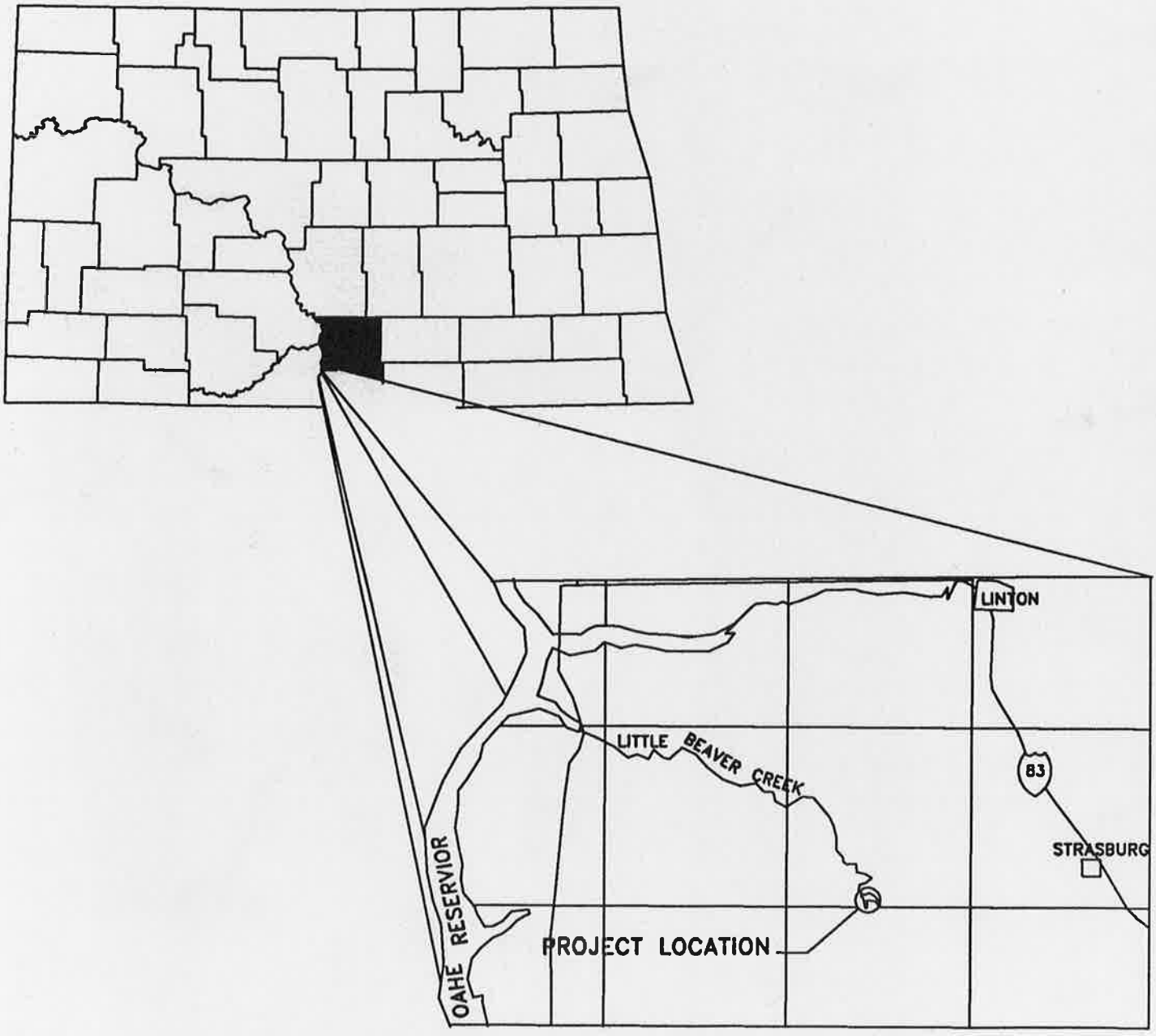
PRELIMINARY ENGINEERING REPORT

WELK DAM IMPROVEMENT

SWC # 400

EMMONS COUNTY



NORTH DAKOTA
STATE WATER COMMISSION

JULY 1991

PRELIMINARY ENGINEERING REPORT

WELK DAM IMPROVEMENTS
SWC PROJECT #400

North Dakota State Water Commission
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I. PURPOSE AND SCOPE

In January of 1991, the North Dakota State Water Commission entered into an agreement with the Emmons County Water Resource District to investigate the feasibility of repairing or replacing of Welk Dam. A copy of the agreement is included in Appendix A. Figure 1 shows the location of Welk Dam within the state.

This report contains a history of activity related to Welk Dam, a description of the study area, hydrologic and hydraulic analysis of the drainage basin, a summary of the preliminary design of the project, a cost estimate based on the preliminary design alternatives, an environmental assessment, description of land rights and finally, a statement of conclusions, and recommendations regarding the project.

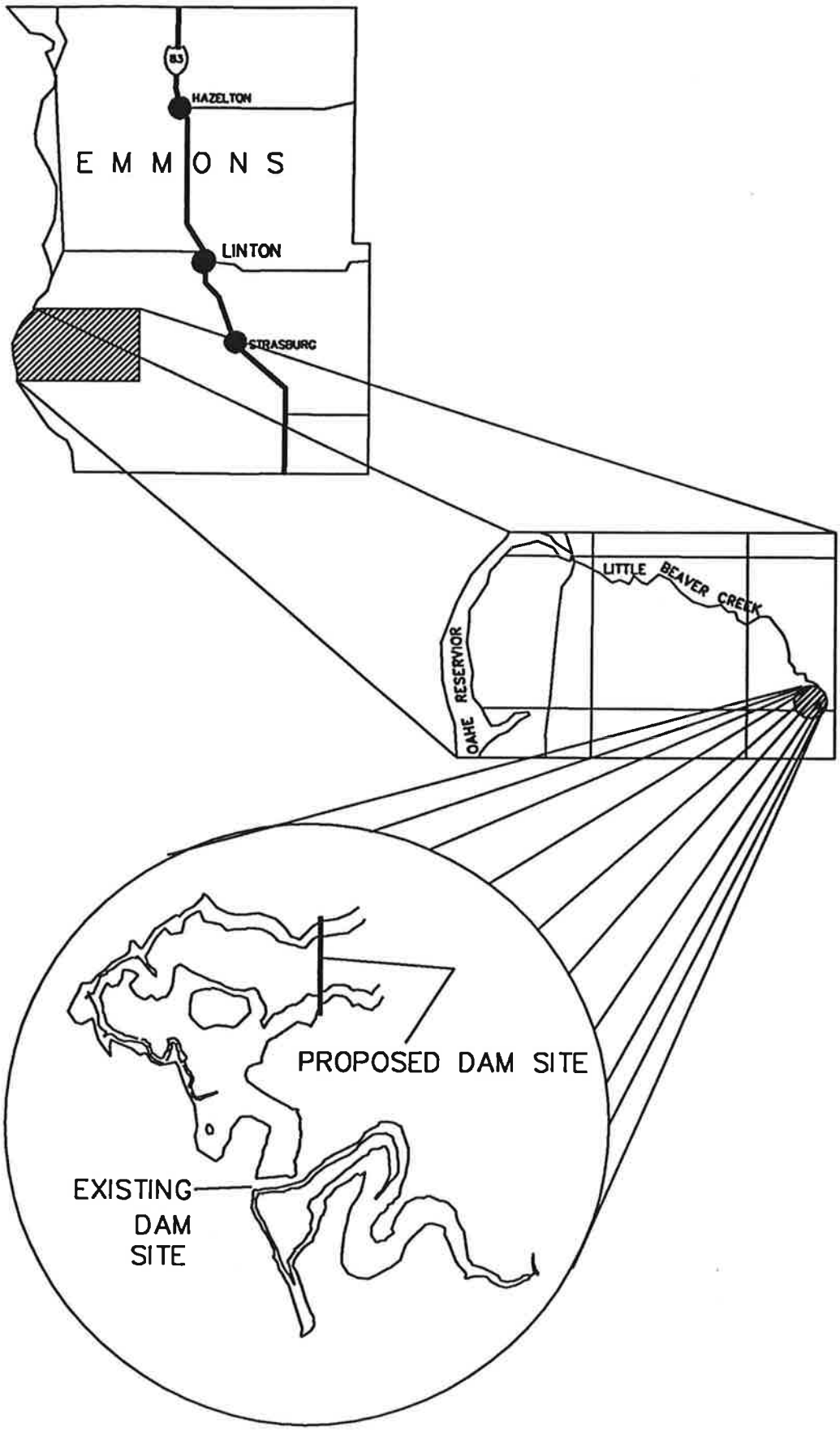


FIG – 1 LOCATION MAP

II. BACKGROUND

Welk Dam was constructed by the Work Progress Administration in the mid-1930s to provide fish habitat and recreation. The dam was first referred to as Meier Dam, until the name was changed to Welk Dam in the late 1940s. Since its construction, the principal spillway has required periodic repair work consisting mainly of guniting concrete on the spillway. Repairs and modifications to the principal spillway occurred in 1945, 1950, 1955, and 1958.

In March 1975, a meeting was held with the Emmons County Water Management District in discussion of designing a downstream dam site. The State Water Commission presented preliminary data for the proposed downstream site. The new site would have a control elevation of 1840 feet (msl), an 87-acre pool, and a 23-foot average depth. The preliminary data presented was from a quadrangular map of the area. There was discussion on the amount of farm land that needed to be acquired and concluded that a topographic map clearly defining the tracts of land would be required. No further progress was made on the project.

The State Water Commission's inspection of Welk Dam in 1990, noted the poor condition of the spillway and undermining, cracking and deterioration of the wingwalls. For safety reasons, the Emmons County Water Resource District has requested an investigation on Welk Dam to provide alternatives for repairing or replacing the dam.

III. DESCRIPTION OF AREA

Location and Basin Description:

Welk Dam is located in the SE1/4 of Section 33, Township 131 North, Range 77 West. The site is seven miles west and one-half-mile south of Strasburg, in Emmons County (see Figure 1). The embankment lies across Little Beaver Creek approximately 11 miles above entry with Oahe Reservoir.

The drainage area above Welk Dam is 16 square miles. The Little Beaver Creek valley flattens and widens upstream of the reservoir. The bluffs rise to elevation 2100 mean sea level (msl). Most of the upstream drainage area is under cultivation with the exception of the steep slopes of the buttes and their tops.

Climate:

Precipitation for crop production is adequate during normal years, although occasionally the area suffers from periods of drought. The total annual precipitation is 17.3 inches. Of this, 14 inches or 82 percent usually falls in April through September, which includes the growing season for most crops. The average temperature is 13 degrees Fahrenheit during the winter and 69 degrees Fahrenheit during the summer.

Geology:

Welk Dam, and its drainage area, lie within the Missouri Plateau in the Great Plains Province. It is on the Coteau slope,

which is the glaciated section of the Missouri plateau. Soil formations are Bearpaw and Vebar series which consist of deep, well-drained, slowly permeable soils on glacial till plains. Slope ranges from 1 to 50 percent.

Hydrology:

A hydrologic analysis of the watershed was performed using the HEC-1 computer model, developed by the U.S. Army Corps of Engineers. It was used to determine the peak discharges and flow volumes of various frequency storms. It formulates a mathematical hydrologic model of the watershed based on the following data: The amount of rainfall, the rainfall distribution, soil type, land use, and the hydraulic characteristics of channels and drainage areas. The HEC-1 model is designed to calculate the surface runoff of the watershed, in relation to precipitation, by representing the basin as an interconnected system of hydrologic and hydraulic components. Each component of the model represents an aspect of the precipitation-runoff process within a portion of the subbasin. These components were put into the model to determine the magnitude and duration of runoff from hydrologic events with a range of frequencies.

The model was developed to determine the hydrologic response of Welk Dam watershed. The results gained from the model included: (1) inflow hydrographs, (2) reservoir stage hydrographs, and (3) outflow hydrographs.

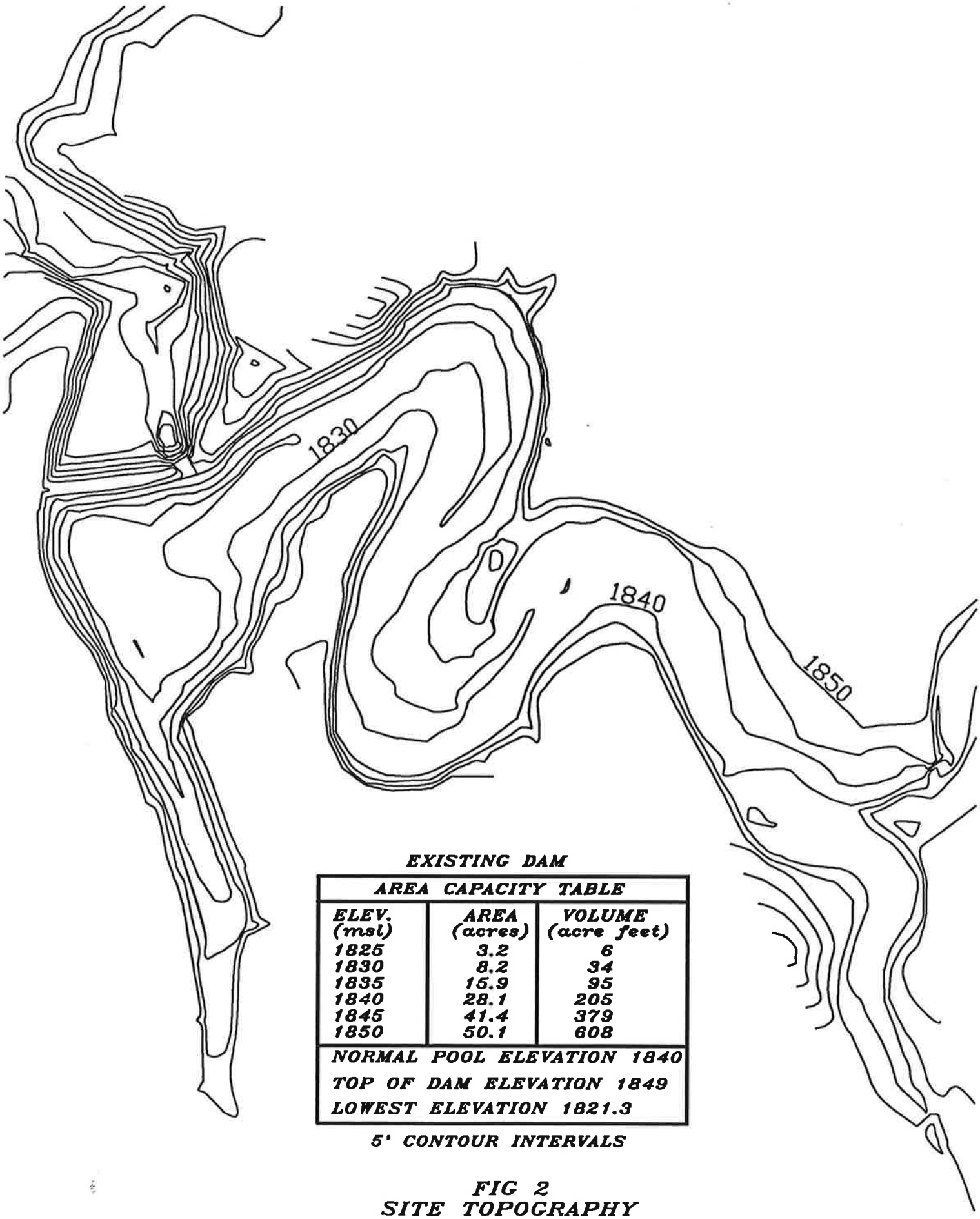
Dam Description:

The Welk Dam embankment is a rolled earth-filled type whose top elevation is 1849 msl. The 24-foot high embankment has a 3H:1V (3 horizontal to 1 vertical) slopes for both upstream and downstream faces with riprap on the upstream slope. The top of the embankment is 400 feet long and 20 feet wide. A low-level drawdown pipe is not included as part of the structure.

The principal spillway consists of an approach channel, Ogee concrete spillway, and a plunge pool. The approach channel consists of a flat curved earth channel approximately 50 feet long at the same elevation as the principal spillway (1838 msl). The principal spillway is 42 feet wide with a face slope of 1H:1V. The stilling basin consists of the original 10-foot long, flat rubble masonry apron and a secondary drop 10 feet long and 3 feet deep. The crest elevation of the principal spillway is 1840 msl. The reservoir's water surface is at 1840 msl, covers 28.1 acres, and the capacity is 205 acre-feet. The average depth is 7.3 feet and maximum depth is 18.7 feet (See Figure 2 - Site Topography Map).

Dam Design Classification:

Dams are classified according to their potential hazard to property and potential for loss of life, if the dam should suddenly fail. Welk Dam is located in a rural area where there is little probability of future residential development downstream of the dam site. Failure of this dam could result in



EXISTING DAM

AREA CAPACITY TABLE		
ELEV. (msl)	AREA (acres)	VOLUME (acre feet)
1825	3.2	6
1830	8.2	34
1835	15.9	95
1840	28.1	205
1845	41.4	379
1850	50.1	608
NORMAL POOL ELEVATION 1840		
TOP OF DAM ELEVATION 1849		
LOWEST ELEVATION 1821.3		

5' CONTOUR INTERVALS

FIG 2
SITE TOPOGRAPHY

damage to agricultural land and township roads, however, no loss of life would be expected. Therefore, Welk Dam is considered a low hazard dam. The embankment height is 24 feet, classifying Welk Dam as classification II, according to the North Dakota Dam Design Handbook.

Sedimentation:

The rate of sedimentation in reservoirs is dependent upon the amount of soil eroded from the watershed and transported into the reservoir. There are several factors which determine the amount of sediment that is carried by surface runoff. Among them are soil type amount of runoff, slope of land, land use, and conservation practices used. Also contributing to the sediment accumulation is the organic material that is generated within the reservoir itself.

Sedimentation in the Welk Dam could be reduced by examining the watershed to determine land treatment measures which could reduce the erosion rate. Treatment practices include conservation cropping systems, crop residue use, stubble mulching, strip cropping, contour plowing, grassed waterways, windbreaks and buffers, and sediment catching ponds.

There is limited data available on the total sediment accumulation in the reservoir. An original topographic map of the reservoir area is not available and no sedimentation surveys of the reservoir have been completed. Comparing the elevations

upstream and downstream of the dam, sedimentation has occurred and is estimated at 2 feet deep.

IV. DESCRIPTION OF PROJECT

Discussion of Alternatives:

Action must be taken to prevent Welk Dam from failing due to a high runoff event. The existing spillway is in poor condition. The spillway has incurred extensive undermining with cracking and deterioration of the wingwalls.

There are four alternatives considered that will either improve the existing spillway or construct a new dam downstream. The first alternative consists of breaching the existing embankment and draining the reservoir. The second alternative consists of restoring the existing spillway. The third alternative is replacing the spillway with a new outlet structure. The outlet structures to be considered are corrugated metal pipes and a concrete chute. A new dam constructed downstream will be the fourth alternative.

Alternative One

Breaching the Embankment:

The first alternative is breaching the embankment and draining the reservoir. This could be done immediately, preferably in the fall before the next spring runoff. Depending on the level of the reservoir, it may be necessary to siphon or pump the level of the reservoir down a few feet prior to breaching the embankment. Lowering the reservoir level prior to breaching the embankment would reduce the risk of damaging downstream areas.

An option to drain the reservoir would be to excavate a notch in the downstream half of the embankment, install a gated culvert, backfill around the culvert, and excavate the upstream side of the embankment allowing the reservoir to drain through the culvert at an orderly rate. The controlled releases through the culvert would help prevent downstream erosion and decrease the sediment load of the released flows. Breaching the embankment would provide less control over the releases and could result in downstream flooding, erosion, and sedimentation problems.

A channel, with a maximum depth of approximately 4 feet, would be required upstream and downstream of the embankment to provide adequate drainage of the reservoir through the breach. The channel would need to extend approximately 100 feet upstream and downstream of the embankment.

After the reservoir is drained, the culvert would be removed and the embankment would remain breached. It would be necessary to remove the spillway for hazardous precautions in case the embankment is filled, the responsible party would need to provide the proper outlet for the dam. The spillway would be dismantled and buried near the site or could be hauled away.

Breaching the embankment and draining the reservoir would eliminate the risk of damage caused by a dam failure. However, the loss of the reservoir to recreation may not outweigh the

circumstances. The breached area would be available as a site for a new spillway which might be built at some later date. The cost summary for breaching and draining Welk Dam is provided in Table 1. The total cost for this alternative is $18,000.

Cost Estimate - Alternative One

Item	Unit	Total
Mobilization	LS	$ 1,500.00
Travel	LS	1,500.00
Coffer Dam	LS	1,500.00
Demolish Structure	LS	3,500.00
Excavate Notch	LS	3,000.00
Drain Lake	LS	1,000.00
Widen and Stabilize Notch	LS	1,000.00
Seeding and Cleanup	LS	500.00
Subtotal		$13,500.00
Engineering 10%		1,350.00
Administration 10%		1,350.00
Contingencies		1,800.00
Total		$18,000.00

Alternative Two

Rehabilitating Spillway:

The second alternative would consist of restoring the spillway through the use of gunite. There has been excessive undermining to the spillway creating large voids underneath the concrete. Gunite would be pumped into the voids to add support and stabilize the spillway.

An inspection of the spillway was performed by boring holes into the concrete floor. The borings consisted of 2-inch holes drilled at random throughout the face of the spillway. The depths of the voids were measured in each hole and recorded. The

largest void found was 27 inches below the 12-inch concrete slab. This void was located on the west side of the weir wall approximately halfway down. Borings on the bottom of the spillway face revealed void depths of 17 inches and 9 inches below the concrete slab. The voids were located on the west half, there were no voids discovered on the east half of the weir. The thickness of the concrete slab varied from 12 to 16 inches thick throughout the face of the spillway.

Holes were drilled on the crest of the spillway, but no voids were found. Therefore, it does not appear that the seepage is entering directly in front of the spillway. Since the voids were only found on the west half of the weir, it has been concluded that the water is entering from under the west wingwall.

Several holes were drilled randomly across the first 8-inch thick concrete apron. The depths of the voids below the concrete apron ranged from 10 to 13 inches. The second apron was 12 inches thick with voids ranging from 6 to 10 inches. The secondary drop just below the toe of the dam had 18-inch holes bored which revealed a void with a 6-inch depth, with water filling the void.

The amount of gunite needed to fill the voids is estimated at 75 cubic yards. The total cost estimate for rehabilitation is $25,000. Rehabilitation would not include wingwall repair.

Rehabilitation of the wingwalls would be difficult because of their deteriorated condition. The wingwalls could probably be replaced, but the problem would be tying them into the weir and providing stability for the spillway. This alternative does address the undermining of the spillway, but the wingwalls would not be improved.

Cost Estimate - Alternative Two

Item	Quantity	Unit	Cost	Total
Mobilization	1	LS	$1,500.00	$ 1,500.00
Travel	1	LS	2,000.00	2,000.00
SWC Labor	1	LS	7,000.00	7,000.00
SWC Equipment	1	LS	2,500.00	2,500.00
Grout	75	CY	80.00	6,000.00
Misc. Materials	1	LS	500.00	500.00
	Subtotal			$19,500.00
	Engineering 10%			1,950.00
	Administration 10%			1,950.00
	Contingencies			1,600.00
	Total			$25,000.00

Alternative Three

Construction of a New Spillway:

The third alternative consists of replacing the existing spillway with a new outlet structure. A corrugated metal pipe and concrete chute were analyzed. The outlet structure design will be addressed in the following sections of hydrology, hydraulics, and preliminary design. A preliminary cost estimate will be also provided for each structure.

Hydrology:

Precipitation design amounts were determined once the dam was classified. Outlet works are required to have flow capacities such that they pass the runoff from precipitation events as suggested by its classification.

Based on the North Dakota Dam Design Handbook, the requirement for a class II dam is that the dam is to withstand the 50-year event without overtopping. A 6-hour rainfall, 10-day rainfall, 24-hour rainfall, and 10-day snowmelt precipitation tables were used for the 50-year event. The 6-hour rainfall event was found to be the critical event for the watershed and was used for dam design criteria. Table 3 shows the resulting peak inflows and total volumes for a 50-year event.

Table 1 - Peak Inflows and Volumes for Design 50-Year Event

Frequency	Peak Inflows (cfs)	Total Inflow Volume (acre-feet)	Peak Stage (ft) msl
6-hour rainfall	1924	756	1845.44
24-hour rainfall	1601	1498	1844.90
10-day rainfall	1744	2644	1845.13
10-day snowmelt	1304	2424	1844.33

Hydraulics:

An area-capacity curve for the reservoir was developed through a field survey. The normal surface pool elevation is 1840 msl which covers 28.1 acres, a volume of 205 acre-feet, maximum depth of 18.7 feet, and an average depth of 7.3 feet. The

minimum lake elevation recorded is 1821.3 msl. The top of the embankment is at an elevation of 1849 msl.

The normal surface pool elevation will be constant for each of the proposed outlet structures. The existing dam does not have an emergency spillway and based on the classification, an emergency spillway is not required. Table 2 shows the area capacity for the new dam site.

Table 2
Area-Capacity Curve

Elevation (feet)	Area (acres)	Volume (ac-ft)
1825	3.2	6
1830	8.2	34
1835	15.9	95
1840	28.1	205
1845	41.4	379
1850	50.1	608

The elevation capacity curve and the inflow hydrographs were then used to determine reservoir stages and outflow hydrographs by routing the inflows through the reservoir using the HEC-1 model. The outflow hydrographs were used to determine the design criteria for the outlet structures.

Preliminary Design

A. CMP Spillway.

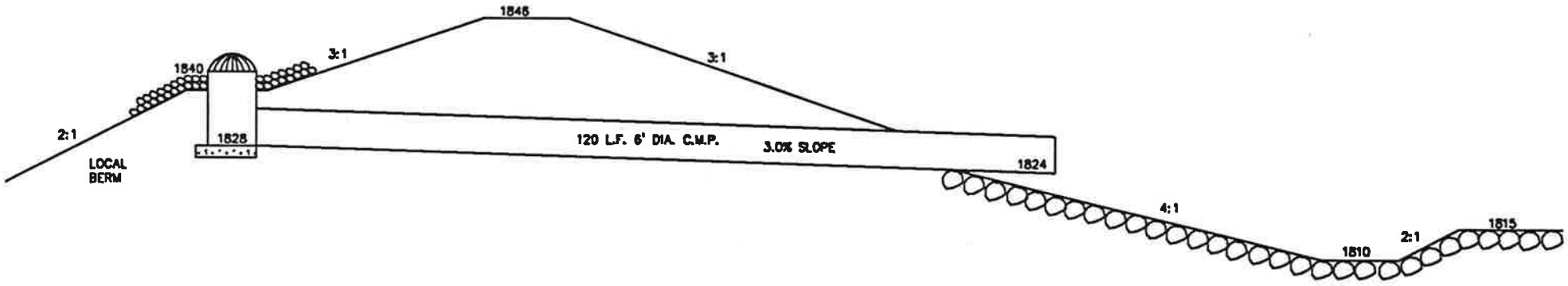
Two corrugated metal pipes 120 feet in length and 6 feet in diameter will be considered as a replacement for the deteriorated spillway. The inlet would have a 12-foot drop and a 96-inch

intake opening with trash guard. The inlet will have a crest elevation of 1840 msl with the invert of the CMP's at elevation 1828 msl. The CMP's will be laid at a slope of 3.33 percent with the outlet at elevation 1824 msl. The outlet structure consists of a standard cantilevered outlet with stilling basin (See Figure 3). The embankment would have a 14-foot wide top at 1849 msl, with 3:1 side slopes that will tie into the existing embankment (See Figure 4).

The deteriorated spillway would be removed and disposed on-site or hauled away. The old spillway location would be plugged with earth-filled material. A soil investigation may be required to find proper fill material for the embankment. Additional riprap will be needed on the face of the embankment for erosion protection.

The critical event for design criteria was the 6-hour rainfall 50-year event. The peak outflow through the pipes was 1245 cubic feet per second (cfs). Inflow from the 50-year rainfall event will cause the reservoir to rise to an elevation of 1847.4 msl. The top of the embankment (1849 msl) would not be overtopped by the 50-year rainfall event.

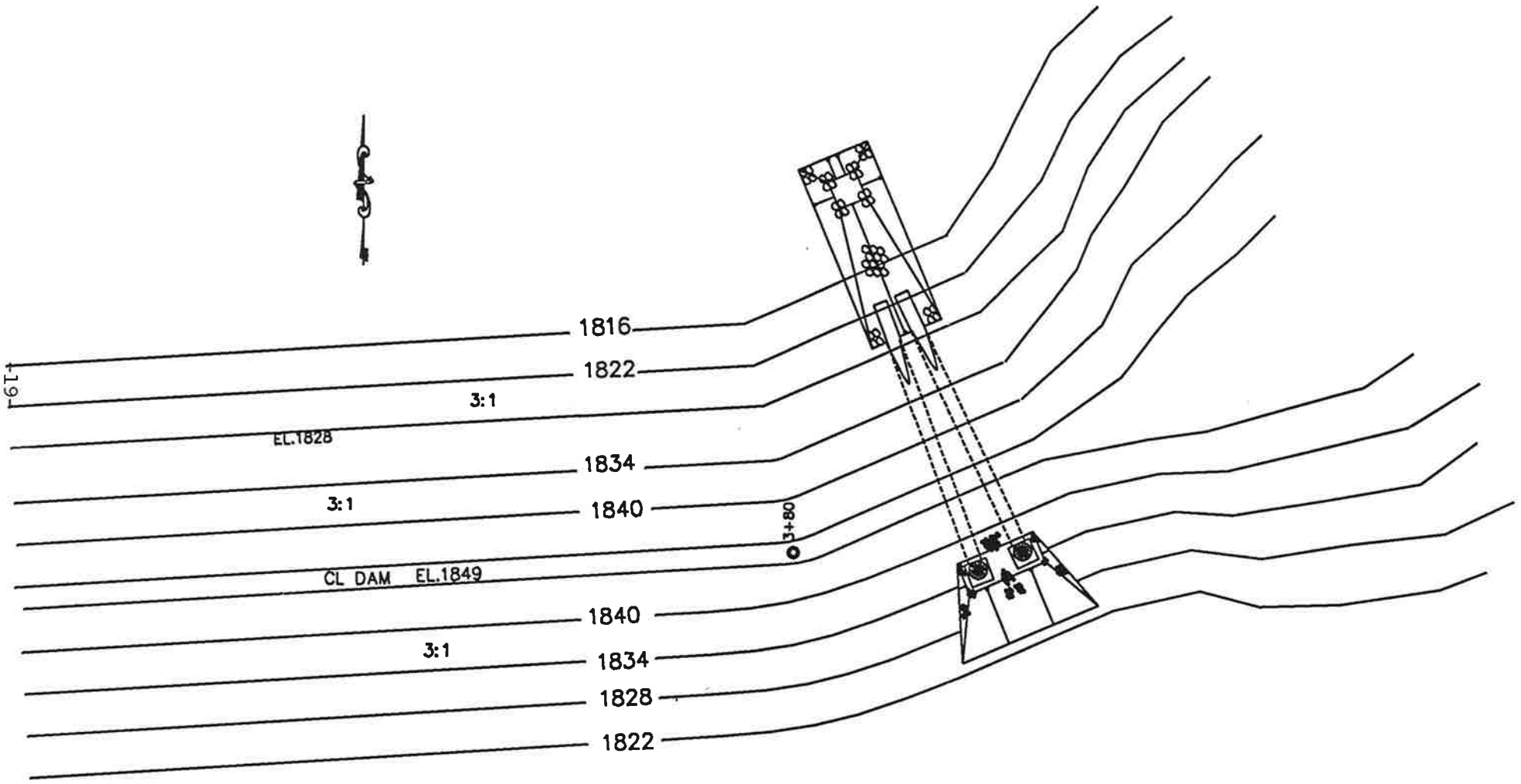
A low-level drawdown system will also be implemented. A low-level (hypolimnetic) water quality control structure would improve the water quality by removing stagnant water from the



PROFILE — 6' CMP

NO SCALE

Figure 3



PLAN VIEW – TWO 6' CMP

NO SCALE

Figure 4

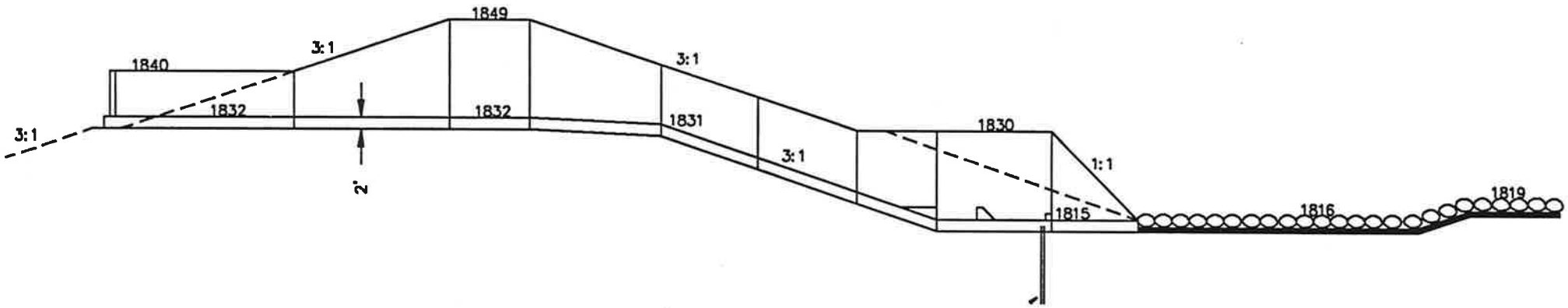
bottom of the reservoir. The total cost of for CMP spillway is $145,000.

Cost Estimate - Alternative 3A

Item	Quantity	Unit	Cost	Total
Mobilization	1	LS	$10,000.00	$ 10,000.00
Water Control	1	LS	15,000.00	15,000.00
Demolish Spillway	1	LS	10,000.00	10,000.00
Excavation	5,000	CY	1.50	7,500.00
72-inch Dia. CMP	240	LF	75.00	18,000.00
96-inch Diameter Inlet Structure	2	Ea.	6,000.00	12,000.00
Embankment	8,000	CY	2.00	16,000.00
RR Filter Material	120	CY	15.00	1,800.00
Rock Riprap	400	CY	25.00	10,000.00
Cathodic Protection	1	LS	3,700.00	3,700.00
Low-Level Drawdown System	1	LS	6,000.00	6,000.00
Seeding	1	LS	1,000.00	1,000.00
	Subtotal			$111,000.00
	Engineering 10%			11,000.00
	Administration 10%			11,000.00
	Contingencies			12,000.00
	Total			$145,000.00

B. Concrete Chute.

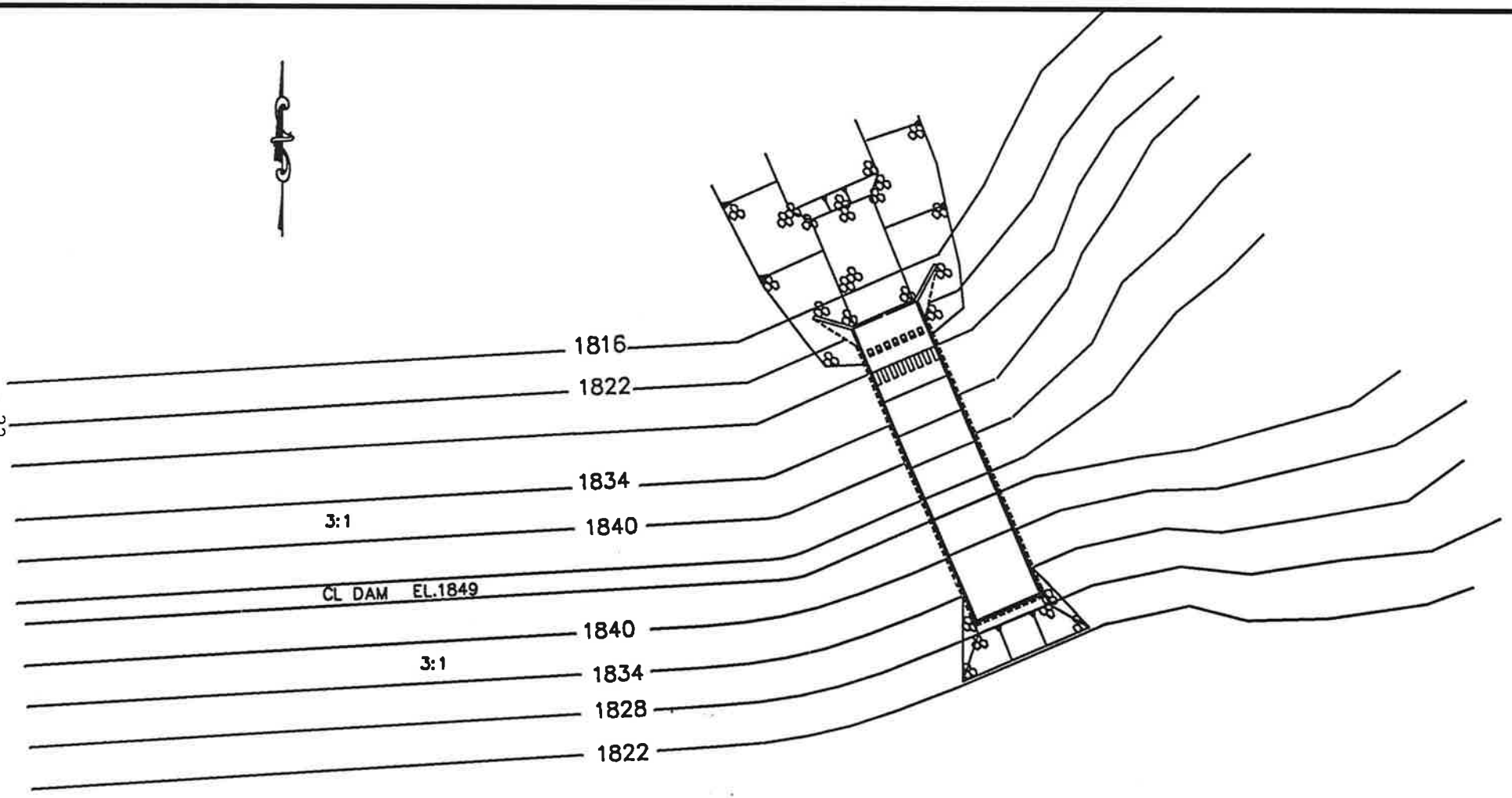
A concrete chute would be another option for replacement of the deteriorated spillway. The chute would be located in the same area as the original spillway. The concrete chute would be 30 feet wide, 150 feet in length, and have a crest elevation of 1840 msl (See Figure 5). The concrete chute would have a height of 8 feet. The wingwalls on the concrete chute would be at a 3H:1V slope tying into the top of the embankment at 1849 msl (See Figure 6). This alternative also includes a low-level drawdown.



PROFILE – CONCRETE CHUTE

NO SCALE

Figure 5



PLAN VIEW – CONCRETE CHUTE

NO SCALE

Figure 6

The critical event for design criteria was the 6-hour 50-year rainfall event. The peak outflow over the chute was 1887 cfs. Inflow from the 50-year event will cause the reservoir to rise to an elevation of 1843.2 msl. The top of the embankment (1849 msl) would not be overtopped by the 50-year event. The preliminary estimated cost for a concrete chute is $315,000.

Cost Estimate - Alternative 3B

Item	Quantity	Unit	Cost	Total
Mobilization	1	LS	$15,000.00	$ 15,000.00
Water Control	1	LS	25,000.00	25,000.00
Demolish Spillway	1	LS	10,000.00	10,000.00
Excavation	4,500	CY	1.50	6,750.00
Concrete	365	CY	250.00	91,250.00
Resteel	73,000	CY	0.50	36,500.00
Embankment	4,000	CY	2.00	8,000.00
RRR Filter	200	CY	15.00	3,000.00
Rock Riprap	600	CY	25.00	15,000.00
Low-Level Drawdown	1	LS	8,000.00	8,000.00
Misc. Metals	1	LS	12,000.00	12,000.00
Seeding	1	LS	1,000.00	1,000.00
Steel Sheet Piling	360	LF	25.00	9,000.00
	Subtotal			$240,000.00
	Engineering 10%			24,000.00
	Administration 10%			24,000.00
	Contingencies			27,000.00
	Total			$315,000.00

Alternative Four

Construction of New Dam:

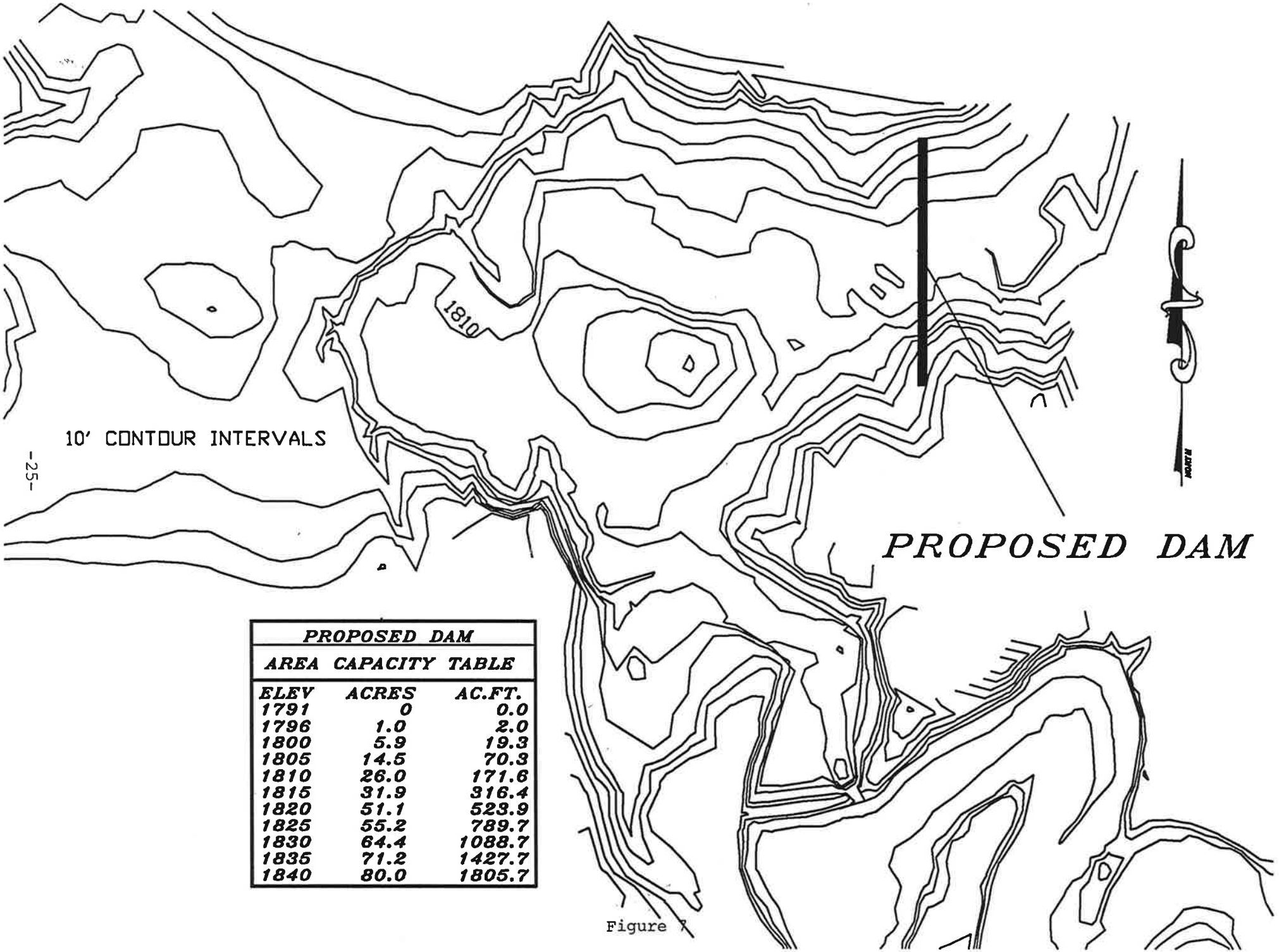
The fourth alternative would be to construct a new dam downstream from the existing dam and use the existing embankment for a settling basin. The dam would be located one mile downstream from the existing dam site. The new dam location is in a rural area where there is little probability of future residential development downstream of the dam site. Failure of

this dam could result in damage to agricultural land and township roads, however, no loss of life would be expected. Therefore, the new dam is considered a low hazard dam. The embankment height is 36 feet, classifying the dam as classification III, according to the North Dakota Dam Design Handbook (See Figure 7).

Hydrology:

Precipitation design amounts were determined once the dam was classified. Outlet works of a dam are required to have flow capacities such that they pass the runoff from precipitation events as suggested by its classification.

Based on the North Dakota Dam Design Handbook, the requirements for a class III dam are: 1) the principal spillway must pass the flows of a 25-year event without the use of a non-structural emergency spillway, 2) the emergency spillway must pass the flows of a 100-year event within acceptable velocity limits, 3) the dam is to withstand the 0.3 PMP event without overtopping. A 10-day rainfall, 24-hour rainfall, 6-hour rainfall, and 10-day snowmelt precipitation tables were used for the 25-year and 100-year events, and a 0.30 PMP event. The 6-hour rainfall event was found to be the critical event for the watershed and was used for dam design criteria. Table 3 shows the resulting peak inflows and total volumes for 6-hour rainfall events.



PROPOSED DAM		
AREA CAPACITY TABLE		
ELEV	ACRES	AC.FT.
1791	0	0.0
1796	1.0	2.0
1800	5.9	19.3
1805	14.5	70.3
1810	26.0	171.6
1815	31.9	316.4
1820	51.1	523.9
1825	55.2	789.7
1830	64.4	1088.7
1835	71.2	1427.7
1840	80.0	1805.7

Figure 7

Table 3 - Peak Inflows and Volumes for Design Frequency 6-Hour Rainfall Event

Event	Peak Inflows (cfs)	Total Inflow Volume (acre-feet)
25-year	1427	754
100-year	2284	1208
0.3 PMP	5783	3203

An area-capacity curve for the new dam site was developed through a field survey. The elevation capacity curve and the inflow hydrographs were then used to determine reservoir stages and outflow hydrographs by routing the inflows through the reservoir using the HEC-1 model. Table 4 shows the area capacity for the new dam site.

Table 4 - New Dam Site

Elevation (feet)	Area (acres)	Volume (ac-ft)
1791	0	0
1795	1.0	2.0
1800	5.9	19.3
1805	14.5	70.3
1810	26.0	171.6
1815	31.9	316.4
1820	51.1	523.9
1825	55.2	789.7
1830	64.4	1088.7
1835	71.2	1427.7
1840	80.0	1805.7

Principal Spillway:

Several alternatives were evaluated for the design of the principal spillway. The alternatives included a 6-foot diameter reinforced concrete pipe (RCP), a 5 1/2-foot RCP, a 5-foot RCP,

and a concrete chute. The alternatives were evaluated by considering flow capacity, hydraulic efficiency, and preliminary construction costs. Based upon the criteria, the 5 1/2-foot RCP was chosen for the principal spillway design. Table 5 shows the results of the hydrologic study for the proposed 5 1/2-foot diameter RCP (See Figure 8 and 9 for Hydrographs).

Table 5 - Results of Hydrologic Study
Proposed 5 1/2-foot Diameter RCP

Event	Inflow (cfs)	Outflow (cfs)	Stage (feet)
25-year 6-hour rainfall	1427	733	1835.00
100-year 6-hour rainfall	2284	1938	1836.51
0.3 PMP	5826	5823	1838.07

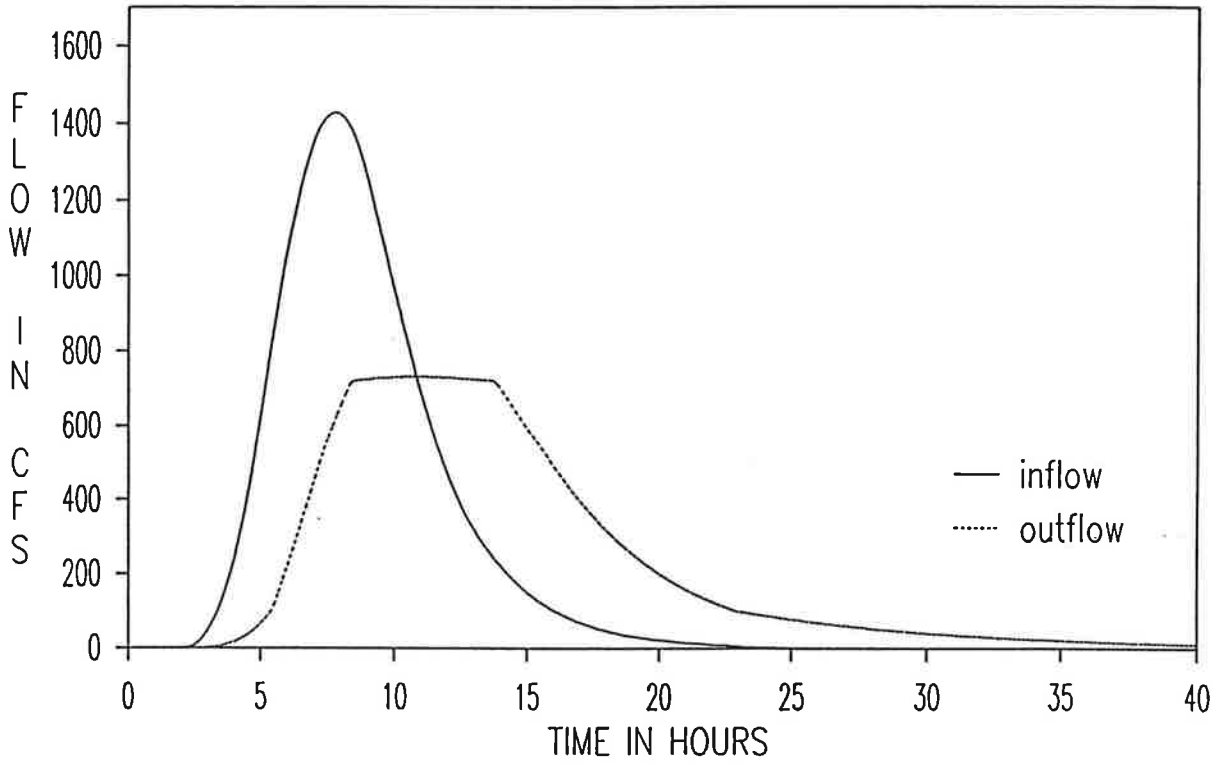
The principal spillway inlet will be at an elevation of 1830 msl. The proposed reservoir will have a surface area of 64.4 acres, and a volume of 1088.7 acre-feet. The maximum depth of the reservoir will be 39 feet and have an average depth of 16.9 feet.

With the normal surface level at 1830 msl, an island will be formed on the reservoir. The island will have a peak elevation of 1845.5 msl, and cover an area of 3.2 acres at the normal water surface level.

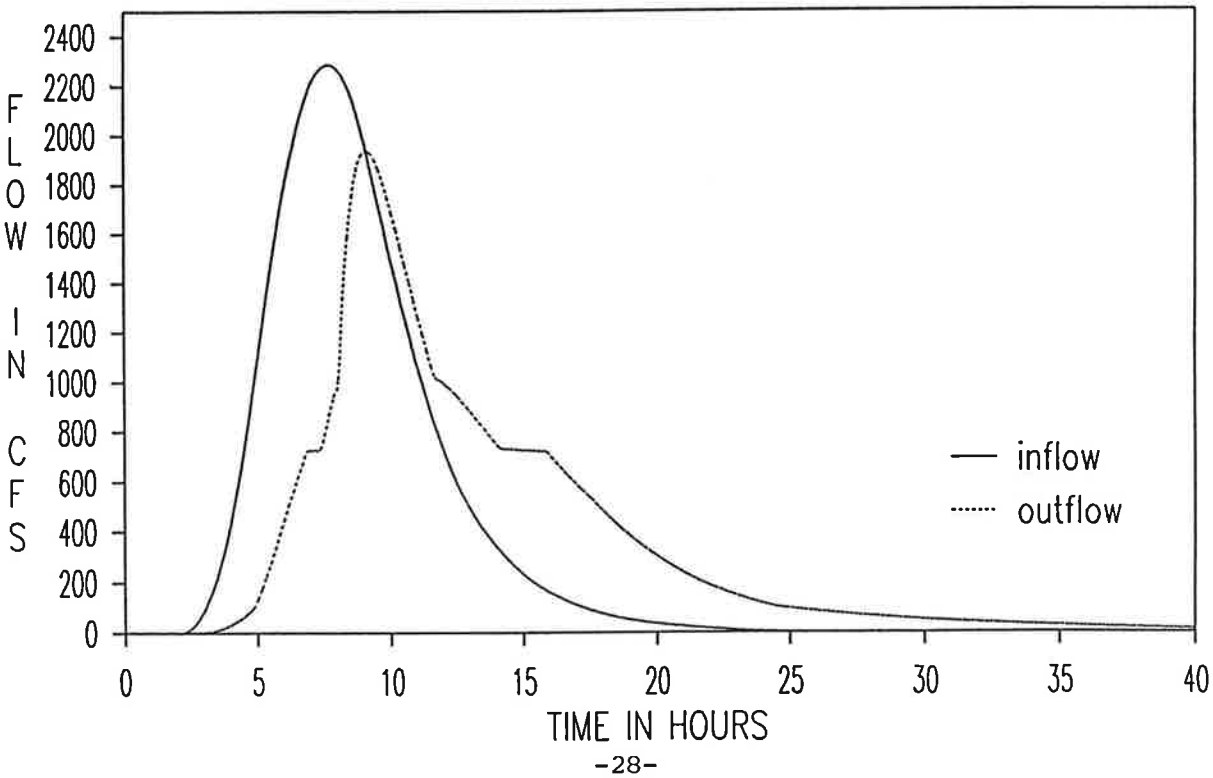
The principal spillway will consist of a inlet box structure, 5 1/2 foot RCP, and plunge pool (See Figure 10). The spillway would have a 24-foot drop inlet with the pipe invert at

Welk Dam Hydrographs

25 Year 6-Hour Rainfall

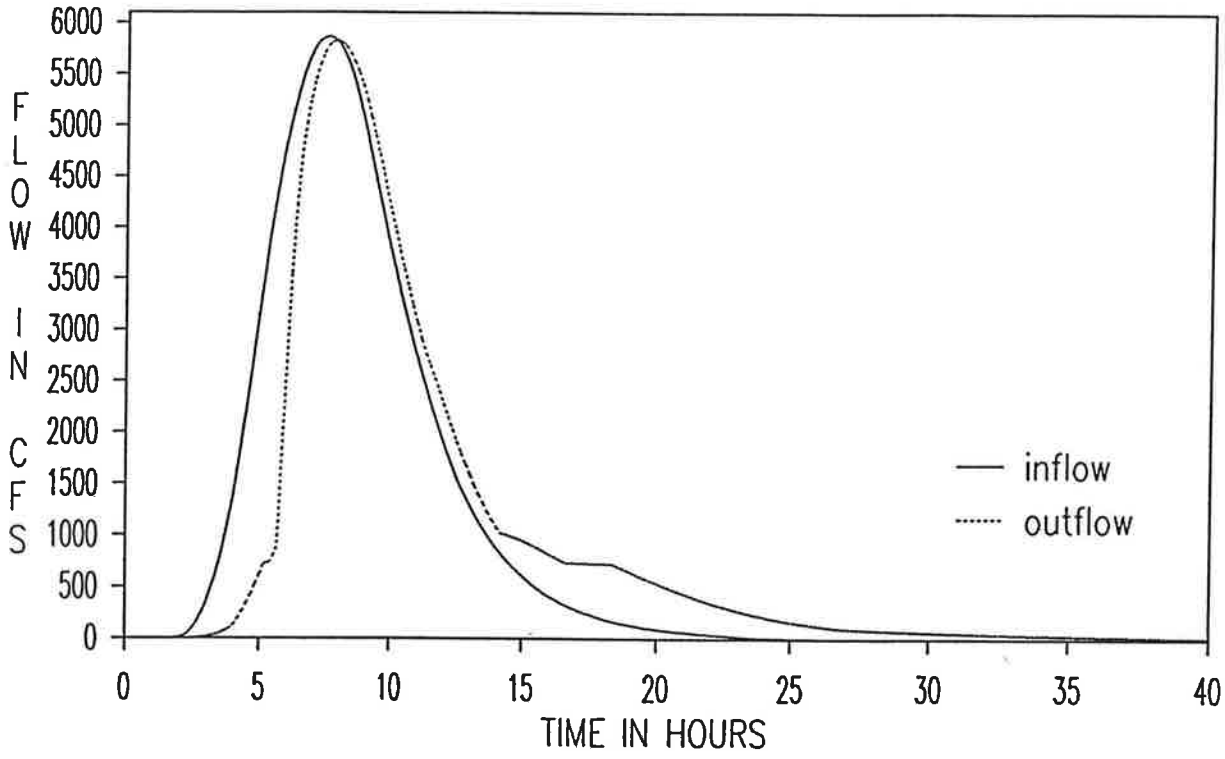


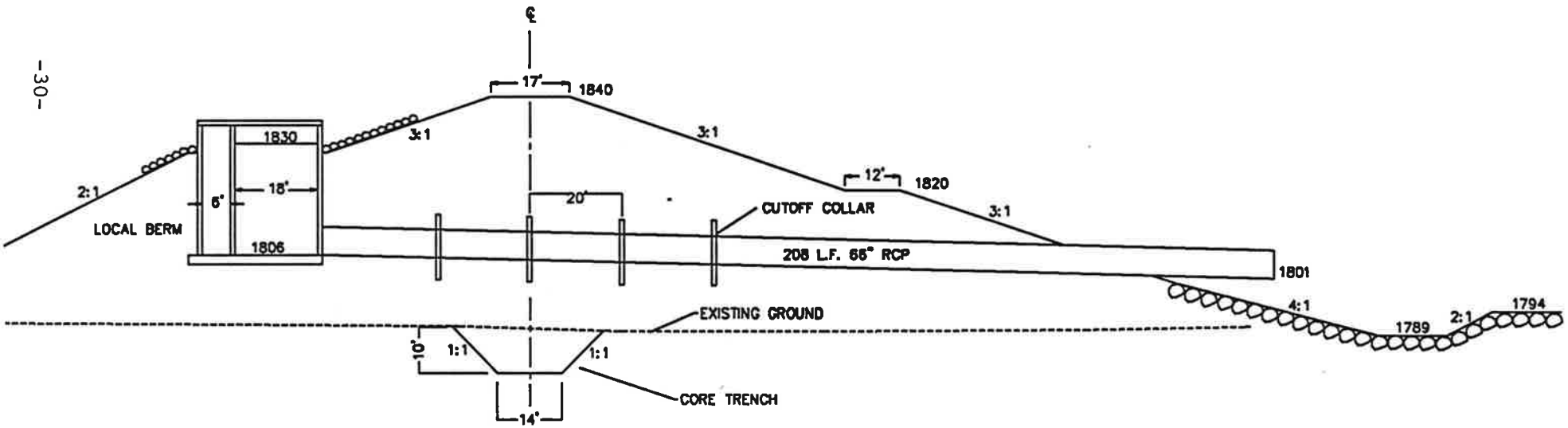
100 Year 6-Hour Rainfall



Welk Dam Hydrograph

0.3 PMP





TRANSVERSE PROFILE OF DAM AT PRINCIPAL SPILLWAY WELK DAM SWC# 400

1806 msl. The RCP is 208 feet in length with a 2.5 percent slope with the outlet invert at elevation 1801 msl. The reinforced concrete pipe will consist of thirteen - 16-foot sections. Within the length of the spillway there will be 6 reinforced concrete anti-seep collars. The outlet structure consists of a standard cantilevered outlet with stilling basin.

A low-level drawdown pipe will be implemented to discharge water into the principal spillway structure. The low-level drawdown structure or hypolimnetic discharge structure is designed to counteract accelerated aging in reservoirs. The low-level drawdown structure removes nutrient-rich water from the bottom of a thermally stratified reservoir, leaving the better quality water behind, and thus increasing the usefulness and life span of the reservoir. Improved water quality conditions result in a positive benefit to the fishery and to all other recreational uses.

Emergency Spillway:

A grassed emergency spillway will be located on the west side of the reservoir discharging to a separate drainage basin to the west. The emergency spillway will have a bottom width of 200 feet and a crest elevation of 1835.5 msl. The reservoir covers 72.1 acres and the capacity is 1463.5 acre-feet at the emergency spillway crest. The suggested design criteria for establishing the crest of the emergency spillway is based on the 25-year event.

The location of the emergency spillway is a natural swale that will discharge to the west of the reservoir. The existing peak elevation is 1837.3, with a base width of 200 feet. The spillway crest would be excavated to 1835.5 msl, with the side slopes of 3:1, and tying into the existing contours to preserve the natural ground with the minimum amount of disturbance. A one percent slope is designed for the downstream and upstream channel tying into existing ground at 1830 msl (See Figure 11). Seeding the excavated area would be required to prevent soil erosion to the emergency spillway channel.

Embankment Design:

The new dam embankment would be a rolled earth-fill type whose top elevation is 1840 msl. The 49-foot high embankment will have 3H:1V upstream slope and the downstream face will have a slope of 3H:1V. The top of the embankment is 800 feet long and 17 feet wide. The criteria for the dam is preliminary and a soil investigation will be needed to verify site and construction data.

Rock riprap will be provided for protection to the upstream face of the dam. It would be placed from 5 feet below the permanent pool elevation to 5 feet above. Flood resistant vegetation would need to be planted above the riprap to protect the embankment for those days that the water is more than 5 feet above the permanent pool elevation. Rock riprap would consist of hard, durable rock, well graded; placed at a thickness of 18

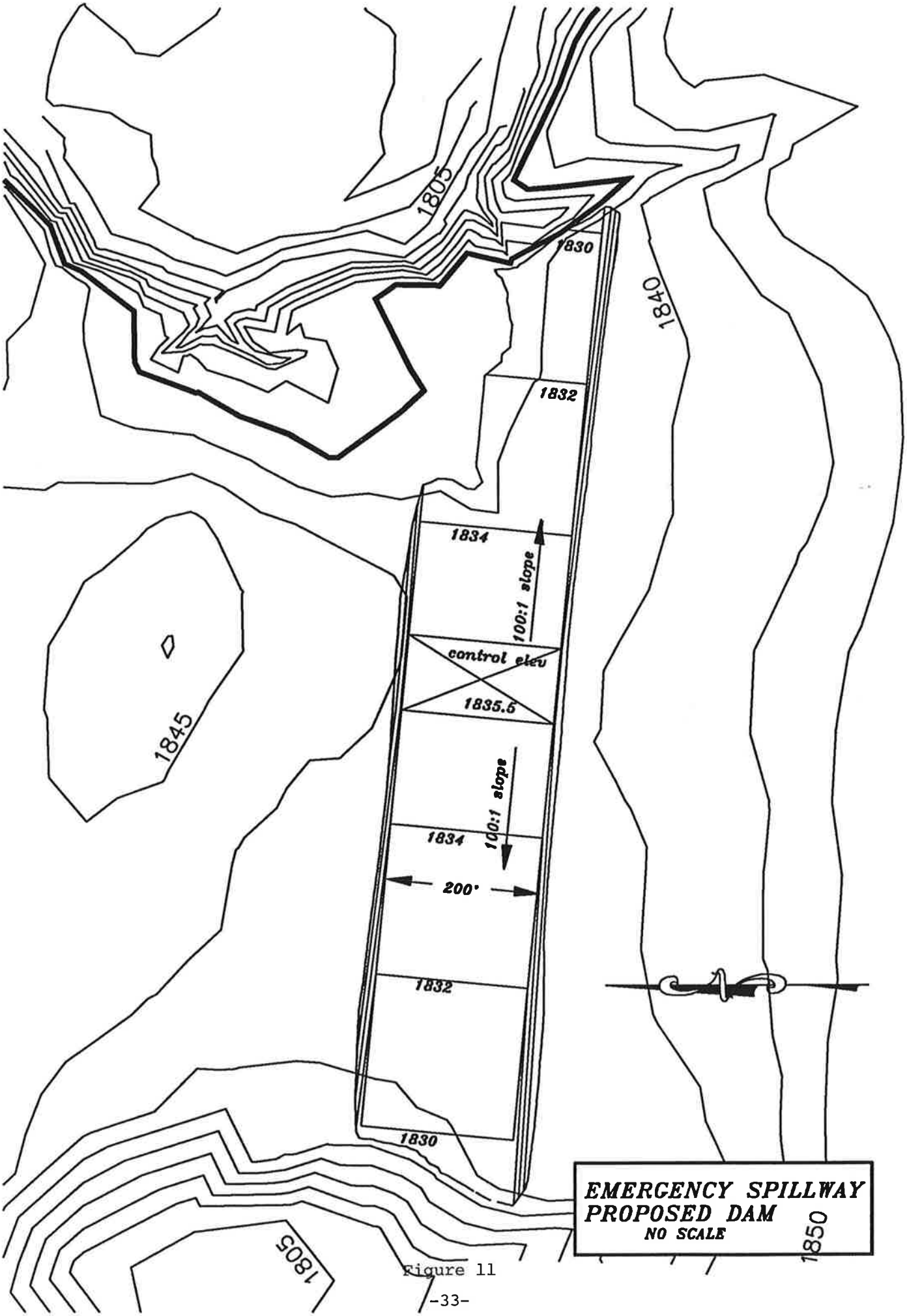

1805
1830
1840
1832
1834
100:1 slope
control elev
1835.5
1845
100:1 slope
1834
200'
1832
1830
1805
1850
EMERGENCY SPILLWAY
PROPOSED DAM
NO SCALE

Figure 11

inches on 6 inches of well-graded gravel filter material. The embankment would need 500 cubic yards of riprap and 300 cubic yards of filter material to be placed for vertical height of 10 feet along the entire dam face. Rock riprap will also be placed downstream from the outlet structure and in other areas where erosion may occur.

The existing embankment from the dam upstream would be breached and the dam would be used as sedimentation pond. Lowering the embankment to an elevation of 1830 msl would leave the reservoir with a depth of 8.7 feet, an area of 8.2 acres, and a total volume of 34 acre-feet.

Cost Estimate - Alternative 4

Item	Quantity	Unit	Cost	Total
Mobilization	1	LS	$10,000.00	$ 10,000.00
Water Control	1	LS	20,000.00	20,000.00
Stripping Topsoil	27,200	SY	0.25	6,800.00
Core Trench Excavation	8,000	CY	2.25	18,000.00
Embankment	150,000	CY	1.20	180,000.00
Water for Compaction	2,000	M GAL	5.00	10,000.00
Concrete	400	CY	300.00	120,000.00
Reinforcing Steel	40,000	LBS	0.50	20,000.00
66-inch RCP	208	LF	25.00	5,200.00
Low-Level Drawdown	1	LF	6,000.00	6,000.00
Drainage Piping	1	LS	12,000.00	12,000.00
Drain Fill	500	CY	20.00	10,000.00
Rock Riprap Filter	800	CY	12.50	10,000.00
Rock Riprap	3,000	CY	20.00	60,000.00
Misc. Metals	1	LS	10,000.00	10,000.00
Seeding	20	Ac.	300.00	6,000.00
	Subtotal			$504,000.00
	Engineering 10%			50,400.00
	Administration 10%			50,400.00
	Contingencies			50,200.00
	Total			$655,000.00

V. ENVIRONMENTAL ASSESSMENT

The project would have minimal environmental impacts. Replacing the principal spillway as in Alternative Three would improve the safety due to prevention of structural failure and soil erosion. While breaching the embankment would provide less flood protection for downstream areas and leave the surrounding area short of water supply during drought times, construction of a new dam downstream would alter the landscape in certain areas. Areas affected by the construction of the embankment would need to be re-landscaped and reseeded to native grass.

Local changes in air quality and noise levels would be noticeable during the construction phase of the project. If the project is pursued, the State Historical Society should be contacted concerning any historical, archaeological, or cultural resources that may be affected.

VI. LAND RIGHTS

The Emmons County Water Resource District and the State of North Dakota obtained the easements for the land to be flooded or inundated by the construction of Welk Dam in 1936. No additional land will need to be obtained in Alternative One, Two, and Three. Land rights, either by purchase or easement, will be required for Alternative Four, the construction of a new dam. The new site will consist of approximately 82.7 acres in Section 33, Township 131 North, Range 77 West. The cost for this land acquisition is not figured into the cost estimate proposal for the alternative. If the alternative for construction of a new dam is pursued, it is recommended that the entire reservoir be fenced. Fencing will greatly enhance the recreational aspects of the project, including improved water quality conditions.

VII. SUMMARY

Welk Dam was constructed in 1936 and the last recorded repair work that has been done on the spillway was in 1958. Thus, the existing spillway is in poor condition due to the extensive undermining, cracking, and deterioration of the wingwalls. The Emmons County Water Resource District entered into an agreement with the North Dakota State Water Commission and the North Dakota State Game and Fish Department to investigate the feasibility of repairing or replacing Welk Dam.

Four alternatives are considered that will either improve the existing spillway or construction of a new dam downstream. The first alternative consists of breaching the existing embankment and draining the reservoir. The second alternative consists of the use of gunite to restore the existing spillway. Replacing the spillway with a new outlet structure is the third alternative. The fourth alternative to be considered will be the construction of a new dam downstream.

As part of the agreement, the North Dakota State Water Commission's survey crew did a field survey of the existing site, and the proposed downstream dam site for area capacity data. Welk Dam has a normal pool surface of 1840 msl, with a Ogee weir as the principal outlet structure. At this elevation the reservoir covers 28.2 acres, maximum depth of 18.7 feet, a total volume of 205 acre-feet, and with an average depth of 7.3 feet. The top of

the embankment is at an elevation of 1849 msl, with no emergency spillway available.

An on-site structural investigation was done by the State Water Commission's construction crew to provide information to amount of undermining that has occurred to the spillway. Inspection of the spillway was performed by drilling borings (2-inch holes) across the face of the spillway. The largest void is 27 inches deep, with an average void depth of 13 inches throughout the spillway. The voids were located on the west half of the spillway. There were no voids discovered on the east half.

The first alternative discussed is the breaching of the embankment and draining the reservoir. This could be done immediately, preferably in the fall before the next spring runoff.

Breaching the embankment and draining the reservoir would eliminate the risk of damage caused by a dam failure. However, the loss of the reservoir for water supply during drought conditions and recreation may not outweigh the circumstances. The breached area would be available as a site for a new spillway which might be built at some later date. The total cost for this alternative is $18,000.

The second alternative consists of the use of gunite to restore the spillway. The amount of gunite that would be needed to fill the voids is estimated at 75 cubic yards. The total cost estimate for rehabilitation is $25,000. This rehabilitation would not include work done on the wingwalls of the spillway. Rehabilitation of the wingwalls would be impossible because of their deteriorated condition. The wingwalls could probably be replaced, but the problem would be tying them into the weir and providing stabilization for the spillway.

The third alternative is replacing the spillway with a new outlet structure. The outlet structures to be considered are corrugated metal pipes and a concrete chute. The deteriorated spillway would be removed and disposed on-site or hauled away. The outlet structure would be located in the same location as the existing Ogee weir. Because of the classification, an emergency spillway is not required for the dam. A low-level drawdown system will be implemented for removing stagnant water to improve water quality.

Two corrugated metal pipes 120 feet in length and 6 feet in diameter, will be considered as a replacement for the deteriorated spillway. The inlet will have a crest elevation of 1840 msl, with the invert of the CMP's at elevation 1828 msl. The pipes will be laid at a slope of 3.33 percent with the outlet at elevation 1824 msl. The outlet structure consists of a standard cantilevered outlet with stilling basin. The embankment would

have a 14-foot wide top at 1849 msl, with 3:1 side slopes that will tie into the existing embankment. The total cost for replacing the spillway with two CMP's is $145,000.

A concrete chute would be another option for replacement of the deteriorated spillway. The chute would be located in the same area as the original spillway. The concrete chute would be 30 feet wide, 150 feet in length, and have a crest elevation of 1840 msl. The concrete chute would have a height of 8 feet. The wingwalls on the concrete chute would be at a 3H:1V slope tying into the top of the embankment at 1849 msl. The preliminary estimated cost for a concrete chute is $315,000.

The fourth alternative would be to construct a new dam downstream from the existing dam and use the existing embankment for a settling basin. The new dam's height is 36 feet classifying the dam as classification III, according to the North Dakota Dam Design Handbook.

The principal spillway inlet will be at an elevation of 1830 msl. The new formed reservoir will have a surface area of 64.4 acres, a volume of 1088.7 acre-feet. The maximum depth of the reservoir will be 39 feet and have an average depth of 16.9 feet. With the normal surface level at 1830 msl, an island will be formed on the reservoir. The island will have a peak elevation of 1845.5 msl and cover an area of 3.2 acres at the normal water surface level.

The principal spillway will consist of a inlet box structure, 5 1/2-foot RCP, and plunge pool. The spillway would have a 24-foot drop inlet with the pipe invert at 1806 msl. The RCP is 208 feet in length with a 2.5 percent slope with the outlet invert at elevation 1801 msl.

A low-level drawdown pipe will be implemented to discharge water into the principal spillway structure. An emergency spillway will be located on the west side of the reservoir discharging to a separate drainage basin to the west. The criteria for the dam is preliminary and a soil investigation will be needed to verify site and construction data.

The existing embankment from the dam upstream would be breached and the dam would be used as sedimentation pond. Lowering the embankment to an elevation of 1830 msl would leave the reservoir with a depth of 8.7 feet, an area of 8.2 acres, and a total volume of 34 acre-feet.

The cost estimate for a new dam would be $655,000. Land acquisition and the soil investigation are not figured into the engineer's cost estimate.

VIII. RECOMMENDATION

The existing spillway is in poor condition. Extensive undermining to the weir and deteriorating wingwalls is affecting the integrity of the dam. The spillway should be either repaired, replaced, or the dam breached. Several alternatives have been studied and are being proposed as solutions to prevent the collapse of Welk Dam due to a high runoff event. The repair of the existing spillway, construction of a new spillway, or new dam located immediately downstream are acceptable from an engineering standpoint. The estimated construction costs for each alternative are substantially different.

Cost Estimate - Alternatives

Alternatives	Cost	Life Expectancy (years)
Breach Dam	$ 18,000	Life
Repair of Existing Spillway	25,000	5-10
New Spillway		
a) CMP Spillway	145,000	20-30
b) Concrete Chute	315,000	50-60
New Embankment	655,000	50-60

If the Emmons County Water Resource District does not repair or replace the spillway, it is recommended the embankment be breached this fall at a cost of $18,000.00. The decision to proceed with one of the alternatives is the responsibility of the Emmons County Water Resource District.

APPENDIX A - AGREEMENT

SWC Project #400
January 11, 1991

A G R E E M E N T

Investigation of Repairing or Replacing Welk Dam

I. PARTIES

THIS AGREEMENT is between the North Dakota State Water Commission, hereinafter Commission, through its Secretary, David Sprynczynatyk; the North Dakota State Game and Fish Department, hereinafter Department, through its Commissioner, Lloyd Jones; and the Emmons County Water Resource District, hereinafter District, through its Chairman, Glen McCrory.

II. PROJECT, PURPOSE, AND LOCATION

The District and the Department have requested the Commission to investigate the feasibility of repairing or replacing of Welk Dam. The dam is located in Section 33, Township 131 North, Range 77 West, near Strasburg, North Dakota. The purpose of this agreement is to acquire the proper topographic data necessary for preliminary design to repair and improve the existing dam, and a preliminary design for a new dam downstream.

III. PRELIMINARY INVESTIGATION

The parties agree that further information is necessary concerning the proposed project. Therefore, the Commission shall conduct the following:

1. A field survey of the existing embankment, reservoir and the proposed new dam site which includes topographic data and area-capacity data;

2. A study of the hydrology of the watershed upstream of the dam;

3. A preliminary design of the outlet works necessary to safely and efficiently pass the design flood through the existing dam and the proposed new dam;

4. Preliminary cost estimates for the repairing or replacing of the dam; and

5. Prepare a preliminary engineering report presenting the results of the investigation.

IV. COSTS

The District and Department shall each deposit $1,800 with the Commission prior to investigation commencement to help defray the Commissions costs associated with this investigation.

V. RIGHTS-OF ENTRY

The District agrees to obtain written permission from any affected landowners for any field investigations by the Commission, which are required for the preliminary investigation.

V. INDEMNIFICATION

The District hereby accepts responsibility for and holds the Commission, the Department, their employees, their agents, the State Engineer, and the Commissioner free from all claims and damages to public or private property, rights, or persons arising out of this investigation. In the event a suit is initiated or judgment rendered against the Commission, the Department, their

employees, or agents, the District shall indemnify them for any judgment arrived at or judgement satisfied.

VII. CHANGES TO THE AGREEMENT

Changes to any contractual provisions herein will not be effective or binding unless such changes are made in writing, signed by all parties and attached hereto.

NORTH DAKOTA STATE WATER COMMISSION
By:

DAVID A. SPRYNCZYNATYK
Secretary

DATE:
18 Jan 91

WITNESS:
Dale L Frink

NORTH DAKOTA GAME AND FISH DEPARTMENT
By:

LLOYD JONES
Commissioner

DATE:
1/22/91

WITNESS:

EMMONS COUNTY WATER RESOURCE DISTRICT
By:

GLEN MCCRORY
Chairman

DATE:
1/28/91

WITNESS:
Helen Kenschler

APPENDIX B - WATER QUALITY ANALYSIS

NORTH DAKOTA
STATE DEPARTMENT OF HEALTH
AND CONSOLIDATED LABORATORIES
State Capitol
600 E. Boulevard Avenue
Bismarck, North Dakota 58505-0200

ENVIRONMENTAL HEALTH SECTION

1200 Missouri Avenue
P.O. Box 5520
Bismarck, North Dakota 58502-5520
Fax #701-258-0052

June 11, 1991

Stan Hanson
Division of Engineering
North Dakota State Water Commission
900 East Boulevard
Bismarck, ND 58505

Dear Mr. Hanson:

Enclosed are the results of the water quality samples collected at Welk Dam on May 14, 1991. These results are typical for most small reservoirs in the state. Please note the greater ammonia and phosphate concentrations at the five meter-depth interval. These greater concentrations are likely caused by the low dissolved oxygen at this depth. These results suggest a hypolimnetic withdrawal would be a practical component of any dam restoration effort on Welk Dam.

For your information, Welk Dam will continue to be sampled this summer as one of 30 lakes which will be assessed as part of the Department's Lake Water Quality Assessment Project. This assessment will also include a characterization of the lake's watershed in addition to describing the current trophic state of the lake.

If you have any questions concerning these results or the lake assessment effort, please feel free to contact me at 221-5214.

Sincerely,

Michael J. Ell
Environmental Scientist
Division of Water Quality

MJE:krh
Enc.
cc: Fred Ryckman, Game and Fish Department - Bismarck
Gene Van Eckout, Game and Fish Department - Jamestown

North Dakota State Department of Health
Division of Water Quality

Lake or River Name Wilk Dam Storet No. 381325

Observer M. ECC Date 5-14-91 Time 14:30

Location Description SW of spillway deepest area

Ambient Temp. 75-80 Wind Speed & Direction SE 10-20

Cloud Cover 30 % of 100 County Emmons Secchi 2.3 (m)

Comments good clarity. Lot of turtles

Depth (m) or Location	Sample Collected	Temp (C)	D.O. (mg/l)	Comments
0		18.6°	13.4	
1	X	18.5	13.4	
2		18.2	13.2	
3		17.5	12.3	
4		16.2	10.4	
5	X	13.8	2.8	Bottom
~~5~~ 4.5		13.8	5.0	
6				

Revised 12/10/90

North Dakota State Department of Health
and Consolidated Laboratories
6/ 6/91
Emmons County

Log Number: 91-R228 Type: 2

Date Collected: 5/14/91 Date Received: 5/15/91
Time Collected: 14:30 Time Received: 8:55
Site: 381325 Welk Dam
SW of spillway deepest area
Collected by: Mike Ell
Comments:

Analyte		Result		Uncertainty		Date	Time	Analyst
Copper (Cu)	{ 1129}	(14	ug/L	5.0	ug/L	5/22/91	8:49	Mike
Zinc (Zn)	{ 1130}	43.	ug/L	4.	ug/L	5/22/91	8:49	Mike
Barium (Ba)	{ 1156}	55.5	ug/L	5.16	ug/L	5/22/91	8:49	Mike
Sodium (Na)	{ 1211}	367.	mg/L	35.1	mg/L	5/21/91	9:12	Mike
Magnesium (Mg)	{ 1212}	39.2	mg/L	3.1	mg/L	5/21/91	9:12	Mike
Potassium (K)	{ 1219}	22.0	mg/L	1.47	mg/L	5/21/91	9:12	Mike
Calcium (Ca)	{ 1220}	49.3	mg/L	4.55	mg/L	5/21/91	9:12	Mike
Manganese (Mn)	{ 1225}	0.040	mg/L	0.003	mg/L	5/21/91	9:12	Mike
Iron (Fe)	{ 1226}	0.126	mg/L	0.011	mg/L	5/21/91	9:12	Mike
Chromium (Cr)	{ 4124}	1.17	ug/l	0.50	ug/l	6/ 3/91	11:00	Sujit
Arsenic (As)	{ 4133}	13.3	ug/l	3.0	ug/l	5/30/91	13:00	Sujit
Selenium (Se)	{ 4134}	5.	ug/l	3.	ug/l	5/21/91	12:00	Sujit
Cadmium (Cd)	{ 4148}	(0.2	ug/l	0.20	ug/l	5/24/91	14:00	Sujit
Lead (Pb)	{ 4182}	2.2	ug/L	1.0	ug/L	5/20/91	15:15	Sujit
Chloride	{ 5217}	13.0	mg/l	1.6	mg/l	5/22/91	14:00	Kolleen
Depth	{ 9050}	1.0	Meters		Meters	5/14/91	14:30	Other
Ammonia (N)	{ 9085}	0.022	mg/l	0.002	mg/l	5/16/91	17:10	Kolleen
pH	{ 9305}	8.90				5/15/91	10:47 *	Jeni
Carbonate (CO3)	{ 9310}	52.	mg/l	10.	mg/l	5/15/91	11:25	Jeni
Bicarbonate (HCO3)	{ 9315}	511.	mg/l	10.	mg/l	5/15/91	11:25	Jeni
Hydroxide (OH)	{ 9320}	0.	mg/l	1.	mg/l	5/15/91	11:25	Jeni
Total Alkalinity (CaCO3)	{ 9325}	505.	mg/l	10.	mg/l	5/15/91	11:25	Jeni
Conductivity	{ 9330}	1807.	umhos/cm		umhos/cm	5/15/91	11:01	Jeni
Phosphate (Total) (P)	{ 9415}	0.648	mg/l	0.056	mg/l	5/15/91	16:30	Kolleen
Sulfate as (SO4)	{ 9440}	523.	mg/l	54.	mg/l	5/22/91	11:30	Kolleen
Nitrate + Nitrite (N) Tot	{ 9557}	0.015	mg/l	0.005	mg/l	5/21/91	11:00	Kolleen
Total Kjeldahl Nitrogen	{ 9575}	2.63	mg/l	0.339	mg/l	6/ 4/91	15:45	Kolleen
Total Hardness (as CaCO3)	{ 9840}	285.	mg/l		mg/l			
Cation Sum	{ 9905}	22.23	me/l		me/l			
Anion Sum	{ 9910}	21.37	me/l		me/l			
Difference	{ 9915}	0.856	me/l		me/l			
Percent Difference	{ 9920}	1.96	%		%			
Percent Sodium	{ 9925}	73.6	%		%			
Sodium Adsorption Ratio	{ 9930}	9.46						
Total Dissolved Solids(C)	{ 9935}	1320	mg/l		mg/l			

* Exceeded EPA Holding Time

Per. Kollien Koppinger Chemist

North Dakota State Department of Health
and Consolidated Laboratories
6/ 6/91
Emmons County

Log Number: 91-R230 Type: 2

Date Collected: 5/14/91 Date Received: 5/15/91
Time Collected: 14:30 Time Received: 8:55
Site: 381325 Welk Dam
SW of spillway deepest area
Collected by: Mike Olson
Comments:

Analyte		Result		Uncertainty		Date	Time	Analyst
Copper (Cu)	{ 1129}	< 14	ug/L	5.0	ug/L	5/22/91	10:51	Mike
Zinc (Zn)	{ 1130}	31.	ug/L	3.	ug/L	5/22/91	10:51	Mike
Barium (Ba)	{ 1156}	62.3	ug/L	5.79	ug/L	5/22/91	10:51	Mike
Sodium (Na)	{ 1211}	339.	mg/L	32.4	mg/L	5/21/91	9:12	Mike
Magnesium (Mg)	{ 1212}	36.0	mg/L	2.9	mg/L	5/21/91	9:12	Mike
Potassium (K)	{ 1219}	19.7	mg/L	1.32	mg/L	5/21/91	9:12	Mike
Calcium (Ca)	{ 1220}	45.0	mg/L	4.15	mg/L	5/21/91	9:12	Mike
Manganese (Mn)	{ 1225}	0.081	mg/L	0.006	mg/L	5/21/91	9:12	Mike
Iron (Fe)	{ 1226}	0.145	mg/L	0.013	mg/L	5/21/91	9:12	Mike
Chromium (Cr)	{ 4124}	1.61	ug/l	0.50	ug/l	6/ 3/91	11:00	Sujit
Arsenic (As)	{ 4133}	14.2	ug/l	3.0	ug/l	5/30/91	13:00	Sujit
Selenium (Se)	{ 4134}	4.	ug/l	3.	ug/l	5/21/91	12:00	Sujit
Cadmium (Cd)	{ 4148}	< 0.2	ug/l	0.20	ug/l	5/24/91	14:00	Sujit
Lead (Pb)	{ 4182}	1.9	ug/L	1.0	ug/L	5/20/91	15:15	Sujit
Chloride	{ 5217}	13.6	mg/l	1.7	mg/l	5/22/91	14:00	Kolleen
Depth	{ 9050}	5.0	Meters		Meters	5/14/91	14:30	Other
Ammonia (N)	{ 9085}	0.253	mg/l	0.020	mg/l	5/16/91	17:10	Kolleen
pH	{ 9305}	8.71				5/15/91	10:47 *	Jeni
Carbonate (CO3)	{ 9310}	37.	mg/l	10.	mg/l	5/15/91	11:25	Jeni
Bicarbonate (HCO3)	{ 9315}	543.	mg/l	10.	mg/l	5/15/91	11:25	Jeni
Hydroxide (OH)	{ 9320}	0.	mg/l	1.	mg/l	5/15/91	11:25	Jeni
Total Alkalinity (CaCO3)	{ 9325}	506.	mg/l	10.	mg/l	5/15/91	11:25	Jeni
Conductivity	{ 9330}	1796.	umhos/cm		umhos/cm	5/15/91	11:01	Jeni
Phosphate (Total) (P)	{ 9415}	0.792	mg/l	0.068	mg/l	5/15/91	16:30	Kolleen
Sulfate as (SO4)	{ 9440}	497.	mg/l	52.	mg/l	5/22/91	11:30	Kolleen
Nitrate + Nitrite (N) Tot	{ 9557}	0.043	mg/l	0.005	mg/l	5/21/91	11:00	Kolleen
Total Kjeldahl Nitrogen	{ 9575}	2.19	mg/l	0.282	mg/l	6/ 4/91	15:45	Kolleen
Total Hardness (as CaCO3)	{ 9840}	261.	mg/l		mg/l			
Cation Sum	{ 9905}	20.49	me/l		me/l			
Anion Sum	{ 9910}	20.87	me/l		me/l			
Difference	{ 9915}	-0.385	me/l		me/l			
Percent Difference	{ 9920}	-0.93	%		%			
Percent Sodium	{ 9925}	73.8	%		%			
Sodium Adsorption Ratio	{ 9930}	9.13						
Total Dissolved Solids(C)	{ 9935}	1250	mg/l		mg/l			

* Exceeded EPA Holding Time

Per. Kolleen Koppinger Chemist