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 ELEMENT

ALTERNATE ROUTE B

(MISSOURI RIVER TO WESTERN KANSAS)

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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:

State	Annual Water Requirement (2020) for Alternative Route B (1,000 Acre-Feet)	
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:

Study Level	Pump Capacity From River (1,000 c.f.s.)	Average Annual Volume of Water Available (million acre-feet)
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 alinement of the canals is shown on Figure 2. Although the alinements 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 alinement.

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 Alinement

The canal would be routed along ridge lines to minimize conflicts with prime farmland, transportation routes, cities, and wildlife habitat. Such an alinement 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 Nebraksa. 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:

Month	Percent Total Year Demand	Month	Percent Total Year Demand
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:

	Max System (3.404 MAFA)		Min System (1.615 MAFA)	
	Lake Size AC.	Land Req'd AC.	Lake Size AC.	Land Req'd AC.)
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 1to 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

(COSTS IN $ MILLIONS)

	SOUTH ROUTE (CFS)			NORTH ROUTE (CFS)			
ITEM	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

(COSTS IN $ THOUSANDS)

Annual OM&R Costs		SOUTH ROUTE (CFS)			NORTH ROUTE (CFS)			
	ITEM	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 & Communication		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

South Route	Acre-Feet Demand		Acre-Feet In System		System Equivalent Head		kWh Per AF Per Foot Head		Energy Cost ($/kWh)		Energy Cost (Millions)
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
North Route											
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

(COSTS IN $ MILLIONS)

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

(COSTS IN $ MILLIONS)

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

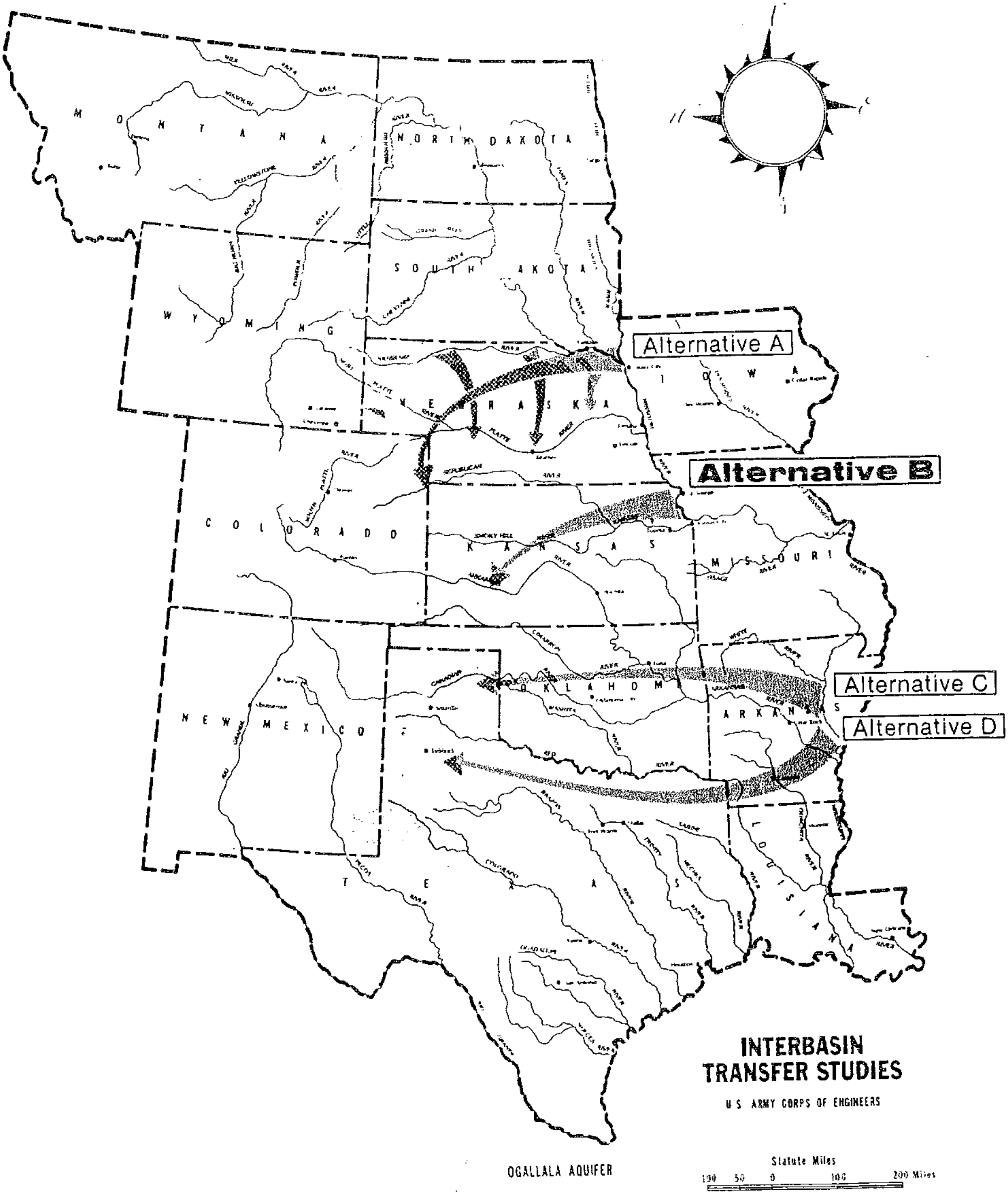


Figure 1 VICINITY MAP

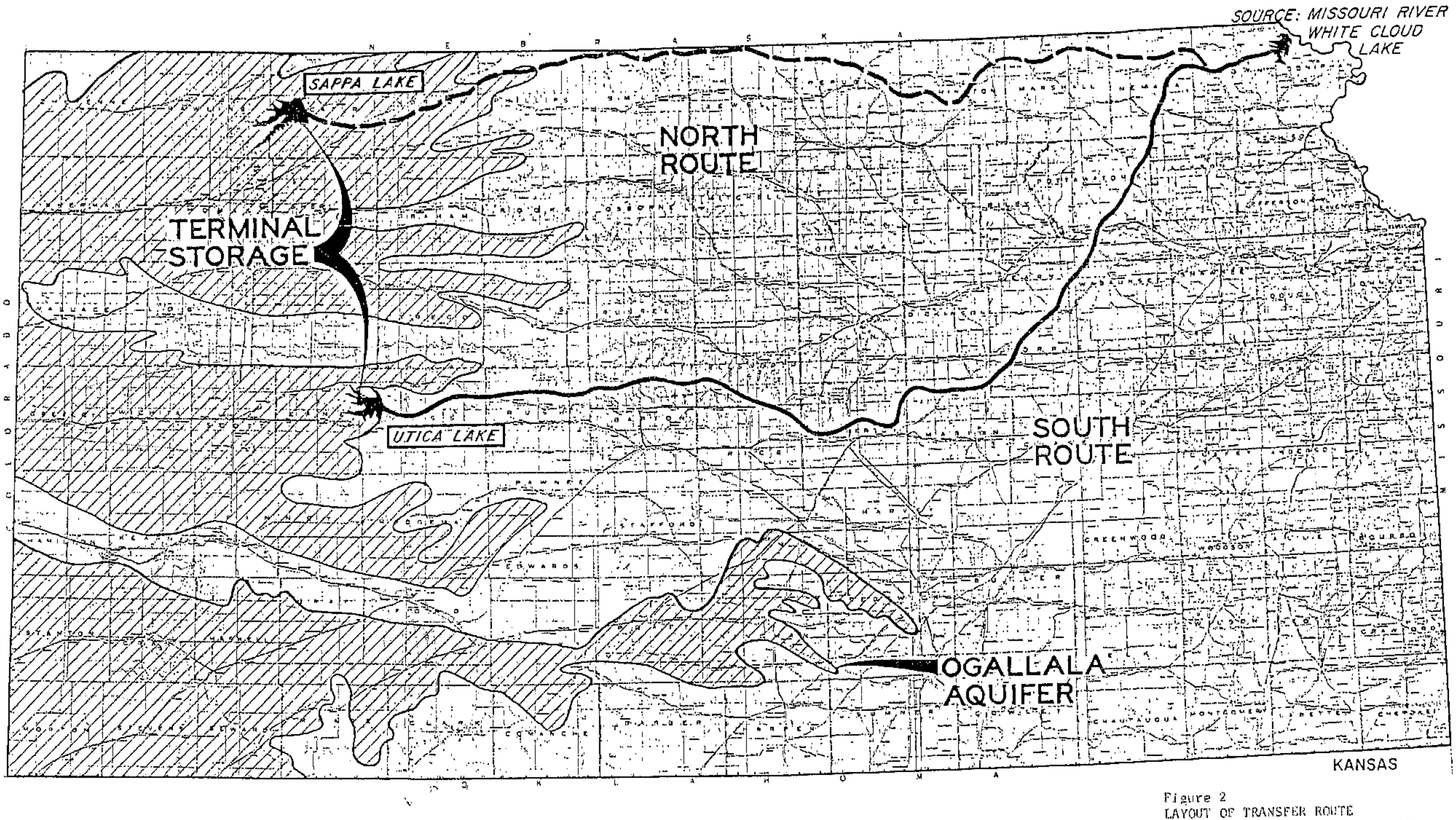
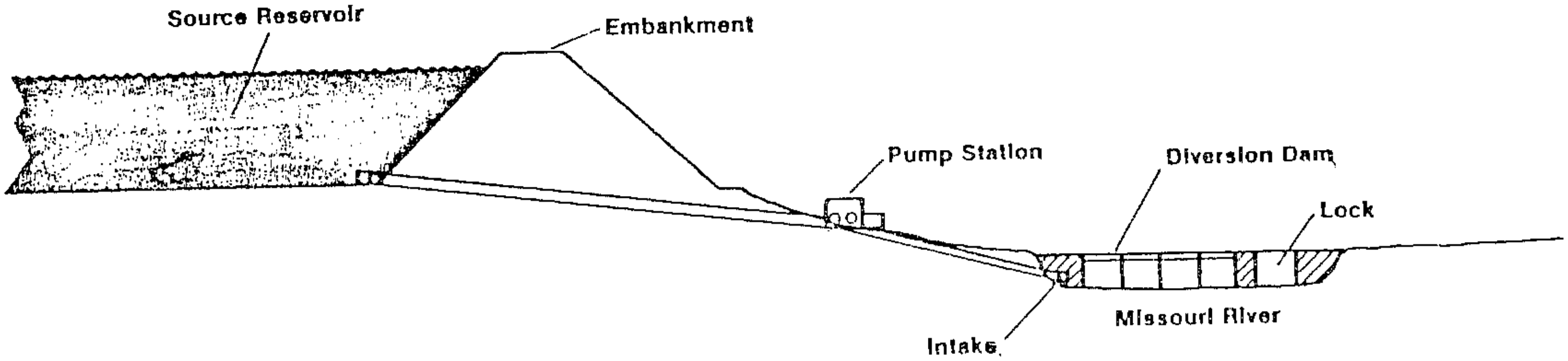


Figure 2
LAYOUT OF TRANSFER ROUTE
ALTERNATIVE B--HIGH PLAINS STUDY



Source Features

Figure 3

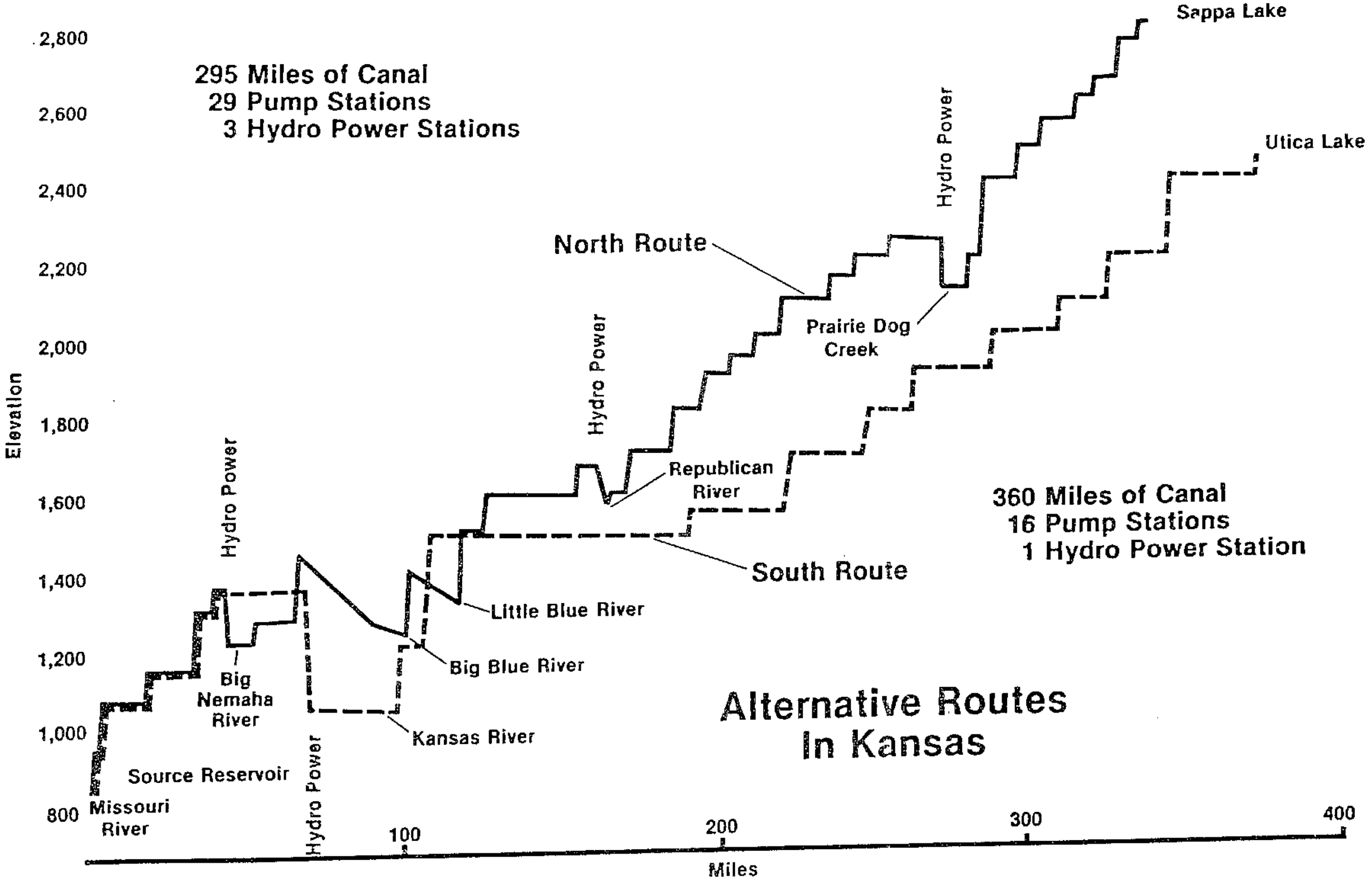
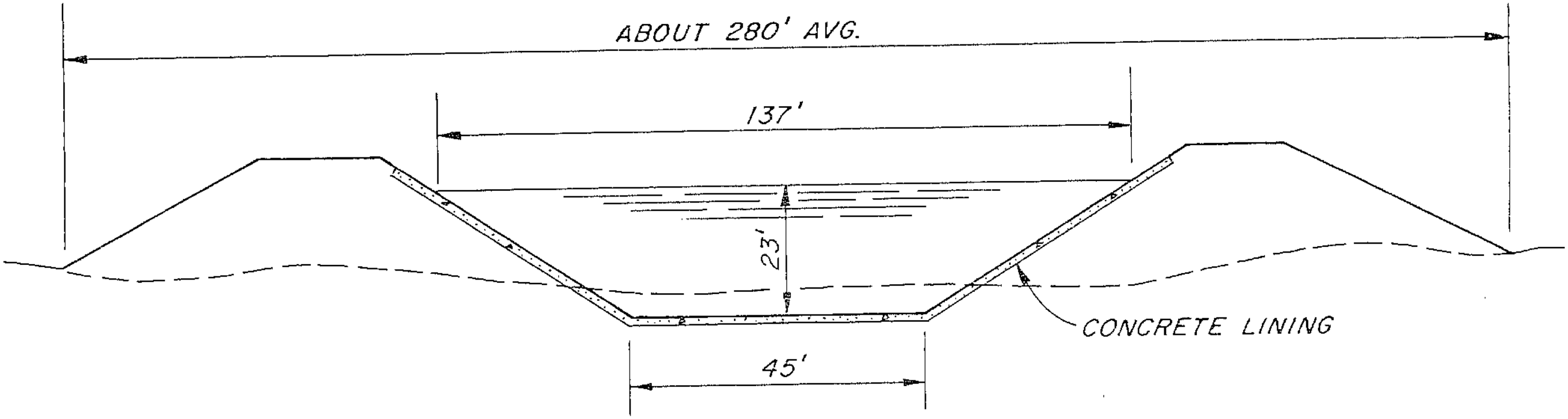
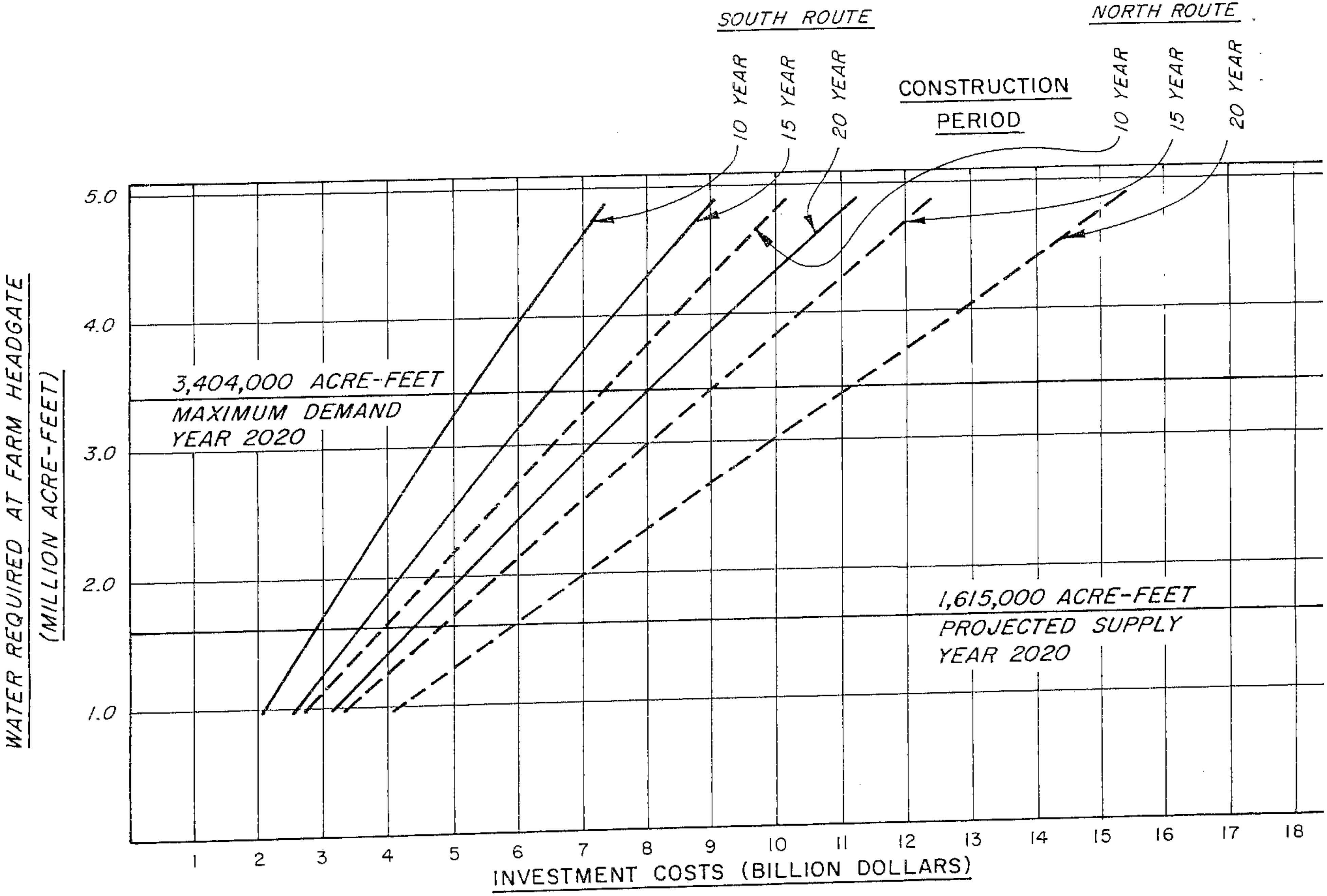

Alternative Routes
In Kansas
295 Miles of Canal
29 Pump Stations
3 Hydro Power Stations
360 Miles of Canal
16 Pump Stations
1 Hydro Power Station
North Route
South Route
Sappa Lake
Utica Lake
Hydro Power
Hydro Power
Hydro Power
Hydro Power
Prairie Dog Creek
Republican River
Little Blue River
Big Blue River
Kansas River
Big Nemaha River
Source Reservoir
Missouri River
Elevation
2,800
2,600
2,400
2,200
2,000
1,800
1,600
1,400
1,200
1,000
800
100
200
300
400
Miles

Figure 4



6,830 C.F.S. CANAL

FIGURE 5 - TYPICAL CANAL DESIGN



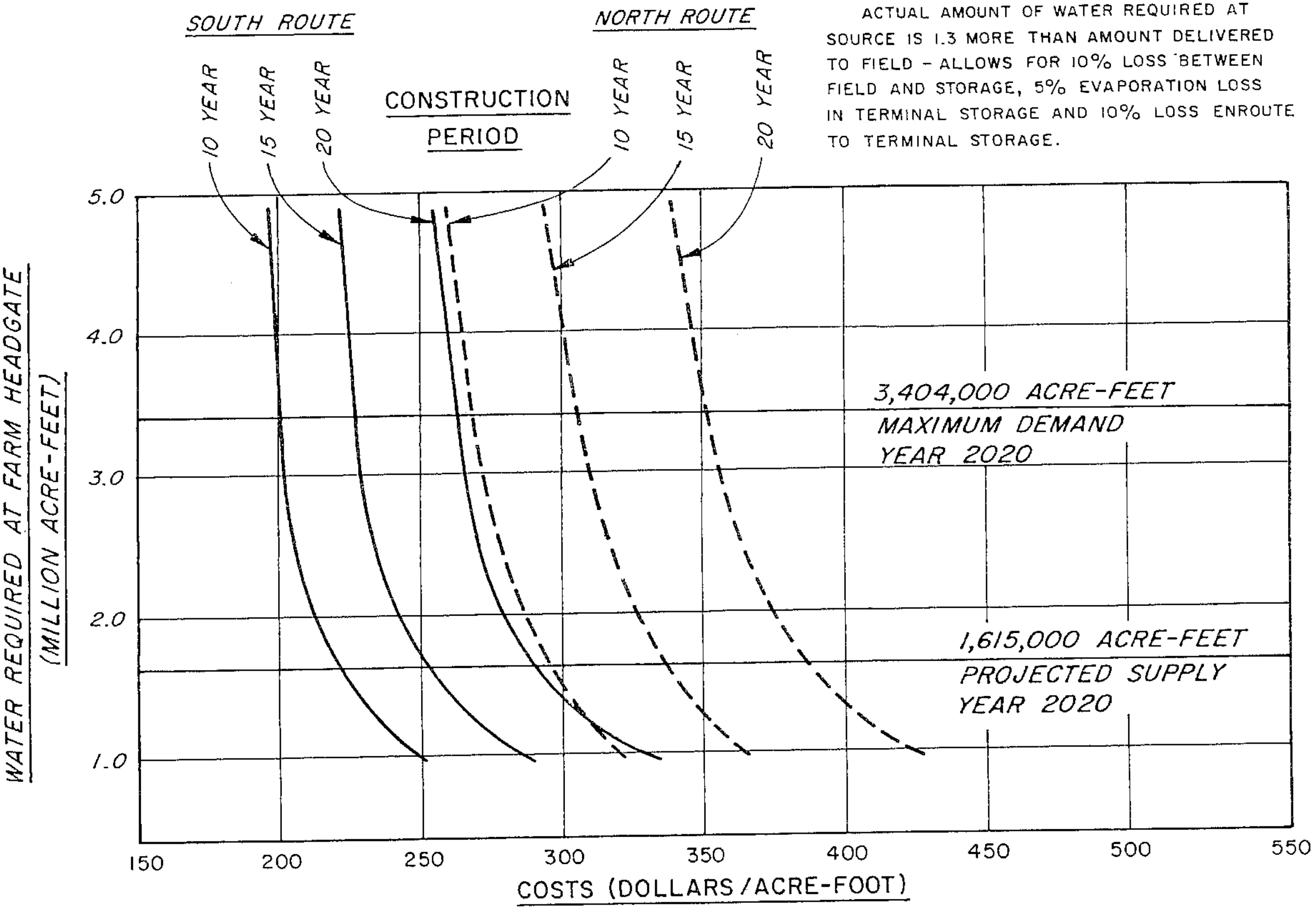
WATER TRANSFER SYSTEMS COST

1977 PRICE LEVEL - KANSAS CITY DISTRICT - CORPS OF ENGINEERS

FIGURE 6

NOTE:

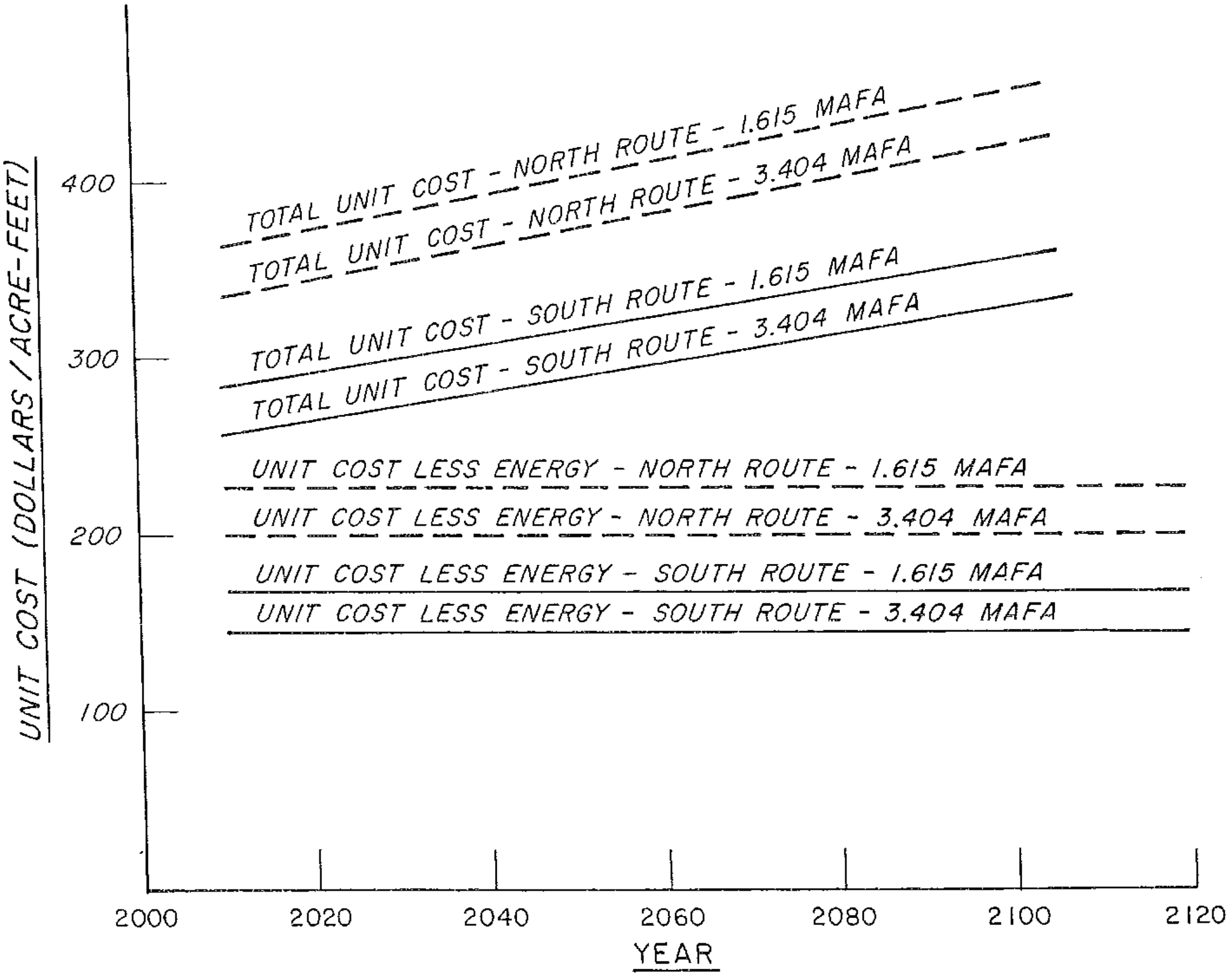
ACTUAL AMOUNT OF WATER REQUIRED AT SOURCE IS 1.3 MORE THAN AMOUNT DELIVERED TO FIELD - ALLOWS FOR 10% LOSS BETWEEN FIELD AND STORAGE, 5% EVAPORATION LOSS IN TERMINAL STORAGE AND 10% LOSS ENROUTE TO TERMINAL STORAGE.



COST OF WATER DELIVERED TO TERMINAL STORAGE

1977 PRICE LEVEL - KANSAS CITY DISTRICT - CORPS OF ENGINEERS

FIGURE 7



NOTE:
COSTS REFLECT 15-YEAR CONSTRUCTION PERIOD.

ANNUAL COSTS WITH PROJECTED ENERGY COSTS

KANSAS CITY DISTRICT - CORPS OF ENGINEERS

FIGURE 8

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. North Route	1.615 MAFA	3.404 MAFA
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)

1. North Route	TOTAL COST	COST/AF	TOTAL HEAD(FT)
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