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EX-POST EVALUATION OF FLOOD CONTROL INVESTMENTS: A CASE OF BALDHILL DAM AND LAKE ASHTABULA IN NORTH DAKOTA

by

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CHAPTER I

INTRODUCTION

Ex-post evaluation of multiple purpose water projects is important for identifying the full range of actual project benefits. The basic rationale for the ex-post evaluation is to help improve ex-ante planning rather than merely a critique of the project implementation. The essence of ex-post evaluation is to provide a feedback to help improve future ex-ante planning procedures.

Ex-ante estimates are prepared based on the anticipated costs and benefits of the proposed project to test its economic feasibility. Normally the projects are sanctioned for implementation only if the proposed benefit-cost ratio is more than unity. However, there is a gap between expectations and realities once the project is in operation. The reason for this divergence could be that the ex-ante estimates were inaccurate, where (i) some benefit categories are not even identified and estimated, and/or (ii) basic assumptions and estimates of costs and benefits are incorrect.

Howe (1971) states that an incredible feature of public resource investment is that few investigations have been done after-the-fact to determine the extent to which expectations were borne out by experience. Such observations would be of great value in improving the planning process and guarding the taxpayer's dollar. That such analyses are ignored seems strange in an economy where private sector investments are typically put to clear-cut financial tests of the correctness of their plans.

Haveman (1972) indicated that neither the criteria for ex-post evaluation nor approaches for measuring economic results are at all well developed. The application of the ex-ante economic analysis to public expenditure programs requires that such analyses demonstrate some prospect of isolating those programs and investments which would increase the net social return. Also the real improvements in public sector performance will not be achieved unless information on the inputs (costs) and outputs (benefits) of ongoing and completed government projects is incorporated into the decision making process.

Theiler (1969) while evaluating the effects of flood protection on land use in the Coon Creek, Wisconsin watershed, indicated that the Soil Conservation Service (SCS) has frequently counted the intensification of agricultural land resulting from increased flood protection, as a benefit. However, he concluded that actual land use changes were far less than predicted by SCS. The reasons were less related to the watershed project than they were to changes in farming practices which raised questions concerning the adequacy of project evaluation techniques.

The results of the pilot study by Haveman (1972) on the John H. Kerr Reservoir, North Carolina indicated that even after 20 years of project operation, the realized economic benefits attribute to the project fell far short of the estimated benefits. The reason he concluded was that post project natural streamflows had a far lower frequency of flood levels than would have been expected from the ex-ante project report.

Hanke and Walker (1974), in their reevaluation study of the Mid-State Project in South-central Nebraska, identified three factors which lead to this unsound investment: (i) the discount rate used in the ex-ante analysis was too low, (ii) multi-purpose benefits from flood control and fish and wildlife enhancement were overstated, and (iii) "new lands" did not yield significant net national benefits.

A post-audit analysis of Pick-Sloan Missouri Basin Program by Arthur D. Little, Inc. (1975) indicated that the irrigation benefits were overestimated and other benefits--electric power, flood control, navigation fish and wildlife--were underestimated. The electric power and flood control benefits alone accounted for 86 percent of the total program benefits. The reestimated benefit-cost was 3.4 as against the original 2.6.

Thus, there is growing concern about the process of project selection in view of the poor performance of projects where there is a great deviation between expectations and realities. Sound investment decisions cannot be made without accurate information. Accurate ex-ante estimates would help identify sound projects and minimize the deviations between expectations and realities. The experience gained from ex-post analysis of projects could be used to improve ex-ante estimating procedures so that future planning strategies are more accurately evaluated. Though there are obstacles to conducting ex-post evaluation studies, most can be overcome.[1/] The present study is an ex-post evaluation of a flood control project. The improvements in flood control methodologies are needed because the information available on flood frequencies and magnitudes as well as on flood control benefits are inadequate.

1/ Haveman indicated several obstacles to ex-post investment evaluation. They include the data and measurement problems such as the with-without versus before-after problem, the stochastic nature of anticipated project outputs, the nonmarket external impacts of projects and the time pattern of the outputs (see Haveman, 1972).

Objectives

The objective of the study is an ex-post evaluation of the Baldhill and Lake Ashtabula project in North Dakota. The following are the specific objectives:

i) to examine the ex-ante costs and benefits estimates of the project,

ii) to estimate the ex-post costs and benefits over the life of the project,

iii) to evaluate the performance of the project, and

iv) to draw lessons for future ex-ante planning and evaluation studies.

Hypotheses

The results of the study will test the following hypotheses:

i) the project costs are normally underestimated and project benefits are overestimated in ex-ante analyses

ii) the environmental development benefits such as recreation, and fish and wildlife are measured only in physical terms, if at all, in ex-ante estimates

iii) several of the planned project benefit categories were not realized.

Study Plan

The case study approach used here is highly useful for in-depth evaluation and to improve measurement methodologies. This project has been selected because of the following characteristics: (i) multipurpose, (ii) a long development period (32 years since it started operation in 1951), (iii) moderate degree of apparent success, and (iv) data is available on various categories of project benefits and costs over time.

CHAPTER II

PROJECT DESCRIPTION

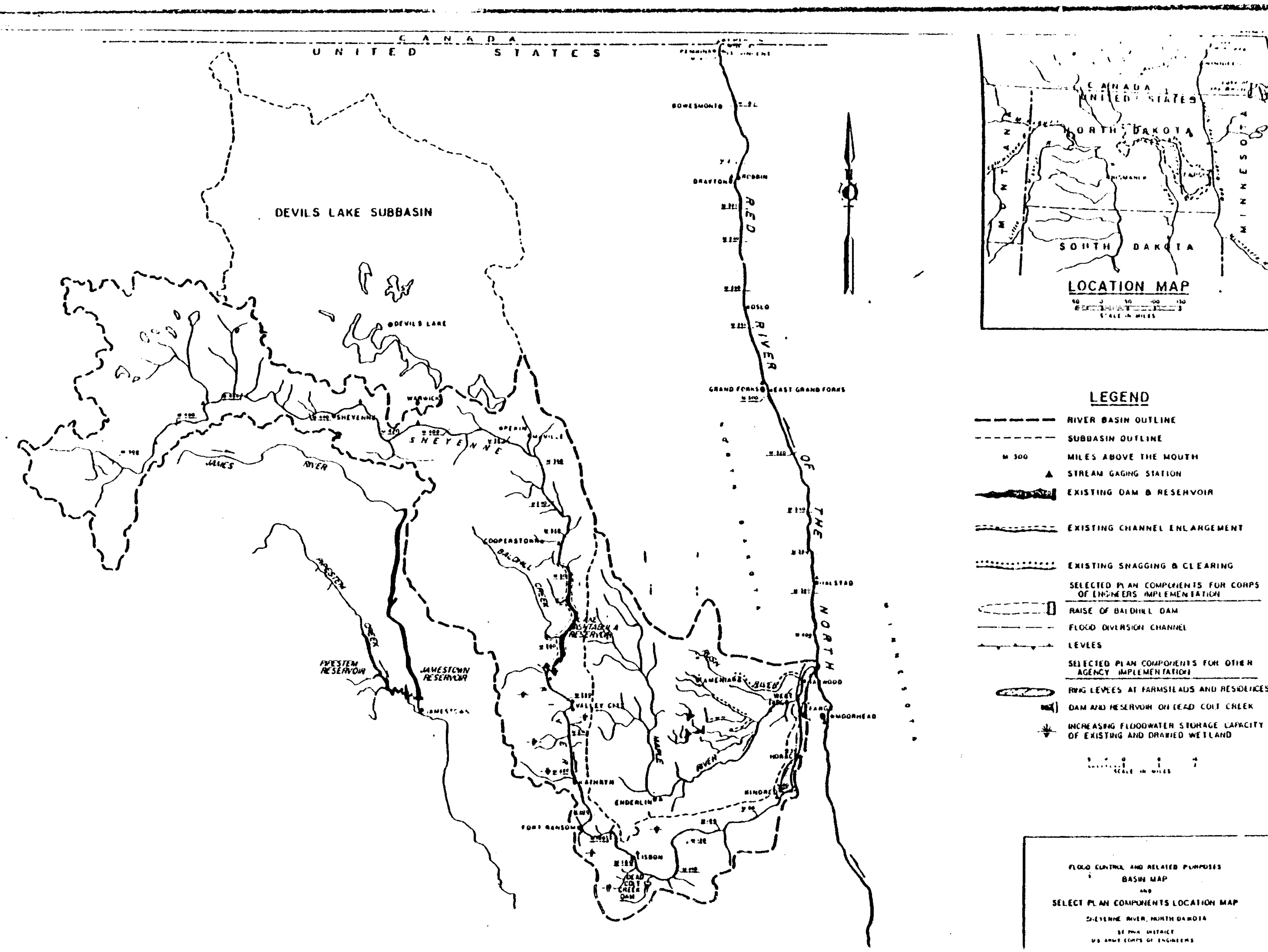
History and Location

Residents of the Sheyenne River Basin in North Dakota had experienced excessive spring water flows followed by extremely low summer flows since the area was first settled. From information presented at public hearings it was established that the 1882 flood inundated large portions of Valley City and Kindred, in addition to extensive areas of cropland. Other major floods occurred in 1897 and 1916. Equally as serious as the flood problem have been the low flow conditions during which stream flow has been inadequate for pollution abatement, water supply, livestock watering and recreational purposes. A plan to construct a multiple purpose reservoir for flood control and water supply was, therefore, recommended in a review report on the Sheyenne River, published as House Document 193, 78th Congress (1944). The project was authorized by the Flood Control Act approved in December 22, 1944. Construction began in July 1947 and the Corps of Engineers began normal operation of the reservoir in the spring of 1952.[1/]

Baldhill Dam and Lake Ashtabula Reservoir are located in Barnes County, North Dakota on the Sheyenne River, which is tributary to the Red River of the North, downstream from Fargo, North Dakota. Baldhill Dam is 271 river miles above the mouth of the Sheyenne River and approximately 16 river miles upstream from Valley City. By highway the dam is about 75 miles west of Fargo, and 12 miles northwest of Valley City (see Figure 1). The drainage area above the dam covers 1,438 square miles exclusive of the adjacent Devils Lake drainage area.

1/ U.S. Army Corps of Engineers, Flood Control, Sheyenne River, North Dakota- Baldhill Dam and Lake Ashtabula, Reservoir Regulation Manual, District Office, St. Paul, Minnesota, March 1956, p. 2.

FIGURE 1. Location of Baldhill Project



Description

The project consists of a dam and a dual purpose storage reservoir on the Sheyenne River. The reservoir above Baldhill Dam was designated Lake Ashtabula by Public Law No. 772, 81st Congress, 2nd session September 1950. The Baldhill Dam consists of a compacted earth embankment with a top elevation 1,278.5 feet. The top width is 20 feet, the maximum height is 61 feet and the length from the left abutment to the spillway structure is approximately 1,650 feet. Lake Ashtabula has a normal pool elevation of 1,266 feet and is approximately 27 miles long and 0.6 mile wide. The shore line is about 78 miles at normal full pool and is moderately regular. The reservoir has a surface area of 5,430 acres with a total capacity of 70,700 acre feet. The dead storage of the reservoir is 1,200 acre feet.

The reservoir has a net useful storage of 69,500 acre feet to provide flood protection and to meet water supply and pollution abatement requirements downstream. The flood control storage is made available in the reservoir by releasing water after October 1 of each year to assure a drawdown to, at least, an elevation of 1,262.5 feet by March 1. Normally, the reservoir is filled to the elevation of 1,266 feet by the spring runoff. The dual use of a part of the reservoir storage is possible since floods on the Sheyenne River occur in the spring as a result of snow melt. The reservoir is operated for spring flood control, with the subsequent release of the stored water used to meet the water supply and pollution abatement objectives during low flow periods.

Approximately 7,816 acres of land were purchased for the Baldhill Dam and Lake Ashtabula project and about 667 acres are under easement, making a total of about 8,483 acres available for all purposes. Much of the federally owned land acquired for the project is leased for the purposes of wildlife management. The lands immediately below the dam are used by the U.S. Fish and Wildlife Service.

Climate and Ecology

The average annual precipitation over the Lake Ashtabula basin is less than 19 inches. Months with the highest average precipitation are June, July and August. The estimated annual snowfall in this region is about 32 inches. It is the combination of the spring snowmelt and the additional runoff from the spring rains that has caused the majority of the damaging floods on the Sheyenne River.

Vegetation or land cover of the river basin is oriented to agricultural use, with most of the flat or gently sloping land under cultivation while the steeper lands are used for grazing. Lake Ashtabula has improved fishing conditions several times over that of the pre-impoundment condition of the Sheyenne River. Recreational fishing is very popular. The U.S. Fish and Wildlife Service operates a fish hatchery directly below the dam.

Lake Ashtabula is a nutrient-rich water body which produces frequent algae blooms and large fish populations. The Sheyenne River carries sediments and nutrients into the lake. The entire area around the lake is heavily farmed or ranched. Run-off from the highly fertilized fields and feedlots eventually finds its way into the lake. Due to algae blooms, swimming and other water oriented activities have declined. However, the lake remains very productive for fishing. If water quality were improved, recreational activities would be expected to increase because clean water is very important for many water-related recreation activities.

CHAPTER III

EX-ANTE PROJECT BENEFITS AND COSTS

The major benefits anticipated in 1944, when the project proposal was completed by the Corps of Engineers, included the water supply benefits (municipal water supply, rural water supply, and stream pollution control) and flood control benefits. The details of the anticipated benefits and their estimation are discussed below.

Water Supply Benefits

Municipal Water Supply Benefits

The estimation of benefits from an improved municipal water supply is based on a rating method which includes the alleviation of the hazards, nuisances, and any inconveniences caused by inadequate and unsatisfactory water supplies. The benefit is found by comparing the values of the existing supply with that to be supplied by the project, using the rate being paid for water in the municipality, and the estimated consumption of water in 1950 (assumed to be the average consumption over the life of the project).

Estimated annual benefits are:

Valley City	$ 6,400
Lisbon	$ 1,480
Fargo	$33,500
TOTAL	$41,380

Rural Water Supply Benefits

An adequate stream flow would be of value to the rural areas principally because it would permit an increase in livestock numbers. The lack of the water supplies during drought periods causes ranchers to deplete herds, thereby eliminating an important source of income. The Corps made a canvass, in the affected areas along the Sheyenne River and nearby watercourses, of men and organizations who had knowledge of agricultural property values in the region. Their opinions were sought concerning the appreciation of land values in the vicinity of a nearly dry stream if it were assured to have a continuous flow of water. They were asked not to consider any effect on ground water or the possibility of irrigation. Thus, their opinions were limited to the evaluation of an adequate flow for livestock watering. The results of this survey were an appreciation in average land values of $11.50 per acre for a distance of 1 3/4 miles on each side of the stream. In some localities there are adequate facilities for livestock watering but in others there are not. Therefore, in this report, a conservative land value appreciation of $7 per acre was used for a strip 1 mile wide on each side of the stream. The length was limited to the reach from the reservoir (Baldhill site) to Kindred, a distance of 95 miles. The area to be benefitted was estimated to be about 640 acres in each mile strip on each side of the stream. The low water flow in the river below Kindred is increased somewhat by springs. The total benefits from the increase in land value with an interest rate of 4 percent is:

$$95 \times 2 \times 640 \times \$7 \times 0.04 = \$34,050$$

This estimate is assumed to include any incidental benefits such as water supply for rural domestic purposes.

<u>Stream Pollution Benefits</u>

The provision of a sufficient quantity of water to dilute municipal sewage and packing plant wastes would remove odors and other forms of nuisances, which have resulted in numerous lawsuits. A direct measure of benefits from sufficient water is impossible. However, the North Dakota State Department of Health has suggested an indirect method of evaluation which is satisfactory and conservative. In 1941, the municipalities of over 1,000 population and industries are expected to provide an 85 percent reduction in the biochemical oxygen demand (BOD) of their sewage wastes and municipalities of less than 1,000 population to provide a 35 percent reduction. Benefits are the cost of providing the BOD reduction of 35 or 85 percent, as the case may be, by means other than dilution[1/].

The annual benefit is obtained by reducing the capital cost of an additional treatment plant to an annual basis, using an interest rate of 4 percent, and an amortization period of 40 years. To this is added estimated maintenance and operation costs. On an average during the period 1931-41 the regulated stream flow (with the project) would have been sufficient to meet only 45.5 percent of the additional flow required below West Fargo, 42 percent below the Fargo-Moorhead area, and 25.6 percent below the Grand Forks area. Pro-rating the total estimated benefits accordingly, the resulting annual benefits from abatement of stream pollution were estimated at $24,700.

Summary of Benefits

The possible annual benefits from an increased flow of water in the Sheyenne River for water supply and pollution abatement are:

Municipal water supply	$41,380
Stream pollution abatement	24,700
Rural water supply	34,050
Total annual benefits	$100,130

1/ These estimates were based on 1941 conditions.

Flood Control Benefits

The direct damages consist of damage to buildings and furnishings in both rural and urban areas and reduced yields due to late seeding and to weed infestation. Other direct damages involve losses in livestock, stored seed grain, cut wood and hay, and damage to farm machinery and fences. There are no direct crop loss. Tangible indirect damages include loss of business due to interruption of operations and transportation, reduced incomes caused by evacuation and reoccupation of premises, additional costs in caring for stock and other farm operations, increased cost of transportation due to detours, and the cost of temporary protective measures. There are no appreciable intangible damages. In the Red River Valley there is very little damage during flood periods to livestock, since it can be evacuated to higher ground, or to buildings which, in general, are located on high ground.

The direct, indirect, and total damages for the floods of 1882, 1897, and 1916, are estimated for the principle damage centers (cities) and the agricultural reaches (see Table 1). The average annual damages are calculated for these cities and agricultural reaches (see Table 2). Valley City accounted for 40 percent of the total flood damages of $881,300.

The flood-control benefits which would result from the plan of improvement described above consist of flood damages which would have been prevented in the Sheyenne River watershed over the period of record. Indirect flood-control benefits were set at 19.5 percent of the direct flood-control benefits, the same percent as determined from the ratio of indirect to direct damages (see Table 1). Direct project benefits are given in Table 3. Valley city accounted for 72 percent of these direct project benefits.

TABLE 1. Damages for the Three Floods of Record (1882, 1897, and 1916)

Nature and location of damage	Direct Damages			Damages for the Three Floods			
	1882	1897	1916	Direct	Indirect	Total	Ratio, indirect to direct
Urban:							
Valley City	$293,800	$ 7,100	$ 2,300	$303,200	$ 50,300	$353,500	0.166
Kindred	3,000	0	0	3,000	1,000	4,000	.333
Southwest Fargo	39,800	39,800	0	79,600	18,300	97,900	.230
West Fargo	54,500	54,500	0	109,000	22,000	131,000	.202
Harwood	2,500	2,500	0	5,000	1,000	6,000	.200
Agricultural:							
Reach 1	20,000	2,500	0	22,500	4,800	27,300	.214
Reach 2	64,100	64,100	13,500	141,700	30,400	172,100	.215
Bridges	50,000	26,000	0	76,000	16,500	92,500	.217
Total	$527,700	$196,500	$ 15,800	$740,000	$141,300	$881,300	0.195

SOURCE: U.S. Senate, 78th Congress, 2nd Session, "... Flood Control on the Sheyenne River, North Dakota," (The Baldhill Dam Report), Document 193, 1944.

Table 2. Average Annual Flood Damages Without the Project

Nature and location of damage	Average Annual Damages		
	Direct	Indirect	Total
Urban:			
Valley City	$ 5,050	$ 840	$ 5,890
Kindred	50	20	70
Southwest Fargo	1,330	300	1,630
West Fargo	1,820	370	2,190
Harwood	80	20	100
Agricultural:			
Reach 1	370	80	450
Reach 2	2,360	510	2,870
Bridges	1,270	270	1,540
Total	$12,330	$2,410	$14,740

SOURCE: U.S. Senate, 78th Congress, 2nd Session, "... Flood Control on the Sheyenne River, North Dakota," (The Baldhill Dam Report), Document 193, 1944.

TABLE 3. Flood-control Benefits from Project

Damage center or reaches	Direct benefits for floods of record				Average annual direct benefits (60 years of record)
	1882	1897	1916	Total	
Urban:					
Valley City	$293,800	$ 7,100	$2,300	$303,200	$5,050
Kindred	3,000	0	0	3,000	50
Southwest Fargo	0	10,000	0	10,000	170
West Fargo	0	13,600	0	13,600	230
Harwood	0	600	0	600	10
Agricultural:					
Reach 1	20,000	2,500	0	22,500	380
Reach 2	0	16,000	3,400	19,400	320
Bridges:	24,000	26,000	0	50,000	830
Total	--	--	--	$422,300	7,040

Total average annual direct benefits	$7,040
Total average annual indirect benefits	$1,370
Total average annual direct and indirect benefits	$8,410

SOURCE: U.S. Senate, 78th Congress, 2nd Session, "... Flood Control on the Sheyenne River, North Dakota," (The Baldhill Dam Report), Document 193, 1944.

Recreational, Fish and Wildlife Benefits

No ex-ante estimates were made of the recreation, fish and wildlife benefits for the project. However, in the Definite Project Report (1947), future recreational developments were mentioned.

Ex-ante Costs

The pre-construction cost estimates for Baldhill project included federal and non-federal investments. Included in the estimates of annual costs is amortization, on the sinking fund basis, of Federal and non-federal investments during an assumed economic life of 50 years. The Corps uses the very questionable practice of varying the interest charge and amortization rates between the federal and non-federal cost calculations and types of investments. The federal cost calculations should have been based on, at least, a rate of 4 percent which would have raised costs. Cost estimates were based on costs prevailing in July 1941. The details of the ex-ante cost estimates are given in Table 4.

Ex-ante Benefit-Cost Ratio

When the benefit-cost ratio is used for selecting projects for investment, the formal decision criterion is not to accept projects with a ratio of less than one. In the case of Baldhill project a favorable benefit-cost ratio of 1.70 was calculated by Corps of Engineers based on the ex-ante benefit and cost estimates (see Table 5). The project was anticipated to provide about 92 percent of the total benefits as water supply benefits and about 8 percent as flood control benefits.

TABLE 4. Ex-ante Cost Estimates

	Federal and Non-federal Costs		Estimates		Percent
	Fixed Cost (Capital)				
i)	Federal investment:				
	Baldhill Reservoir:				
	Baldhill reservoir		$ 69,500		
	Earth dam		238,300		
	Control structure		343,900		
	Spillway		87,500		
	Channel approaches		70,300		
	Relocate State Highway No. 26		174,600		
	Total Federal investment			$ 984,100	73.37
ii)	Non-Federal investment:				
	Baldhill Reservoir:				
	Highway relocations, bridges, and utilities	$ 36,000			
	Flowage acquisition	208,000			
			$244,000		
	Fargo diversion:				
	Dam	86,000			
	Ditch (including bridge)	23,600			
	Lands and rights-of-way	3,600			
			113,200		
	Total non-Federal investment			357,200	26.63
	Total first cost			$1,341,300	100.00
	Annual Charges (operation and maintenance)				
i)	Federal:				
	Interest, $984,100 at 3 percent		$ 29,520		
	Amortization:				
	Machinery and metal parts (25 years), $108,800 at 2.74 percent	$ 2,980			
	Balance of investment (50 years), $875,300 at 0.886 percent	7,760			
			10,740		
	Operation of dam		1,500		
	Maintenance of dam		3,000		
	Stream gaging		500		
	District office expense		1,000		
	Total Federal annual charges			46,260	72.42
ii)	Non-Federal:				
	Interest, $357,200 at 4 percent		$ 14,290		
	Amortization:				
	Bridges and metal parts (25 year), $5,420 at 2.4 percent	$ 130			
	Balance of investment[1/] (50 year), $182,500 at 0.655 percent	1,200			
			1,330		
	Operation of diversion dam		400		
	Maintenance:				
	Fargo diversion dam and ditch	$ 600			
	River channel	1,000			
			1,600		
	Total non-Federal annual charges			17,620	27.58
	Total Federal and non-Federal annual charges			63,880	100.00

[1/] Non-Federal cost ($357,200) minus appraised value of land assumed recoverable ($169,280) minus cost of 25-year life structure ($5,420).

SOURCE: U.S. Senate, 78th Congress, 2nd Session, "... Flood Control on the Sheyenne River, North Dakota," (The Baldhill Dam Report), Document 193, 1944.

The following conclusions were drawn for construction of the Baldhill project: (1) that the flood damages along the Sheyenne River are insufficient to justify any relief on the basis of flood-control benefits alone; (2) that an acute shortage of water exists in the Sheyenne River and in the parent stream, the Red River of the North; and (3) that the construction of the project is justified economically due to its high benefit-cost ratio of 1.70. The project was recommended for construction on the Sheyenne River by the Corps of Engineers in March 1944.

Table 5. Ex-ante Annual Benefit Cost Ratio for Baldhill Project[a/]

		Estimates	Percent
Flood control		$ 8,410	7.75
Water benefits:			
Municipal water supply	$41,380		
Municipal pollution abatement	24,700		
Rural water supply	34,050		
Total water benefits		100,130	92.25
Total annual benefits		108,540	100.00
Total annual costs		63,880	
Benefit-cost ratio		1.70	

SOURCE: U.S. Senate, 78th Congress, 2nd Session, "... Flood Control on the Sheyenne River, North Dakota," (The Baldhill Dam Report). Document 193, 1944

a/ The estimates are based on 1941 price levels.

CHAPTER IV

EX-POST PROJECT COSTS AND BENEFITS

Improvements in the ex-ante procedures for planning future investments require a regular feedback mechanism on the performance of past investments. This section examines the actual expenditure made on the project and the benefits realized. Construction of the Baldhill Dam and Lake Ashtabula project began in July 1947. In the spring of 1950 the dam, although not entirely completed, was placed under emergency operation because of severe flooding conditions. The dam was completed subsequently and formally dedicated on September 21, 1952. Thus the project has been operating for 32 years out of the 50 year expected life which is an adequate period on which to evaluate performance. The ex-post analysis is, consequently, based on this 32 year period.

Project Costs

The cost of dam construction was $154,326. The total land acquisition amounted to $716,500; where the local interests contributed $208,000 and the rest was the Federal contribution (U.S. Army Corps of Engineers, 1956). The total cost of new works through 1981 was $3,307,636 (see Table 6). The new works consisted mainly of recreational facilities and structures related to the operation of the reservoir. The total maintenance costs were $7,983,793 which went mostly for maintaining the reservoir and recreational facilities. The total federal costs were $11,291,429 while the total non-federal costs were $892,495. The non-federal costs were mainly for land acquisition, road relocation and for the Fargo diversion which was completed in 1972. Thus of the total cost of $12,183,924, about 93 percent was the Federal contribution while only 7 percent came from non-federal sources. The new works accounted for about 29 percent of the total federal expenditures and maintenance works for about 71

Table 6. Federal and Non-federal Cost, Baldhill Project (1945-81)

(current prices)

Year	Federal New Works (dollars)	Federal Maintenance (dollars)	Federal Total (dollars)	Non-federal Total (dollars)	Total Federal and Non-federal (dollars)
1945	28	—	28	—	28
1946	10,603	—	10,603	—	10,603
1947	61,179	—	61,179	—	61,179
1948	466,305	—	466,305	208,000[a]	674,305
1949	1,237,810	—	1,237,810	—	1,237,810
1950	523,053	337	523,390	35,000[b]	558,390
1951	162,741	35,563	198,304	—	198,304
1952	144,532	21,210	165,742	—	165,742
1953	67,746	20,767	88,513	—	88,513
1954	23,733	47,560	71,293	—	71,293
1955	16,223	23,824	40,047	—	40,047
1956	9,823	24,256	34,079	—	34,079
1957	—	24,984	24,984	—	24,984
1958	—	22,724	22,724	—	22,724
1959	15,054	20,868	35,922	—	35,922
1960	15,446	24,254	39,700	—	39,700
1961	1,274	32,062	33,336	—	33,336
1962	6,982	30,386	37,368	—	37,368
1963	7,499	41,716	49,215	—	49,215
1964	12,245	43,154	55,399	—	55,399
1965	17,527	60,485	78,012	—	78,012
1966	4,029	79,225	83,254	—	83,254
1967	4,436	50,353	54,789	—	54,789
1968	8,964	73,955	82,919	—	82,919
1969	57,294	63,669	120,963	—	120,963
1970	93,310	92,074	185,384	—	185,384
1971	12,398	308,502	320,900	—	320,900
1972	77,502	241,048	318,550	578,495[c]	897,045
1973	16,000	353,194	369,194	—	369,194
1974	75,614	445,571	521,185	—	521,185
1975	64,383	285,741	350,124	—	350,124
1976	3	681,167	681,170	—	681,170
1977	—	417,675	417,675	—	417,675
1978	18,352	864,196	882,548	—	882,548
1979	145,604	1,403,430	1,549,034	—	1,549,034
1980	744	1,141,031	1,141,775	—	1,141,775
1981	200	1,008,809	1,009,009	—	1,009,009
TOTAL	3,378,636	7,983,793	11,362,429	821,495	12,183,924
Percent	29.74	70.26	100.0		

[a] This amount was contributed by local interests for land acquisition. The total amount spent for land acquisition was $716,500.

[b] Contribution to Barnes County by Eastern North Dakota Water Development Association to help defray costs of road relocation.

[c] Cost of the Fargo Division, completed in 1972, where City of Fargo shared $323,857 and State of North Dakota shared $249,638.

SOURCE: U.S. Army Corps of Engineers, St. Paul District, unpublished records for various years.

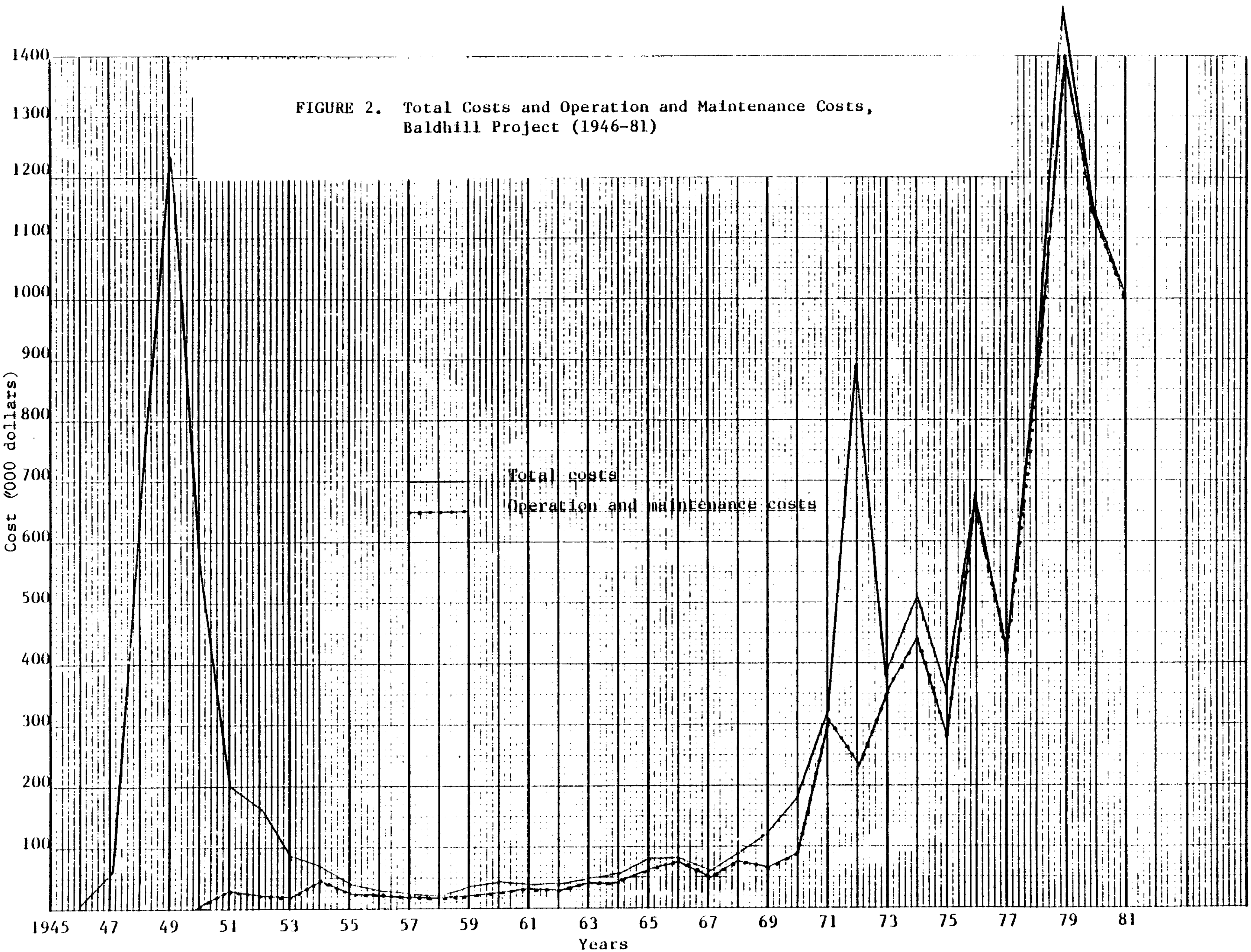
percent. The operation and maintenance costs have increased significantly during the 1970's (see Figure 2).

Project Benefits

The major project benefits realized were flood control, recreation and fishing benefits. Few of the anticipated project water supply benefits-stream pollution abatement, municipal water supply and rural water supply-were realized. There are some suggestions that some of these benefits have been obtained but the Corps has not attempted to count these benefits. Since the project was first placed in operation the discharges from the reservoir have been large enough to maintain a live stream below Baldhill Dam. Undoubtedly, the addition of natural flows at low flow periods has materially increased the pollution carrying capacity of the stream. The value of such added capacity is unknown; it might even be negative because added capacity might encourage further pollution. The original estimates of benefits were based on the supposition that augmenting the stream flow would reduce the cost of treating the effluent from the cities below the dam, particularly at Valley City. However, Valley City abandoned its treatment plant in 1961 because it was obsolete. The city now uses a lagoon system, and does not discharge any effluent directly into the stream (McMartin, 1974). Hence, pollution abatement for Valley City is no longer a project benefit.

None of the cities below Baldhill use the stored water for municipal or industrial uses, though Fargo is now equipped to do so should the need arise. Valley City makes indirect use of the Sheyenne River by allowing floodwater to overflow into a gravel pit, which in turn feeds the acquifer from which the

FIGURE 2. Total Costs and Operation and Maintenance Costs, Baldhill Project (1946–81)



city water supply is pumped (McMartin, 1974). But it is difficult to quantify the recharges due to floodwater. The scarcity of potable water is still a problem in the reservoir area. The Corps drilled 12 wells and the U.S. Geological Survey (USGS) drilled ten test wells around the reservoir area during 1960 to 1964 mainly to increase the possibilities of providing drinking water to cottages and recreational areas along the shores of the reservoir. Most of them were dry (USGS Groundwater Studies, 1964, McMartin, 1974). The cities, however, primarily use wells for their municipal water supply. No specific records of water use by the cities are available to quantify municipal water supply benefits due to the project operation.

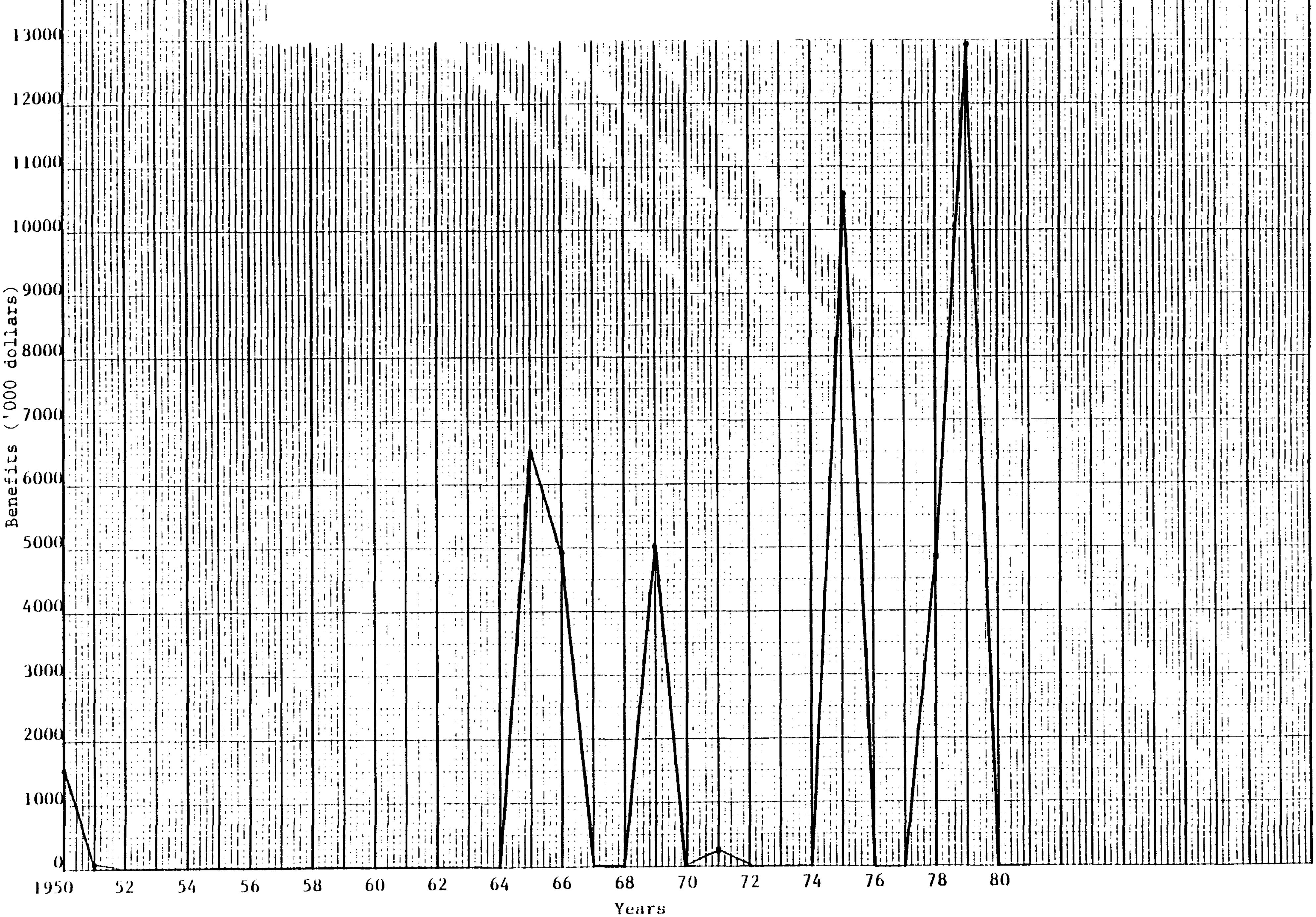
One of the more important ex-ante purposes was to furnish domestic and livestock water to the farmers in the lower valley during periods when the river is dry. The farm wells also ran dry when the river is not flowing. It was believed that water from the reservoir would alleviate the condition by raising the water table in the region. However, there is no evidence to confirm that the presence of reservoir water has recharged the wells.

None of the water supply benefits has actually occured due to the project operation. Hence, for the ex-post evaluation of the project, no benefits are included for water supply. Only flood control, recreation and fishing benefits are counted.

Flood Control Benefits

The major flood control benefits that have accrued since the project's operation are from protection of agriculture, transportation and urban facilities. These benefits were larger than anticipated in the original project proposals. During the total project's operation period of 32 years (from 1950 to 1981), floods occurred in 9 years with varying magnitudes (see Figure 3).

FIGURE 3. Flood Control Benefits, Baldhill Project (1951-81)



Agricultural Benefits

The major agricultural damages prevented were to crops and pasture (reduced yield due to late seeding, replanting, refertilizing, and weed infestation). Other agricultural damages prevented were those to livestock, poultry, stored grain, irrigation and drainage facilities, farm machinery, fences and soil. Of the total flood control benefits of $46,533,100, agricultural benefits accounted for $1,377,600 or three percent (see Table 7). However, the percentage varied depending on the severity of flood. The method of estimating the agricultural damages is given in Appendix I.

Transportation Benefits

Transportation benefits include mainly the damages prevented to bridges, culverts, roads and waterways. The transportation benefits accounted for $524,400 or about one percent of the total project benefits (see Table 7). Here again, the percentage varied with the severity of floods. The method for calculating transportation benefits is also given in Appendix I.

Urban Benefits

Urban facilities include flood damages to residences, businesses, industries, churches, schools, automobiles, house trailers, public property, and the contents of all these facilities. In addition this category encompasses damages to streets and utilities such as water, gas, electricity, sanitary sewer, storm sewer, and telephone. Finally, expenditures for temporary housing, cleanup, flood relief and additional fire and police protection are included. Of the total flood control benefits of $46,533,100, urban benefits alone accounted for about 96 percent (see Table 7). The method of determining the urban benefits is described in Appendix I.

Table 7. Flood Control Benefits, Baldhill Project (1950-81)

(current prices)

Year	Transportation Benefits (dollars)	Agricultural Benefits (dollars)	Urban Benefits (dollars)	Total Benefits (dollars)
1950	25,000	262,000	1,225,000	1,512,000
1951	1,000	34,000	6,000	41,000
1952	--	--	--	--
1953	--	--	--	--
1954	--	--	--	--
1955	--	--	--	--
1956	--	--	--	--
1957	--	--	--	--
1958	--	--	--	--
1959	--	--	--	--
1960	--	--	--	--
1961	--	--	--	--
1962	--	--	--	--
1963	--	--	--	--
1964	--	--	--	--
1965	113,000	235,000	6,208,000	6,556,000
1966	16,000	26,000	4,883,000	4,925,000
1967	--	--	--	--
1968	--	--	--	--
1969	42,000	65,000	4,976,000	5,083,000
1970	--	--	--	--
1971	57,500	77,100	62,000	196,600
1972	--	--	--	--
1973	--	--	--	--
1974	--	--	--	--
1975	6,900	54,500	10,313,100	10,374,500
1976	--	--	--	--
1977	--	--	--	--
1978	40,000	160,000	4,700,000	4,900,000
1979	223,000	464,000	12,258,000	12,945,000
1980	--	--	--	--
1981	--	--	--	--
TOTAL	524,400	1,377,600	44,631,100	46,533,100
Percent	1.13	2.96	95.91	100.00

SOURCE: U.S. Army Corps of Engineers, Records on Baldhill and Lake Ashtabula, St. Paul District, for various years.

Recreation Benefits

Recreation is one of the benefits not claimed in the Corps ex-ante estimates to justify the project. Yet, recreation benefits have become increasingly important. The visitation records show an impressive trend showing a substantial increase in recreation benefits through 1976. Several steps were taken to encourage recreational activities after the project was commissioned for full operation. A master plan for administration and development of the project land and water areas of Lake Ashtabula was approved in May 1953. Recreation facility development proceeded in accordance with the master plan. Also the water level in the reservoir during summer months is kept at a maximum in terms of depth and water surface to provide more opportunities for recreation. Within a fifty mile radius of the easily accessable Lake Ashtabula, there are no other major water oriented recreational facilities.

Visitations at Lake Ashtabula have steadily increased since 1957. During the last five to six years there has been an average increase of 4 to 5 percent per annum (U.S. Army Corps of Engineers Records, 1979). The lake is also used in the winter months for fishing and snowmobiling. The yearly visitor days were developed from traffic counts taken at each site and based on 3.8 people per car. The value of the visitor days was calculated by the Corps of Engineers based on the point rating method taking into account the quality, relative scarcity, ease of access and esthetic features of the recreational activities (for details see Federal Register Vol. 44, No. 242, Dec. 14, 1979). The average value used in 1981 was $2.00 per visitor day. This value was deflated based on urban consumer price index, and used to estimate the recreational values for different years. The total recreational benefits for the project through 1981 was $8,684,249 (see Table 8).

Table 8. Recreation Benefits, Baldhill Project (1957-81)

(current prices)

Year	Number Visitation	Value (dollars)
1957	31,000	20,150
1958	48,000	31,200
1959	67,500	43,875
1960	105,000	68,900
1961	183,000	118,300
1962	261,000	182,300
1963	291,300	233,040
1964	294,200	241,244
1965	314,000	266,900
1966	241,600	207,776
1967	224,000	199,360
1968	233,400	212,394
1969	229,900	211,508
1970	232,200	222,912
1971	386,833	375,228
1972	453,200	471,328
1973	448,666	480,072
1974	479,300	522,437
1975	496,600	566,124
1976	573,900	671,463
1977	573,500	688,200
1978	505,400	667,128
1979	439,900	642,254
1980	338,900	542,240
1981	407,100	797,916
TOTAL	7,859,399	8,684,249

SOURCE: U.S. Army Corps of Engineers, St. Paul District, unpublished records for various years.

Commercial Fish Benefits

Commercial fishing is another benefit category not included in the ex-ante project estimates.[1/] After the construction of the project, Lake Ashtabula provided a good habitat for fish. The U.S. Fish and Wildlife Service (USFWS) Valley City hatchery has stocked Lake Ashtabula every year since 1953. A parcel of Federal land below the dam is used by the U.S. Fish and Wildlife Service (USFSW) for development of fish ponds. The North Dakota Game and Fish Department (NDGFD) constructed a 10 acre fish pond (Sprague, 1963).

Between 1964 and 1978 a total of about 53 species of fish have been reported in the Sheyenne River. Of the total 31 species occur upstream of Baldhill Dam. Fish populations in the reservoir are substantial and the quality of the fishing is acceptable. The estimated average yield of the commercial fishing was about 22 lbs. per acre (Peterka, 1978). The details of the commercial fish harvest since 1953 is shown in Table 9 and in Figure 4. It is seen from the table, that black bullheads dominated the catch followed by yellow perch and white suckers. The values of the fish harvest for each year is based on current market values. On an average, the value of various fish species harvested ranged from $0.50 to $3.50 per pound. The total value of fish benefits is $3,100,773 which is not adjusted for fishing costs. However, this would have only a minor impact on total project benefits.

1/ Adequate records are not available to show with any degree of accuracy the impact of reservoir operations on wildlife. However, observations over the years do permit some general conclusions. Some wildlife resources were destroyed when the reservoir was filled but they were replaced by other types of wildlife. A few unique wildlife values were created, such as a large flock of pelicans that feed each summer in the tailrace of the outlet of Baldhill Dam. In general, the wildlife values created by the project operation are more than equal to those destroyed, but such a conclusion is only a subjective judgement (McMartin, 1974).

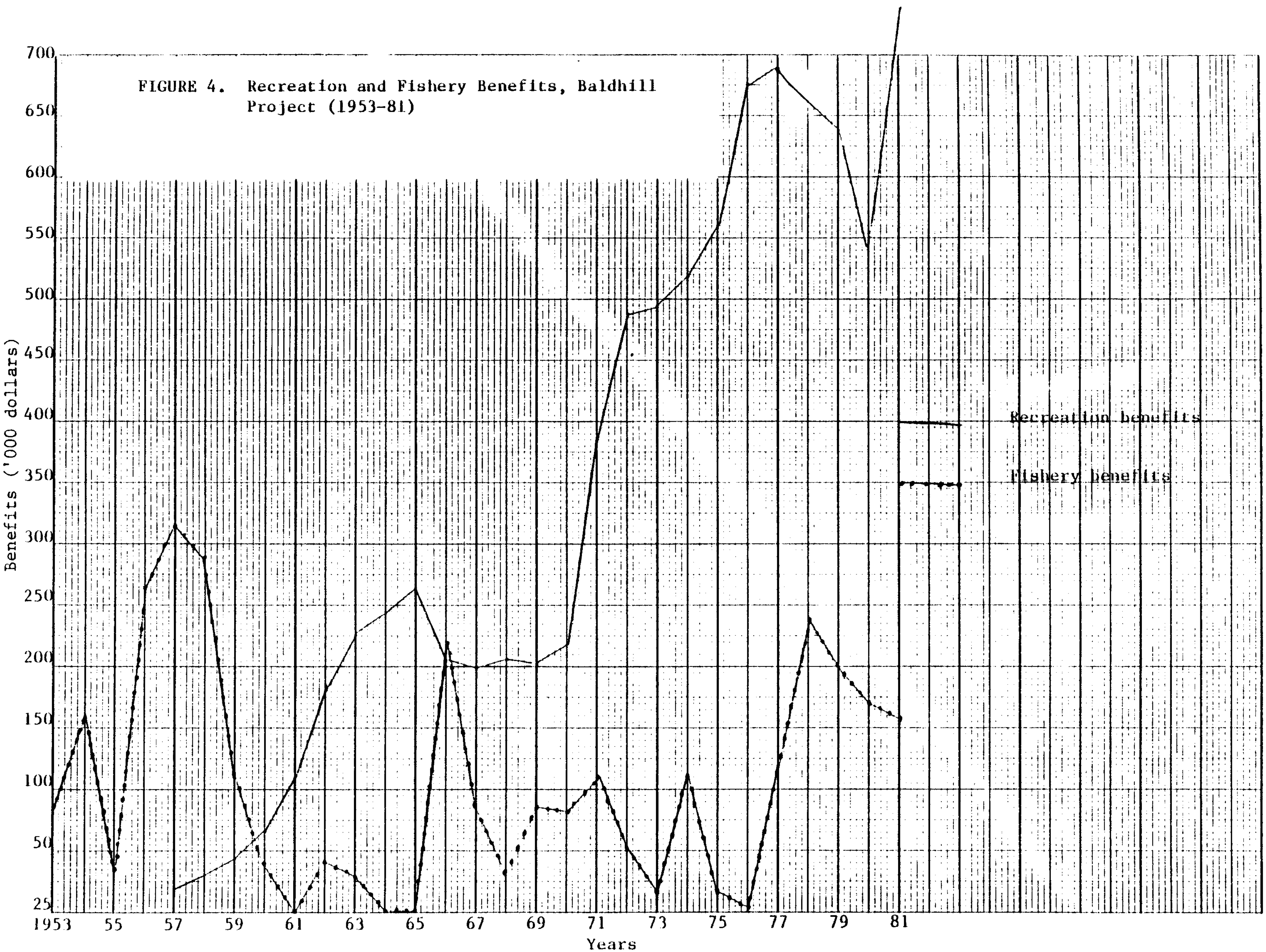
Table 9. Commercial Fish Harvest, Baldhill Project (1953-81)

(current prices)

Year	White Suckers (pounds)	Black Bullheads (pounds)	Yellow Perch (pounds)	Total (pounds)	Total Value (dollars)
1953	---	120,250	---	120,250	78,162
1954	---	251,817	---	251,817	163,681
1955	2,550	44,902	---	47,452	30,844
1956	13,069	394,726	---	407,795	265,067
1957	760	453,621	1,600	455,981	314,627
1958	14,789	363,611	21,752	400,152	284,108
1959	21,230	127,378	7,282	155,890	110,682
1960	11,418	39,695	7,940	59,053	42,518
1961	---	---	---	---	---
1962	---	62,000	---	62,000	43,400
1963	---	39,240	---	39,240	29,430
1964	---	---	---	---	---
1965	---	---	---	---	---
1966	---	294,171	---	294,171	232,395
1967	---	84,002	24,880	108,882	88,194
1968	---	27,300	10,365	37,665	31,636
1969	---	91,770	4,100	95,870	85,324
1970	---	68,390	16,600	84,990	79,891
1971	---	106,700	2,300	109,000	106,820
1972	---	51,200	---	51,200	52,224
1973	---	17,000	---	17,000	18,360
1974	---	85,400	6,900	92,300	110,760
1975	---	18,000	---	18,000	23,580
1976	---	900	---	900	1,170
1977	4,000	83,300	---	87,300	128,331
1978	---	154,200	---	154,200	242,094
1979	---	118,900	---	118,900	208,075
1980	---	94,600	---	95,600	172,080
1981	---	82,800	---	82,800	157,320
TOTAL	67,816	3,276,873	103,719	3,448,408	3,100,773

SOURCE: Game and Fish Department, North Dakota.

FIGURE 4. Recreation and Fishery Benefits, Baldhill Project (1953-81)



Total Ex-post Project Benefits

The analysis shows that substantial project benefits from flood control, recreation and commercial fish harvesting. Although the Corps feels that municipal water supply benefits have also occurred they do not have any firm evidence. Flood control benefits alone accounted for about 80 percent of the total ex-post benefits, followed by recreation and fish benefits (see Table 10).

Table 10. Summary of Ex-post Project Benefits, Baldhill Project, (1950-1981)

Benefits	Value (dollars)	Percent
Flood control	46,533,100	79.79
Recreation	8,684,249	14.89
Fish	3,100,773	5.32
Total	58,318,122	100.00

CHAPTER V

COMPARISON OF EX-ANTE AND EX-POST COSTS AND BENEFITS

Comparison of the project costs and benefits helps evaluate project performance and suggest improvements in the future planning methods. In this chapter, comparisons are made: (1) between estimates of ex-ante and ex-post costs and benefits, and (2) between ex-post costs and benefits. The former indicates how accurately the ex-ante estimates were in predicting project performance while the later shows whether the project was a good investment.

Comparison of Ex-Ante and Ex-Post Estimates

It is important to recognize that the ex-ante estimates were made in an economic environment quite different from today. Most of the costs occurred early during the construction period while most of the benefits, occured in the later stages of the project life. Hence, timing of costs and benefits is important in the comparison. Both costs and benefits were reported in actual prices and had to be converted to 1941 prices through the use of price indexes.[1/] The Engineering News Record's (ENR) construction index was used to deflate costs and transportation benefits and the ENR building index was used to deflate urban benefits. The agricultural prices index (both prices paid and received by farmers) was used to deflate agricultural benefits while the urban

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1/ Although it is possible to compare the costs and benefits at current (1981) prices by updating, it is not done due because we did not want to alter the ex-ante estimates. Updating of the ex-ante (or 1941) costs and benefits to 1981 price levels by various price indexes resulted in a revised ex-ante benefit-cost ratio. The objective of the study is to compare the ex-post estimtes with the original ex-ante estimates, keeping the ex-ante estimates unaltered. By deflating the ex-post estimates to 1941 prices such a comparison can be made between ex-post and ex-ante estimates without changing the original ex-ante estimates.

consumer price index was used to deflate recreation and fishery benefits (see Appendix I for more details).

The ex-ante and ex-post estimates of benefits and costs provide an adequate basis for identifying the deviations between actual and expected outcomes. The ex-post total benefits were about 300 percent more than the ex-ante total benefits (See Table 11). The ex-post total cost estimates were about 100 percent higher than the ex-ante total cost estimates. Thus, ex-ante benefit estimates were underestimated more than ex-ante costs. The major reasons for the underestimation of benefits was that some of the benefits were not identified, and flood frequency was greater than expected. The underestimation of the costs was partly caused by the use of too low an interest rate for federal costs. The Corps used 3 percent for Federal costs and 4 percent for non-Federal.[2/] In addition, the ex-post costs increase due to inflation and additions to the project particularly for recreation facilities. The primary increase in ex-post cost came from higher dam construction costs (about $1.5 million). Land acquisition was the second largest increase in cost, $716,500, with local groups contributing only $208,000 and the rest coming from federal appropriations. The land acquisition cost was about 240 percent above original estimates. The increase in land acquisition cost was partly due to inflation and partly due to the cost increased by a court trial which took place over the value of the land condemned. The court awarded the land owners a price much higher than the appraised price offered by the Corps (McMartin, 1974). In addition, the original cost estimates were low. An average of $35.00 per acre for the 6,000 acres was used to estimate

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2/ U.S. Senate, 78th Congress, 2nd Session, "...Flood control on the Sheyenne River, North Dakota" (The Baldhill Dam Report), Senate Document 193, 1944.

Table 11. Comparison of Ex-ante and Ex-post Estimates, Baldhill Project.[a/]

	Ex-ante Estimates		Ex-post Estimates[b/]	
	Value	Percent	Value	Percent
	(dollars)		(dollars)	
Flood control benefits:				
i) Agricultural	834		13,460	
ii) Transportation	995		3,572	
iii) Urban	6,581		294,501	
Total flood control benefits	8,410	7.75	311,533	72.01
Water supply benefits:				
i) Municipal water supply	41,380		-	
ii) Municipal pollution abatement	24,700		-	
iii) Rural water supply	34,050		-	
Total water supply benefits	100,130	92.25	-	-
Recreation benefits:	-		82,749	19.03
Commercial Fish benefits:	-		38,356	8.86
Total annual benefits	108,540	100.00	432,638	100.00
Total annual costs	63,880		128,693	
Total benefit-cost ratio	1.70		3.36	
Flood control benefit-cost ratio	0.13		2.42	

[a/] Benefits and costs in 1941 prices

[b/] Project life 32 years

land acquisition costs. When land acquisition was actually completed, the total area purchased was 7,816 acres and the average cost including administrative costs to the Corps, was $92.00 per acre.

The other federal costs for construction of new works included buildings and other structures for dam maintenance and recreational facilities. The construction cost for recreation structures amounted to $596,798 (see Table 12). The annual operation and maintenance costs reported in the original ex-ante estimates were about $8,000. But the actual costs were $29,646 which is about a 270 percent increase in costs.

The ex-post analysis of benefits shows a dramatic change in the type of benefits obtained. The ex-ante estimates indicated that water supply benefits account for about 92 percent of the project benefits and the flood control benefits about 8 percent. No ex-ante estimates were made of environmental benefits. However, the ex-post analysis found that water supply benefits were not realized while benefits were obtained from recreation and commercial fishing. Flood control benefits were much more than expected. Thus the ex-ante estimates were poor as they underestimated the benefits and costs, and failed to identify the exact nature of project benefits.

The ex-post flood control benefits accounted for about 72 percent of the total project benefits, while recreation benefits added about 19 percent and commercial fish benefits about 9 percent. The ex-post flood control benefits were 37 times higher than ex-ante flood control estimates, because there was a greater incidence of floods than expected during the 32 years

Table 12. Cost of Recreational Facilities, Baldhill Project (1950-1981)
(current prices)

Year	Value (dollars)
1953	14,403
1954	17,950
1955	11,240
1956	2,862
1957	--
1958	--
1959	15,054
1960	15,446
1961	1,274
1962	6,982
1963	7,499
1964	6,995
1965	10,537
1966	--
1967	--
1968	837
1969	33,496
1970	85,896
1971	--
1972	66,000
1973	16,000
1974	69,871
1975	56,441
1976	--
1977	--
1978	14,625
1979	142,646
1980	744
1981	--
Total	596,798

Source: U.S. Corps of Engineers, St. Paul District, various records.

period.[3/] For example, it was assumed that over a 60 year period, the floods of 1882, 1897, 1916 etc. would occur again with the frequency shown in Table 13. However, the actual floods increased in frequency and magnitude. For example, at Valley City, the post-project floods and flood discharge levels are substantially higher than the pre-project records (see Table 14). There have been 15 flood events at Valley City in the last 100 years; nine of which have occurred since the project was constructed. This represents 60 percent of the flood control benefits that might accrue in a 100 year period.[4/] The flood events after the construction of the project show that two major floods have occurred in 1950 and 1951 immediately after the construction of the reservoir. The benefits from reducing damages from these two floods alone accounted for more than 10 percent of the total ex-post flood control benefits. Out of the nine floods, five were major floods, and represented a significance portion of the flood damages prevented by the project. Since the project has completed 32 years out of 50 years life, [5/]

3/ It is important to note that the ex-post estimates of flood control benefits considered only direct benefits; as it is very difficult to estimate indirect benefits. The ex-ante estimates included direct and indirect benefits where indirect benefits were 19.5 percent of the direct benefits (see Chapter III). The ex-ante estimates would be still lower if only direct benefits were included.

4/ By considering the severity and timing of floods, it is also possible to argue that the benefits due to the 9 floods since the project was constructed, might represent the total flood control benefits for the full 50 year life of the project. Therefore, by dividing the total benefits and costs occurred for the 32 years by the 50 year life of the project the average annual flood control benefits are reduced to ($199,381) but still exceeds the average annual cost ($128,693).

5/ The 50 year project life is considered reasonable. However, there are arguments for a 100 year life for all projects. But when benefits and costs are discounted beyond 50 years, the discounted figures are fairly small. Including additional years will just raise the benefit-cost ratio marginally.

Table 13. Pre-project Flood Frequencies and Discharges at Valley City

Average Frequency in Years	Discharge (cfs)	Year of Flood
120	4,500	1882
100	4,300	
50	3,600	
40	3,400	1897
30	3,200	
25	3,100	1916
20	2,850	
17	2,750	1919
15	2,600	
10	2,250	
5	1,600	1920 and 1941

Source: U.S. Senate, 78th Congress, 2nd Session, "...Flood control on the Sheyenne River, North Dakota", (The Baldhill Dam Report), Senate Document 193, 1944, p. 18.

Table 14. Post-project Natural Peak Flood Flows at Valley City

Year	Natural Peak Flows (cfs)
1950	9,600
1951	1,370
1965	3,890
1966	3,780
1969	5,380
1971	2,320
1975	2,030
1978	2,500
1979	10,250

Source: U.S. Army Corps of Engineers, Sheyenne River, North Dakota, Technical Appendixes, Vol. 1, 1982, p. B-52.

the record of floods provides a comfortable setting for evaluating the benefits.[6/]

The recreation and commercial fish activities provide a continuous stream of benefits each year almost equivalent to the annual operation and maintenance cost of the project (see Table 11). There are also possibilities that these benefits will increase in the future due to increasing demand for recreation. The Baldhill project would have been justified in the ex-ante analysis if the water supply benefits were replaced by the recreation and fish benefits.

Comparison of Ex-Post Benefits and Costs

The Baldhill project was justified for construction based on a benefit-cost ratio of 1.70. However, this ratio relied heavily on water supply benefits which never materialized. The ex-post analysis questions the validity of the original benefit cost ratio as a guide for investment decisions. The ex-ante benefit-cost ratio without water supply benefits would have been 0.13. The discounted measures of project worth and the benefit-cost ratios were calculated with the ex-post benefits and costs for different discount rates

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6/ Haveman argues that time pattern of the project outputs (benefits) of long-lived investment is important. For some investment, an analysis performed a decade following project completion might capture a significant portion of the total life time outputs of the project. For other projects, however, the time stream of expected outputs might display a very slow start, with the bulk of the expected project benefits occurring in the later years of the project's life. In the latter case, the analyst would find it difficult to judge the efficiency of the investment on the basis of its output stream during the first decade. The appraisal of performance in this case is meaningful only after the elapse of a significant period of time after the construction of the project (see Robert H. Haveman, *op. cit.*, p. 9).

(see Table 15).[7/] The benefit-cost ratios at all four discount rates are greater than one. Even at 7-5/8 percent, the benefit-cost ratio is about 1.67 which is almost the same as the ex-ante ratio. Hence, even if the evaluation is made based on the 7-5/8 percent discount rate the project is financially sound. The benefit-cost ratios calculated with only the flood control benefits are also greater than one (see Table 15). The ratio drops to 1.21 with a discount rate of 7-5/8 percent. Hence, even if the Baldhill project is evaluated only for flood control, the benefits are more than the costs.

Average Annual Net Benefits

It is common to evaluate the performance of the projects on the basis of its 'average annual net benefit', where both the present worth of the benefits and the present worth of the costs are multiplied by the capital recovery factor to find their average annual equivalents (see, Price Gittinger, 1978). The average annual net benefits is a good measure of project performance. If the project has a poor performance record, then the average annual benefits would be negative. The average annual net benefits calculated for the 32 years of the Baldhill project are $201,378, $166,868, $135,313, and $88,948 respectively for 3, 4, 5, and 7-5/8 percent discount rates (see Table 16). When only the flood control benefits are included, the project average annual net benefits are still positive.

7/ The discount rates used in the ex-post estimates were 3, 4, 5, and 7-5/8 percent. The 3 percent was used because it was the rate used in the ex-ante estimates. However, 4 and 5 percents reflect a more reasonable real rate for project evaluation purposes. The 7-5/8 percent was the rate established for 1981 level project estimates by Water Resources Council (see 33 Federal Register, 19170, under the formula of Section 704.39 (a) of Water Resources Council). Since the Baldhill project is being evaluated starting with 1981 estimates, the 7-5/8 percent is used. In all the cases, the rates are real rates since all benefits and costs have been deflated.

Table 15. Present Worth of Ex-post Benefits and Costs, Baldhill Project, (1950-1981)

Particulars	Discount Rates (percent) 3	4	5	7 5/8
Flood control benefits:				
i) Agricultural	226,728	188,236	158,465	132,225
ii) Transportation	53,252	42,147	37,743	24,629
iii) Urban	4,187,478	3,250,124	2,548,267	1,750,454
Total flood control benefits	4,467,458	3,480,507	2,740,475	1,907,308
Recreation benefits:	1,089,557	820,174	622,041	385,882
Commercial fish benefits:	652,651	537,195	445,508	348,997
Total annual benefits	6,209,666	4,837,876	3,808,024	2,642,187
Total annual costs	2,099,911	1,858,091	1,660,206	1,583,270
Total benefit-cost ratio	2.96	2.60	2.29	1.67
Flood control benefit-cost ratio	2.13	1.87	1.65	1.21

Table 16. Average Annual Net Benefits, Baldhill Project, (1950-1981)[a/]

Discount rate	Capital recovery factor[b/]	Average annual net benefits: All benefits	Flood control benefits
		-----dollars-----	
3%	0.049	201,378	116,009
4%	0.056	166,868	90,855
5%	0.063	135,313	68,057
7 5/8%	0.084	88,948	27,219

a/ The average annual net benefits at ith discount rate for n years = Present worth of benefits at ith discount rate x capital recovery factor at ith discount rate for n years - present worth of costs at ith discount rate x capital recovery factor at ith discount rate for n years.

b/ $P = \frac{i\,(1 + i)^n}{(1 + i)^n - 1}$

Where i = discount rate
n = project life
p = capital recovery factor

Summary

The ex-ante estimates were made in an economic environment different from that which characterizes the ex-post project period. The ex-ante analysis underestimated the costs and overestimated the water supply benefits. The ex-ante estimates failed to include recreation and commercial fish benefits. The ex-post estimates show that flood control benefits increased considerably more than costs over the 32 years of project operation and placed the project in a favorable position with an ex-post benefit-cost ratio of more than unity with different real discount rates.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The Baldhill reservoir and Lake Ashtabula project in the Sheyenne River, North Dakota, was recommended in U.S. Senate document, No. 193, in 1944 as a dual purpose project for providing water supply and flood control benefits. The water supply benefits were expected to account for about 92 percent and flood control benefits about 8 percent of the total benefits. The project was finally sanctioned for construction with a favorable benefit-cost ratio of 1.7 and an expected life of 50 years. The dam was built by the Corps of Engineers between 1947 and 1952. The project started full operation in 1951 following a heavy flood and had completed 32 years of operation by the end of 1981. The multipurpose nature and the 32 years of operation made the project attractive for an ex-post evaluation.

The ex-post analysis indicated that the total ex-post benefits were about 300 percent higher than total ex-ante benefits while ex-post costs were 100 percent higher than ex-ante costs. The ex-post estimates further indicated that the flood control benefits accounted for about 72 percent of the total project benefits and recreation and commercial fish benefits accounted for the remaining 28 percent. No water supply benefits have resulted from the project.

The underestimation of benefits in the ex-ante estimates was due to the low flood frequency prior to the project and the failure to include recreation benefits. The underestimation of ex-ante costs was primarily caused by the high land acquisition costs, construction of new recreation facilities, and the resulting increases in operation and maintenance expenditures. The increased demand for recreation brought about a heavy investment in structures for recreation and their maintenance. The increases in benefits were mainly due to increased flood frequencies since the projects - i.e. higher than estimated. Of the 15 floods expected in a 100 year period, nine have occurred since the project started partially operating in 1950. The water levels were higher in 1950, 1969, and 1979 than in previous records which substantially raised flood prevention benefits. The benefits from recreation and commercial fish were also significant. The ex-post flood control, recreation and fish benefits were high enough so that they more than offset the lack of water supply benefits.

The ex-post benefit and cost analysis indicates that the project's performance on an overall basis was at least as good as expected. The benefit-cost ratios with different <u>real</u> discount rates ranging from 3 to 7-5/8 are all 1.57 or greater. Even when only the flood control benefits are considered, the benefit-cost ratio is still greater than unity.

What can one learn from the above analysis and how might future ex-ante planning be improved? Sound investment decisions cannot be made without accurate information. The prediction of water supply benefits was based on inadequate data and analysis (although information can never be perfect). The prediction of flood events was based on only three past floods and a record of six years of water levels. Thus the flood control benefits were based on inadequate data. The occurrence of post-project floods suggests that it is very difficult to foresee future flooding, particularly with development changing the potential run-off.

The ex-ante project planning, particularly flood control estimates, could be improved by (1) having a longer period on which to base predictions of post-project flood frequencies; (2) developing models to determine impacts of development trends on flood frequencies; (3) improving the method and data for making estimates of water supply benefits; (4) making projections of recreation demand based on the survey or time-cost methods; and (5) adopting appropriate discount rates for the analysis.

There are almost as many obstacles in estimating ex-post benefits as there are in making ex-ante estimates. The big difference is that with ex-post benefit estimates it is easier to identify the types of benefits. It might also encourage construction agencies to keep better records of project performance. The ex-post cost estimates were fairly straightforward since the Corps keeps good cost records and the project had been operating 32 years. In the future, this type of analysis should be taken a step further, and include a measure of the distribution of benefits and costs by income classes and location.

Finally, the study did not try to improve on the Corps methods of estimating benefits. As mentioned above, the procedures for estimating recreation benefits need improvement. However, the project feasibility rests on the urban flood control benefits of $44.6 million. These, of course, are local benefits based on Corps of Engineers estimated depth damage tables. To the extent these estimates over value property or count growth that would not have occurred without the project the benefits will be too high. An evaluation of this problem will have to await another study. In addition, it goes without saying, that these types of projects provide local benefits at the expense of the nation as a whole.

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APPENDIX I

METHODOLOGY TO EVALUATE FLOOD DAMAGES AND BENEFITS

The information on flood damages before the project period is collected by a detailed survey of the affected regions. Then based on this flood information and existing price levels, the traditional stage-damage, stage-flow, and flow-frequency relationships are drawn for different purposes (urban, agriculture, transportation damges, etc. and for different locations. Then these three relationships are combined to obtain damage-frequency relationships. The stage-damage curves are used to determine the flood damages. The difference in damages between the with and without project conditions is the flood control benefits. (For more details see Easter and Waelti, 1980). Generally, these stage-damage curves will be used as standard curves to determine the flood damages and benefits due to subsequent floods. This is done just by plotting the current year flood levels (stage) on the standard curves and picking the corresponding values for the damages. The damages will also be verified by visiting the flood locations. This will help to improve the standard damage curves. The damage values obtained for different purposes from the standard curves are updated to current year price levels with price indexes.

The following sections describe the estimation of flood benefits at selected locations in the Sheyenne River basin and the method of updating the benefits. This analysis of flood control benefits is based on 1977 conditions.

Evaluation of Flood Damages[1/]

Urban Damages

In 1977, about 2,600 single-family residences were subject to flooding from the 100-year flood in the lower Sheyenne River basin (see Table 1). About 158 commercial buildings, 137 apartment units, and 44 public structures were also subject to flooding. The number of single-family residences in Valley City subject to flooding from the 100-year flood was about one-fourth the total in the lower Sheyenne River Valley. A detailed breakdown by number and type of structures in the 100-year floodplain is shown in the future growth section.

Table 1 - Structures subject to 100-year flooding - lower Sheyenne River Valley, Valley City and Lisbon, 1977

Location	Single-family residences	Multiple-family units	Commercial	Public	Total
Lower Sheyenne River Valley	2,636	137	158	44	2,975
Valley City	625	-	67	0	692
Lisbon	161	-	3	2	166
Total	3,422	137	228	46	3,833

Estimates of residential flood damages were based on inspection of residences in the floodplain. The approximate market value of each residence inspected, ground and first-floor elevations, and depths of flooding without emergency protective measures were determined. The without emergency protective measures condition was assumed to be the base condition.

1/ Most portions of this Appendix are taken from "General Reevaluation and Environmental Impact Statement for Flood Control and Related Purposes, Sheyenne River, North Dakota" Technical Appendices-Appendix G, Vol. 2, August, 1982, U.S. Army Corps of Engineers, St. Paul District.

Estimates of flood damages to residences and contents were obtained from the standardized depth-damage tables developed in the St. Paul District. Field inspection of their appropriateness for the study area was done only for a limited sample in West Fargo.

The market value of residences was verified by city assessors' records of a sample of homes. The estimates of flood damages to commercial and public properties at the selected flood elevations and discharges were obtained from interviews with property owners and public officials.

Agricultural Damages

Discharge-Area Inundated Relationships

The areas inundated by the 1897, 1969, and 1975 floods on the lower Sheyenne River and the 1966 and 1969 floods on reaches 2 to 4 were delineated on USGS quadrangle and county maps. For each reach, the areas flooded and corresponding peak mean daily discharges or peak elevations, together with the estimated minimum channel capacities, served as a basis for developing discharge-area or elevation-area flooded curves.

The crop losses caused by flooding have been determined using the net losses sustained by farmers. All major crops were considered to determine the total potential loss from floods occurring at any time during the growing season. The evaluation takes into account the reduction in yield resulting from late planting after a spring flood, replanting costs when reseeding is possible, a partial or complete loss of crop from flooding during the growing or harvesting periods, and net increases in farm operating costs that result from flooding.

Crop Prices and Incomes

Because of wide fluctuations in crop prices caused by weather and other short-term circumstances, normalized crop prices are calculated by state for evaluating federal water projects (see Table 2). The normalized prices used on this analysis are from the October 1978 Agricultural Price Standards provided by the U.S. Water Resource Council.

The weighted average crop income for each acre in the floodplain based on land use must be derived before crop damages can be estimated. The normalized price for each crop is multiplied times the yield and the percentage of land use for that crop to obtain the per acre income share per crop per reach (see Table 3). When summed across all crops, this provides the weighted average income per acre per reach.

Table 2 - Crop Prices, North Dakota and Minnesota

Crop	Current normalized price (CNP) North Dakota	Current normalized price (CNP) Minnesota
Wheat	$3.80 bu.	$3.45 bu.
Barley	2.47 bu.	2.56 bu.
Soybeans	5.86 bu.	5.95 bu.
Sunflowers	11.00 cwt.(1)	11.00 cwt.(1)
Corn Silage	17.16 ton(2)	Not needed
Hay	41.54 ton	Not needed
Sugar Beets	22.88 ton	23.66 ton

(1) Obtained from local elevators.

(2) Formula used by the University of Minnesota to estimate value of corn silage - (CNP) (2.36 x 6) + 3 = 17.16 for North Dakota.

Table 3 - Weighted gross income per acre (October 1978 prices) (computation: 1978 normalized price x yield/acre x percent land use)

Crop	Unit	1978 current normalized price[1]	Reach 2	Reach 3	Reach 4	Reach 5A	Reach 5B	Reach 5C	Reach 5D	Reach 5E
Corn silage	Ton	$17.16[3]	$1.47	$9.54	$11.68	$5.66	$11.33	$5.66	-	-
Wheat	Bushel	3.80	9.59	15.44	11.40	59.85	63.27	77.06	$86.64	$82.08
Oats	Bushel	1.39	2.02	6.85	6.72	-	-	-	-	-
Barley	Bushel	2.47	5.39	5.19	5.43	30.01	35.20	35.96	31.25	17.66
Flaxseed	Bushel	7.06	2.56	2.87	2.77	-	-	-	-	-
Hay	Ton	41.54	3.32	17.36	18.28	-	6.31	-	-	-
Sunflowers	Cwt	11.00[2]	-	-	-	10.01	10.01	13.12	10.40	23.10
Sugar beets	Ton	22.88	-	-	-	-	-	-	-	-
Potatoes	Cwt	3.53	-	-	-	-	-	-	-	-
Soybeans	Bushel	5.86	-	-	-	-	-	3.16	9.49	17.58
Pasture	Ton	41.54	27.42	11.63	11.63	-	-	-	-	-
Total			51.77	68.88	67.91	119.62	126.12	134.96	137.78	140.42

(1) CNP for North Dakota.
(2) Obtained from Agway Elevator, Grandin, North Dakota.
(3) Formula given by University of Minnesota for estimating value of corn silage: (corn grain price/bushel x 6) + 3 = price/ton, ($2.36 x 6) + 3 = $17.16.

Crop Production Costs

Crop production costs consist of fixed and variable costs. The fixed production costs, which consist of taxes, interest, amortization costs, and overhead costs, are not appreciably affected by flooding because these costs accrue whether or not a farmer raises and harvests a crop. Thus, this analysis considers only the variable production costs associated with planting, raising, and harvesting crops. Variable production costs include cost of seed, land preparation, planting, weed control, cultivation, harvesting, and transportation to market. These costs were obtained from the North Dakota extension service crop budgets. A schedule of normal farm operations was established and variable semimonthly production costs were determined. The variable semimonthly production costs vary across all damage reaches (see Tables 4 and 5).

The net change in variable production costs caused by flooding vary by crop, time of year and reach (see Table 6). Some increases in production costs may be caused by soil reworking, refertilizing, application of additional fertilizer, or replanting. Variable costs may also decrease because the delay in planting may cause farmers to skip otherwise desirable operations. Yields reduced by flooding also decrease harvest expenditures for hauling and storage. Each crop has its own pattern of changes. The seasonal crop loss, foregone harvest costs and replant and investment costs are used to calculate the net change in production costs (see Tables 7, 8, and 9).

Seasonal Loss of Gross Income per Acre

In addition to changes in production costs, farmers lose a share of gross income proportional to the reduced yield caused by flooding. The weighted gross income loss per acre are shown by reach, crop and time of year (see Table 10).

Table 4 - Seasonal variable production costs per acre - reaches 2-4, 5A-5E (October 1978 prices)

Seasonal period	Reaches 2-4							Reaches					
	Wheat	Barley	Oats	Hay	Flax-seed	Corn (silage)	Sun-flowers	5A-5E Wheat	5A-5E Barley	5A-5E Soybeans	5A-5E Sunflowers	5A-5C Corn	5B Hay
To 31 Mar	$6.40	$8.86	$3.81	-	$0.88	-	-	$6.98	$8.99	-	-	-	-
1-15 Apr	6.40	7.24	7.42	-	1.48	-	$9.81	6.96	7.34	-	$9.81	-	-
16-30 Apr	4.82	2.52	7.42	$6.25	2.91	$13.43	13.94	5.25	2.55	-	13.94	$13.43	$6.25
1-15 May	6.22	3.83	5.98	6.25	2.80	10.34	5.72	6.77	3.88	$12.46	5.72	10.34	6.25
16-31 May	0.37	3.57	2.07	0.46	5.04	21.71	5.59	0.41	3.62	8.12	5.59	21.71	0.46
1-15 Jun	1.07	0.89	1.77	0.46	0.52	13.44	1.09	1.17	0.90	6.79	1.09	13.44	0.46
16-30 Jun	1.08	0.89	1.77	7.35	0.23	1.03	4.37	1.17	0.90	6.83	4.37	1.03	7.35
1-15 Jul	0.37	0.37	0.35	0.46	0.23	1.03	4.02	0.41	0.37	0.38	4.02	1.03	0.46
16-31 Jul	0.37	0.79	0.35	7.35	4.89	1.03	3.52	0.41	0.80	0.38	3.52	1.03	7.35
1-15 Aug	0.75	3.15	1.45	0.46	10.73	1.03	0.52	0.81	3.19	0.38	0.52	1.03	0.46
16-31 Aug	3.27	11.54	2.07	7.35	4.01	10.35	0.52	3.57	11.70	0.38	0.52	10.35	7.35
1-15 Sep	9.26	8.81	2.07	-	-	29.98	4.37	10.10	8.93	5.22	4.37	29.98	-
16-30 Sep	6.36	-	1.13	-	-	-	5.21	6.93	-	5.22	5.21	-	-
1-15 Oct	-	-	0.35	-	-	-	1.90	-	-	-	1.90	-	-
16-31 Oct	-	-	-	-	-	-		-	-	-	-	-	-
Preharvest	27.82	28.17	30.94	14.34	14.12	62.02	49.10	30.30	28.56	35.72	49.10	62.02	14.34
Harvest	18.93	24.29	7.07	22.05	19.72	41.35	11.48	20.63	24.62	10.44	11.48	41.35	22.05
Total	46.75	52.46	38.01	36.39	33.84	103.37	60.58	50.93	53.18	46.16	60.58	103.37	36.39

Table 5 Cumulative seasonal production costs per acre - Reach 5 - (October 1978 prices)

Seasonal Period	Wheat	Barley	Soybeans	Sunflowers	Corn	Hay
To 31 Mar	6.98	8.99				
1-15 Apr	13.96	16.33		9.81		
16-30 Apr	19.21	18.88		23.75	13.43	6.25
1-15 May	25.98	22.76	12.46	29.47	23.77	12.50
16-31 May	26.39	26.38	20.58	35.06	45.48	12.96
1-15 Jun	27.56	27.28	27.37	36.15	58.92	10.80
16-30 Jun	28.73	28.18	34.20	40.52	59.95	11.24
1-15 Jul	29.14	28.55	34.58	44.54	60.98	8.00
16-31 Jul	29.55	23.70	34.96	48.06	62.01	8.44
1-15 Aug	22.16	9.41	35.34	48.58	51.34	4.22
16-31 Aug	7.39		35.72	49.10	20.50	
1-15 Sep			26.80	42.68		
16-30 Sep			8.91	32.81		
1-15 Oct				16.29		
16-31 Oct						

Table 6 - Weighted net change in production costs - reaches 2-4, 5A-5E (October 1978 prices)

Seasonal period	Reach 2 Wheat	Reach 2 Barley	Reach 2 Corn	Reach 2 Flax-seed	Reach 2 Oats	Reach 2 Hay	Reach 2 Total
Percent land use(1)	8.7	5.9	1.3	3.3	3.3	4.0	
To 31 Mar	-0.16	-0.37	0	-0.02	0	0	-0.25
1-15 Apr	-0.17	-0.15	0	-0.12	0	0.19	-0.63
16-30 Apr	-0.25	0.12	.03	-0.19	0.12	0.37	-0.20
1-15 May	0.32	0.27	0.13	-0.20	0.24	-0.88	-0.12
16-31 May	0.26	.06	0.27	-0.19	0.22	-0.88	-0.28
1-15 Jun	0.33	0.12	0.40	-0.22	0.32	-0.88	0.07
16-30 Jun	-1.65	-1.43	-0.54	-0.49	-0.15	-0.66	-4.92
1-15 Jul	-1.65	-1.43	-0.54	-0.44	-0.17	-0.66	-4.89
16-31 Jul	-1.65	-0.80	-0.56	-0.36	-0.15	-0.40	-3.90
1-15 Aug	-0.79	-0.29	-0.56	-0.31	-0.13	-0.40	-2.46
16-31 Aug	-0.33		-0.44	-0.26	-0.11	-0.13	-1.27
1-15 Sep			-0.18		-0.09		-0.27
16-30 Sep							
1-15 Oct							
16-31 Oct							

Seasonal period	Reach 3 Wheat	Reach 3 Barley	Reach 3 Corn	Reach 3 Flax-seed	Reach 3 Oats	Reach 3 Hay	Reach 3 Total
Percent land use(1)	12.5	5.0	5.4	2.8	9.3	22.0	
To 31 Mar	-0.17	-0.06	0	-0.02	0	0	-0.2[illegible]
1-15 Apr	-0.26	-0.13	0	-0.11	-0.01	1.03	0.54
16-30 Apr	-0.36	0.10	0.15	-0.16	0.34	2.06	2.1[illegible]
1-15 May	0.47	0.23	0.54	-0.13	0.67	-4.85	-3.1[illegible]
16-31 May	0.35	0.05	1.14	-0.16	0.61	-4.85	-2.9[illegible]
1-15 Jun	0.48	0.105	1.65	-0.19	0.90	-4.85	-1.90
16-30 Jun	-2.37	-1.22	-2.23	-0.41	-0.42	-3.64	-10.29
1-15 Jul	-2.33	-1.22	-2.23	-0.37	-0.49	-3.64	-10.26
16-31 Jul	-1.14	-3.68	-2.23	-0.31	-0.43	-2.18	-8.20
1-15 Aug	-0.47	-3.24	-2.23	-0.26	-0.37	-2.18	-6.42
16-31 Aug			-1.81	-0.22	-0.31	-0.73	-3.54
1-15 Sep			-0.74		-0.26		-1.00
16-30 Sep							
1-15 Oct							
16-31 Oct							

Seasonal period	Reach 4 Wheat	Reach 4 Barley	Reach 4 Corn	Reach 4 Flax-seed	Reach 4 Oats	Reach 4 Hay	Reach 4 Total
Percent land use(1)	10	5	5.4	1.8	9.3	11.0	
To 31 Mar	-0.13	-0.06	0	-0.02	0	0	-0.21
1-15 Apr	-0.19	-0.11	0	-0.11	-0.01	1.03	0.59
16-30 Apr	0.29	0.10	0.16	-0.16	0.35	2.06	2.80
1-15 May	0.37	0.23	0.54	-0.17	0.67	-4.85	-3.21
16-31 May	0.28	0.05	1.14	-0.16	0.61	-4.85	-2.93
1-15 Jun	0.38	0.11	1.65	-0.19	0.90	-4.85	-2.00
16-30 Jun	-1.09	-1.21	-2.23	-0.41	-0.42	-3.64	-9.80
1-15 Jul	-1.09	-1.21	-2.23	-0.37	-0.49	-3.64	-9.83
16-31 Jul	-1.09	-0.60	-2.23	-0.31	-0.43	-2.18	-7.41
1-15 Aug	-0.91	-0.24	-2.23	-0.26	-0.37	-2.18	-6.19
16-31 Aug	-0.38		-1.81	-0.22	-0.31	-0.73	-3.45
1-15 Sep			-0.74		-0.26		-1.00
16-30 Sep							
1-15 Oct							
16-31 Oct							

Seasonal period	Reach 5A Wheat	Reach 5A Barley	Reach 5A Soybeans	Reach 5A Sun-flowers	Reach 5A Corn	Reach 5A Total	Reach 5B Wheat	Reach 5B Barley	Reach 5B Sun-flowers	Reach 5B Corn	Reach 5B Hay	Reach 5B Total
Percent land use(1)	45.0	27.0	13.0	7.0	3.0		45.0	30.0	7.0	6.0	4.0	
To 31 Mar	-.65	-.33				-.98	-.65	-.37				-1.02
1-15 Apr	-.95	-.71		.01		-1.65	-.95	-.79	.01		.16	-1.57
16-30 Apr	1.42	.57		.47	.09	2.55	1.42	.64	.47	.17	.32	3.02
1-15 May	1.83	1.26	.86	.98	.30	5.21	1.83	1.40	.98	.60	-1.46	3.35
16-31 May	1.36	.27	1.80	1.40	.63	5.46	1.36	.30	1.40	1.26	-1.46	2.86
1-15 Jun	1.87	.58	2.40	1.76	.91	7.52	1.87	.64	1.76	1.83	-1.46	4.64
16-30 Jun	-9.28	-6.65	-1.36	-.48	-1.24	-19.01	-9.28	-7.39	-.48	-2.48	-1.09	-20.72
1-15 Jul	-9.28	-6.65	-1.36	-.60	-1.24	-19.13	-9.28	-7.39	-.60	-2.48	-1.09	-20.84
16-31 Jul	-9.28	-3.72	-1.36	-.44	-1.24	-16.04	-9.28	-4.14	-.44	-2.48	-.66	-17.00
1-15 Aug	-4.46	-1.33	-1.36	-.34	-1.24	-8.73	-4.46	-1.48	-.34	-2.48	-.66	-9.42
16-31 Aug	-1.86		-1.36	-.32	-1.00	-4.54	-1.86		-.32	-2.01	-.22	-4.41
1-15 Sep			-.73	-.31	-.41	-1.45			-.31	-.82		-1.13
16-30 Sep			-.49	-.26		-.75			-.26			-.26
1-15 Oct												
16-31 Oct												

Seasonal period	Reach 5C Wheat	Reach 5C Barley	Reach 5C Soybeans	Reach 5C Sun-flowers	Reach 5C Corn	Reach 5C Total	Reach 5D Wheat	Reach 5D Barley	Reach 5D Soy-beans	Reach 5D Sun-flowers	Reach 5D Total	Reach 5E Wheat	Reach 5E Barley	Reach 5E Soy-beans	Reach 5E Sun-flowers	Reach 5E Total
Percent land use(1)	52.0	28.0	3.C	9.0	3.0		57.0	23	9.0	7.0		54.0	13.0	15.0	15.0	
To 31 Mar	-.75	-.34				-1.09	-.82	-.28			-1.10	-.78	-.16			-.94
1-15 Apr	-1.10	-.74		.01		-1.83	-1.21	-.60		.01	-1.80	-1.14	-.34		.01	-1.47
16-30 Apr	1.64	.59		.60	.09	2.92	1.80	.49		.47	2.76	1.70	.28		1.01	2.99
1-15 May	2.11	1.31	.19	1.26	.30	5.17	2.31	1.08	.58	.98	4.95	2.19	.61	.97	2.10	5.87
16-31 May	1.58	.28	.41	1.38	.63	4.68	1.73	.28	1.24	1.40	4.65	1.64	.13	2.07	2.97	6.81
1-15 Jun	2.16	.60	.55	2.36	.91	6.48	2.37	.49	1.66	1.76	6.28	2.25	.28	2.77	3.77	9.67
16-30 Jun	-10.73	-6.89	-.31	-.62	-1.24	-19.79	-11.76	-5.66	-.94	-.48	-18.84	-11.14	-3.20	-1.57	-1.03	-16.94
1-15 Jul	-10.73	-6.89	-.31	-.77	-1.24	-19.94	-11.76	-5.66	-.94	-.60	-18.96	-11.14	-3.20	-1.57	-1.29	-17.20
16-31 Jul	-10.73	-3.86	-.31	-.57	-1.24	-16.71	-11.76	-3.17	-.94	-.44	-16.31	-11.14	-1.79	-1.57	-.95	-15.45
1-15 Aug	-5.15	-1.38	-.31	-.43	-1.24	-8.51	-5.64	-1.13	-.94	-.34	-8.05	-5.35	-.64	-1.57	-.72	-8.28
16-31 Aug	-2.15		-.31	-.41	-1.00	-3.87	-2.35		-.94	-.32	-3.61	-2.23		-1.57	-.69	-4.49
1-15 Sep			-.17	-.38	-.41	-.97			-.51	-.31	-.82			-.85	-.65	-1.50
16-30 Sep			-.11	-.33		-.44			-.34	-.26	-.60			-.56	-.55	-1.11
1-15 Oct																
16-31 Oct																

Note: Wt. net change in production cost = spring replant and invested cost loss minus foregone harvest costs

Table 7 Percentage crop loss per seasonal period, all reaches

Seasonal period	Wheat	Barley	Soybeans	Sunflowers	Corn	Hay	Flaxseed	Oats	Sugar beets	Potatoes	Pasture
					(percent)						
To 31 Mar	7	5					3		3	3	8
1-15 Apr	12	12		3		5	19	5	9	9	8
16-30 Apr	20	21		9	9	10	35	25	15	15	8
1-15 May	45	38	9	15	15	100	46	40	25	25	12
16-31 May	50	53	10	25	22	100	53	48	40	40	17
1-15 Jun	67	65	27	40	40	100	65	53	60	60	22
16-30 Jun	100	100	100	60	100	75	75	64	75	75	27
1-15 Jul	100	100	100	75	100	75	67	75	77	77	23
16-31 Jul	100	56	100	55	100	45	56	66	75	75	19
1-15 Aug	48	20	100	42	100	45	47	56	73	73	17
16-31 Aug	20		100	40	81	15	40	47	68	68	14
1-15 Sep			54	38	33			40	54	54	21
16-30 Sep			36	32					30	30	28
1-15 Oct				22							
16-31 Oct											

Table 8 Spring replant and invested loss cost, reaches 1-4, 6-10 (October 1978 prices)

	Reaches 1-4							Reaches 6-10						
Seasonal period	Wheat	Barley	Oats	Hay	Flaxseed	Corn	Sunflowers	Soybeans	Sunflowers	Wheat	Barley	Sugar beets	Potatoes	Flaxseed
Total variable costs	$46.75	$52.46	$38.01	$36.39	$33.84	$103.37	$60.58	$46.16	$60.58	$48.85	$57.36	$115.40	$319.46	$33.84
To 31 Mar	0	0	0	0	0	0	0	0	0	0	0	1.15	1.28	0
1-15 Apr	0.33	0.31	0.77	5.79	0	0	0.42	0	0.42	0.34	0.34	4.39	5.43	0
16-30 Apr	6.99	7.19	5.44	11.57	1.29	6.62	7.75	0	7.75	6.99	7.86	8.54	56.86	1.29
1-15 May	12.25	13.85	9.99	0	3.05	16.23	15.69	7.43	15.69	12.80	15.14	18.12	109.57	3.05
16-31 May	12.25	13.85	9.99	0	4.77	30.18	22.66	14.86	22.66	12.80	15.14	28.85	130.34	4.77
1-15 Jun	16.50	17.89	13.42	0	6.09	47.03	29.74	21.28	29.74	17.24	19.56	41.77	145.03	6.09

Table 9 Foregone harvest costs, reaches 1-4, 6-10 (October 1978 prices)

Seasonal period	Wheat	Barley	Oats	Hay	Flaxseed	Corn	Sunflowers	Soybeans	Sunflowers	Wheat	Barley	Sugar beets	Potatoes	Flaxseed
Harvest costs	18.93	24.29	7.07	22.05	19.72	41.35	11.48	10.44	11.48	19.77	26.58	14.52	96.28	19.72
To 31 Mar	1.33	1.21	0	0	0.59	0	0	0	0	1.38	1.33	0.44	2.88	0.59
1-15 Apr	2.27	2.91	0.35	1.10	3.75	0	0.34	0	0.34	2.37	3.19	1.31	8.67	3.75
16-30 Apr	3.79	5.10	1.77	2.21	6.90	3.72	1.03	0	1.03	3.95	5.32	2.18	14.44	6.90
1-15 May	8.52	9.23	2.83	22.05	9.07	6.20	1.72	0.94	1.72	8.90	11.96	3.63	24.07	9.07
16-31 May	9.46	12.87	3.39	22.05	10.45	9.10	2.87	1.04	2.78	9.89	13.29	5.81	38.51	10.45
1-15 Jun	12.68	15.79	3.75	22.05	12.82	16.54	4.92	2.82	4.92	13.25	17.81	8.71	57.77	12.82
16-30 Jun	18.93	24.29	4.52	16.54	14.79	41.35	6.89	10.44	6.89	19.77	26.58	10.89	72.21	14.79
1-15 Jul	18.93	24.29	5.30	16.54	13.21	41.35	8.61	10.44	8.61	19.77	26.58	11.18	74.14	13.21
16-31 Jul	18.93	13.60	4.67	9.92	11.04	41.35	6.31	10.44	6.31	19.77	14.88	10.89	72.21	11.04
1-15 Aug	9.09	4.86	3.96	9.92	9.27	41.35	4.87	10.44	4.82	9.49	5.32	10.60	70.28	9.27
16-31 Aug	3.79		3.32	3.31	7.89	33.49	4.59	10.44	4.59	3.95		9.87	65.47	7.89
1-15 Sep			2.83			13.65	4.36	5.64	4.36			7.84	51.99	
16-30 Sep							3.67	3.76	3.67			4.36	28.88	
1-15 Oct							2.53		2.53					
16-31 Oct														

Table 10 - Seasonal loss of gross income per acre - reaches 2-4, 5A-5E (October 1978 prices)
(computation: weighted gross income/acre x seasonal percent crop loss)

Seasonal period	Reach 2 Wheat	Barley	Corn	Flaxseed	Pasture	Oats	Hay	Total
To 31 March	.67	.27		.77	2.19			
1-15 April	1.15	.65		.49	2.19	.10	.17	
16-30 April	1.92	1.13	.13	.90	2.19	.51	.33	
1-15 May	4.32	2.05	.22	1.18	3.29	.81	3.32	
16-31 May	4.79	2.86	.32	1.36	4.66	.97	3.32	
1-15 June	6.43	3.50	.59	1.66	6.03	1.07	3.32	
16-30 June	9.59	5.39	1.47	1.92	7.40	1.29	2.49	
1-15 July	9.59	5.39	1.47	1.72	6.31	1.51	2.49	
16-31 July	9.59	3.02	1.47	1.43	5.21	1.33	1.49	
1-15 Aug.	4.60	1.08	1.47	1.20	4.66	1.13	1.49	
16-31 Aug.	1.92		1.19	1.02	3.84	.95	.50	
1-15 Sept.			.49		5.76	.81		
16-30 Sept.					7.68			
1-15 Oct.								
16-31 Oct.								

Seasonal period	Reach 3 Wheat	Barley	Corn	Flaxseed	Pasture	Oats	Hay	Total	Reach 4 Wheat	Barley	Corn	Flaxseed	Pasture	Oats	Hay	Total
To 31 March	1.08	.26		.09	.93	.34		2.70	.80	.27		.08	.93	.34		2.42
1-15 April	1.85	.62		.55	.93	1.71	.87	6.53	1.37	.65		.53	.93	1.68	.91	6.07
16-30 April	3.09	1.09	.86	1.00	.93	2.74	1.74	11.45	2.28	1.14	1.05	.97	.93	2.69	1.83	10.89
1-15 May	6.95	1.97	1.43	1.32	1.40	3.29	17.36	33.72	5.13	2.06	1.75	1.27	1.40	3.23	18.28	33.12
16-31 May	7.72	2.75	2.10	1.52	1.98	3.63	17.36	37.06	5.70	2.88	2.57	1.47	1.98	3.56	18.28	36.44
1-15 June	10.34	3.37	3.82	1.87	2.56	4.38	17.36	43.70	7.64	3.53	4.67	1.80	2.56	4.30	18.28	42.78
16-30 June	15.44	5.19	9.54	2.15	3.14	5.14	13.02	53.62	11.40	5.43	11.68	2.08	3.14	5.04	13.71	52.48
1-15 July	15.44	5.19	9.54	1.92	2.67	4.52	13.02	52.30	11.40	5.43	11.68	1.86	2.67	4.44	13.71	51.19
16-31 July	15.44	2.91	9.54	1.61	2.21	3.84	7.81	43.36	11.40	3.04	11.68	1.55	2.21	3.76	8.23	41.87
1-15 Aug.	7.41	1.04	9.54	1.35	1.98	3.22	7.81	32.35	5.47	1.09	11.68	1.30	1.98	3.16	8.21	32.91
16-31 Aug.	3.09		7.73	1.15	1.63	2.74	2.60	18.94	2.28		9.46	1.11	1.63	2.69	2.74	19.91
1-15 Sept.			3.15		2.44			5.59			3.85		2.44			6.29
16-30 Sept.					3.26			3.26					3.26			3.26
1-15 Oct.																
16-31 Oct.																

Table 10 - Seasonal loss of gross income per acre - reaches 2-4, 5A-5E (October 1978 prices)
(computation: weighted gross income/acre x seasonal percent crop loss) (cont)

Seasonal period	Reach 5A Wheat	Barley	Soybeans	Sun-flowers	Corn	Total	Reach 5B Wheat	Barley	Sunflowers	Corn	Hay	Total
16-31 March	$4.19	$1.50	$	$	$	$5.69	$4.41	$1.76	$	$	$	$6.17
1-15 April	7.18	3.60		.30		11.08	7.59	4.22	.30		.32	12.43
16-30 April	11.97	6.30		.90	.51	19.68	12.65	7.39	.90	1.02	.63	22.59
1-15 May	26.93	11.40	1.27	1.50	.85	41.95	28.47	13.38	1.50	1.70	6.31	51.36
16-31 May	29.93	15.91	1.41	2.50	1.25	51.00	31.64	18.66	2.50	2.49	6.31	61.60
1-15 June	40.10	19.51	3.80	4.00	2.26	69.67	42.39	22.88	4.00	4.53	6.31	80.11
16-30 June	59.85	30.01	14.09	6.01	5.66	115.62	63.27	35.20	6.01	11.33	4.73	120.54
1-15 July	59.85	30.01	14.09	7.51	5.66	117.12	63.27	35.20	7.51	11.33	4.73	122.04
16-31 July	59.85	16.81	14.09	5.51	5.66	101.92	63.27	19.71	5.51	11.33	2.84	102.66
1-15 Aug	28.73	6.00	14.09	4.20	5.66	58.68	30.37	7.04	4.20	11.33	2.84	55.78
16-31 Aug	11.97		14.09	4.00	4.58	34.64	12.65		4.00	9.18	.95	26.78
1-15 Sept			7.61	3.80	1.87	13.28			3.80	3.74		7.54
16-30 Sept			5.07	3.20		8.27			3.20			3.20
1-15 Oct				2.20		2.20			2.20			3.20
16-31 Oct												

Seasonal period	Reach 5C Wheat	Barley	Soy-beans	Sun-flowers	Corn	Total	Reach 5D Wheat	Barley	Soybeans	Sun-flowers	Total	Reach 5E Wheat	Barley	Soybeans	Sun-flowers	Total
16-31 March	$5.39	$1.80	$	$	$	$7.19	$6.06	$1.56	$	$	$7.62	$5.75	$ .88	$	$	$ 6.63
1-15 April	9.25	4.32		.39		13.96	10.40	3.75		.31	14.46	9.85	2.12		.69	12.66
16-30 April	15.41	7.55		1.18	.51	24.65	17.33	6.56		.94	24.83	16.42	3.71		2.08	22.21
1-15 May	34.68	13.66	.28	1.97	.85	51.44	38.99	11.88	.85	1.56	53.28	36.94	6.71	1.58	3.46	48.69
16-31 May	38.53	19.06	.32	3.28	1.25	62.44	43.32	15.56	.95	2.60	63.43	41.04	9.36	1.76	5.78	57.94
1-15 June	51.63	23.37	.85	5.25	2.26	83.36	58.05	20.31	2.56	4.16	84.98	54.99	11.48	4.75	9.24	80.46
16-30 June	77.06	35.96	3.16	7.87	5.66	129.71	86.64	31.25	9.49	6.24	133.62	82.08	17.66	17.58	13.86	131.18
1-15 July	77.06	35.96	3.16	9.84	5.66	111.68	86.64	31.25	9.49	7.80	135.18	82.08	17.66	17.58	17.32	134.64
16-31 July	77.06	20.14	3.16	7.22	5.66	113.24	86.64	17.50	9.49	5.72	119.35	82.08	9.89	17.58	12.70	122.25
1-15 Aug	36.99	7.19	3.16	5.51	5.66	58.51	41.59	6.25	9.49	4.37	61.70	39.40	3.53	17.58	9.70	70.21
16-31 Aug	15.41		3.16	5.25	4.58	28.40	17.33		9.49	4.16	30.98	16.42		17.58	9.24	43.24
1-15 Sept			1.71	4.99	1.87	8.57			5.12	3.95	9.07			9.49	8.74	18.23
16-30 Sept			1.14	4.20		5.34			3.42	3.33	6.75			6.33	5.39	11.72
1-15 Oct				2.89		2.89				2.29	2.29				5.68	5.68
16-31 Oct																

Seasonal Crop Damage Curves

Total crop damages for each month consists of the loss of net income, which is equivalent to the total weighted increase in production costs combined with the loss of gross crop income for all crops grown in the floodplain. On this basis, the weighted net change in production costs and weighted average loss of gross crop income for monthly periods are added to obtain seasonal crop damages (see Table 11). These crop damage totals are plotted to provide a seasonal crop damage curve for each reach.

Weighted Average Crop Damages per Acre

As indicated by the preceding analysis, the amount of crop damage depends on when a flood occurs. Thus, weighted average crop damages per acre of floodplain area based on flood history must be determined. The weighted average crop damage per acre for each reach is therefore derived by time of year (see Table 12).

Other Agricultural Damages

Other agricultural flood damages evaluated include property damage to fences, buildings other than homes, machinery, stored crops, and other supplies and losses in dairy and beef production and from erosion and sedimentation. Rural development in most of the reaches is distributed rather uniformly over the floodplain. Other agricultural property damages are approximately proportional to the area flooded. Data on these damages were obtained during 1975 in conjunction with a field damage survey done within the Sheyenne River basin. Other agricultural damages for all interviewed farmers during the 1975

Table 11 - Seasonal crop damage per acre - reaches 2-4, 5A-5E (October 1978 prices)

Seasonal period	Reach 2			Reach 3			Reach 4		
	SLGI(1)	WNCPC(2)	SCD(3)	SLGI(1)	WNCPC(2)	SCD(3)	SLGI(1)	WNCPC(2)	SCD(3)
To 31 Mar	3.90	-0.25	3.65	2.70	-0.25	2.45	2.42	-0.21	2.21
1 15 Apr	4.75	-0.63	4.12	6.53	0.54	7.07	6.07	0.59	6.66
16-30 Apr	7.11	-0.20	6.91	11.45	2.13	13.58	10.89	2.80	13.69
1-15 May	15.19	-0.12	15.07	33.72	-3.11	30.61	33.12	-3.21	29.91
16-31 May	18.28	-0.28	18.00	37.06	-2.96	34.10	36.44	-2.93	33.51
1-15 Jun	22.60	0.07	22.67	43.70	-1.90	41.80	42.78	-2.09	34.46
16-30 Jun	29.55	-4.92	24.63	53.62	-10.29	43.33	52.48	-9.80	42.68
1-15 Jul	28.48	-4.89	23.59	52.30	-10.26	42.04	51.19	-9.83	41.36
16-31 Jul	23.54	-3.90	19.64	43.36	-8.20	35.16	41.87	-7.41	34.46
1-15 Aug	15.63	-2.46	13.17	32.35	-6.42	25.93	32.91	-6.19	26.72
16-31 Aug	9.42	-1.27	8.15	18.94	-3.54	15.40	19.91	-3.45	16.46
1-15 Sep	7.06	-0.27	6.79	5.59	-1.00	4.59	6.29	-1.00	5.29
16-30 Sep	7.68		7.68	3.26		3.26	3.26		3.26
1-15 Oct									
16-31 Oct									

Table 11 - Seasonal crop damage per acre - reaches 2-4, 5A-5E (October 1978 prices)(cont)

Seasonal period	5A			5B			5C			5D			5E		
	SLGI (1)	WNCPC (2)	SCD (3)	SLGI (1)	WNCPC (2)	SCD (3)	SLGI (1)	WNCPC (2)	SCD (3)	SLGI (1)	WNCPC (2)	SCD (3)	SLGI (1)	WNCPC (2)	SCD (3)
To 31 Mar (23 Mar)	5.69	-0.98	4.71	6.19	-1.02	5.17	7.19	-1.09	6.10	7.62	-1.10	6.52	6.63	-0.94	5.69
1-15 Apr (8 Apr)	11.08	-1.65	9.43	12.43	-1.57	10.86	13.96	-1.83	12.13	14.46	-1.80	12.66	12.66	-1.47	11.19
16-30 Apr (23 Apr)	19.68	2.55	22.23	22.59	3.02	25.61	24.65	2.92	27.57	24.83	2.76	27.59	22.21	2.99	25.20
1-15 May (8 May)	41.95	5.21	47.16	51.36	3.35	54.71	51.44	5.17	56.61	53.28	4.95	58.23	48.69	5.87	54.56
16-31 May (23 May)	51.00	5.46	56.46	61.60	2.86	64.46	62.44	4.68	67.12	63.43	4.65	68.08	57.94	6.81	64.75
1-15 Jun (8 Jun)	69.67	7.52	77.19	80.11	4.64	84.75	83.36	6.48	89.84	84.98	6.28	91.26	80.46	9.07	89.53
16-30 Jun (23 Jun)	115.62	-19.01	96.61	120.54	-20.72	99.82	129.71	-19.79	109.92	113.62	-18.84	94.78	131.18	-16.94	114.24
1-15 Jul (8 Jul)	117.12	-19.13	97.99	122.04	-20.84	101.20	131.68	-19.94	111.74	135.18	-18.96	116.22	134.64	-17.20	117.44
16-31 Jul (23 Jul)	101.92	-16.04	85.88	102.66	-17.00	85.66	113.24	-16.71	96.53	119.35	-16.31	103.04	122.25	-15.45	106.80
1-15 Aug (8 Aug)	58.68	-8.73	49.95	55.78	-9.42	46.36	58.51	-8.51	50.00	61.70	-8.05	53.65	70.21	-8.28	61.93
16-31 Aug (23 Aug)	34.64	-4.54	30.10	26.78	-4.41	22.37	28.40	-3.87	24.53	30.98	-3.61	27.37	43.24	-4.49	38.75
1-15 Sep (8 Sep)	13.28	-1.45	11.83	7.54	-1.13	6.41	8.57	-0.97	7.60	9.07	-0.82	8.25	18.27	-1.50	16.77
16-30 Sep (23 Sep)	8.27	-0.75	7.52	3.20	-0.26	2.94	5.34	-0.44	4.90	6.75	-0.60	6.15	13.72	-1.11	12.61
1-15 Oct (8 Oct)	2.20		2.20	3.20		3.20	2.89		2.89	2.29		2.29	5.08		5.08
16-31 Oct															

(1) Seasonal loss of gross income per acre.
(2) Weighted net change in production costs.
(3) Seasonal crop damage.

Table 12 - Average annual damages per acre

Reach	Date of flood	Peak mean daily discharge (cfs)(3)	Acres flooded	Crop damage per acre	Crop damage per flood	
2	2 Apr 48	1,900	300	$4.00	$1,200	
	19 May 50	3,030	1,220	17.50	21,300	
	28 Apr 56	1,790	180	10.50	1,900	
	17 Apr 60	1,570	50	5.50	300	
	17 Apr 65	3,070	1,230	5.50	6,800	
	30 Mar 66	3,330	1,650	3.50	5,800	
	19 Apr 69	4,500	2,300	6.00	13,800	
	21 Apr 71	1,810	220	6.50	1,400	
	23 Apr 74	2,160	500	7.50	3,700	
	29-30 Apr 75	1,850	230	11.50	2,600	
Total			7,900		58,800	
Average annual damages per acre						7.44
3	16 May 50	6,397	4,050	32.00	129,600	
	19 Apr 56	2,719	640	11.50	7,400	
	19 Apr 60	2,283	120	11.50	1,400	
	7 Jul 62	2,400	190	42.00	8,000	
	14 Apr 65	3,280	1,200	9.50	11,400	
	15 Mar 66	3,350	1,220	2.50	3,100	
	30 Mar 66	3,950	1,840	4.50	8,300	
	24 Apr 69	4,360	2,300	16.00	36,800	
	1 Jul 75	5,210	2,880	43.00	123,800	
Total			14,400		329,800	
Average annual damages per acre						22.90
4	18 Apr 47	2,300	2,400	$10.00	$24,000	
	7 May 48	2,150	1,900	29.00	55,100	
	14 May 50	3,210	4,880	31.00	151,300	
	8 Apr 52	2,240	2,100	7.00	12,700	
	13 Apr 60	1,820	520	8.00	4,200	
	11 Jul 62	2,310	2,220	39.50	87,700	
	18 Apr 65	2,740	3,580	10.00	35,800	
	3 Apr 66	3,340	5,180	5.50	28,500	
	15 Apr 69	4,600	8,140	9.00	73,300	
	30 Apr 71	1,740	40	25.00	1,000	
	29 Apr 74	1,930	1,360	24.00	32,600	
	5 May 75	1,840	140	28.00	3,900	
	6 Jul 75	4,590	8,100	41.00	328,200(2)	
Total			40,560		840,300	
Average annual damages per acre						20.70

Table 12 - Average annual damages per acre (Cont)

Reach	Date of flood	Peak mean daily discharge (cfs)(3)	Acres flooded	Crop damage per acre	Crop damage per flood	
5A	18 Apr 47	2,300	570	$18.00	$10,300	
	7 May 48	2,150	420	46.00	19,300	
	14 May 50	3,210	1,780	50.00	89,000	
	8 Apr 52	2,240	520	9.00	4,700	
	13 Apr 60	1,820	190	13.00	2,500	
	11 Jul 62	2,310	570	97.00	55,300	
	18 Apr 65	2,740	1,050	18.00	18,900	
	3 Apr 66	3,340	7,200	7.00	15,400	
	15 Apr 69	4,600	7,370	15.00	110,500	
	30 Apr 71	1,740	160	33.00	5,300	
	29 Apr 74	1,930	280	31.00	8,700	
	5 May 75	1,840	210	43.00	9,000	
	6 Jul 75	4,590	7,970	98.00	772,000	
Total			23,290		1,120,900	
Average annual damage/acre						48.13
5B	18 Apr 47	2,300	280	19.00	5,300	
	7 May 48	2,150	210	54.00	11,300	
	14 May 50	3,210	870	58.00	50,500	
	8 Apr 52	2,240	250	11.00	2,700	
	13 Apr 60	1,820	90	15.00	1,300	
	11 Jul 62	2,310	280	99.00	27,700	
	18 Apr 65	2,740	510	19.00	9,700	
	3 Apr 66	3,340	1,070	8.00	8,600	
	15 Apr 69	4,600	3,590	16.00	57,400	
	30 Apr 71	1,740	80	45.00	3,600	
	29 Apr 74	1,930	130	43.00	5,600	
	5 May 75	1,840	100	52.00	5,200	
	6 Jul 75	4,590	3,890	101.00	387,700	
Total			11,350		576,600	
Average annual damage/acre						50.80
5C	18 Apr 47	2,300	100	21.00	2,100	
	7 May 48	2,150	80	55.00	4,400	
	14 May 50	3,210	320	59.00	18,900	
	8 Apr 52	2,240	90	12.00	1,100	
	13 Apr 60	1,820	30	16.00	500	
	11 Jul 62	2,310	100	109.00	10,900	
	18 Apr 65	2,740	190	21.00	4,000	
	3 Apr 66	3,340	390	10.00	3,900	
	15 Apr 69	4,600	1,320	18.00	23,800	
	30 Apr 71	1,740	30	45.00	1,300	
	29 Apr 74	1,930	50	44.00	2,200	
	5 May 75	1,840	40	52.00	2,100	
	6 Jul 75	4,590	1,430	111.00	156,700	
Total			4,170		231,900	
Average annual damage/acre						55.61

Table 12 - Average annual damages per acre (cont)

Reach	Date of flood	Peak mean daily discharge[3] (cfs)	Acres flooded	Crop damage per acre	Crop damage per flood	
5D	18 Apr 47	2,300	1,910	$22.00	42,000	
	7 May 48	2,150	1,420	56.00	79,500	
	14 May 50	3,210	5,990	63.00	377,400	
	8 Apr 52	2,240	1,740	12.00	20,900	
	13 Apr 60	1,820	650	17.00	11,100	
	11 Jul 62	2,310	1,910	116.00	221,600	
	18 Apr 65	2,740	3,540	22.00	77,900	
	3 Apr 66	3,340	7,410	10.00	74,100	
	15 Apr 69	4,600	24,800	19.00	471,200	
	30 Apr 71	1,740	550	39.00	21,500	
	29 Apr 74	1,930	930	37.00	34,400	
	5 May 75	1,840	710	51.00	36,200	
	6 Jul 75	4,590	26,800	116.00	3,072,600	
Total					4,540,400	
Average annual damage/acre			78,360			57.94
5E	18 Apr 47	2,300	650	21.00	13,700	
	7 May 48	2,150	480	53.00	25,400	
	14 May 50	3,210	2,030	58.00	117,700	
	8 Apr 52	2,240	590	12.00	7,100	
	13 Apr 60	1,820	220	16.00	3,500	
	11 Jul 62	2,310	650	116.00	75,400	
	18 Apr 65	2,740	1,260	20.00	24,000	
	3 Apr 66	3,340	2,520	10.00	25,200	
	15 Apr 69	4,600	8,420	18.00	151,600	
	30 Apr 71	1,740	190	45.00	8,500	
	29 Apr 74	1,930	310	43.00	13,300	
	5 May 75	1,840	240	51.00	12,200	
	6 Jul 75	4,590	9,100	117.00	1,052,500	
Total			26,600		1,530,100	
Average annual damage/acre						57.52

(1) This total has been adjusted to account for the effects of a multiple-peak flood (1050).
(2) The damage per flood figure has been adjusted to account for two independent floods in the same year.
(3) Discharge at Kindred-area flooded is estimated from profiles.

flood were divided by the acres flooded on their farms. All interviewed farmers thought that these damages would not vary by season. On the basis of these data, other agricultural property damages were estimated at $12.11 per acre for reaches 5A, B, C, D, and E. Survey information for reaches 2-4 was gathered in 1965 and updated for price increases. Damages in these reaches (2-4) were less than those in reach 5 because of the narrowness of the floodplain in this upper reach. Farmers in reaches, 2-4, could move most of the damageable property to low risk areas. Other agricultural flood damages per acre flooded were calculated for each flooded reach (Table 13).

Table 13 - Other agricultural damages per acre (October 1978 prices)

Reach	Damage per acre flooded
2	$3.41
3	6.10
4	5.45
5	12.11

Transportation Damages

The agricultural nature of the area is reflected in its road system. The majority of the roads are gravel section-line roads which tie into major blacktop highways. Because of the frequency of flooding, most of the roads are elevated above the flood levels. Flood damage to the road system consist mostly of bridge approach washouts, culvert washouts, and shoulder scouring. Floods also damage railroads, airports, and waterways. Prior flood damage surveys were used to estimate the damages to these systems. Elevation-damage or discharge-damage curves are used to calculate the annual transportation damages (see Table 14).

Table 14 - Average annual transportation damages (October 1980 prices)

Reach	Damages
2	$38,000
3	39,000
4	29,000
5	77,000

Updating of Damages and Benefits

No new detailed damage information has been gathered since 1977. All elevation-damage or discharge-damage relationships represent the 1977 development condition. Since 1977, considerable development has taken place in West Fargo, Riverside, Harwood, and the surrounding subdivisions. Most of this development conforms to floodplain regulations.

In simple terms, these regulations require that first-floor elevations be above the 100-year flood elevation; basements must be of nonporous materials, generally poured concrete; and drainage slopes away from the structures.

Damages and benefits have been updated to October 1980 prices so they can be compared with the costs of the alternatives. The method of updating used for each damage category is summarized below.

Agricultural

A detailed reanalysis was performed on two sample reaches (5-B and 5-D) using current normalized prices issued on 1 October 1980 and 1980 farm management budgets. In addition to these steps, the 1978 and 1979 floods were added to the flood history. Average annual damages per acre for reach 5-B decreased from $50.80 to $33.53 and for reach 5-D from $57.52 to $34.24. The 1980 damage per acre is 66 percent of the comparable figure for reach 5-B and 60 percent of the 1978 average for reach 5-D. On the basis of similar land use, damages per acre for reaches 2 through 5-C were reduced to 66 percent of their 1978 value. Damages for reaches 5-D through 5-E were reduced to 60 percent of their 1977 weighted damages per acre. (see Table 15).

Table 15 - Weighted seasonal crop damage, sample reaches 5-B and 5-D

Seasonal period	Seasonal crop damage	
	Reach 5-B	Reach 5-D
31 March (23 March)	$2.99	$3.61
1-15 April	12.16	13.60
16-30 April	20.26	21.46
1-15 May	52.78	53.17
16-31 May	75.61	80.64
1-15 June	63.28	66.48
16-30 June	79.22	93.35
1-15 July	80.31	94.80
16-31 July	67.77	84.23
1-15 August	36.66	44.94
16-31 August	17.57	24.15
1-15 September	4.44	8.21
16-30 September	2.98	6.11
1-15 October	2.05	2.13

Table 16 combines the above information with the flood history.

Other Agricultural

Other agricultural damages have been increased using the change in agricultural prices paid index from October 1978 to October 1980 (979/761 = 1.286).

Average Annual Agricultural and Other Agricultural Damages

The mean daily discharge-frequency or elevation-frequency relationships were combined to determine the frequency-area flooded. The average annual area flooded has been determined for each damage reach by integrating the area under the curve. The weighted average crop damages per acre flooded and the other agricultural damages per acre flooded multiplied by the annual area flooded indicate the total damages for each reach (see Table 16, 17, 18 and 19).

Transportation

Transportation damages were updated using the change in the *Engineering News Record's* (ENR) construction index.

Urban

Urban damages were divided into three categories: residential, commercial, and public. Data on damages in each category for specific floods were gathered over several years but primarily in 1976 and 1977. The data were updated to October 1978 prices using the ENR's building index to put all of the information on a common base for the Stage 2 report. This index is fairly representative for short-term updating. With no additional information this index, which increased by 34 percent from 1976 to 1980, would have been used again to update the base information to 1980 price levels.

Table 16 - Average annual crop damages per acre - sample reaches

Reach	Date of flood	Elevation (feet msl)	Acres flooded	Crop damage per acre	Crop damage per flood
5B	18 Apr 47	914.2	2,600	$18.20	$47,320
	7 May 48	913.9	2,460	52.80	129,888
	14 May 50	915.0	3,280	63.40	207,952
	8 Apr 52	914.1	2,590	12.80	33,152
	13 Apr 60	912.5	1,700	15.50	26,350
	11 Jul 62	914.2	2,600	77.20	200,720
	8 Apr 65	915.23	3,440	12.80	44,032
	3 Apr 66	915.22	3,420	6.70	22,914
	15 Apr 69	915.4	3,600	16.60	59,760
	30 Apr 71	912.3	1,590	38.00	60,420
	29 Apr 74	913.1	1,990	38.50	70,645
	5 May 75	912.5	1,700	48.50	82,450
	6 Jul 75	915.47	3,890	64.10	140,379
	28 Mar 78	913.02	1,960	2.99	5,860
	7 May 79	915.85	5,340	52.80	281,952
Total			42,160		1,413,794
Average annual damage/acre				$33.53	
5D	18 Apr 47	897.72	13,500	19.10	257,850
	7 May 48	895.65	3,600	53.20	191,520
	14 May 50	897.80	13,700	65.80	901,460
	8 Apr 52	897.69	13,450	13.60	182,920
	11 Jul 62	896.21	4,400	91.90	404,360
	18 Apr 65	897.99	15,000	19.10	286,500
	3 Apr 66	898.23	17,500	7.60	133,000
	15 Apr 69	899.02	25,100	17.50	439,250
	6 Jul 75	899.44	29,000	94.80	2,749,200
	29 Mar 78	898.23	17,500	3.61	63,175
	21 Apr 79	899.31	28,200	20.80	586,560
Total			180,950		6,195,795
Average annual damage/acre				34.24	

Table 17 - Average annual crop damages per acre

Reach	October 1978 prices and flood history	October 1980 prices and flood history
2	$7.44	$4.91
3	22.90	15.11
4	20.72	13.68
5A	48.13	31.77
5B	50.80	33.53
5C	55.61	36.70
5D	57.94	34.24
5E	57.52	33.94

Table 18 - Average annual other agricultural damages per acre

Reach	October 1978 prices	October 1980 prices
2	$3.41	$4.39
3	6.10	7.85
4	5.45	7.01
5 (A,B,C,D,E)	12.11	15.58

Table 19 - Average annual agricultural damages

Reach		Acres flooded	Damage per acre	Average annual damages
2	Crop	400	$4.91	$1,960
	Other agricultural		4.39	1,760
3	Crop	600	15.11	9,070
	Other agricultural		7.85	4,710
4	Crop	2,100	13.68	28,730
	Other agricultural		7.01	14,720
5A	Crop	1,500	31.77	47,660
	Other agricultural		15.58	23,370
5B	Crop	1,000	33.53	33.530
	Other agricultural		15.58	15,580
5C	Crop	550	36.70	20,190
	Other agricultural		15.58	8,570
5D	Crop	8,100	34.24	277,340
	Other agricultural		15.58	126,200
5E	Crop	3,000	33.94	101,820
	Other agricultural		15.58	48,740