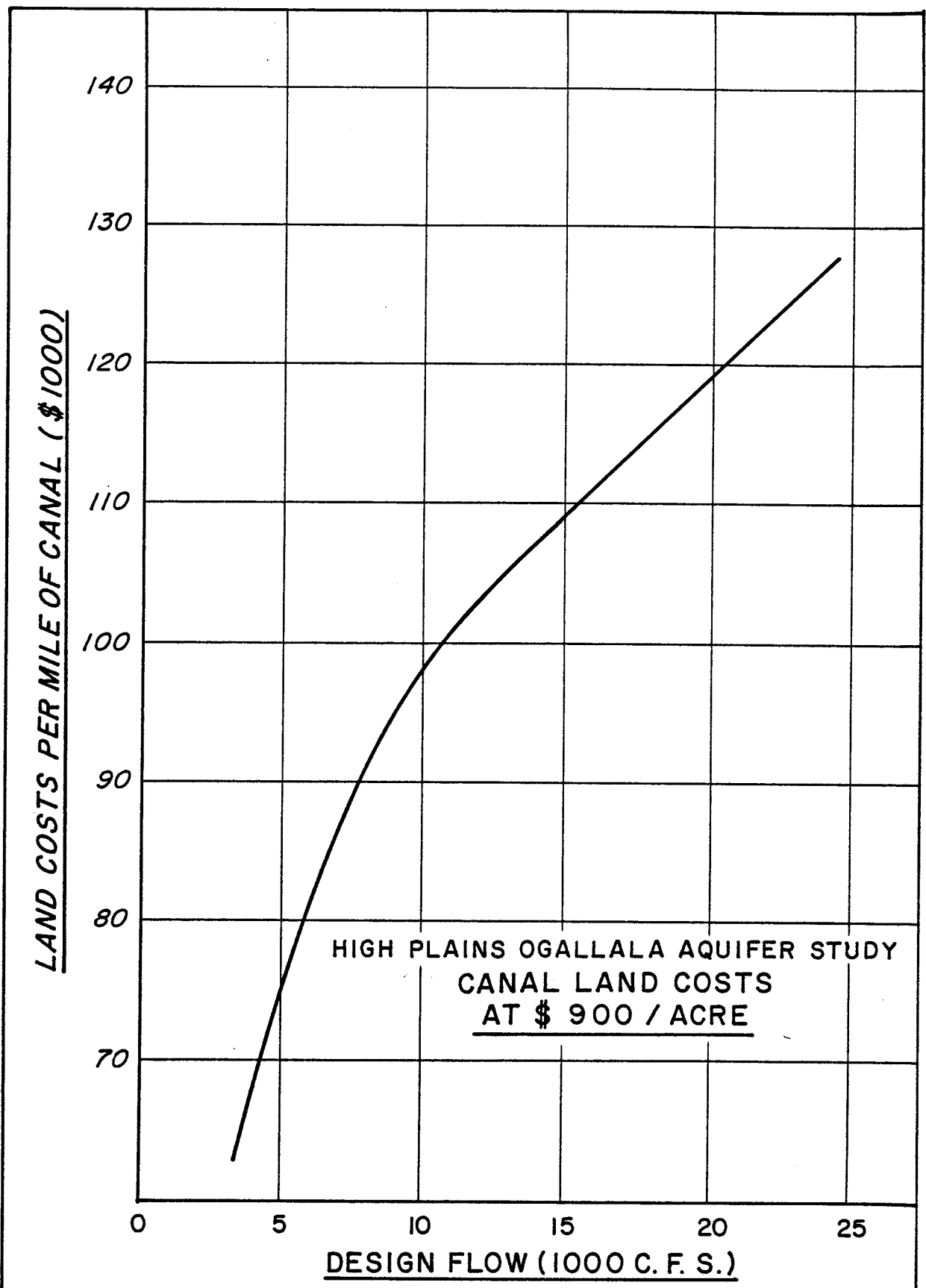


Figure 7

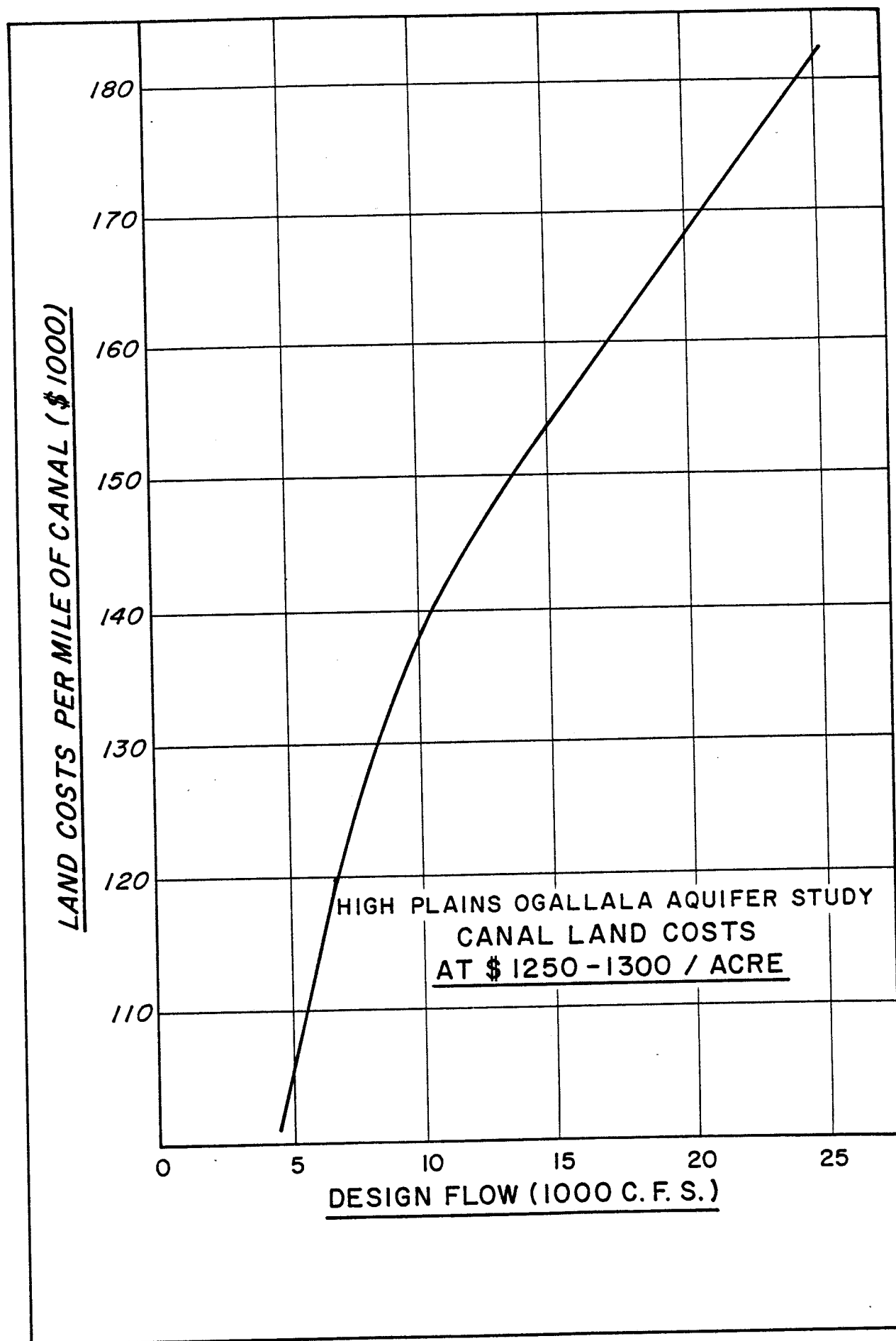


Figure 8

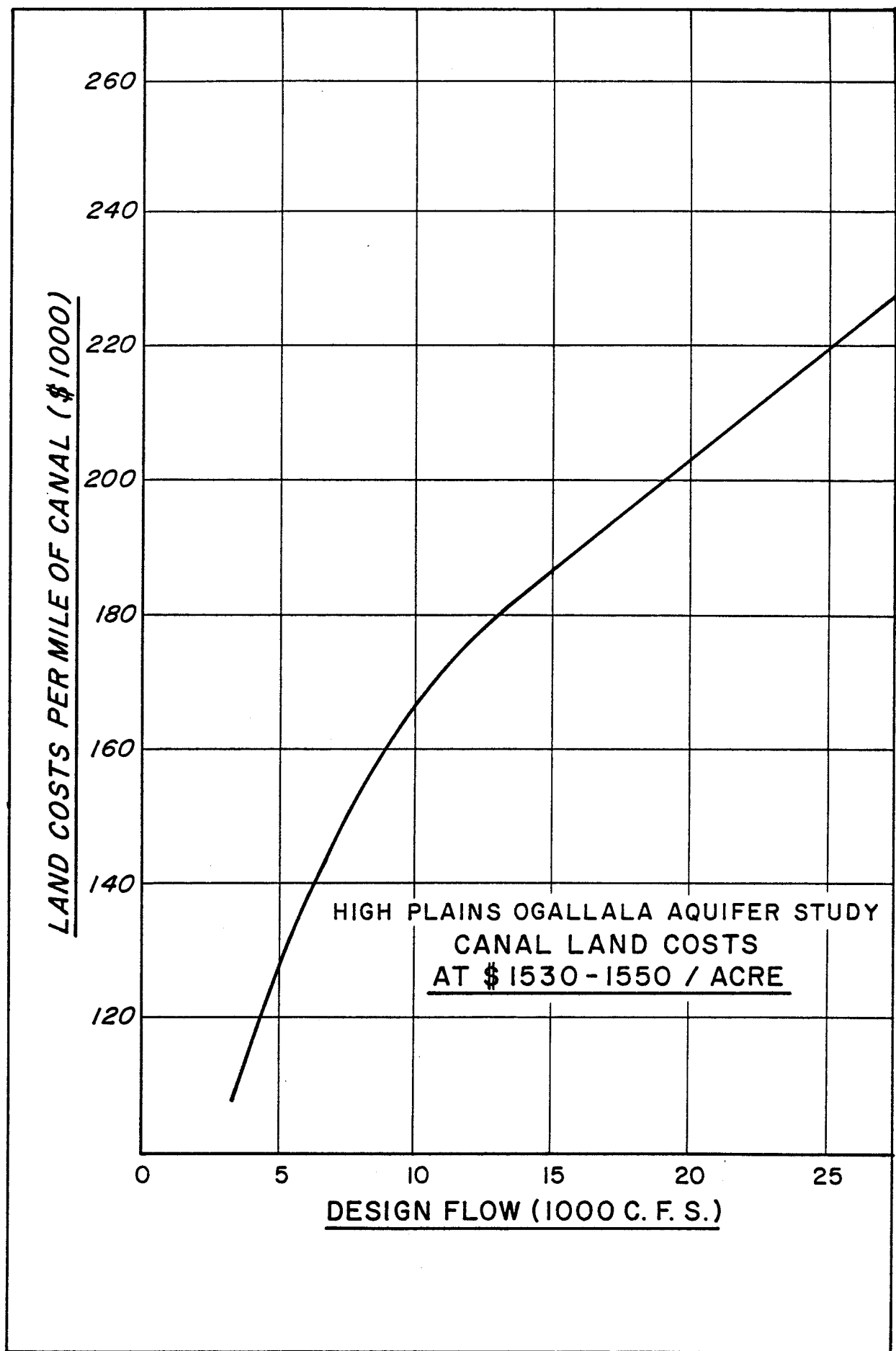


Figure 9

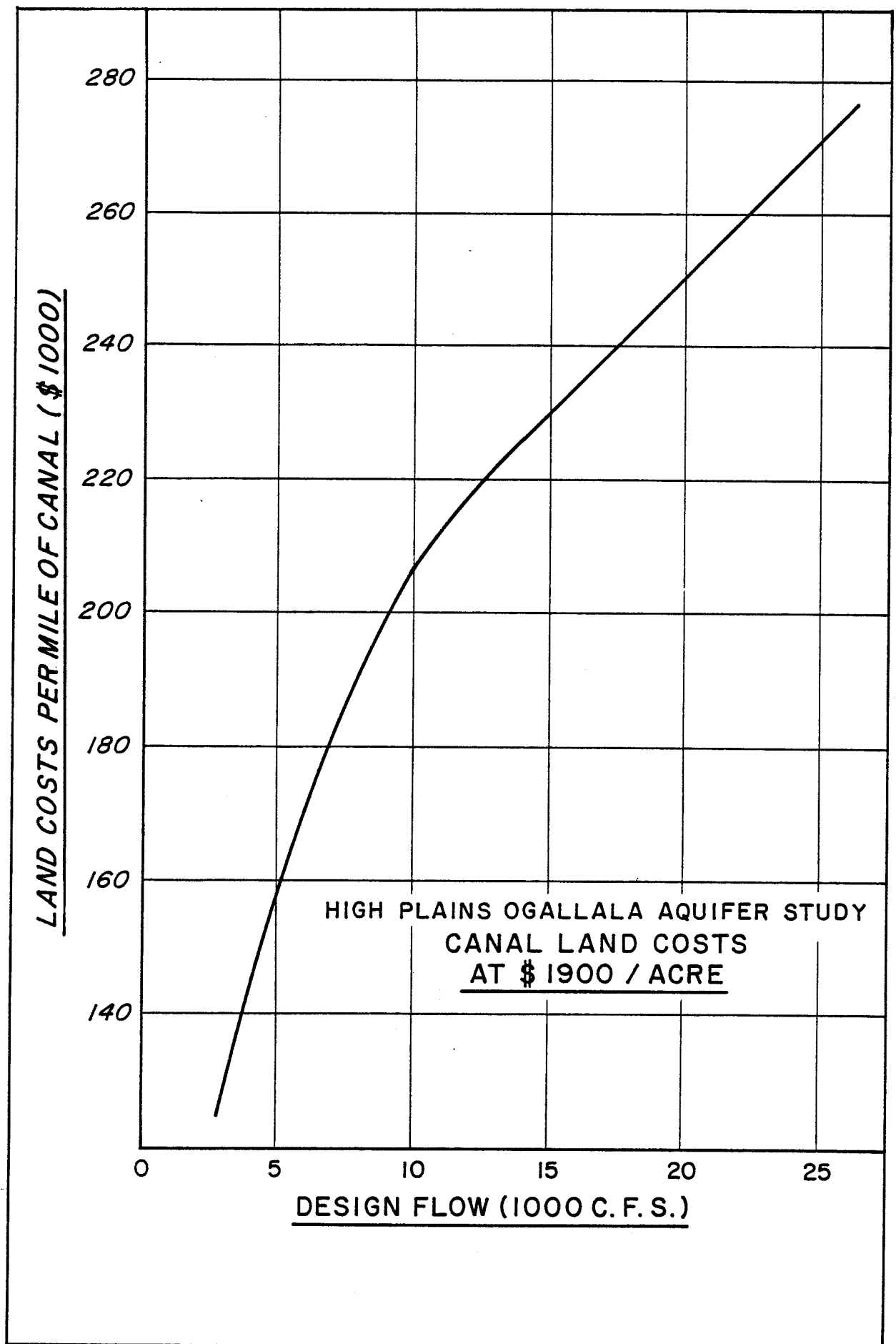


Figure 10

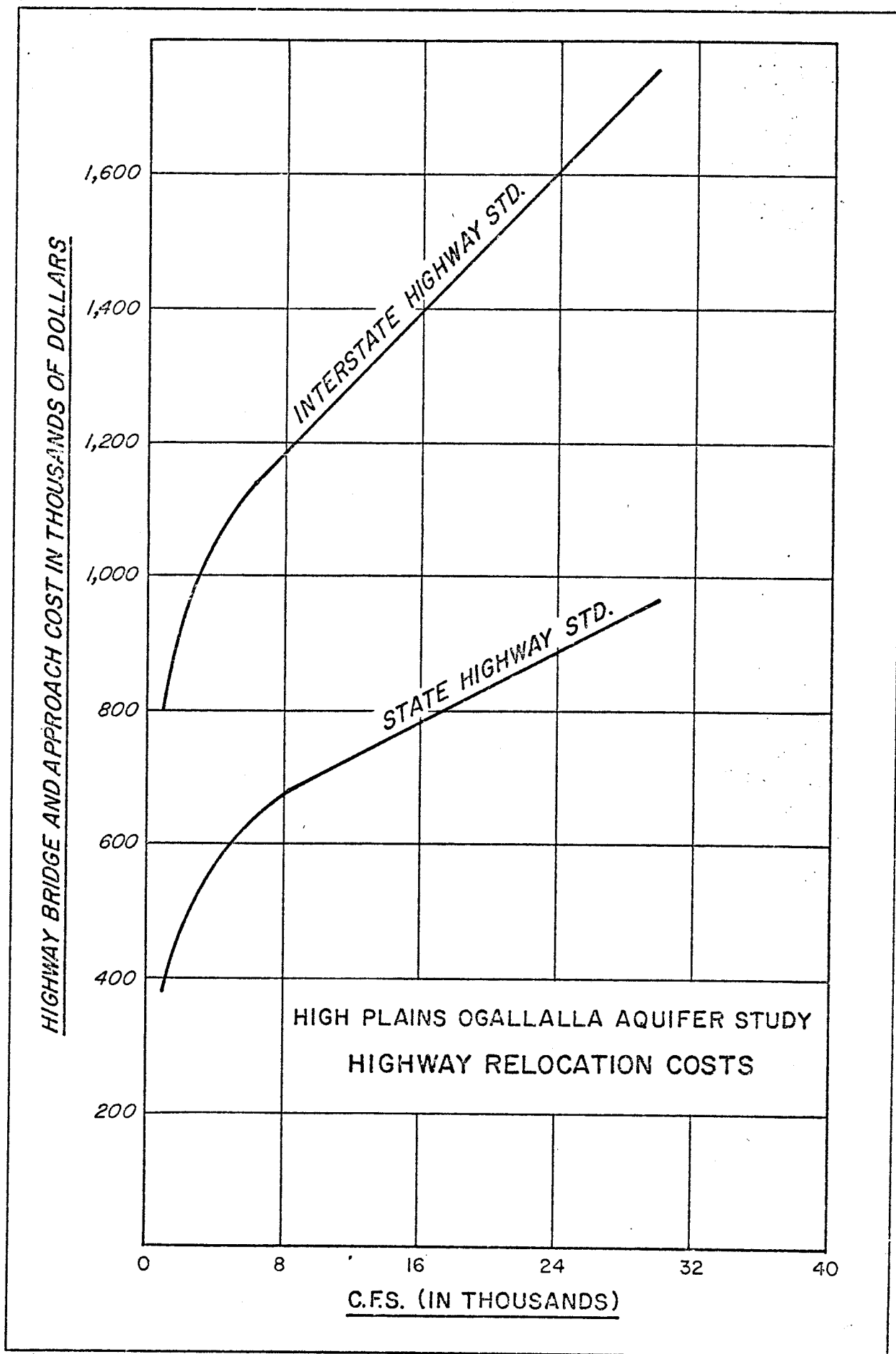


Figure 11

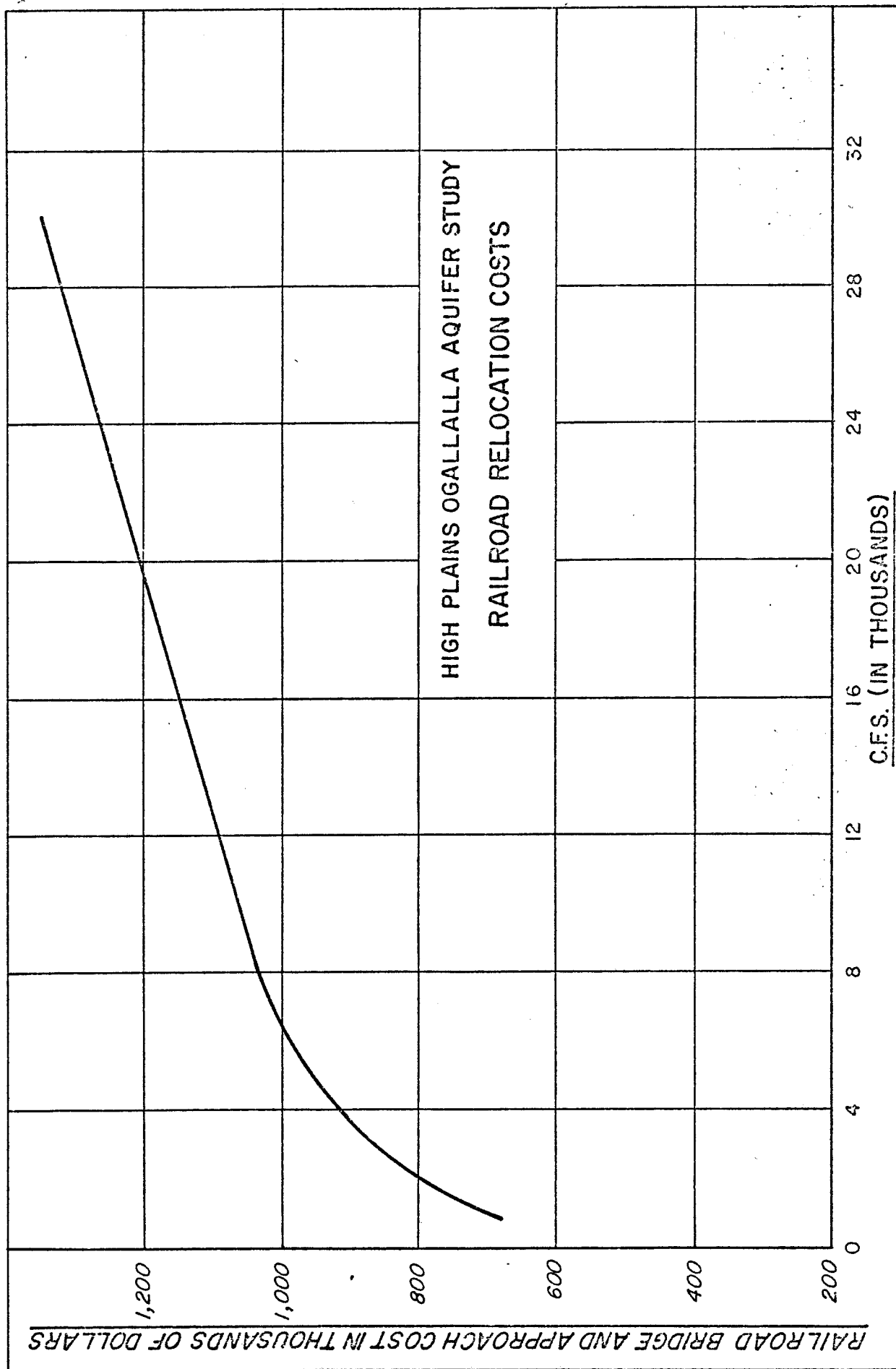


Figure 12

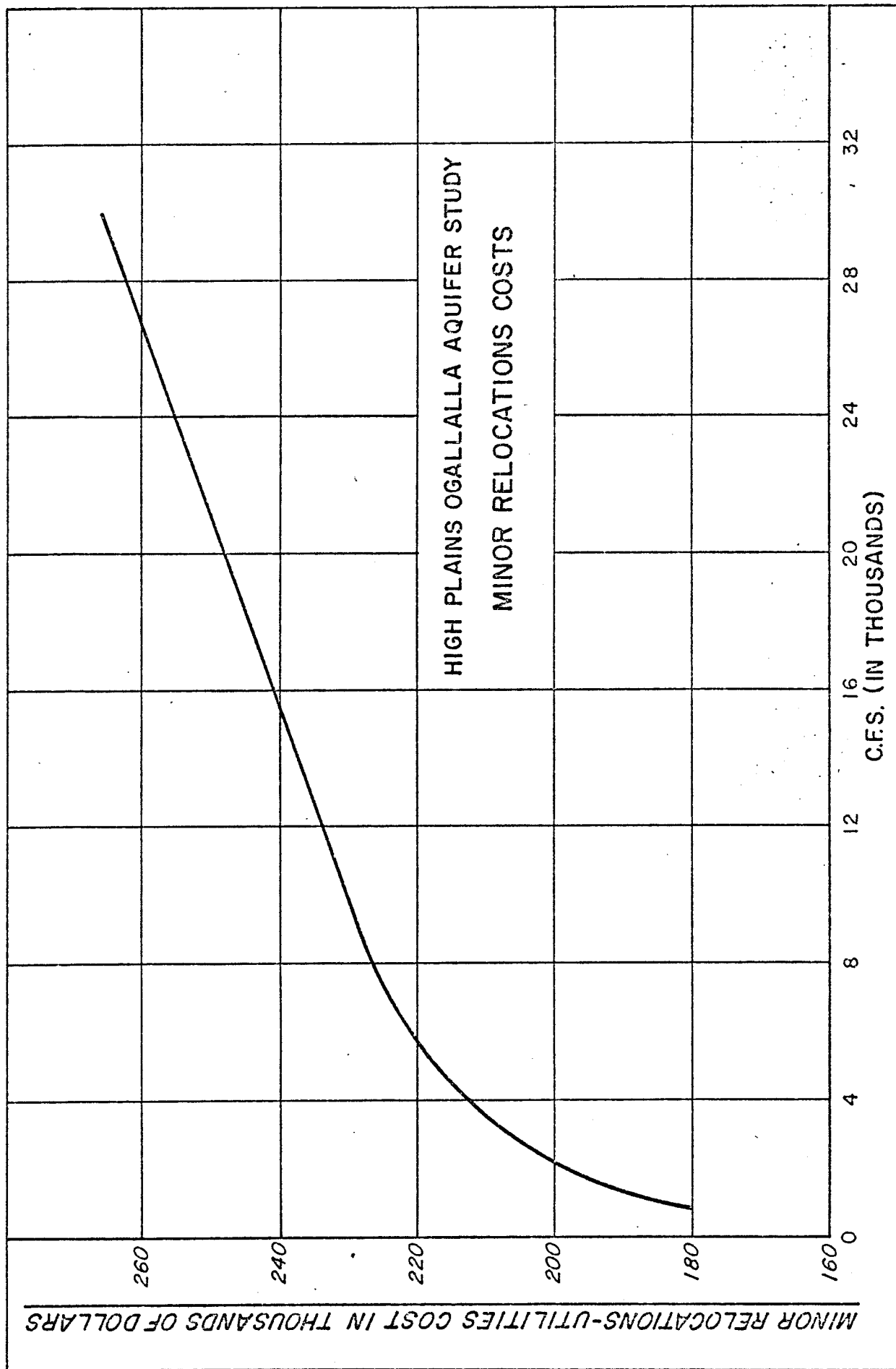


Figure 13

RELOCATION ITEM**COST PER MILE****HIGHWAYS**

INTERSTATE	\$ 2,200,000
U. S. / STATE	1,300,000
F. A. S.	600,000
COUNTY	200,000

RAILROADS

1,500,000

TRANSMISSION PIPELINES

NATURAL GAS	900,000
CRUDE OIL	700,000
OIL PRODUCTS	400,000

POWERLINES

TRANSMISSION	120,000
DISTRIBUTION	30,000

TELEPHONE LINES

20,000

RURAL WATERLINES

20,000

HIGH PLAINS OGALLALA AQUIFER STUDY
RELOCATION COST ESTIMATES
FOR DAMS AND RESERVOIRS

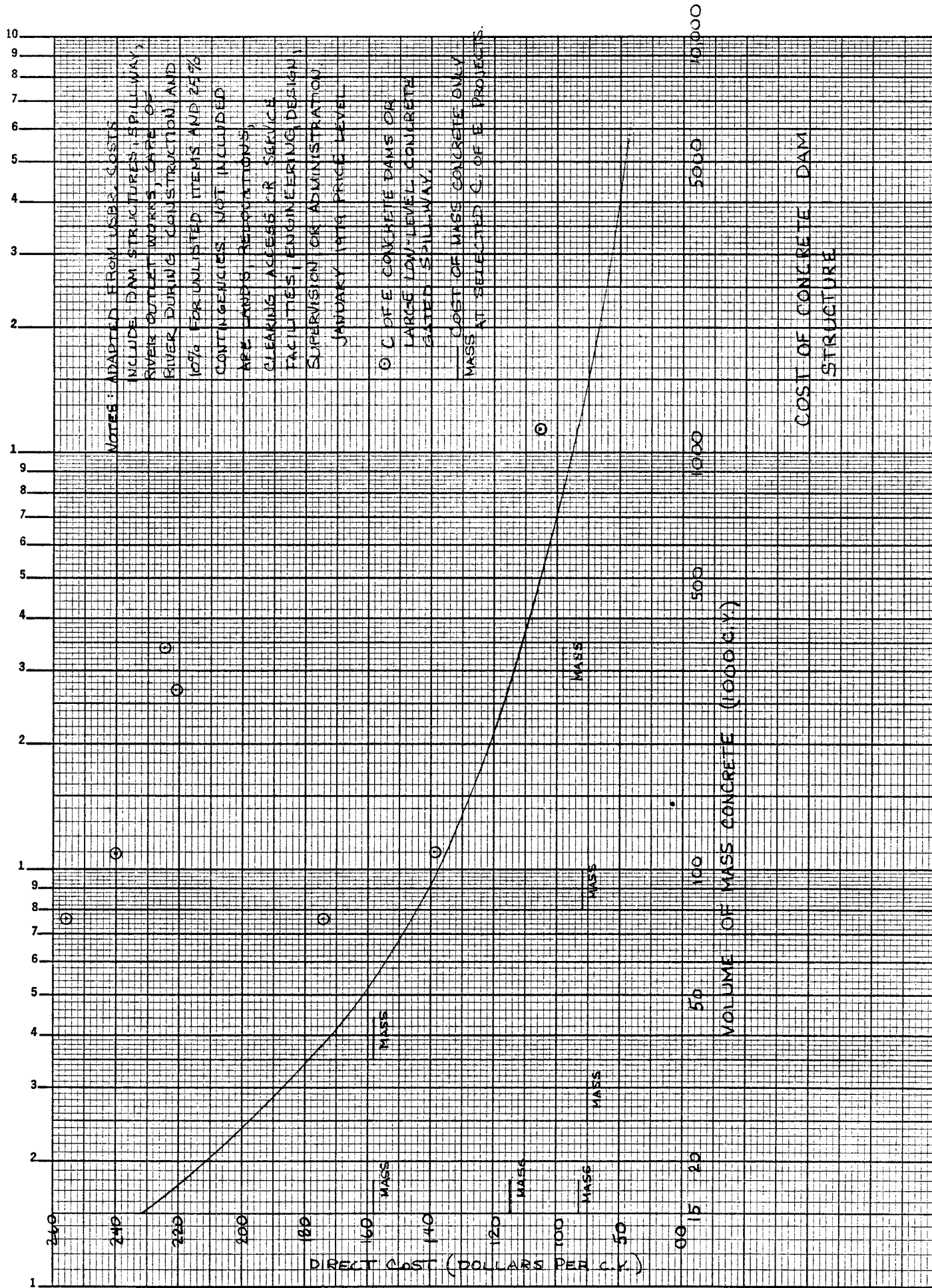


Figure 15

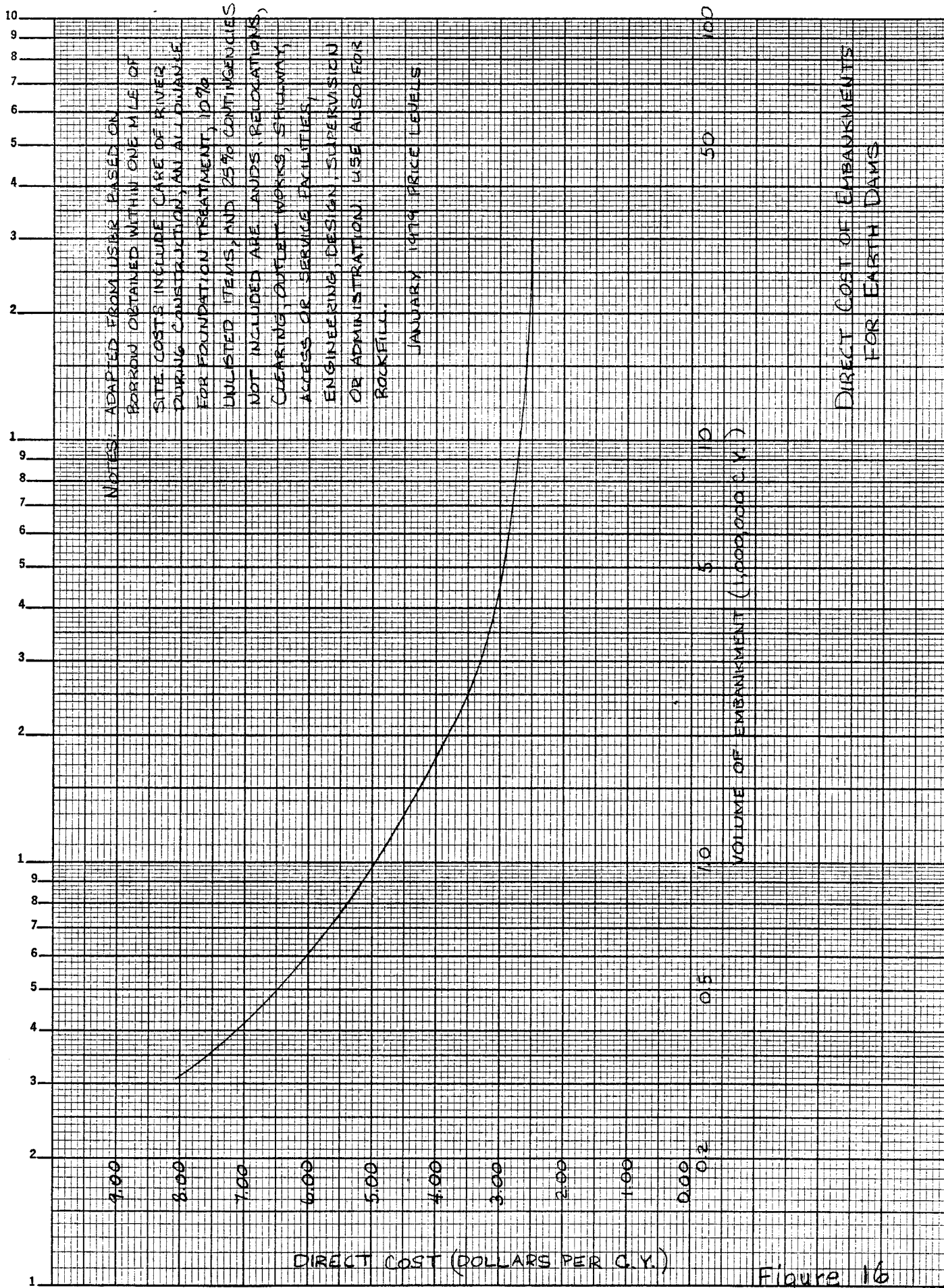


Figure 16

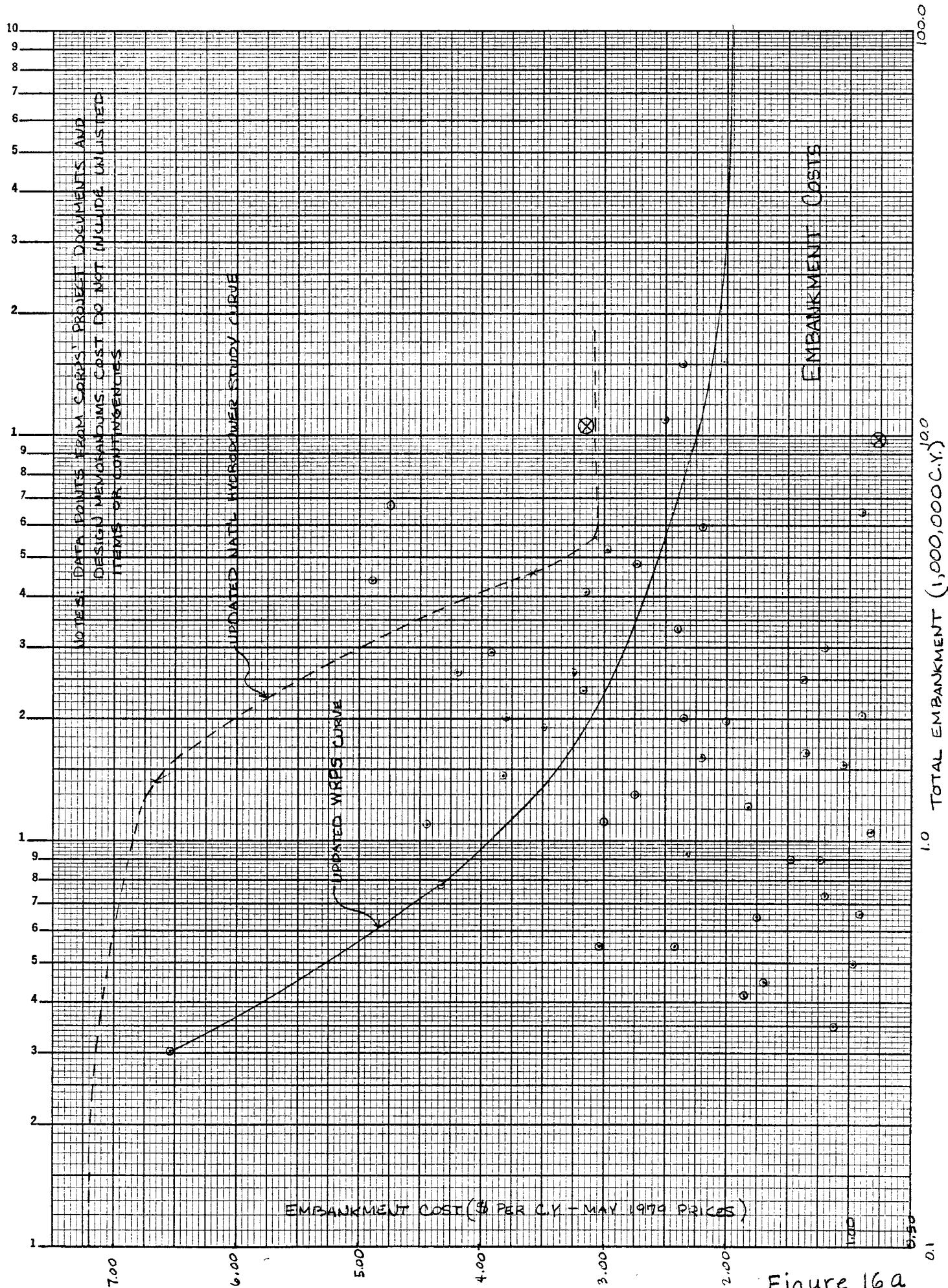


Figure 16a

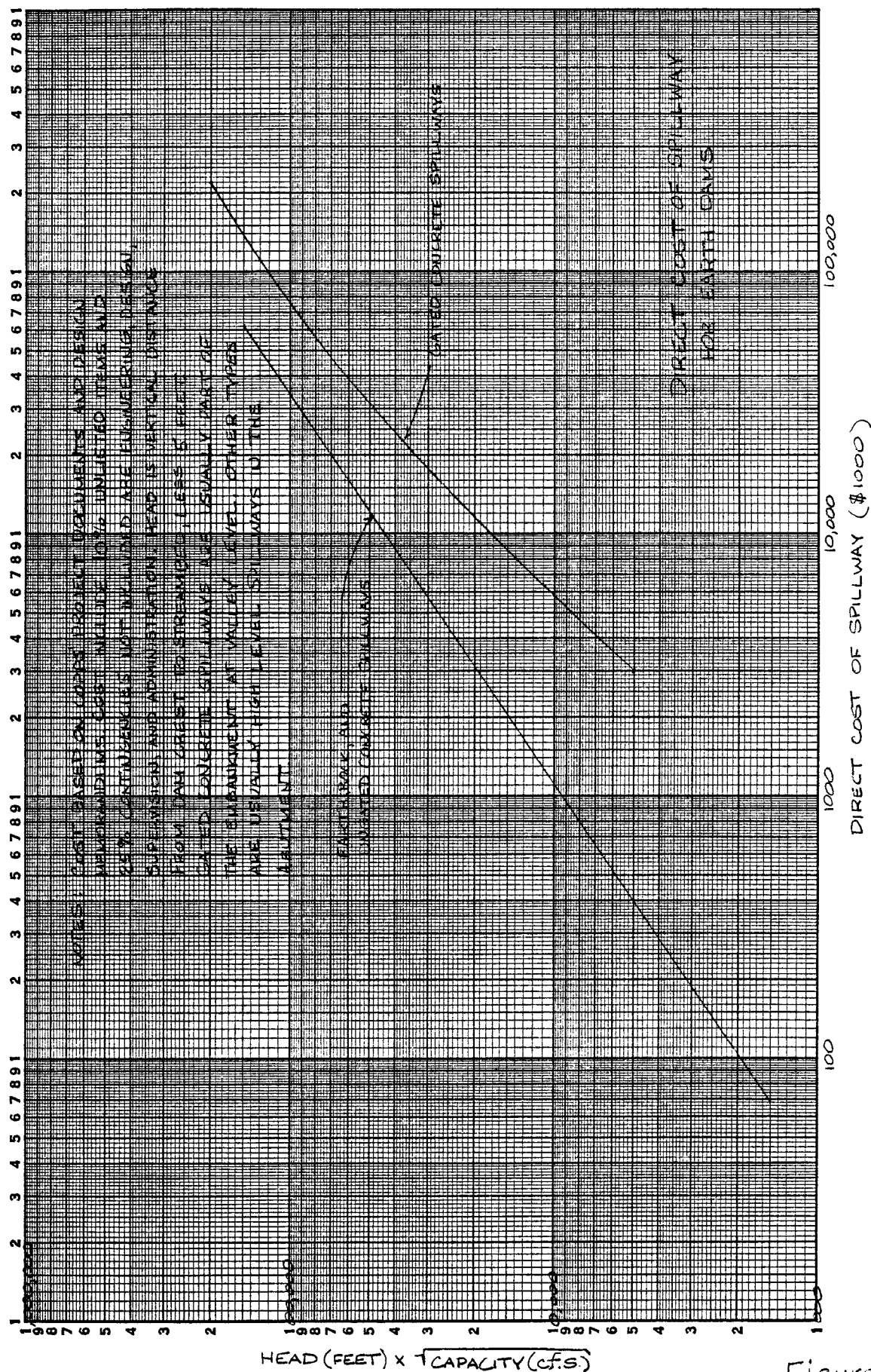


Figure 17

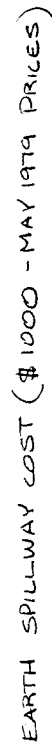


Figure 17a

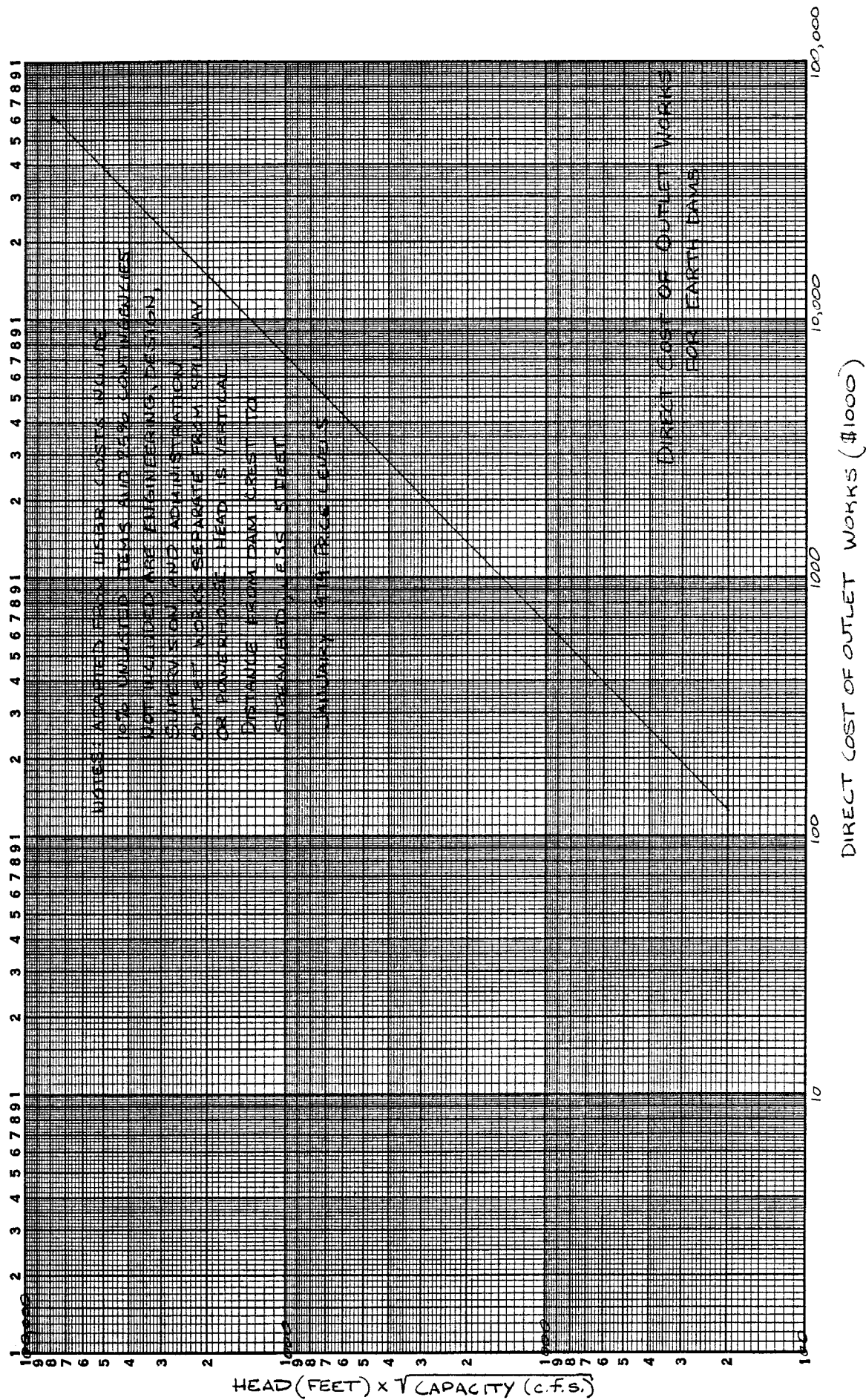


Figure 18

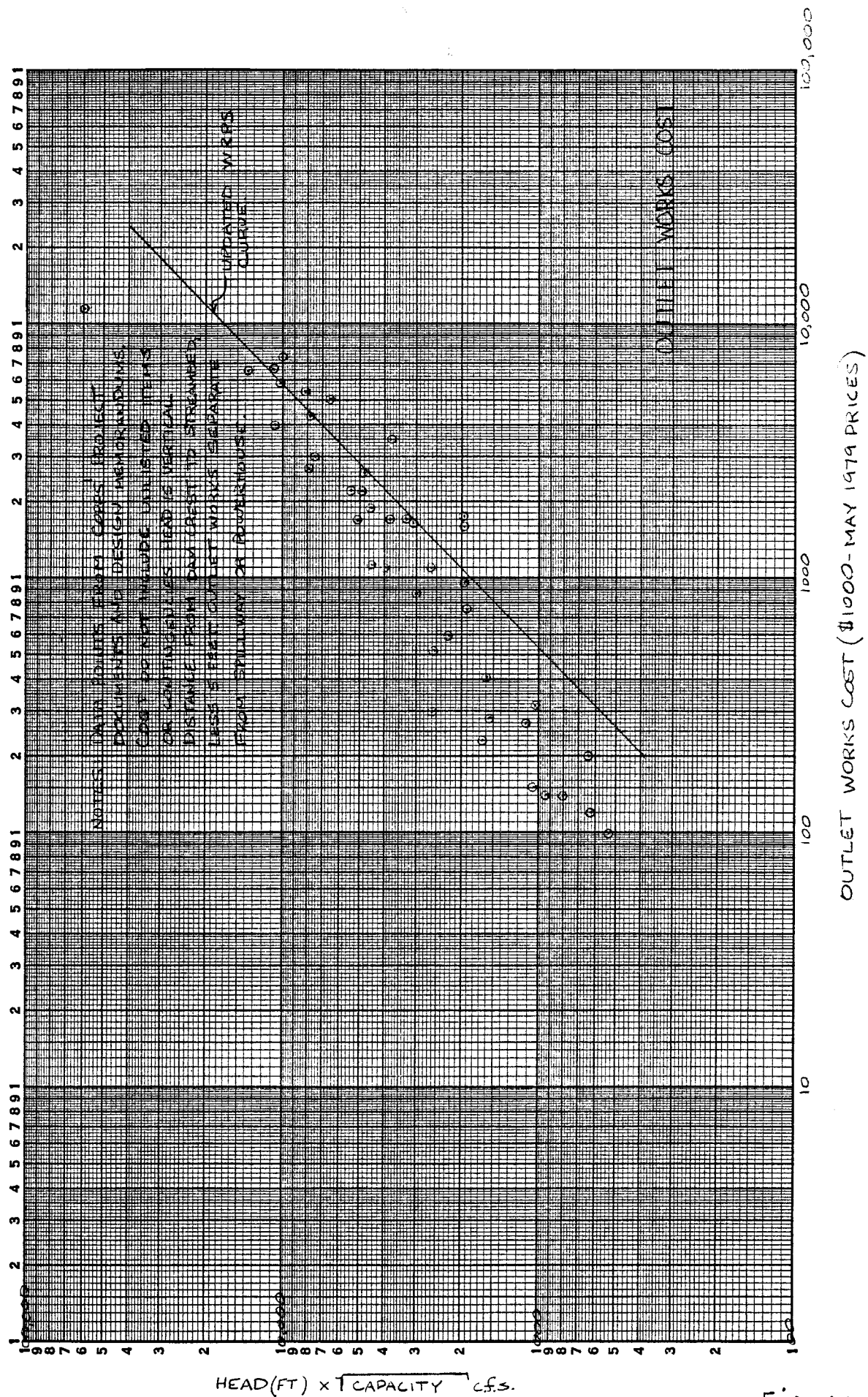


Figure 18a

NOTES: 1. RAILROADS FROM WHICH COSTS IN THE FOUNDATION OF THE DIVERSION DRAWS WITH
2. IN ALL SECTIONS, UNLESS OTHERWISE SPECIFIED, THE DIVISION DRAWS WITH
3. UNLUBRICATED RAILS, AND 2% CONTINGENCY, WHICH IS THAT OF THE
UNCOMPARABLE TO SPECIFIC SECTION, WHICH IS SPECIFIC TO THE DIVISION
BEFORE THE DIVISION, WHICH HAS THE SPECIFIC COST, WHICH IS INCLUDED
IN COSTS ARE ENGINEERING DESIGN SUPERVISION, OR ADJUDICATION

RAILROAD 1/2 INCH PRICE LEVELS

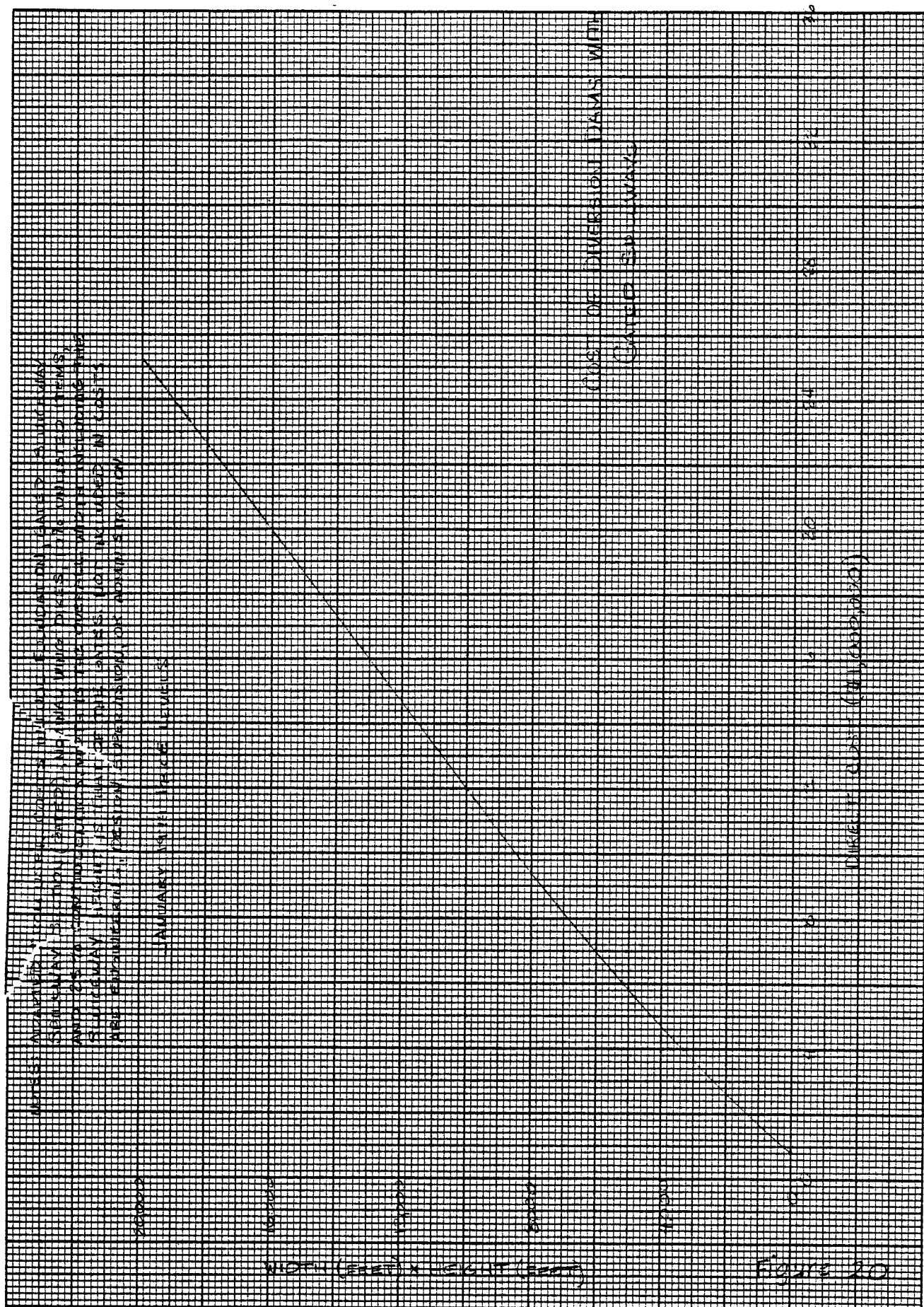
WIDTH (FEET) & HEIGHT (FEET)

COST OF DIVERSION DRAWS WITH
UNLUBRICATED RAILS

DIRECT COST (\$1,000,000)

FIGURE 10

K+E 10 X 10 TO 1/2 INCH 46 1323
7 X 10 INCHES
MADE IN U. S. A. •
KEUFFEL & ESSER CO.



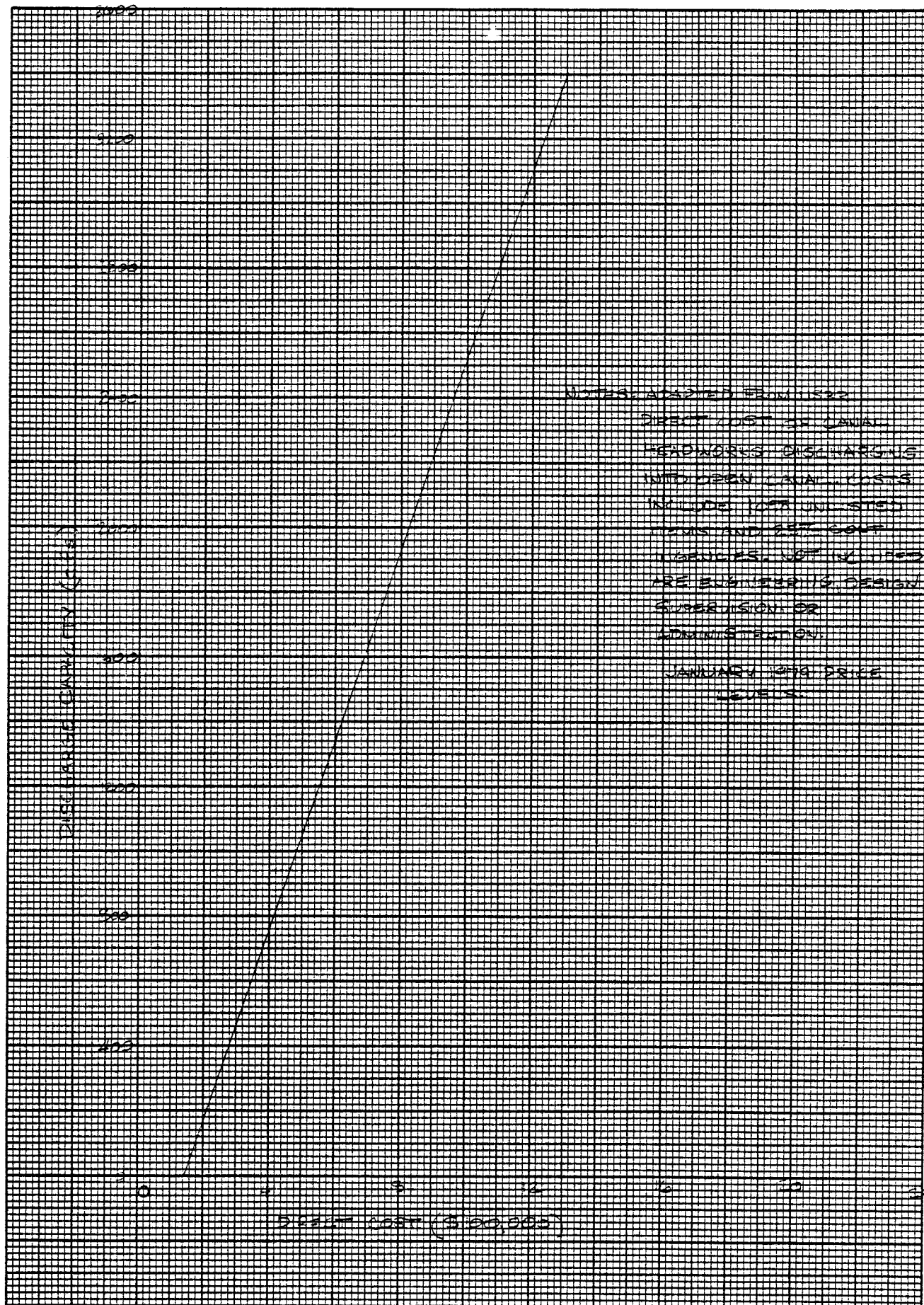


Figure 21

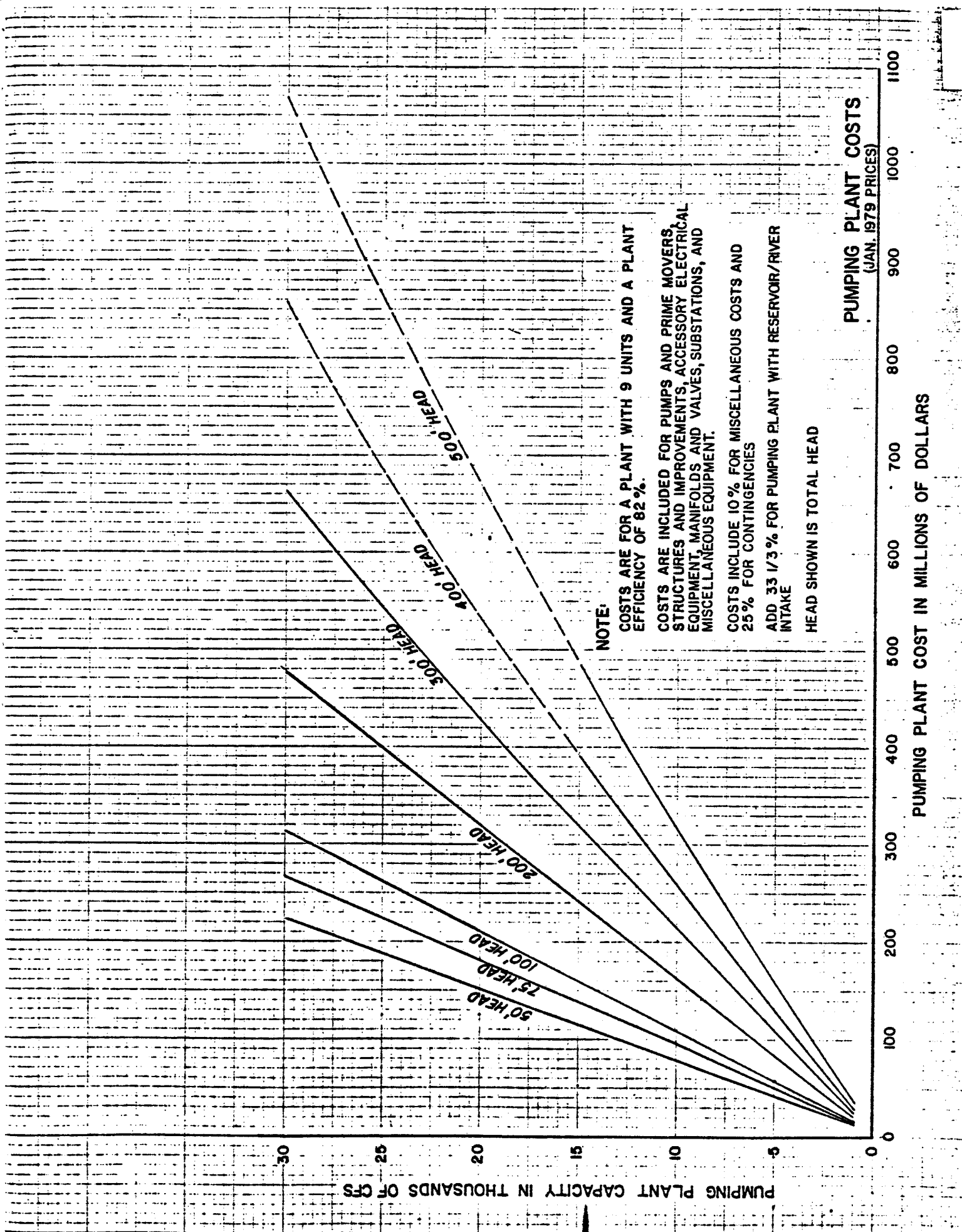


Figure 22

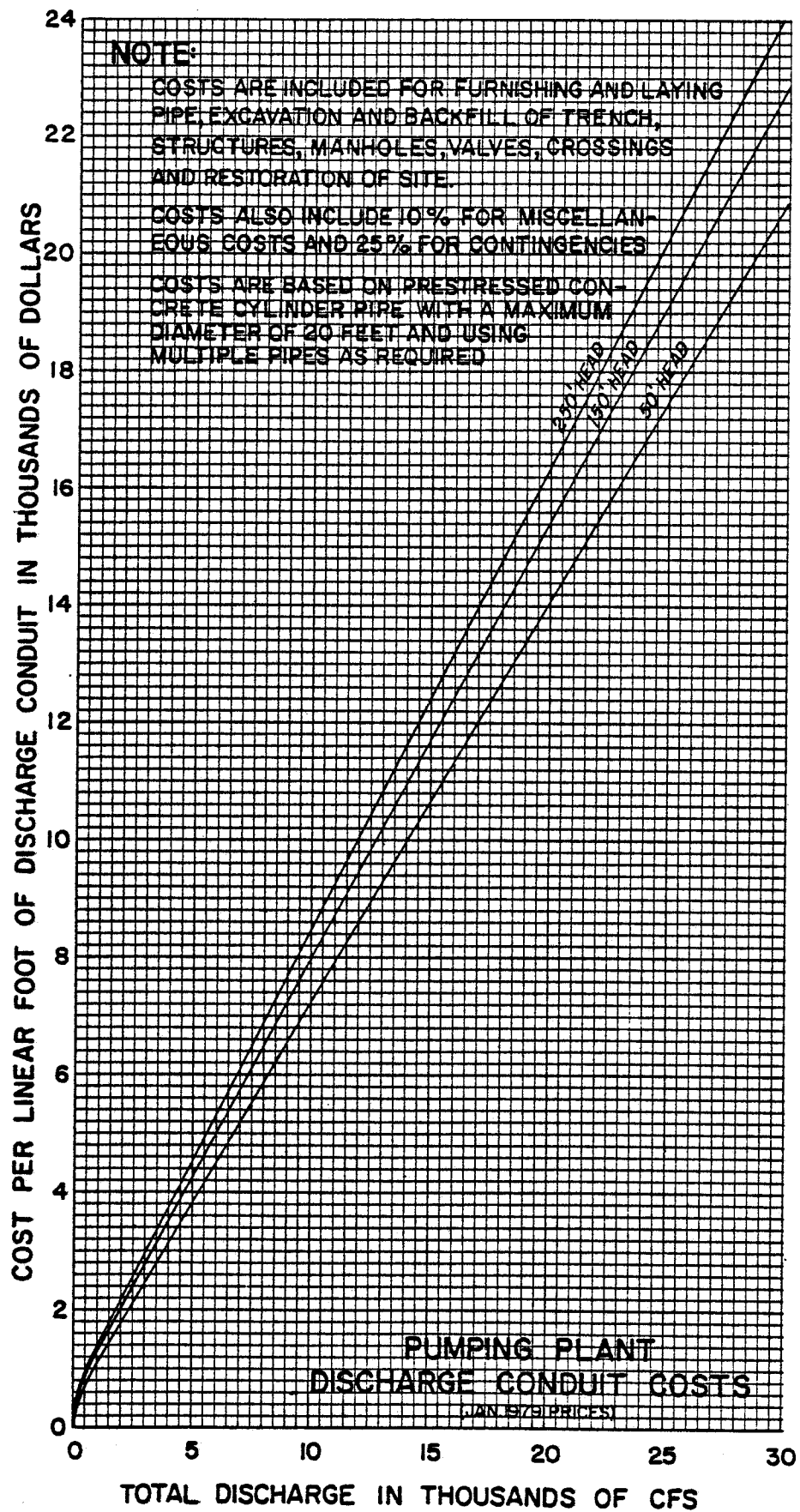


Figure 23

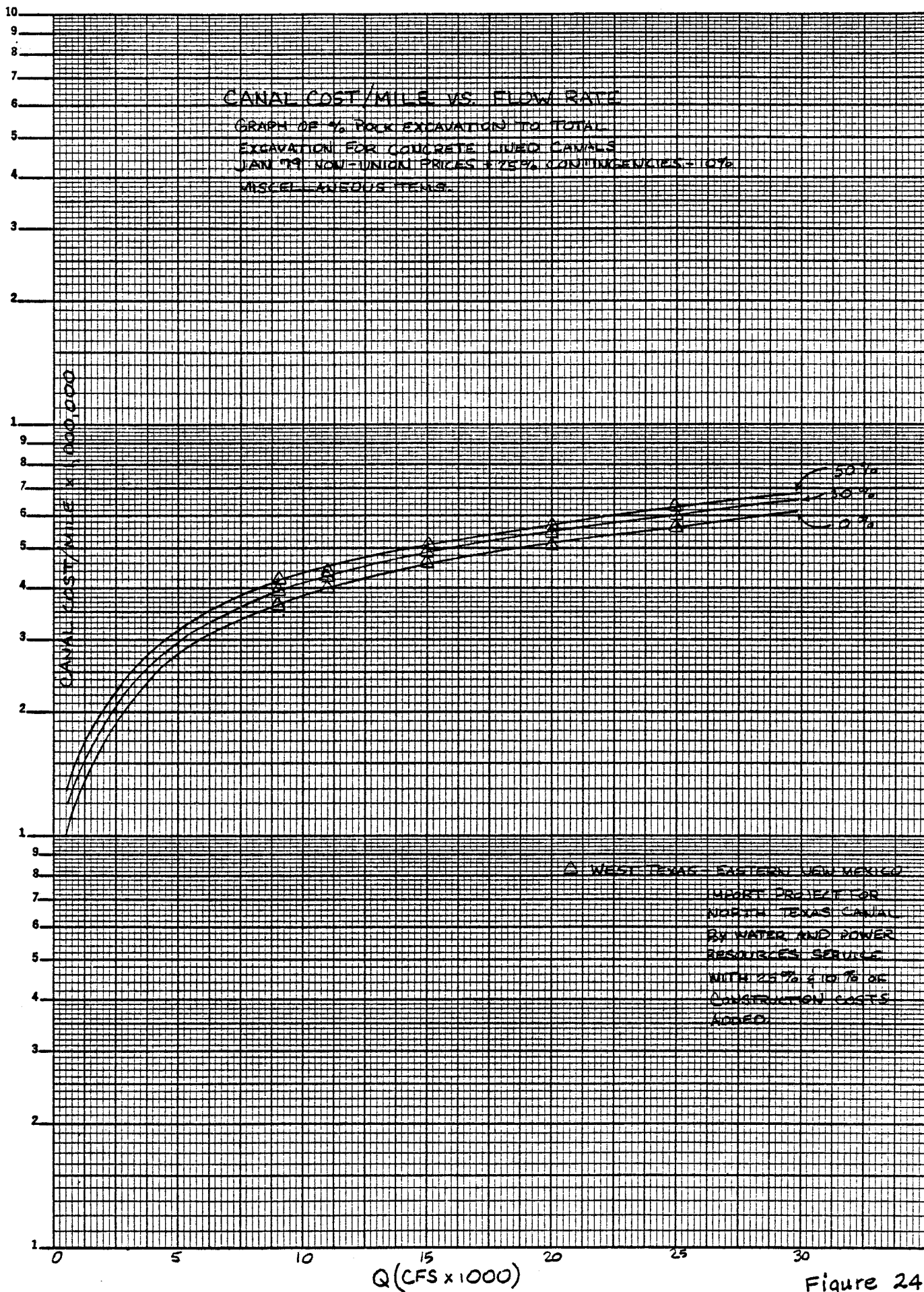


Figure 24

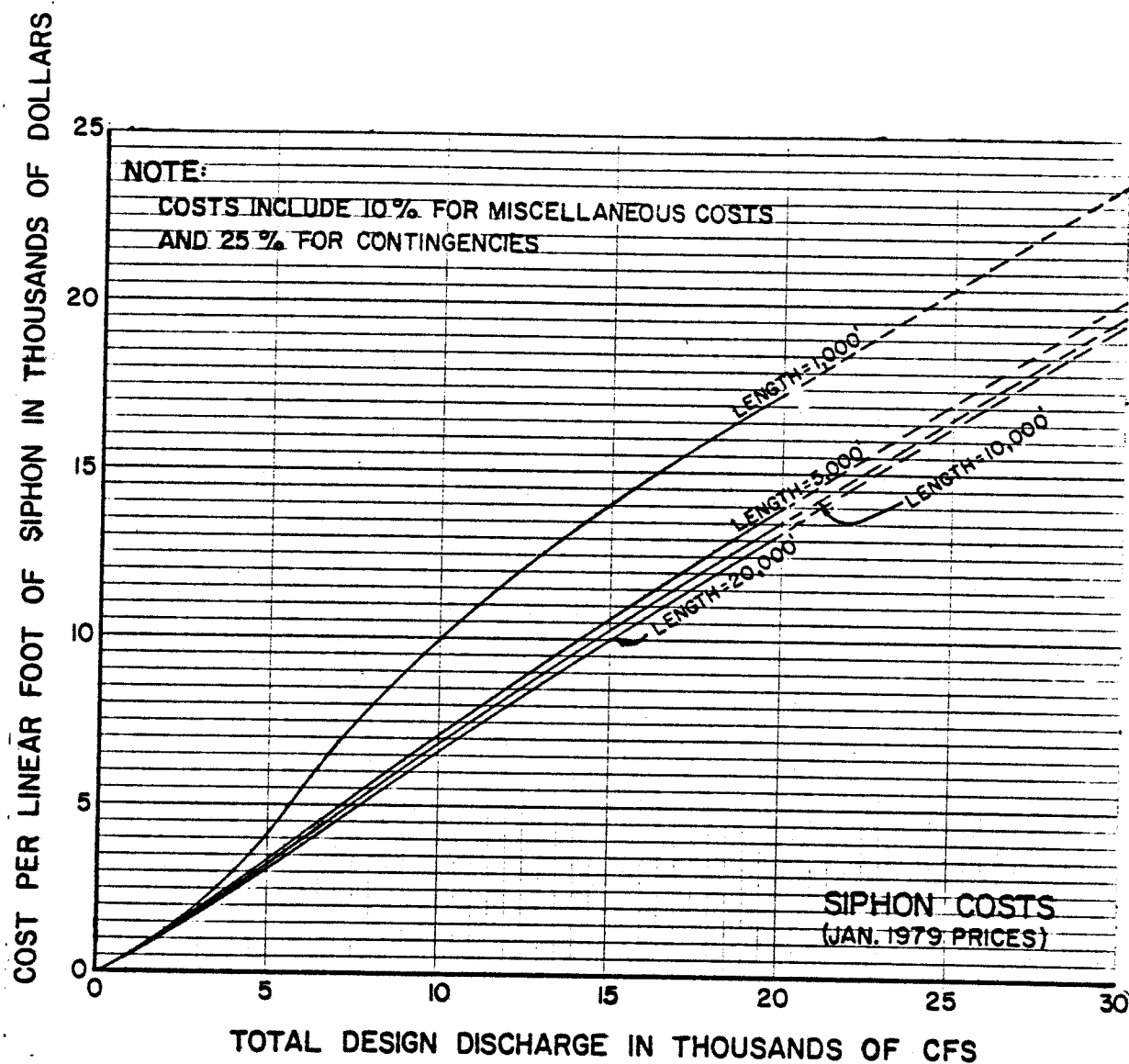


Figure 25

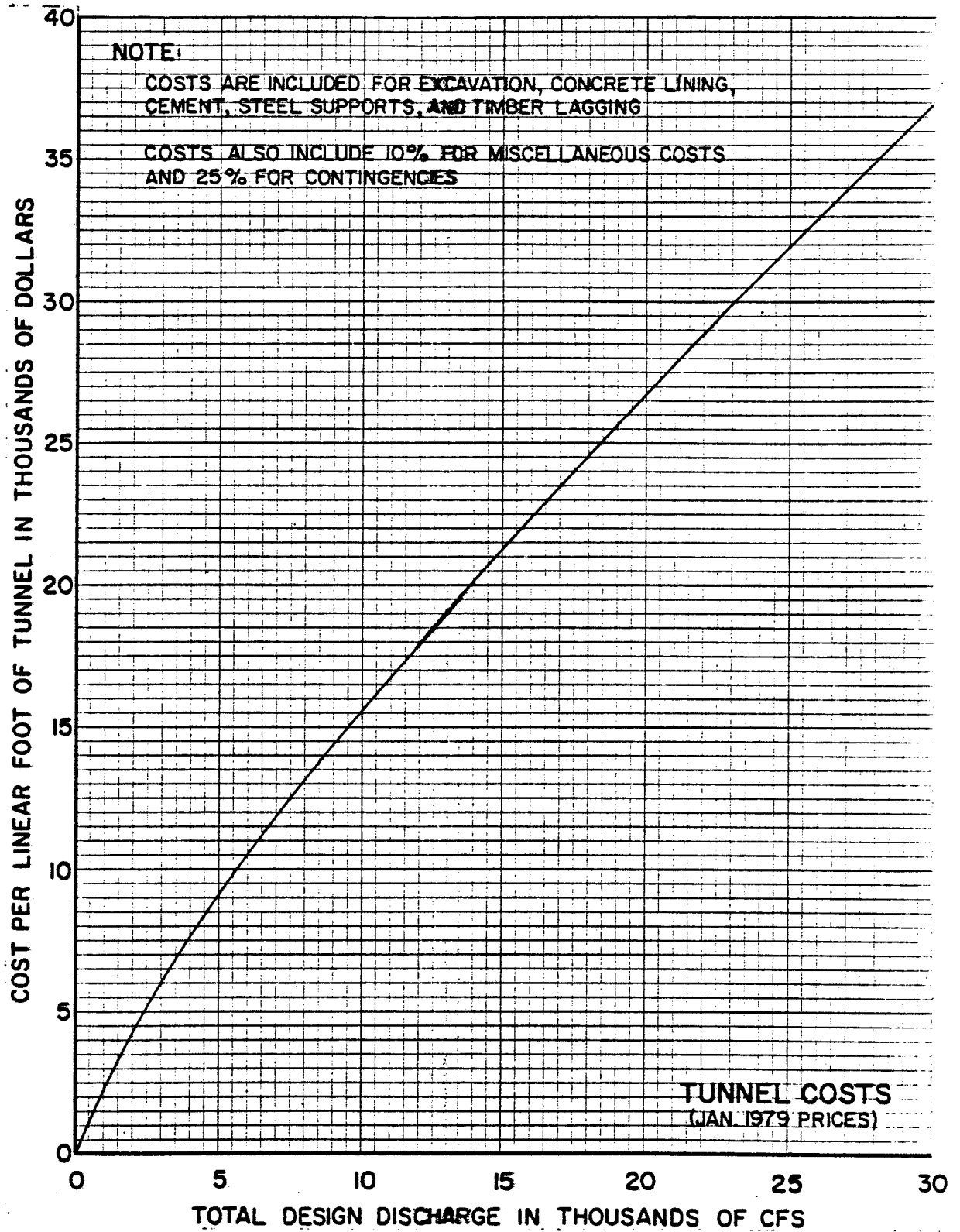


Figure 26

KE LOGARITHMIC
3 X 5 CYCLES
46 7522
MADE IN U. S. A. •
KEUFFEL & ESSER CO.

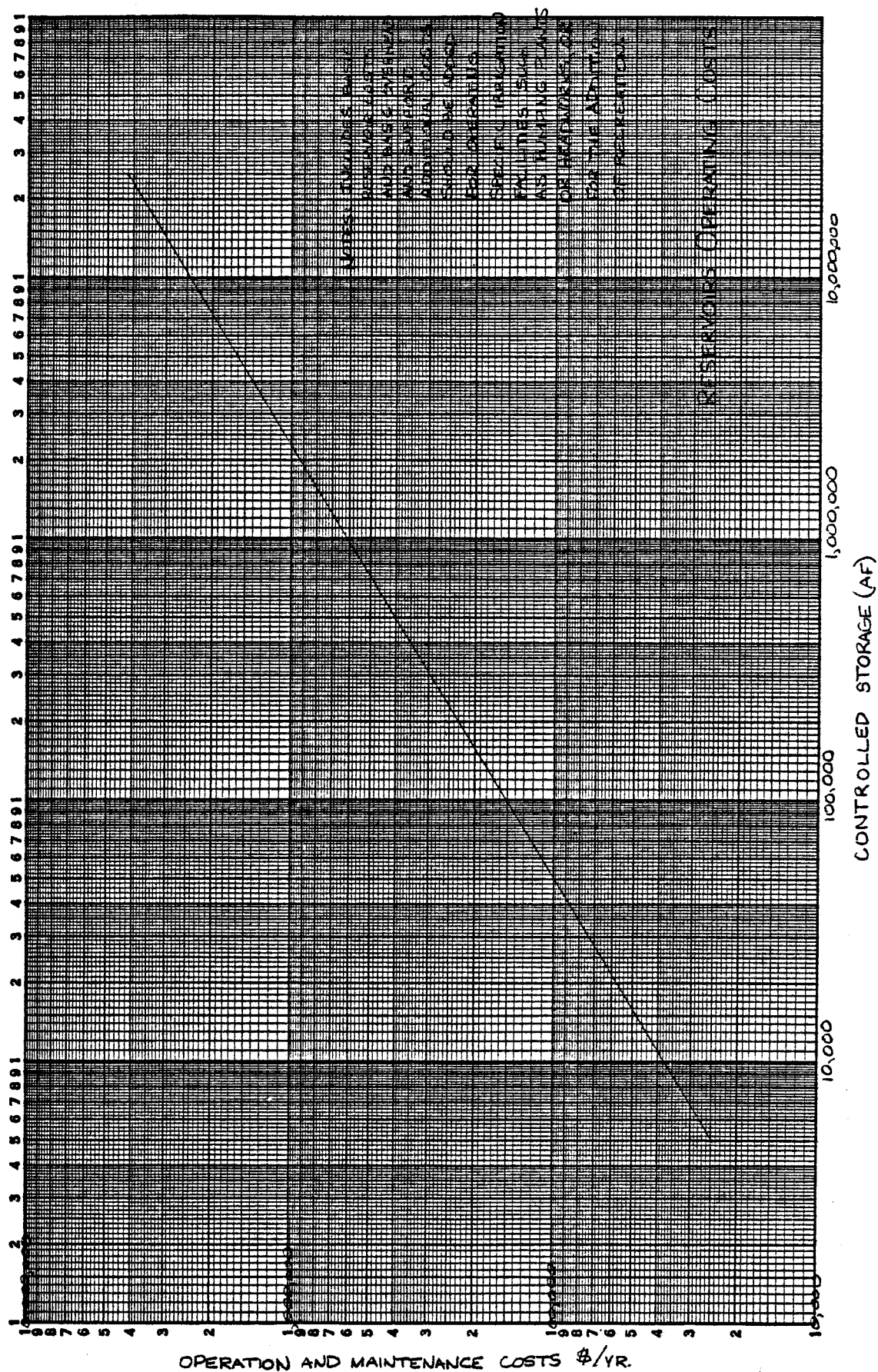


Figure 27

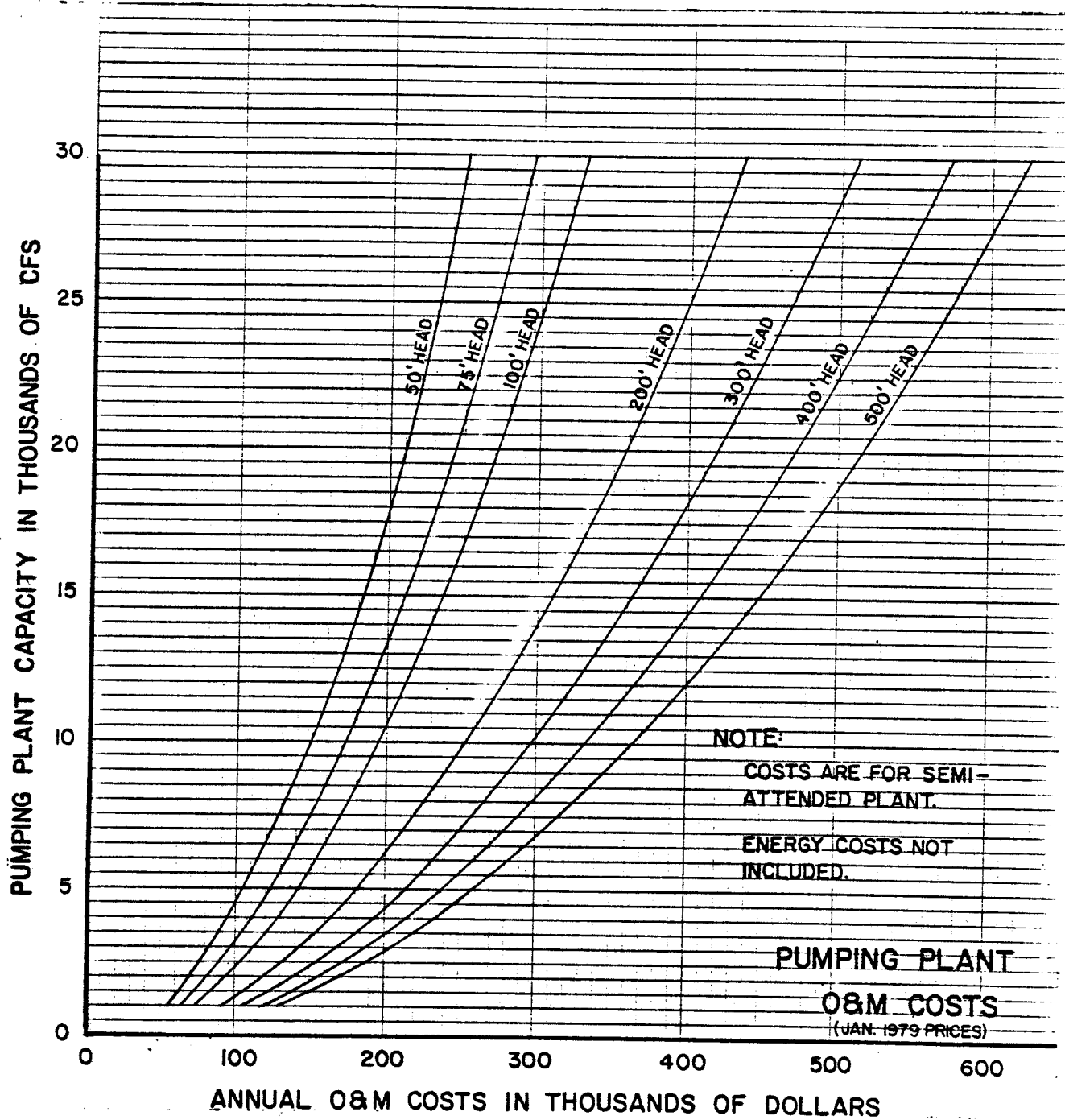


Figure 28

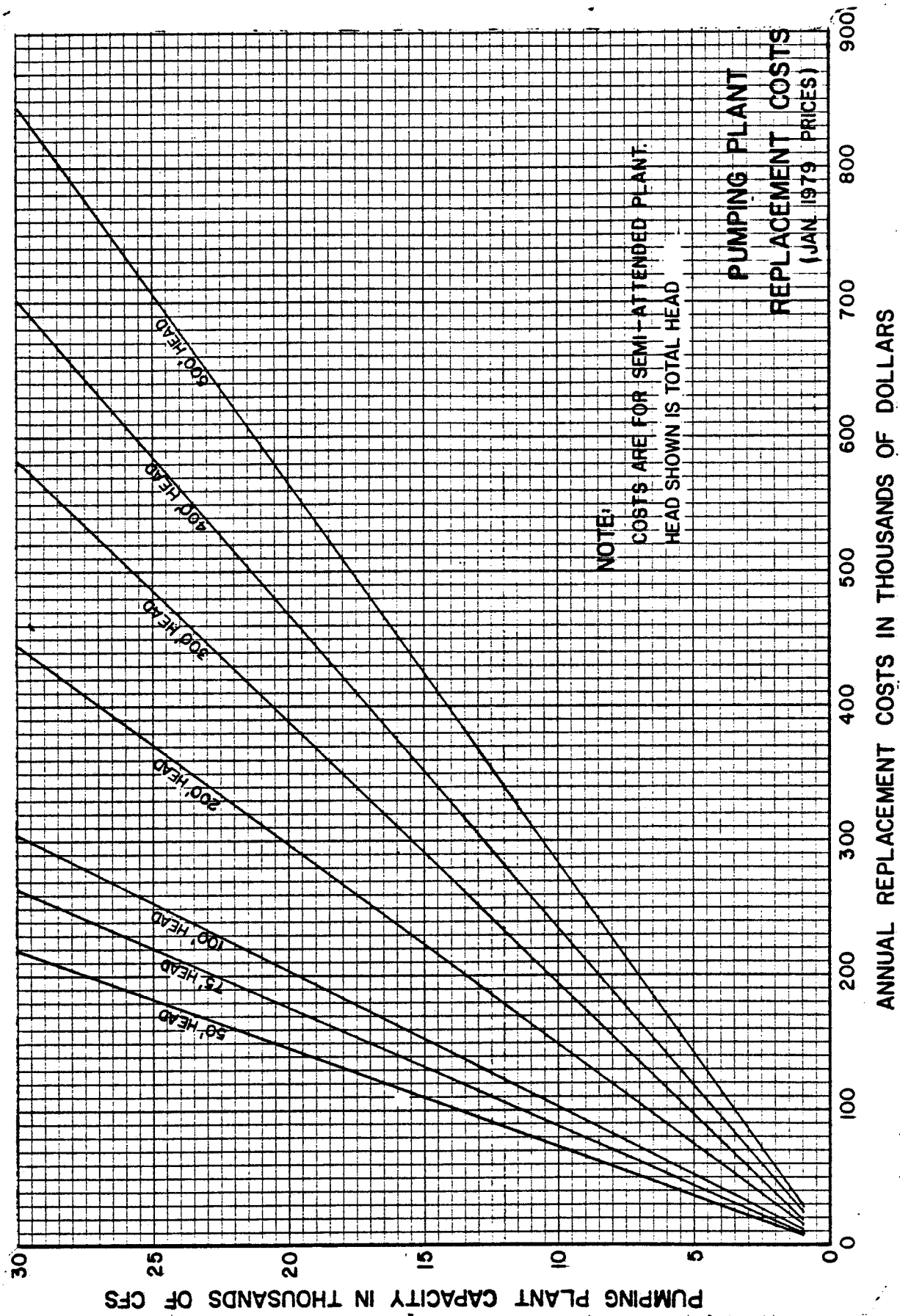


Figure 29

K&E 10 X 10 TO 1/2 INCH 46 1323
7 X 10 INCHES
MADE IN U.S.A.
KEUFFEL & ESSER CO.

ANNUAL COST/MILE (\$ X 1000)

OPERATION AND MAINTENANCE
GRAPH FOR CONCRETE CONVEYANCE FACILITIES
JAN. 1973 PRICES
5% FOR CONTINGENCIES

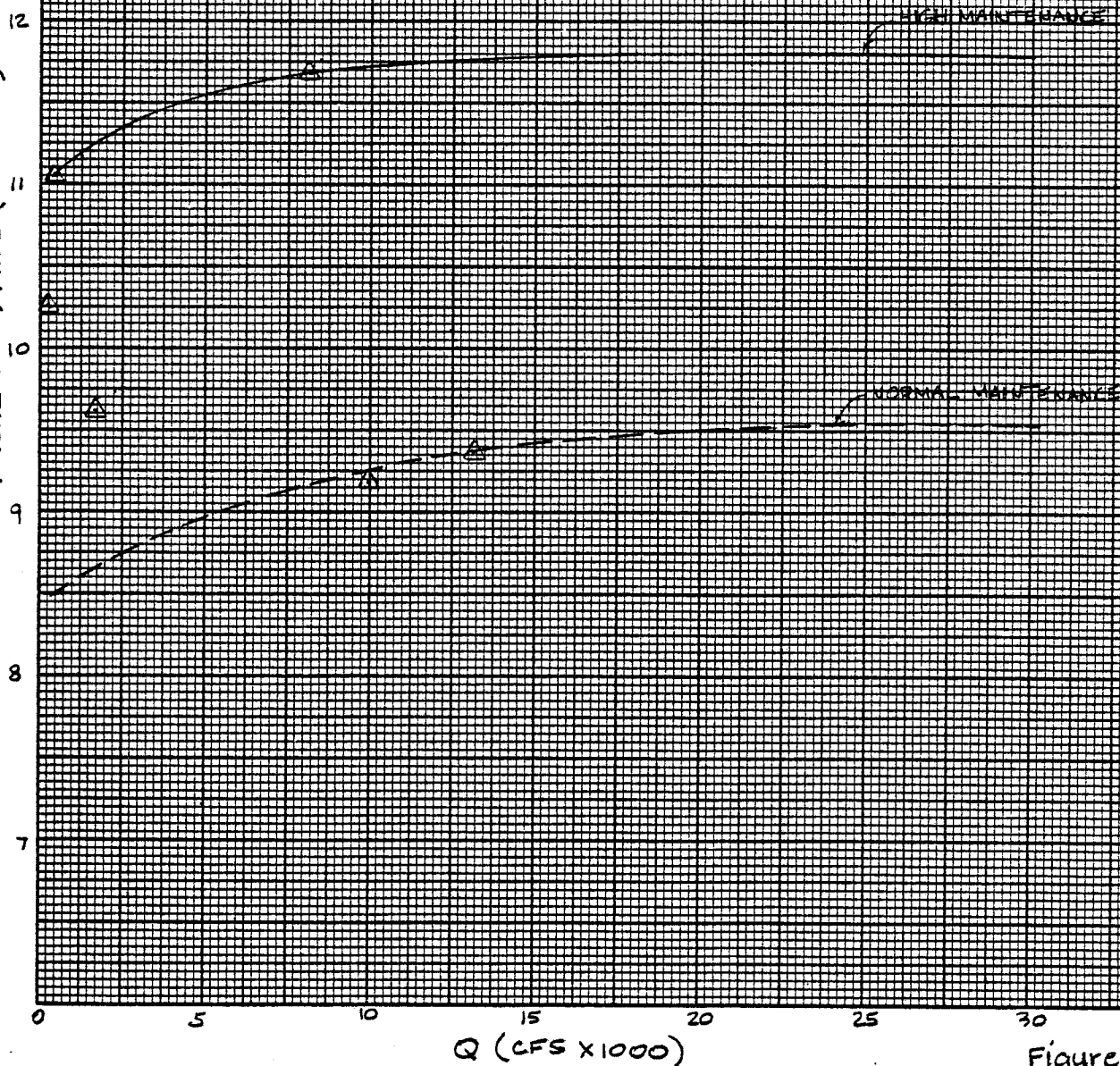


Figure 30

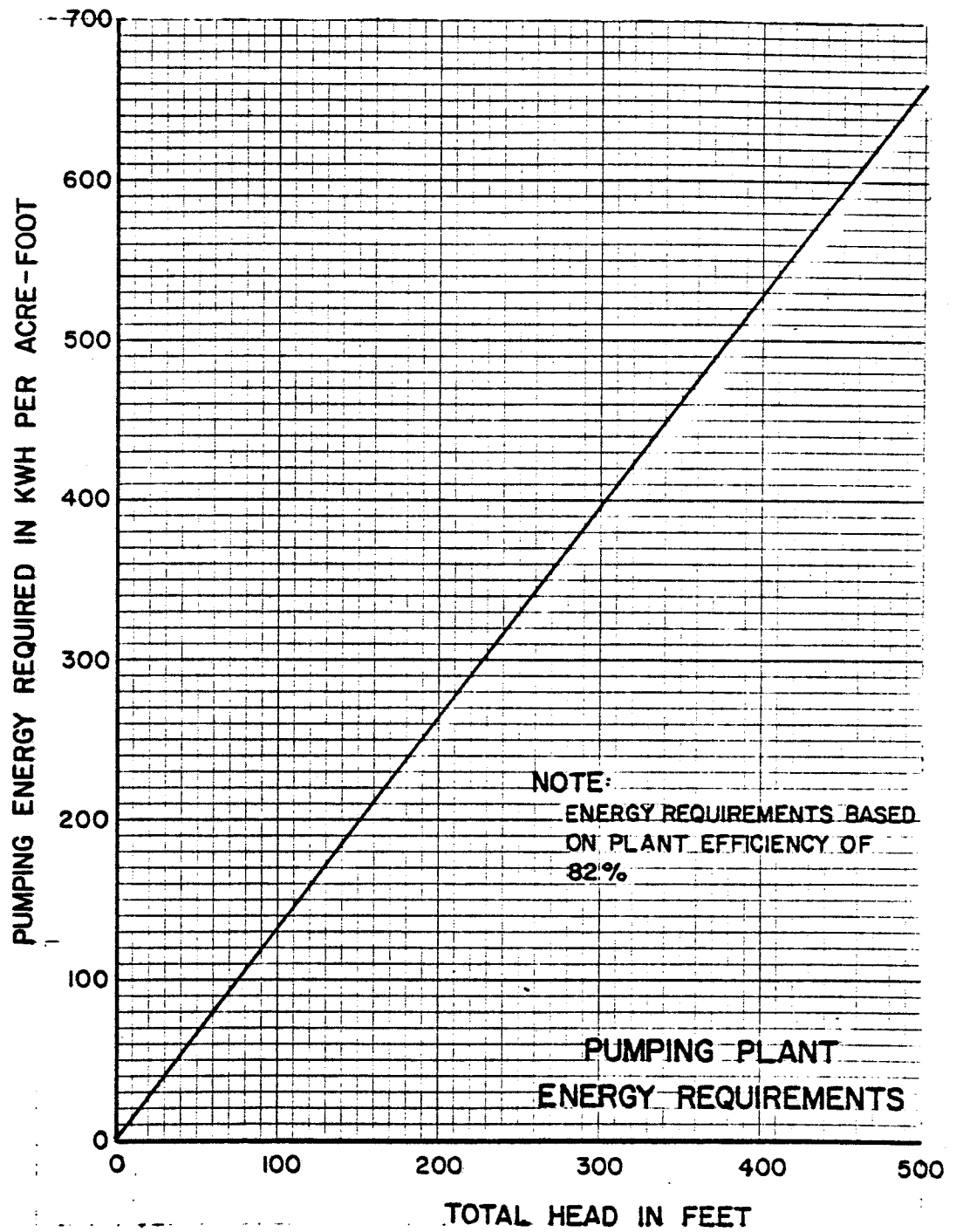


Figure 31