US Army Corps of Engineers

December 1981

FINAL REPORT TO CONGRESS

THE STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION ACT OF 1974 SECTION 32, PUBLIC LAW 93-251

Appendix E - Missouri River Demonstration Projects

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Rock Toe With Tie-Backs

Precast Block Paving

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THE STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION ACT OF 1974 SECTION 32, PUBLIC LAW 93-251

APPENDIX E

MISSOURI RIVER DEMONSTRATION PROJECTS

VOLUME 1 OF 2

Consisting of

A COMPREHENSIVE SUMMARY REPORT ON TWENTY-EIGHT STREAMBANK EROSION CONTROL DEMONSTRATION PROJECTS ON THE MISSOURI RIVER IN THE THREE REACHES: GARRISON DAM TO LAKE OAHE, FT. RANDALL DAM TO NIOBRARA, AND GAVINS POINT DAM TO PONCA

U.S. ARMY CORPS OF ENGINEERS
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APPENDIX E

Missouri River Demonstration Projects

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MISSOURI RIVER, GARRISON DAM TO
LAKE OAHE, NORTH DAKOTA

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Section 32 Program Streambank Erosion Control Evaluation and Demonstration Act of 1974

MISSOURI RIVER, GARRISON DAM TO LAKE OAHE, NORTH DAKOTA DEMONSTRATION PROJECT REPORT

I - INTRODUCTION

A. PROJECT NAMES AND LOCATIONS.

Seventeen demonstration projects have been constructed on the Missouri River in this reach between Garrison Dam and Lake Oahe. The names and locations of all the demonstration projects are shown in Table 1-1. All locations are designated according to 1960 river mileage.

B. AUTHORITY.

The authority for the projects in this reach is the Streambank Erosion Control Evaluation and Demonstration Act of 1974, Section 32, Public Law 93-251, as amended by P.L. 94-587, Water Resources Development Act of 1976, Section 161.

C. PURPOSE AND SCOPE.

The purpose and scope of this report is to describe the bank erosion problems, the types of bank protection used, and evaluate the performance of the 17 Section 32 demonstration projects on the Missouri River, between Garrison Dam and Lake Oahe, constructed and monitored by the Omaha District.

D. PROBLEM RÉSUMÉ.

Essentially all river stages in the open reach of the river downstream of Garrison Dam and above Lake Oahe have been confined within

Table 1-1
SECTION 32, GARRISON DAM TO LAKE OAHE

Project Name	Bank	Project Limits 1960 River Mileage	Status	Initial Project Completion Date
Eagle Park	L	1324.6-1322.0	completed	Aug 77
Sandstone Bluff I	L	1369.3-1367.4	completed	Jul 79
Sandstone Bluff II	L	1367.4-1365.5	completed	Jul 79
Lewis & Clark 4-H Camp	L	1358.0-1356.5	completed	Aug 79
Sanger	R	1346.0-1345.0	completed	Nov 79
Burnt Creek	L	1322.0-1320.0	completed	Jul 80
I-94	R	1318.5-1316.0	completed	Sep 80
Pretty Point (Phase I)	R	1343.8-1342.4	completed	Aug 81
Price I (Phase I)	R	1342.4-1339.0	completed	Aug 81
Coal Lake Coulee (Phase I)	L	1359.2-1358.6	completed	Jun 81
Knife Point I (Phase I)	L	1374.0-1373.3	completed	Jun 81
Wildwood (Phase I)	L	1345.1-1344.2	completed	May 81
Price II (Phase I)	L	1338.8-1338.0	completed	May 81
Fort Lincoln (Phase I)	R	1311.1-1309.8	completed	Jun 81
Horseshoe Butte (Phase I)	R	1335.7-1334.0	completed	Jun 81
Knife Point II (Phase I)	R	1380.2-1378.8	completed	Jun 81
Hancock (Phase I)	R	1386.0-1384.5	completed	Jun 81

the channel below the high river banks with the exception of short reaches near the mouths of the Knife and Heart Rivers. The Knife and Heart River areas are occasionally subject to flooding from tributary runoff. Overbank flooding has been essentially eliminated since closure of Garrison Dam in 1955 which controls river flows in this reach. This is in contrast to pre-dam conditions when overbank flooding occurred practically every year. Sediment loads in this reach consist of bed material load derived from the river bed, and bed material and wash load derived from eroded river banks.

Bank erosion in this reach results in a permanent net loss of high valley lands. High valley lands are being converted to river channel and sand bar areas, while the width between high banks continues to increase. This process, unless halted, would eventually transform the present river into a wide area of sand bars and channels, occupying an increasing proportion of the valley width between bluffs.

There are about 109 miles of erodible bankline in the reach between Garrison Dam and Lake Oahe. Between 1954 and 1975 the total high overbank area lost to erosion in this reach amounted to 1,692 acres. This is equivalent to 1.1 acres per river mile per year. Within this reach the loss of high bank land in any one year is usually concentrated over a few thousand feet of bankline in one or more locations. The location of active erosion may shift from place to place with time. Over the years every stretch of erodible bankline is potentially subject to active erosion. The continuing threat of bankline erosion is a particular problem for those activities where proximity to the river bank is either desirable or necessary. These include but are not limited to irrigation intakes, summer homes, power plant intakes, and recreation facilities. The preservation of forest land is of special concern since much of the remaining uncleared woodlands in the Missouri River bottoms are concentrated near the river banks.

II-HISTORICAL DESCRIPTION

A. GENERAL DESCRIPTION

1. GEOMORPHOLOGY

a. Physiography. The Garrison Dam to Lake Oahe reach of the Missouri River is a part of the Missouri Plateau section of the Great Plains Physiographic Province. The region to the east of the Missouri River has a distinctly glaciated terrain, mantled by glacial drift that averages 100 feet in thickness. These glacial deposits have altered all but the major preglacial topographic features and have obliterated the former drainage patterns east of the Missouri River. Smooth ground moraine areas are set off by hummocky topography of end or terminal moraines. Large areas of the plateau are characterized by outwash channels, lake bed depressions and other features inherent to glaciation. West of the Missouri River, although having some glacial features, is mainly a well-drained, rolling country of moderate relief. There are glacial deposits filling the valleys, but preglacial features have not been so altered as those east of the Missouri River. Bedrock formations (Fort Union beds) are more conspicuously exposed in the higher ground. In this area, the glacial drift is much older than that east of the river and a mature drainage pattern has developed over the terrain.

b. Topography. The Missouri valley in this region varies from 2 to 4 miles in width and has entrenched its valley 200 to 600 feet below the general level of the plateau. It has a distinct flood plain floor upon which the Missouri River meanders from one side to the other in a series of large bends and loops. The bluffs along the valley sides are high and gullied. In many places where the river flows against the bluffs, steep cliffs have been cut. Young tributary gullies extend back into the highlands for distances up to 5 miles and have developed a badlands topography that fringes the main valley in many places. Prominent terraces are developed along the main valley. These occur at all levels from the crest of the valley sides down to almost flood plain level. These terraces appear to be old abandoned levels of the ancient riverbed. They are definitely stream cut and many of them contain large deposits of sands and gravels. The gradient of the river along this reach varies between 0.75 and one foot per mile.

c. **Geology**. Bedrock along this reach of the Missouri River consists of sedimentary deposits of the lower Tertiary Period (Paleocene Epoch). The two formations encountered along this reach are, in ascending order, the Cannonball Formation and the Tongue River Formation, which together form the Fort Union Group. The Fort Union deposits are, for the most part, of shallow marine or continental orgin. The bedrock along the upstream portion of this reach and in the vicinity of Garrison Dam is the Tongue River Formation. The Tongue River Formation is composed of calcareous sandstone, clayey and silty shale, and lignite. As the river approaches Washburn, North Dakota, the Cannonball becomes the most prominent formation. The Cannonball consists of marine sandstones and shales. These formations are exposed primarily along the walls of the valley as they are buried by the valley overburden of the flood plain.

Evidence indicates the floor of the valley along this reach has been scoured out to a maximum depth of about 200 feet below the present river level. However, it is most often less. The materials that have filled the valley are sands, gravels, clay (alluvium and colluvium), and glacial till. The overburden along the valley walls consist primarily of glacial till in the higher elevations, while alluvium and terrace deposits are common at lower elevations. A geologic profile at the Garrison Dam site is shown on plate 0-2.

2. **RIVERBANK DESCRIPTION.**

a. **Bank Soil Types.** Bank material adjacent to river channels are formed of fine to medium textured alluvium deposits. Particles sizes vary from a fine grained clay to a coarse gravel; with silty fine sand, sandy silt and fine sand the predominant texture.

b. **Upper Bank Land Use.** Although most of the Missouri River floodplain has been converted to agricultural use (cropland and hayland), considerable riparian woodland remains. Most woodland areas range from 50 to 250 acres in size. Except for the Game Management Areas (lands administered by the North Dakota Game and Fish Department), the woodlands are used extensively for cattle pasture and feedlots.

3. **HYDROLOGIC CHARACTERISTICS.** The climate of the reach of the Missouri River from Garrison Dam to Bismarck is semi-arid. In an average year the annual precipitation totals 17 inches. More than 75 percent of this amount falls during the six month period of April through September. June normally is the wettest month with an average of 3.9 inches. December is normally the driest month with an average of .4 inch.

Daily maximum temperatures for July, the warmest month, average 84° F, with daily minimum temperatures averaging 58° F. In January, the coldest month, daily maximum temperatures average 19° F, while daily minimum temperatures average -2° F. The average freeze-free period is 134 days, from May 13 to September 24.

The Missouri River generally is frozen over from November 25 to April 1, with the ice reaching a thickness of about 29 inches by the end of February. Flow is controlled by Garrison Dam, which virtually eliminates the threat of serious floods. In general, major flooding on the tributaries to this reach is usually a result of the spring snow melt runoff. The maximum discharge recorded on the Knife River at Hazen was 35,300 c.f.s. on June 24, 1966. The maximum discharge recorded on the Heart River near Mandan was 30,500 c.f.s. on April 19, 1950. The projected 100-year release from Garrison Dam is 70,000 c.f.s.

4. **EXISTING CHANNEL CONDITIONS.** Between Garrison Dam and Lake Oahe there are presently a total of 87 unprotected open river miles. The river channel width between high banks is about 2,100 feet. Essentially all river stages in the open river reach downstream from the dam have been confined within the channel below the high river banks.

The river channel area between high banks contained three characteristic areas: the normal flow channel, high sand bars, and islands. The normal flow channel lies in a sandy bed that has been degrading slowly since the closing of Garrison Dam. The degradation has been accompanied by channel meandering and braiding. Between the high banks, bar areas give way to the channel and channel areas become bars. Main channels fill in to become inactive chutes, and secondary channels open up to become main channels. The location of the normal flow channel continually shifts in response to these processes, resulting in a gradual widening of the area occupied by channel, sand bars, and islands.

5. **ENVIRONMENTAL CONDITIONS.** The Missouri River provides the highest quality river fishery in North Dakota. Primary game fish species are walleye, sauger, northern pike, rainbow and brown trout, and coho and chinook salmon. Important nongame species include channel catfish, white bass, goldeyes, carp, buffalo and shovelnose sturgeon. The river has been rated as Class I, Highest Valued Fishery Resource by the NDGFD. It provides fish species that are of high interest to area anglers. The good quality, cold water that is released at Garrison Dam helps to maintain the fishery.

The riparian woodlands found along the Missouri River provides some of the best habitat in the state. Two big game species, white-tailed deer and turkeys, attain their highest population levels along the Missouri River. Recent NDGFD surveys indicate that approximately 3,000 deer and 2,000-2,500 turkeys winter between Garrison Dam and Bismarck. In addition, waterfowl rest during migration on the numerous sandbars. In an average year, 2,000-4,000 mallard ducks winter on the open river below the dam.

The Missouri River also provides quality habitat for a wide range of resident nongame species including a host of songbirds and small mammals. Avian species include the red-tailed hawk, brown thresher, least flycatcher, western meadowlark and orchard oriole. Common mammal species include beaver, muskrat, long-tailed weasel and badger. Least terns, uncommon in North Dakota, have been known to nest on the numerous sandbars on the Missouri River.

Endangered Species that range in the area include the bald eagle, peregrine falcon and whooping crane. All are migrants in the area. Bald eagles winter in the river reach, and are also known to nest in the region. Whooping crane and peregrine falcon sitings are uncommon, but bald and golden eagles are common along the river. Most of the eagle use occurs in a reach 10 miles downstream from Garrison Dam. Peak eagle numbers usually occur in December as eagles migrate south, and in March on the return migration.

B. DEMONSTRATION PROJECT REACH

1. HYDRAULIC CHARACTERISTICS.

a. Channel Widths and Depths. The flood plain width (distance between high bank) averages over 2,100 feet and varies from 1,200 feet to over 5,000 feet in some areas. The main channel widths range from

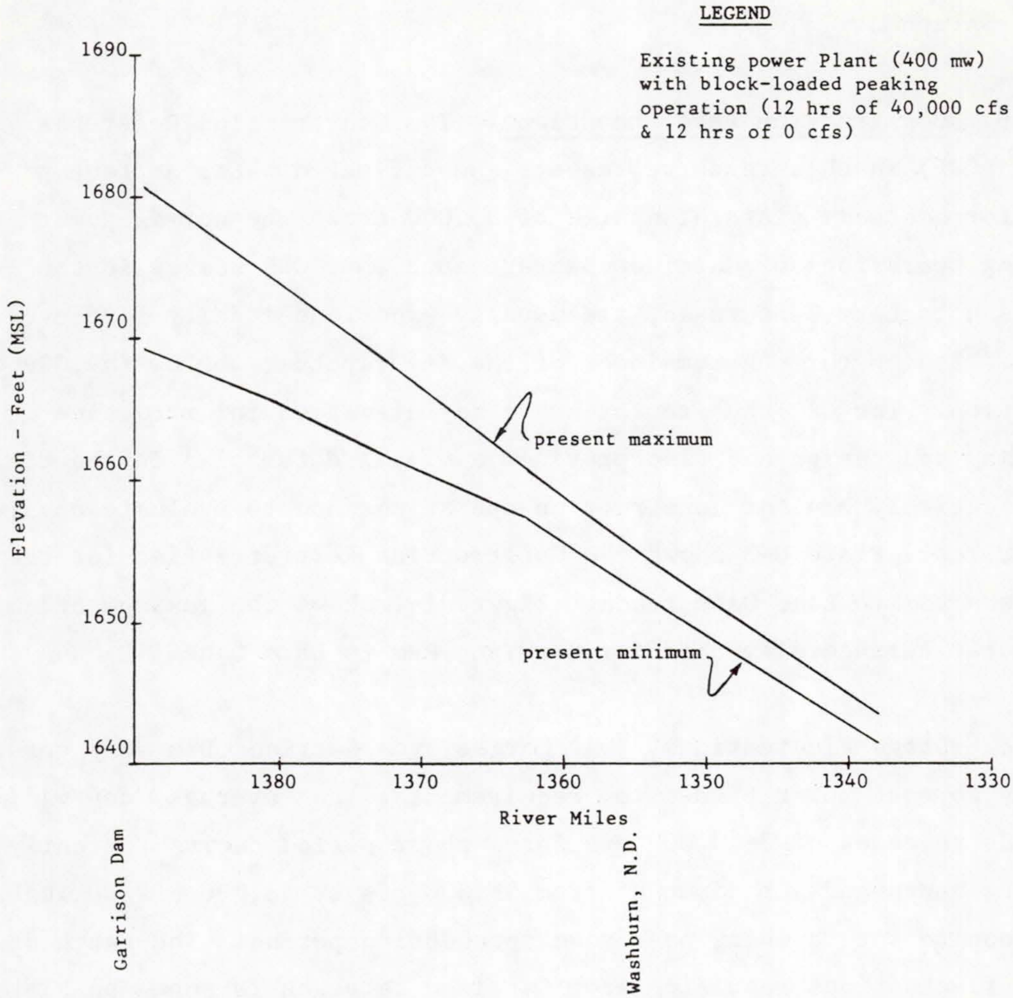
400 feet and 20 feet. The main channel widths and depths vary each day due to the routine power peaking operations of Garrison Dam which causes sizable fluctuation in daily releases, as discussed in subparagraph c.

b. **Construction Reference Plane.** The Construction Reference Plane (CRP) in this reach represents the estimated water surface profile for a steady state discharge of 35,000 cfs. The normal power peaking operations of Garrison Dam are such that CRP stages in the Garrison to Lake Oahe reach, are usually experienced daily for several hours. Stages for the remainder of the day fluctuate below the CRP elevation. The CRP thus represents a key elevation for structure planning and design and also provides a visual datum plan in the field to effectively monitor construction operations and to evaluate completed structures. Plate 0-3 shows the Construction Reference Plan for the Garrison Dam to Lake Oahe reach. Figure 1-1 shows the maximum and minimum water surface elevation for Garrison Dam to Lake Oahe.

c. **Stage Fluctuations.** Discharges from Garrison Dam vary considerably to meet power production requirements. An "average" day will include releases of 0-10,000 cfs for a short period during the early morning hours and a maximum of from 35,000 cfs to 38,000 cfs during the forenoon to late evening peak power proudction period. The range of stage fluctuations resulting from Garrison releases is shown on Plate 0-3. Plate 0-4 indicates the flow duration curve for Garrison Dam to Lake Oahe reach.

FIGURE 1-1

DOWNSTREAM WATER SURFACE PROFILES
BELOW GARRISON DAM



d. Sediment Characteristics. The sediment characteristics of the Garrison to Oahe reach are typical of a reach in a state of degradation, in which the upstream reservoir traps virtually all incoming sediment load. Sediment load in the downstream reaches, therefore, consist of bed material load derived from the river bed, and bed material and wash load derived from eroded river banks and tributary inflows. The average annual measured load ranges from 0 downstream of the Dam to 7,621,000 tons per year at the Bismarck sediment measuring station. Variation in the annual sediment loads over the past twenty years has ranged from 2,346,800 tons in 1977 to 15,367,080 tons in 1971. A tabulation of the average annual measured load at Bismarck since closure of Garrison Dam is given in Table 1-2. The channel bed is thought to be armored with a layer of relatively nonmovable coarse sands, gravels and cobbles for a distance of approximately 3 miles downstream of the Dam. Downstream of the armored reach the bed surface is composed of coarse to fine grained sediments with the D50 grain sizes averaging about 0.7 mm at the upstream end of the reach and decreasing exponentially to a value of approximately 0.25 mm fifty miles downstream. The average monthly values for the percent sand, silt and clay distributions of the suspended material, including the D10, the D50 and the D90 particle size gradations of the bed material, at the downstream end of the degradation reach near Bismarck, North Dakota is given in Table 1-3. From this table it can be seen that approximately 27% of the measured suspended load is silt and clay while the remaining 71% is made up of suspended sand size particles. Approximately 50% of the bed material is finer than .23 mm.

Table 1-2

WATER DISCHARGE AND SUSPENDED SEDIMENT RECORD AT BISMARCK, NORTH DAKOTA

	WATER DISCHARGE AND SEDIMENT LOAD RECORD				
YEAR	DISCHARGE (AC-FT)	SEDIMENT (TONS/YR)	YEAR	DISCHARGE (AC-FT)	SEDIMENT (TONS/YR)
1947	21,010,000	94,196,330	1963	10,440,000	3,816,000
1948	21,620,000	77,226,550	1964	14,380,000	6,487,000
1949	18,334,200	45,298,080	1965	17,130,000	12,741,000
1950	17,360,000	52,597,800	1966	15,670,000	7,481,000
1951	20,120,000	47,054,300	1967	19,250,000	8,821,000
1952	22,795,000	69,548,500	1968	18,260,000	8,211,000
1953	16,520,000	41,312,200	1969	21,760,000	8,105,000
1954	17,660,000	15,818,660	1970	20,520,000	9,714,490
1955	13,880,000	10,794,000	1971	23,330,000	15,367,080
1956	14,940,000	9,862,000	1972	22,750,000	14,381,000
1957	11,310,000	5,448,000	1973	16,695,000	3,933,100
1958	12,650,000	5,760,000	1974	18,354,000	4,366,900
1959	13,400,000	5,339,000	1975	25,798,000	6,621,800
1960	10,419,000	3,419,000	1976	24,652,000	6,387,400
1961	11,650,000	4,119,000	1977	16,620,000	2,346,800
1962	13,610,000	6,170,000	1978	20,050,000	4,415,300

Table 1-3

SUMMARY OF SEDIMENT PARTICLE SIZE ANALYSIS MISSOURI RIVER AT BISMARCK, NORTH DAKOTA

Month	Average Suspended Particle Size By Percent Finer			Average Bed Particle Size for Selected Percentages in Millimeters		
	Sand (%)	Clay (%)	Silt + Clay (%)	10% (mm)	50% (mm)	90% (mm)
Oct	81	--	19	0.41	0.23	0.14
Nov	83	--	17	0.41	0.23	0.14
Dec	84	--	16	0.41	0.23	0.14
Jan	43	--	57	0.43	0.22	0.19
Feb	66	--	34	0.50	0.24	0.12
Mar	57	41	43	0.40	0.23	0.15
Apr	68		32	0.51	0.26	0.17
May	63		37	0.55	0.25	0.16
Jun	73		27	0.45	0.24	0.14
Jul	79		21	0.59	0.22	0.14
Aug	79		21	0.34	0.23	0.15
Sep	74		26	0.38	0.23	0.14

Suspended Sample Period: 1965 Thru 1967 Water Year

Bed Sample Period: 1964 Thru 1967 Water Year

e. **Degradation.** Degradation in this reach, since the closure of Garrison Dam in 1955, ranges from 8 feet immediately below the dam to about 2 feet, 50 miles downstream. Degradation in the reach immediately below the dam is currently averaging about 0.2 feet per year.

f. **Streambank Erosion Rates.** Aerial photography surveys for different years have been analyzed to obtain estimates of valley lands lost due to bank erosion. The results shown in Table 1-4 indicate that the average annual erosion losses since closure of Garrison Dam significantly decreased, but still remains a critical problem. The erosion rates by river mileage for the reach from Garrison Dam to Lake Oahe are shown in Table 1-5. The erosion along this reach is not limited to the high bank areas.

Islands and vegetated bar areas are also lost rapidly due to erosion. Unlike the high bank area, the higher island areas cannot be recreated naturally. Although new vegetated bar/island areas are developing it appears that the rate of higher vegetated bar/island destruction exceeds the rate of formation.

Table 1-4

MISSOURI RIVER BANK EROSION LOSSES GARRISON DAM TO BISMARCK, NORTH DAKOTA

Period	Length of Time (years)	Total Erosion Loss (acres)	Erosion Average Loss (acres/year)
1938-1946	8.0	1394	174
1946-1954	8.0	2167	271
1954-1958	2.0	215	108
1956-1958	2.0	183	92
1958-1960	1.8	192	106
1960-1964	4.2	355	85
1964-1968	4.3	271	63
1968-1972	4.0	265	66
1972-1975	1.7	134	79
1974-1975	1.1	76	69
Pre-Dam Conditions			
1938 - 1954	16.0	3561	222
Post Dam Conditions			
1954 - 1975	21.1	1692	80

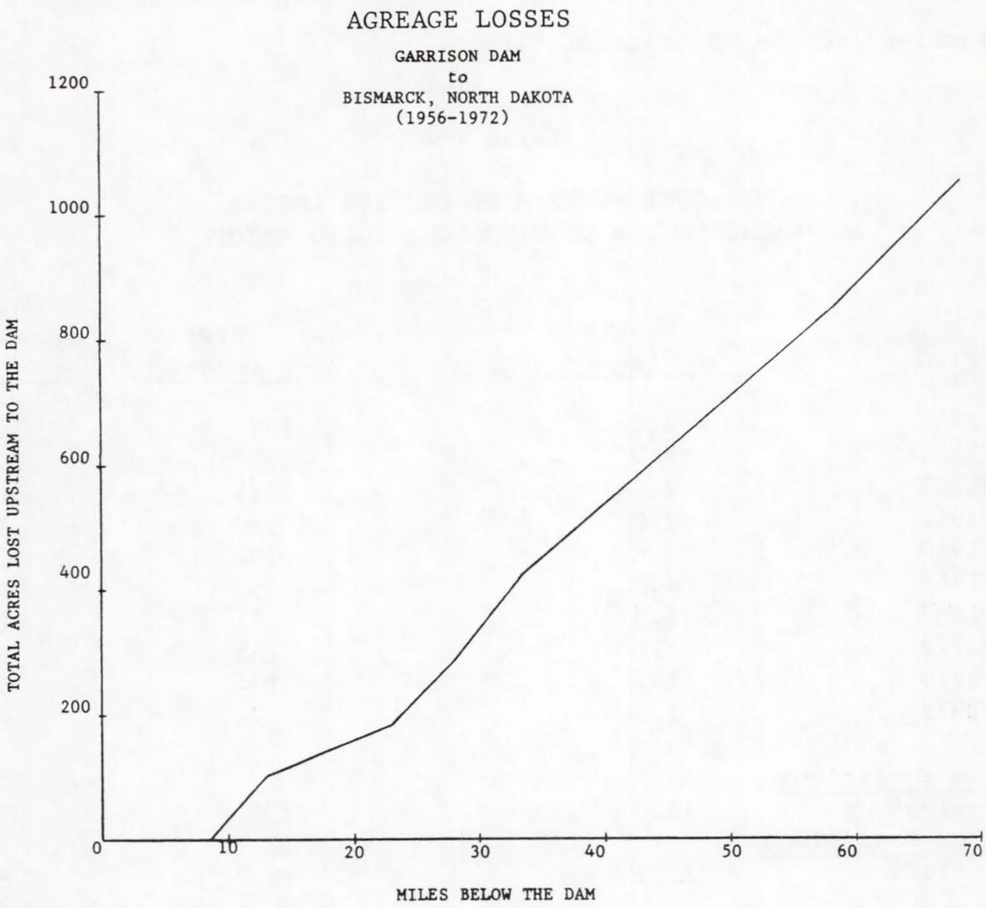
Table 1-5

EROSION RATES WITH DISTANCE DOWNSTREAM FROM DAM GARRISON DAM TO LAKE OAHE (1966 - 1975)

Miles Below Dam	Existing Power Peaking Fluctuations/Ft.	Erosion Rate (Acres/Mile/Year)
0 - 20	10.5 - 4.5	8.0
20 - 40	4.5 - 1.5	22.0
40 - 60	1.5 - 0.8	20.5
60 - 79	0.8 - 0.5	18.0

The acreage losses below Garrison Dam between 1956 and 1972 are shown in Figure 1-2.

FIGURE 1-2



g. Slope. The slope of the energy grade line averages approximately 0.75 feet per mile. Since the velocity head is usually small, the slopes of the channel bottoms, the water surface and the energy grade line are nearly equal. The slope varies with time, location and river stage from approximately 0.45 feet per mile below Bismarck to 0.85 feet per mile near Washburn.

h. Bank Soil Types. The upper bank soil types at the Eagle Park, Sandstone Bluff I and II and Lewis and Clark 4-H Camp are shown in Table 1-6.

Table 1-6

EVALUATION OF NEAR BANK SOILS

Project Area	River Mile	Soil Classification	Atterberg Limits L.L.	Atterberg Limits P.I.	Gradation % Finer Than Sieve #200	#80	#40
Eagle Park	1323.0	Fat Clay, CH (Top Soil)	53	33			
		Silty Sand, SM (Bank Mat'l)	NP	NP	41	100	
Sandstone Bluff I & II	1368.0	Silty Sand, SM and	NP	NP			
		Sandy Silt, ML	27	12	67	97	100
Lewis & Clark 4-H Camp	1357.5	Fat Clay, CH (Topsoil)	61	38			
		Silty Sand, SM (Bank Mat'l)	NP	NP	30	91	100

i. **Existing Erosion Protection.** Approximately 24 percent of the channel length in the Garrison Dam to Lake Oahe reach of the Missouri River flows along sections of bluff contact which tend to stabilize the channel meander characteristics and reduce the overall streambank erosion rates. The locations of existing erosion control structures in this reach are shown in Table 1-7. These structures were constructed under other Federal Programs or are local self-help projects.

Table 1-7

EXISTING EROSION CONTROL PROTECTION (OTHER THAN SECTION 32 PROJECTS)

River Mile (1960 Mileage)	Bank
1372.5 to 1371.5	R
1371.5 to 1370.0	R
1365.0 to 1363.0	L
1365.0 to 1363.5	R
1362.3 to 1361.5	L
1361.5 to 1359.8	R
1351.5 to 1348.0	L
1351.5 to 1348.0	R
1332.5 to 1330.0	L
1332.5 to 1329.0	R
1329.0 to 1327.0	L
1329.0 to 1325.0	R

III - DESIGN AND CONSTRUCTION

A. GENERAL

In keeping with the Streambank Erosion Control Evaluation and Demonstration Act of 1974, the salient feature of each demonstration project was the control of streambank erosion by the employment of river management techniques using a variety of structural bank protection measures in combinations appropriate for local river conditions. Typical structural elements considered for each test reach were revetments, earth core dikes, and artificial hardpoints, each discussed in detail in Section III B below. The general design considerations investigated for each demonstration site are described below. Critical technical factors affecting the structural design and stability included undercutting at the toe of the bank, weathering in the zone of stage variation, and ice action. Because of the control imposed by the Garrison Dam in this reach, it was unlikely that design stages would be exceeded, or would the protection works be damaged by frequent overtopping. The river stages experienced always remained below the top of existing high banks and varied between well defined limits.

1. **FIELD CONDITIONS**. The field conditions, listed below, are physical conditions which must be evaluated to permit development of structural designs that are equally functional, constructible, and environmentally acceptable.

- Channel location and alignment (main and secondary)
- Channel geometry (cross-section)
- Bar/island formation (location orientation, elevation, material)
- Near-bank flow conditions (depth, velocity)
- Bank height, configuration, materials
- High bank land use
- Riverbed and bank material types and conditions
- Stage-duration relationship (average daily and long-term probability)

•Tributary streams and surface runoff locations

•Groundwater seepage

•Potential wind/wave erosion

•Potential boat wake wave erosion

•Existing erosion controls (natural, manmade)

•Degradation projections

2. **CONSTRUCTIBILITY FACTORS**. Constructibility factors are those practical factors relative to actual construction materials, operations, and techniques which must be considered to assure optimum project economics and to minimize potential environmental impacts.

a. Material sources (stone, earth, cobbles, gravel)

•Quality

•Quantity available

•Location from project (haul distance)

•Cost, at source (royalties, quarrying, gathering)

b. Land access to structural locations

•Haul road location and conditions

•Near bank-conditions (height, soils, vegetation)

•Mobilization and materials handling sites

c. River access (floating plant construction)

•River depths along project bankline

•Near-bank conditions

•Mobilization and material handling sites

•River depths, distance, and alignment from project site to potential mobilization and material handling sites

3. **Engineering Objectives**. Engineering objectives are those goals established to provide perspective and scope to individual project formulation and design.

- Least-cost, multipurpose problem solutions
- Materials
- Construction techniques
- Structure type, location, and orientation

4. **Environmental Objectives.** These are environmental considerations taken into account in the formulation and general design of individual projects.

- Minimize woodland clearing or the disturbance of any other sensitive or unique habitat
- Protect important or critical habitat
- Avoid disturbance of endangered fish and wildlife species during construction
- Create desirable aquatic habitat with structure configuration or various types of structure materials
- Consider structure designs that improve pedestrian and wildlife access to the water's edge
- Preserve the natural appearance and a esthetics of the waterway conceal structures with topsoil and native vegetation; low profile structures are generally less noticeable
- Avoid destruction of or protect cultural resources as appropriate

B. BASIS OF DESIGN FOR EACH TYPE OF PROTECTION

Typical bank protection schemes considered for demonstration sites in the Garrison Dam to Lake Oahe reach of the Missouri River are shown on Plates 0-7, 0-8 and 0-9 and discussed in the following paragraphs.

The range of stone material application rates for structures constructed in this reach are as follows:

Structure Type	Range of Stone Material Application Rates (Tons/Linear Foot)
Reinforced Revetment	2.8 - 6.0
Window Revetment	3.5 - 9.5
Rehabilitated Revetment	3.0 - 3.0
Composite Revetment	2.8 - 4.9
Bankline Revetment	3.0 - 3.0
Window Refusal	4.4 - 7.3
Hardpoint	6.1 - 10.3
Dike	8.2 - 8.6
Tree Retard	0.2 - 0.2

1. **REVETMENT**. Revetments consist of a facing of stone or other material placed adjacent and parallel to the bankline to protect against erosion. These structures are generally utilized where river flows are concentrated along the bank and where depths, bankline configuration or bankline conditions preclude the use of other methods.

Typical demonstration structure layouts intentionally leave 200 to 1,000 feet of unprotected bank between structure segments. The extent of interstructure erosion is limited by the prevailing water depth and velocity riverward of the structure alignment (the theoretical line connecting the riverward extremity of all the structures in the stream); the bank height and composition; and the structure spacing. As the river erodes into the bank, the flow path becomes larger since the water entering the erosion "bight" must return to the original bank location at the next downstream structure. Accordingly, the energy gradient becomes proportionally less as the size of the bight grows. Thus, at a given river stage (discharge) the bight ceases to grow when the velocity and eddy is no longer sufficient to remove material from the bank. The resulting configuration and cross section of the "stable" bank will remain stable as long as extended duration flows do not exceed the flow level which created that configuration.

Revetments in this river reach have three distinct zones in which stresses differ, and accordingly, the material requirements can be varied. The toe zone is that portion of the structure below normal low-water, subject only to river current erosion. Material in this zone must be of sufficient size and quality to resist the erosive force of the river velocities continually flowing adjacent to it; and it must be of sufficient gradation and quantity to form a reasonably dense blanket over the slope, down to the depth of anticipated maximum scour to eliminate the possibility of fines being removed through the material. This material is seldom exposed to freeze-thaw or wet-dry action, or ice and debris movement. Accordingly, material of relatively inferior mechanical properties (weak, brittle, soft, etc.) should function adequately in this zone, if of sufficient size to resist movement by the flow.

The splash zone is that portion between the normal high-water and normal low-water. This is the zone of highest stress. The material is frequently exposed to wet-dry and freeze-thaw cycles, ice and debris movement, wave-wash, and erosive river currents. These stresses will generally require high quality stone; however, some combination of gravel, clay, filter cloth, etc., may be functional here.

The bank zone is that portion above normal high-water. Material in this zone is continually exposed to weathering, and periodically exposed to high stage erosion, wave-wash, ice and debris, and traffic by animals or man. It appears that a tough vegetation cover on a graded bank would be an optimum solution. However, types of vegetation and the minimum degree of grading to provide a durable, low-maintenance solution need development. In some cases, a stronger treatment may be necessary, such as gravel, clay, soil cement, etc. General revetment applications include variations of three basic designs, as field conditions, environmental, and cultural considerations dictate.

a. Windrow Revetment.

(1) The Windrow Revetment structure, shown on Plate 0-9, consists of a linear mound of stone placed on the ground, or partially

or totally buried in the overbank. The Windrow Revetment is placed immediately adjacent and parallel to the general alignment of the eroding bank. In theory, a minimum windrow is placed first and then the bank erodes, the stone is undercut, and sloughs down the bankline and blankets the new bank at a naturally established slope. Then stone material is added on an as-needed basis until equilibrium (i.e., a stable bank) is established. This provides a structure containing the least possible amount of stone, and accordingly, the least cost for a revetment-type structure. Variable factors that require evaluation include stone gradation, mound size and shape, minimum initial application rate, size and shape of the excavated trench, structural segment lengths and spacing, and an estimate of the ultimate depth of scour. The Windrow Revetment is an excellent technique in areas where river flows are unusually deep and swift along the toe of the bankline. This technique avoids the excessive quantity of material needed to effect a fill within the water area in such situations. However, the presence of improvements or heavy timber usually necessitates substitution of alternative techniques in areas otherwise suited to windrow revetment.

(2) Two types of windrow revetments are constructed. Type A consists of a stone fill placed in a notch excavated into the existing vertical riverbank. The exposed structure surface is covered or backfilled with excavated material. Type B consists of a stone fill placed in a trench excavated landward of the existing riverbank. The structure surface and the remainder of the trench is covered or backfilled with excavated material. Type A is used in areas where minimum clearing is required and requires a 10-foot bank height above the construction reference plane. Type B is generally used where the upper bank is clear of vegetation. There is no required bank height above the construction reference plane for Type B.

b. Composite Revetment.

(1) The Composite Revetment structure, shown on Plate 0-7, technique is used where flows are concentrated along the bankline, but

where depths or curvature precludes hardpoint systems and bankline or environmental conditions preclude windrow revetment. Composite revetment consists of a toe of erosion-resistant material, an upperbank treatment covering the zone of normal seasonal fluctuations, and a freeboard zone that is generally vegetated. Toe crown elevations are normally placed at the estimated low water elevations to reduce exposure to freeze-thaw and wet-dry cycles and thus permit the use of relatively low quality erosion- resistant material in the toe. Toe material is generally placed on the natural riverbed; however, minor excavation is accomplished whenever necessary to provide an adequate structural section.

(2) The upper bank treatment generally includes erosion resistant material placed in a configuration which best satisfies aesthetic, environmental, and economic criteria. Five variations of upper bank protection techniques for composite revetments have been demonstrated. One type consists of a simple uniform blanket of gravel over the stone toe. Another type consists of a blanket of cobbles and spalls or low-grade material over the stone toe. The third type consists of a blanket of gravel or cobbles and spalls extending from the riverward crown of the revetment toe up to the construction reference plane with vegetation placed from the construction reference plane to three feet above the construction reference plane. The vegetation consists of freshly cut willow or cottonwood saplings laid in random fashion overlapping each other to largely cover the excavated slope. Filter cloth over the graded upper bank armored by a layer of gravel or cobbles and spalls is another upper bank protection technique. The fifth technique consists of a layer of rolled clay placed on the graded upper bank covered by a thin layer of gravel.

c. **Reinforced Revetment.**

(1) Reinforced revetment, shown on Plate 0-8, consists of a toe of erosion-resistant material placed somewhat riverward of the

bankline in channel depths less than ___ feet within ___ feet of the highbank. The toe is then reinforced by intermittent stone-filled tiebacks, which are placed on the riverbank or in an excavated trench and extend landward from the toe to or into the riverbank. The toe fill material may either be high quality stone, low grade material, or both. The fill material used in the tieback is generally stone. The toe material is placed on the riverbed generally parallel to the natural bankline. The toe fill crown is generally constructed to the normal water surface elevation but may be lower. The stone tiebacks slope upward from the crown of the toefill to several feet above the normal water surface elevation at the existing bankline. Between tiebacks, the upper bank may be graded to fill in the voids between tiebacks, the bank, and the toe. The upper bank surface of reinforced revetment may be covered with either gravel or topsoil and seeded to satisfy aesthetic and environmental consideration.

(2) There are five different types of reinforced revetments. Type I is utilized in deep river conditions and can be used in high or low bank conditions. The cells between tiebacks, 20 feet in length, are backfilled with excavated material to the original ground surface. Type II is utilized when a sloping narrow underwater bench exists. The intermittent tiebacks are 25 feet in length and the upper bank is sloped as necessary to provide random fill between tiebacks. Type III is utilized in shallow river conditions with a wide underwater bench. The intermittent tiebacks are 40 feet in length. The upper bank is cut and sloped as necessary to provide random fill between tiebacks. Types II and III reinforced revetment have toe crowns that slope from the construction reference plane at the landward edge to two feet below the construction reference plane at the riverward edge. Type IV is utilized in shallow or deep river conditions where a narrow underwater bench exists. The intermittent tiebacks are 25 feet in length. Type IV does not require any back fill between tiebacks. Type V is used in shallow or deep river conditions with a wide underwater bench. The

intermittent tiebacks are 40 feet in length. Type V does not require any fill between tiebacks. Types IV and V reinforced revetment have toe crowns that are placed 2 feet below the construction reference plane.

2. **HARDPOINTS**. The hardpoint structure, shown on Plate 0-9, consists of two components: a short spur 30 to 50 feet long of erosion resistant material extending from the bank into the river; and a root of erosion-resistant material 30 to 50 feet long placed in a trench excavated landward from the bankline. Hardpoint systems are used when possible in lieu of revetment systems as a more economical measure and also to develop diversity in the aquatic and near-bank-environment. They are best utilized along relatively long convex-shaped or straight bankline increments having water depths of 5 to 10 feet. The first upstream hardpoint in multi- hardpoint systems may be of heavier section than the "shaded" downstream hardpoints, or all other hardpoints in the series. The crown width of the spur varies up to 10 feet maximum and is generally inversely proportional to water depth. This width may also reflect maintenance and access considerations. The crown elevation is generally at the normal water surface at the riverward end, and slopes up to varying elevations at the bankline, depending on bank height and root types. There are two basic root types: a deep "V" trench excavation for high banks and a wide, shallow trench for low banks. Spurs are angled 10°-20° downstream of the normal to the bankline and are designed to provide an adequate amount of material to withstand anticipated scour conditions.

3. **EARTH CORE DIKE**. The Earth Core Dike structure consists of a mounded sandfill dike extending riverward of the bankline protected on its upstream face by a stone toe and covered by a thin layer of rock. A stone-filled root is excavated into the bankline to prevent flanking of the structure. This dike may incorporate a specially designed flow control section to permit a limited flow through the

structure which would preserve or enhance downstream aquatic habitat. The structure serves to hold higher-velocity flows away from the erodible high bank, and may be curved downstream to produce a "shadow" effect; that is, erosion- producing flows may not return to the bankline for some distance downstream of the earth core dike terminus. These dikes are generally constructed at a time when shallow water areas exist and where immmediately available earth or sand can be borrowed to construct the fill.

4. **WINDROW REFUSAL**. A windrow refusal is usually constructed at the upstream end of each revetment segment to prevent flanking of the revetment as the interstructure bight develops and flow concentrations return to the original bank location. Each refusal generally consists of erosion-resistant material placed in a 30 to 100 foot trench excavated landward from the bankline. Refusals are usually angled 10° - 20° downstream of the normal to the bankline, depending upon local bankline conditions.

5. **TREE RETARDS**. Tree retards consist of locally available trees placed horizontally in the river and perpendicular to the bank at a designed spacing. Each tree retard unit will generally consist of two trees, each 30 to 40 feet in length, spaced approximately 100 feet apart. The trees will be anchored well below the water level by cable and 55-gallon concrete filled drums. A small stone root will anchor and protect the landward end of each retard. It will consist of a trench excavated, as necessary, from the riverbed to a point about 5 feet into the high bank, and backfilled with stone after the tree trunks have been placed in it. Horizontal stability will be provided by a cable stringer extending downstream from anchors buried in the bank.

The function of the tree retard is to provide a partial screening of the bank and with the passage of time the branched portion of the trees should catch debris and sediment. Eventually small bars should form in the gaps between the tree retard units.

Environmentally, the tree retard system offers several advantages to more conventional approaches. Trees that fall into a river are a natural erosion protection system. However, this is a temporary condition due to flow fluctuations and ice. The anchored tree retard system is a minor improvement over naturally fallen trees. Very minimum clearing would be required in the construction of the tree retard system. The trees also create excellent fish habitat.

6. **SPECIAL CONTRACT PROVISIONS.** Bidding schedules, plans, and specifications advertised for each demonstration project contained options for allowing the bidder to utilize low grade material in all structures specified in the construction schedule as "Stone or Low Grade Material" or to utilize all high quality stone in these structures. The low bid for utilization of stone and low grade material was accepted unless the low bid for utilization of all stone did not exceed the stone and low grade material low bid by a predetermined percentage. This percentage was based on District bid experience for similar contracts and an engineering determination of the premium worth of construction utilizing high quality materials exclusively, and varied from contract to contract.

Stone, as specified for the contracts in this reach, was defined as durable material meeting specified acceptability levels based on service records and laboratory tests, such as petrographic analysis, specific gravity, absorption, wetting and drying, soundness in magnesium sulfate, and freezing and thawing. Gradations were determined by field conditions or experimental considerations. Neither the breadth nor the thickness of any piece of stone shall be less than one-third of its length. Stone shall be reasonably well-graded from coarse to fine. Dirt and fines of less than ½-inch maximum cross section accumulated from interledge layers or from blasting or handling operations shall not exceed 5 percent by weight. Acceptance testing of field boulders for compliance with quality requirements was not required.

Low grade materials, such as softer sandstones, limestone or chalk, were suitable for utilization to provide the bulk necessary in the toe of revetments and the core of hardpoints, provided laboratory testing, field tests, and service records demonstrated minimum acceptability within the specifications. Stone requirements were specified only by minimum specific gravity, a maximum allowable absorption and loss after a reasonable period of immersion, a liberal gradation range, and a requirement that it be obtained from the source and placed in the structure without excessive deterioration or mechanical breakdown.

Gravels, cobbles, and spalls used to provide an upper bank treatment are specified as tough, durable particles reasonably free from flat, thin, and elongated pieces, and containing no objectionable quantities of soft, friable materials or organic matter. Gradation limits may be liberal to promote trial of locally available material and possibly material from the channel bed in the vicinity of the structures utilizing gravel. Gradations specified at each demonstration site in this reach are discussed in Section C.

C. CONSTRUCTION DETAILS AT EACH DEMONSTRATION PROJECT

1. **SANDSTONE BLUFF PARTS I AND II PROJECT**. The general plan for this project is shown on Plates 4-1 and 4-2. The demonstration project consists of 32 segments of reinforced revetment totalling 9,300 linear feet, 500 linear feet of windrow revetment, 32 windrow refusals for a total length of 1665 linear feet, and 5 hardpoint structures totalling 579 linear feet. Typical sections of the structure types used in this project are shown on Plates 1-2 and 1-3. Two reinforced revetments are Type I and consist of the "toe" fill (stone or low grade material) placed adjacent to the high bank, and the "tieback" stone fills placed in trenches excavated into the high bank. Twenty-seven reinforced revetments are Type II and consist of toe fill (stone or low grade material) placed a short distance riverward of the high bank; stone fill tiebacks, extending from the toe fill crown to or into the high bank; and cut/fill slopes between and landward of the tiebacks, which form the lower, upper and highback bank zones. Three reinforced revetments are Type III and consist of all provisions applicable to reinforced Type II, revetment except that tiebacks are 40 feet long. The average stone material application rates for this project area are shown in Table 1-8.

Table 1-8

AVERAGE STONE MATERIAL APPLICATION RATES

Structure Rate	Average Stone Material Application Rate (Tons/Linear Foot)
Reinforced Revetment	5.7
Windrow Revetment	4.5
Windrow Refusal	6.3
Hardpoints	6.1

Table 1-11 provides a construction program for the Sandstone Bluff Parts I and II project which includes material quantities and costs by structure. Tables 1-9 and 1-10 display the specific stone gradations.

Table 1-9

STONE GRADATION FOR REINFORCED REVETMENT TIEBACKS AND WINDROW REVETMENT

Weight or Size Stone	Percent of Total Weight Lighter Than or Passing
200 lbs	100
50 lbs	35 - 60
2-inch screen	0 - 15

Table 1-10

STONE GRADATION FOR REINFORCED REVETMENT TOE

Weight or Size Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

The stone material used in the construction of this project was required to meet the following standards: bulk specific gravity, saturated surface dry basis, Method CRD-C 107-69, required not less than 2.40; soundness in magnesium sulfate, ASTM Standard C88-76, required a loss of 5 cycles of not more than 12 percent; and soundness in freezing and thawing, AASHO Designation T103-62, required a loss at 12 cycles not to exceed 10 percent.

Typical photographs of reinforced revetment at the Sandstone Bluff Area are shown on Photos 1, 2, and 3. Photos 4 and 5 show hardpoint structures.

Table 1-11

SANDSTONE BLUFF I AND II CONSTRUCTION PROGRAM

Structure*	Type*	Total Length (Ft)	Date Start	Date End	Total Stone (tons)	Total Exc (CY)	Total Gravel (tons)	Other	Total Cost	Cost/ft. of Structure
1369.31	WRF	100	11/78	11/78	611	539			8,599.41	85.99
1369.3										
0+00 to 3+50	RR	350	11/78	7/79	1966	1476	127		28,423.46	81.21
5+50 to 9+50	RR	400	11/78	7/79	2399	1061	166		33,313.69	83.28
11+50 to 13+50	RR	200	11/78	7/79	1210	289	84		16,313.10	81.57
15+50 to 17+50	RR	200	11/78	7/79	1254	259	87		16,824.74	84.12
20+00 to 24+00	RR	400	11/78	7/79	2112	572	169		28,832.72	72.08
26+00 to 30+00	RR	400	11/78	7/79	2219	475	171		29,975.89	74.94
33+00 to 36+00	RR	300	11/78	7/79	1578	925	127		22,545.18	75.15
37+50 to 40+50	RR	300	11/78	7/79	1577	589	129		21,880.87	72.94
1369.2	WRF	48	11/78	11/78	306	295			4,356.86	90.77
1369.1	WRF	50	11/78	11/78	321	272			4,495.51	89.91
1369.0	WRF	50	11/78	11/78	302	286			4,289.62	85.79
1368.9	WRF	50	11/78	11/78	390	267			5,334.90	106.70
1368.8	WRF	50	11/78	11/78	302	267			4,251.62	85.03
1368.75	WRF	50	11/78	12/78	301	267			4,239.31	84.79
1368.7	WRF	50	11/78	12/78	302	267			4,251.62	85.03
1368.61	WRF	50	8/78	9/78	308	265			4,321.48	86.43
1368.6										
0+00 to 1+50	RR	150	8/78	9/78	824	416	72		11,695.44	77.97
3+00 to 4+50	RR	150	8/78	9/78	824	434	73		11,741.44	78.28
6+00 to 9+00	RR	300	8/78	9/78	1897	1124	192		27,520.07	91.73
11+00 to 13+00	RR	200	8/78	9/78	1135	652	142		16,695.85	83.48
15+00 to 16+50	RR	150	8/78	9/78	837	775	104		12,893.47	85.96
18+00 to 19+50	RR	150	8/78	9/78	831	113	61		11,065.61	73.77
21+00 to 24+00	RR	300	8/78	9/78	1576	758	130		22,216.56	74.06
27+00 to 31+00	RR	400	8/78	9/78	2273	1064	172		31,828.63	79.57
35+00 to 40+00	RR	500	8/78	10/78	3028	996	154		40,806.68	81.61
43+00 to 48+00	RR	500	8/78	10/78	3143	1085	150		42,360.33	84.72
51+00 to 53+50	RR	250	8/78	10/78	1453	1554	109		22,084.43	88.34
56+00 to 58+00	RR	200	8/78	10/78	1209	1083	69		17,738.79	89.69
1368.5	WRF	30	8/78	9/78	184	161			2,587.04	86.23
1368.4	WRF	30	8/78	9/78	180	156			2,527.80	84.26
1368.3	WRF	50	8/78	9/78	314	271			4,407.34	88.15
1368.2	WRF	50	8/78	9/78	300	280			4,253.00	85.06
1368.1	WRF	50	8/78	9/78	306	278			4,322.86	86.46
1368.0	WRF	50	8/78	9/78	303	269			4,267.93	85.36
1367.8	WRF	50	8/78	9/78	351	269			4,858.81	97.18
1367.7	WRF	50	8/78	9/78	304				3,742.24	74.84
1367.6	WRF	50	8/78	10/78	302	290			4,297.62	85.95
1367.5	WRF	36	8/78	10/78	307	268			4,315.17	119.87
1367.4	WRF	50	9/78	10/78	302	267			4,251.62	85.03

Table 1-11 contd.

SANDSTONE BLUFF I AND II CONSTRUCTION PROGRAM

Structure*	Type*	Total Length (Ft)	Date Start	Date End	Total Stone (tons)	Total Exc (CY)	Total Gravel (tons)	Other	Total Cost	Cost/ft. of Structure
1367.31	WRF	50	9/78	10/78	295	267			4,165.45	83.31
1367.3										
0+00 to 2+00	RR	200	8/78	10/78	1229	924			16,976.99	84.88
4+00 to 6+00	RR	200	9/78	10/78	1260	895	183		19,130.60	95.65
8+00 to 12+00	RR	400	9/78	10/78	2495	1960	181		36,443.45	91.11
16+00 to 19+00	RR	300	9/78	10/78	1588	1281	127		23,330.28	77.93
22+00 to 24+00	RR	200	9/78	10/78	1064	876	86		15,719.84	78.55
1367.2	WRF	50	9/78	10/78	300	269			4,231.00	84.62
1367.1	WRF	50	9/78	10/78	305	267			4,288.55	85.77
1367.0	WRF	40	9/78	10/78	303	318			4,365.93	109.15
1366.9	WRF	50	9/78	10/78	300	268			4,229.00	84.58
1366.8	HP	153	9/78	10/78	601	577			8,552.31	55.90
1366.71	WRF	50	9/78	10/78	299	267			4,214.69	84.29
1366.7										
0+00 to 1+50	RR	150	9/78	10/78	915	646	66		13,215.65	88.10
3+00 to 7+00	RR	400	9/78	11/78	2095	2289	172		32,087.45	80.22
10+00 to 12+50	RR	250	9/78	11/78	1534	1278	105		22,489.54	89.96
14+00 to 17+00	RR	300	9/78	11/78	1576	1382	128		23,444.56	78.15
1366.6	WRF	50	9/78	10/78	302	281			4,279.62	85.59
1366.5	WRF	50	9/78	10/78	602	267			7,944.62	158.89
1366.41	WRF	50	9/78	10/78	304	268			4,278.24	85.56
1366.4	HP	105	9/78	10/78	608	385	26		8,514.48	81.09
1366.3	HP	112	9/78	10/78	606	409	35		8,627.86	77.03
1366.21	WRF	50	9/78	10/78	307	282			4,343.17	86.86
1366.2	WR	500	9/78	11/78	2243	2000			31,611.33	63.22
1366.11	WRF	75	10/78	11/78	452	428			6,420.12	85.60
1366.1										
0+00 to 5+00	RR	500	10/78	12/78	2742	2498	213		40,880.02	81.76
7+50 to 10+50	RR	300	10/78	12/78	1621	1277	124		23,748.51	79.16
1365.9	WRF	58	10/78	11/78	300	266			4,225.00	72.84
1365.8	HP	103	10/78	11/78	605	500	16		8,607.55	83.57
1365.7	HP	106	10/78	11/78	601	701	16		8,960.31	84.53
1365.61	WRF	48	10/78	11/78	302	257			4,231.62	88.16
1365.6	RR	300	10/78	12/78	1514	1025	99		21,677.34	72.26

SUBTOTAL	$ 980,000.00
Clearing and Grubbing	15,000.00
Seeding	2,000.00
Monitoring & Evaluation	36,000.00
Engineering and Design	39,000.00
Supervision and Administration	56,000.00
TOTAL COST	$1,128,000.00

*WRF = Windrow Refusal, RR = Reinforced Revetment, HP = Hardpoints

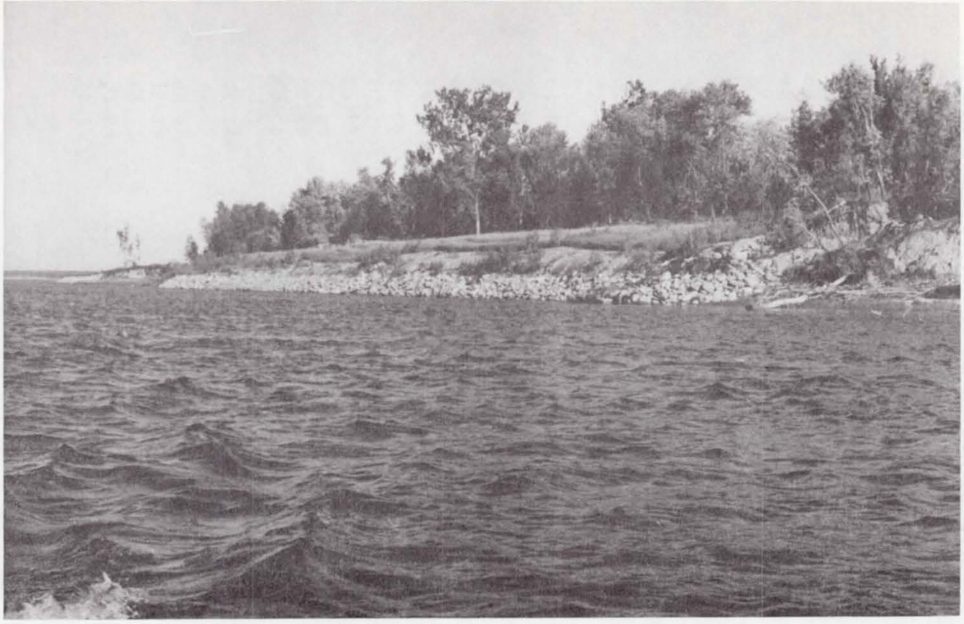


Photo 1. Reinforced Revetment 1368.6, Station 35+00 to 40+00, approximately 13 months after completion. (Photo taken July 1979)

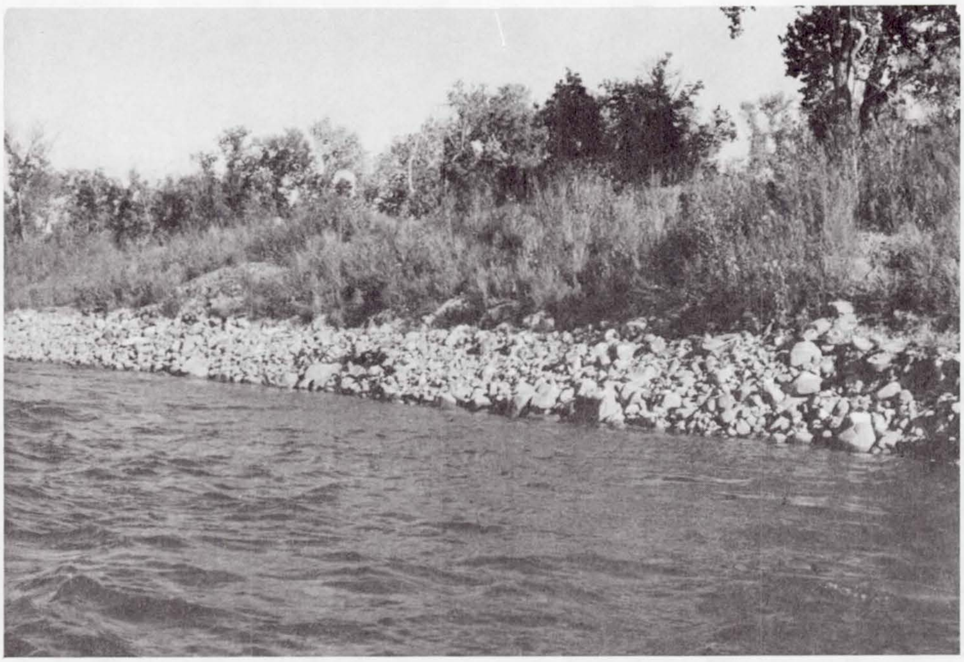


Photo 2. Reinforced Revetment 1368.6, Station 43+00 to 48+00, approximately 13 months after completion. (Photo taken July 1979)

Sandstone Bluff Area
Photos 1 and 2

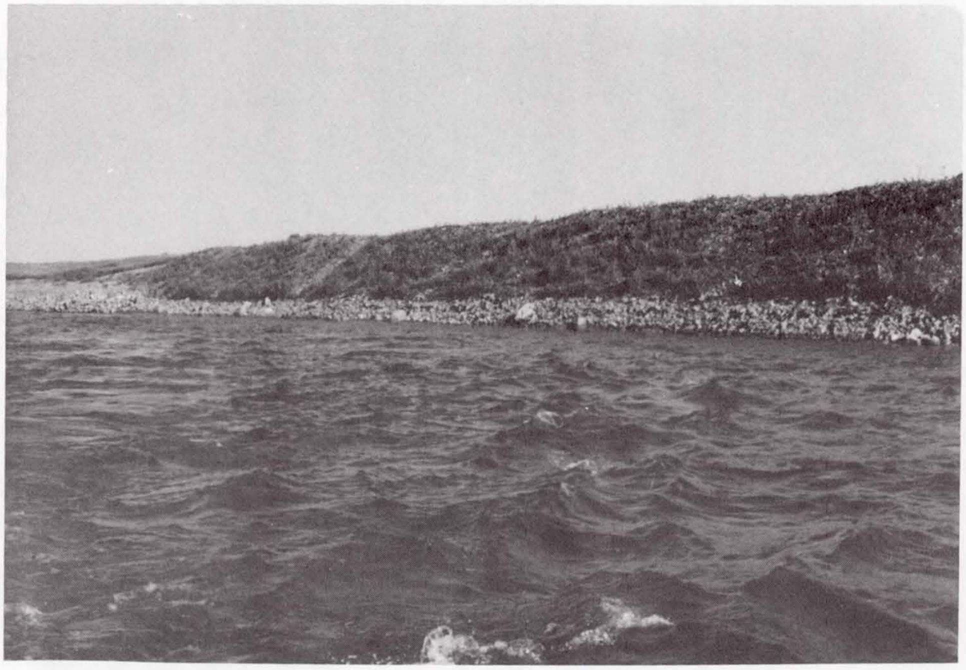


Photo 3. Reinforced Revetment 1366.7, Station 3+00 to 7+00, approximately 9 months after completion.

Sandstone Bluff Area
Photo 3

Photo 4. Hardpoint 1366.8, approximately 9 months after completion. (Photo taken July 1979)

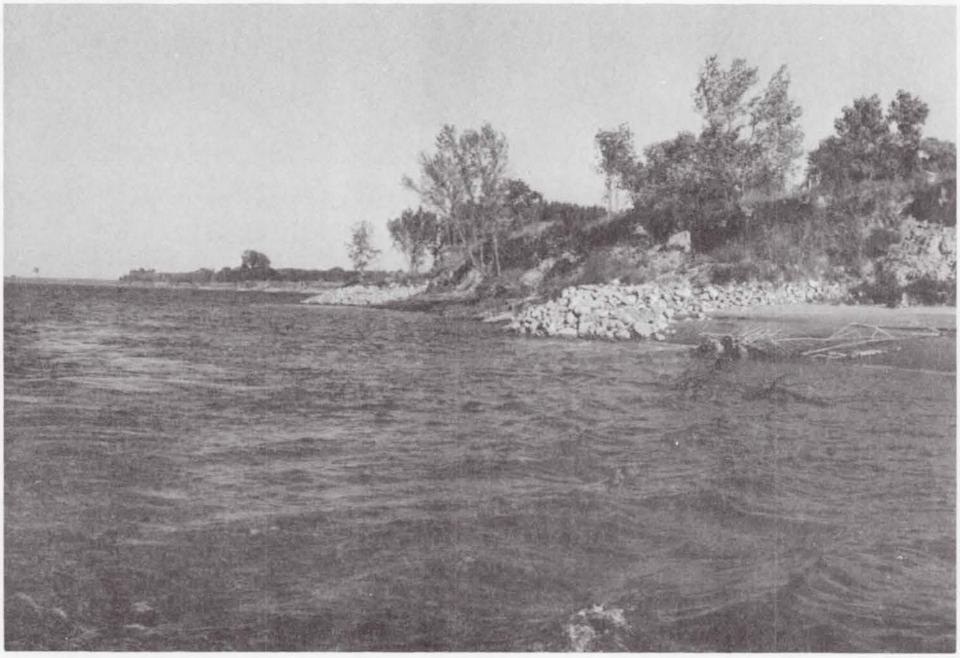


Photo 5. Hardpoints 1366.4 and 1366.3. (Photo taken July 1979)

Sandstone Bluff Area
Photos 4 and 5

2. **LEWIS AND CLARK 4-H CAMP PROJECT.** The general plan for this project is shown on Plate 6-1. The demonstration project consists of approximately 2,350 linear feet of reinforced revetment in three segments, three 50 linear feet of windrow refusal, and three hardpoint structures totalling 180 linear feet. The reinforced revetments are Type I, II, and III, which are described in more detail in Section III, paragraph B.I.C. Table 1-15 provides a construction program which includes material quantities and costs by structure. The average stone material application rate for each structure type is shown in Table 1-12. Table 1-13 and 1-14 display the specific stone gradations for the various structural components.

Table 1-12

Structure Type	Average Stone Material Application Rate (Tons/Linear Foot)
Reinforced Revetment	5.2
Windrow Refusals	7.3
Hardpoints	10.3

Table 1-13

STONE GRADATION FOR REINFORCED REVETMENT TIEBACKS, WINDROW REFUSAL AND HARDPOINT UPPER PAVING FILL AND ROOT

Weight Per Price	Percent of Total Weight Lighter Than or Passing
200 lbs	100
50 lbs	35 - 60
2-inch screen	0 - 15

Table 1-14

STONE GRADATION FOR REINFORCED REVETMENT TOE, AND HARDPOINT CORE

Weight or Size Per Piece	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

The stone material used in the construction of this project was required to meet the following standards: bulk specific gravity, saturated surface dry basis, Method CRD-C 107-69, required not less than 2.40. Soundness in magnesium sulfate, ASTM Standard C88-76, required a loss of 5 cycles of not more than 12 percent; and soundness in freezing and thawing for ledge rock, Method Modified Designation T103-62, required a loss at 12 cycles not to exceed 10 percent.

Photographs of typical reinforced revetment stuctures at the Lewis & Clark 4-H Camp Area are shown on Photos 6, 7, 8, 9, and 10. Photos 11 and 12 show hardpoint structures.

Table 1-15

LEWIS AND CLARK 4-H CAMP CONSTRUCTION PROGRAM

Structure*	Type*	Total Length (Ft)	Date Start	Date End	Total Stone (tons)	Total Exc (CY)	Total Gravel (tons)	Total Cost	Cost/ft. of Structure
1357.91	WRF	50	9/78	11/78	293	416		4,411.59	88.23
1357.90	RR	600	9/78	11/78	3055	2407	285	45,533.10	75.89
1357.74	WRF	50	9/78	11/78	311	420		4,642.73	92.85
1357.73	RR	750	9/78	11/78	4045	1889	410	58,243.00	77.66
1356.89	HP	60	9/78	11/78	637	190	12	8,400.21	140.00
1356.84	HP	60	9/78	11/78	711	174	11	9,279.53	154.66
1356.79	HP	60	9/78	11/78	509	158	13	6,760.87	112.68
1356.75	WRF	50	9/78	11/78	487	100		6,238.41	124.77
1356.74	RR	1000	9/78	11/78	5019	3833	496	74,883.62	74.88

Subtotal	218,393
Clearing and Grubbing	8,000
Seeding	2,500
Monitoring	17,000
Supervision and Administration	14,000
Engineering and Design	18,000
TOTAL COST	$278,000

*WRF = Windrow Refusal; RR = Reinforced Revetment, HP = Hardpoints

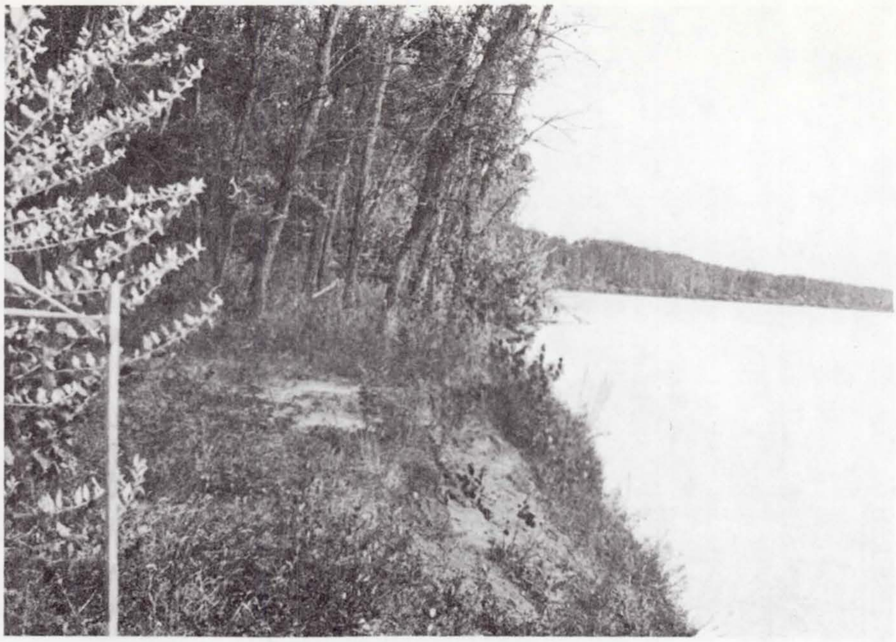


Photo 6. Reinforced Revetment 1357.50, prior to construction. (Photo taken 15 September 1978)

Photo 7. Placement of rock toe on Revetment 1357.50 (Photo taken 15 September 1978)

Lewis & Clark 4H Camp Area
Photos 6 and 7

Photo 8. Reinforced Revetment 1357.73, approximately 8 months after completion. (Photo taken 22 August 1979)

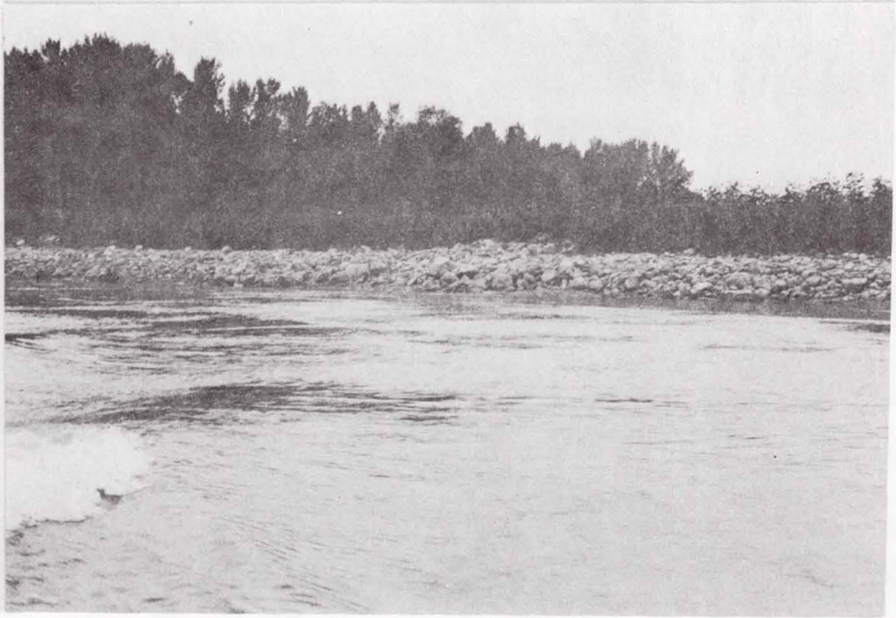


Photo 9. Downstream portion of Reinforced Revetment 1357.73 approximately 8 months after completion. (Photo taken 22 August 1979)

Lewis & Clark 4H Camp Area
Photos 8 and 9

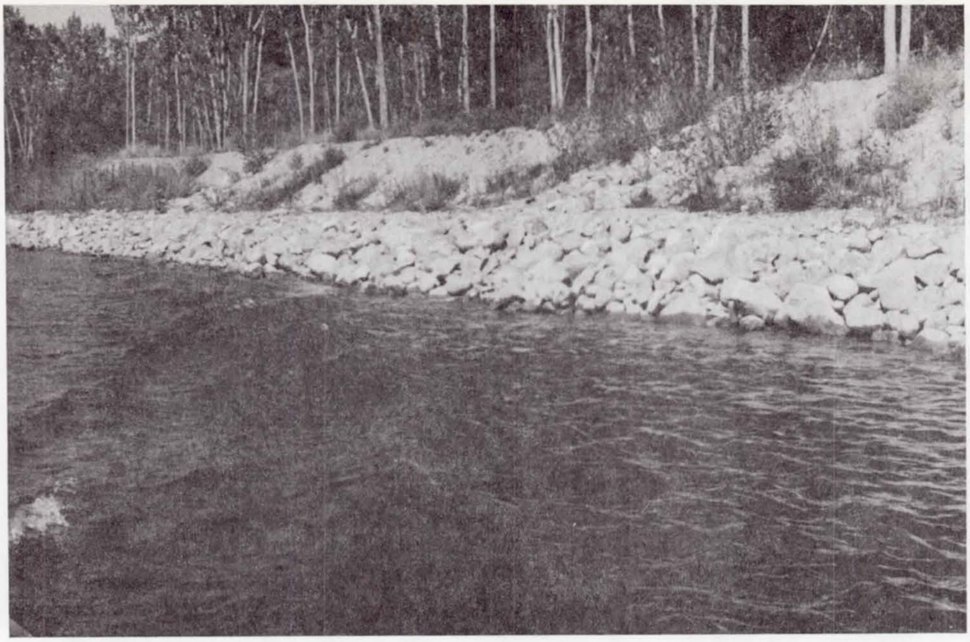


Photo 10. Reinforced Revetment 1357.73, approximately 9 months after completion.
(Photo taken 15 September 1979)

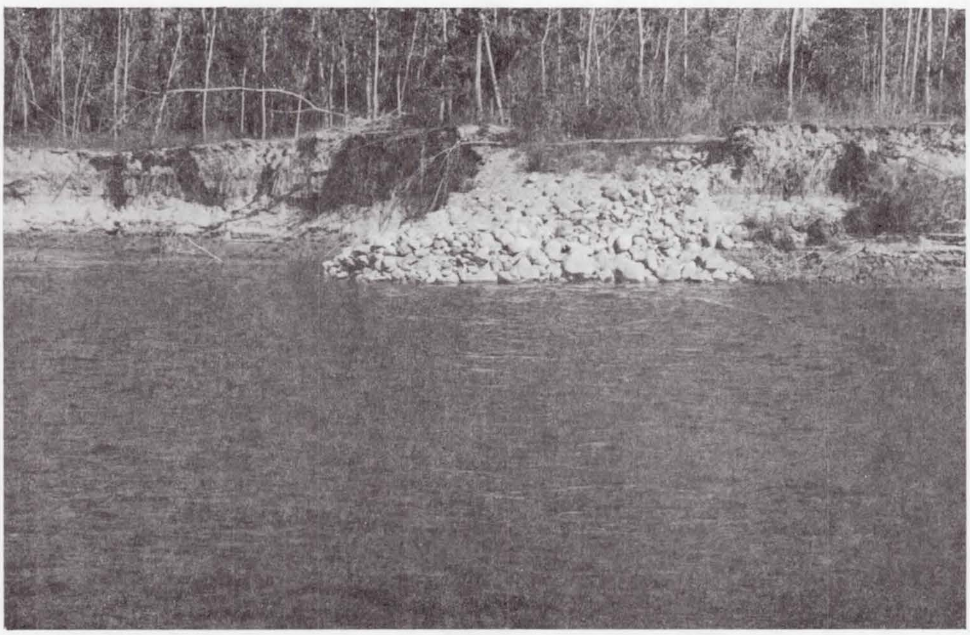


Photo 11. Hardpoint 1356.84, approximately 8 months after completion.
(Photo taken July 1979).

Lewis & Clark 4H Camp Area
Photos 10 and 11

Photo 12. Hardpoints 1356.89, 1356.84, and 1356.79 approximately 10 months after completion. (Photo taken September 1979)

Lewis & Clark 4H Camp Area
Photo 12

3. **SANGER PROJECT.** The general plan for this project is shown on Plate 7-1. The demonstration project consists of approximately 1,500 linear feet of earth core dike. An environmental notch is incorporated into the structure to allow a small amount of water to flow behind the structure for environmental enhancement. Typical sections of the structure are shown on Plates 7-2 and 7-3. Revetment facing for the earth core dike consists of four types with two variations of the upper bank treatment for Types A and C, as shown on Plate 7-2.

Table 1-18 indicates the construction program which includes material quantities and costs by structure. Table 1-16 and 1-17 displays the specified stone gradations.

Table 1-16

STONE FOR UPPER SEGMENTS OF EARCH CORE DIKE

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
200 lbs	100
50 lbs	35 - 60
2-inch screen	0 - 15

Table 1-17

STONE FOR TOE REVETMENT OF EARCH CORE DIKE

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

During and after construction photographs of Earth Core Dike 1345.5 ar shown on Photos 13 through 18.

Table 1-18

SANGER CONSTRUCTION PROGRAM

Structure*	Type*	Total Length (Ft)	Date Start	Date End	Total Stone (tons)	Total Exc (CY)	Total Gravel (tons)	Other	Total Cost	Cost/ft. of Structure
1345.5	Dike									
0+50 to 0+50		100	9/20/79	11/19/79	330	-	-	-	4,224.00	42.24
0+50 to 5+50		500	9/20/79	11/19/79	3830	-	1765	10,975 CY Emb	101,137.75	202.28
5+50	Env. Gap		9/20/79	11/19/79	1130	-	95	195 CY Emb 435 SY FC	17,782.25	
5+50 to 14+50		900	9/20/79	11/19/79	6429	-	1750	9,280 CY Emb	128,996.70	143.33
14+50 to 15+00		50	9/20/79	11/19/79	1000	-	188	1,094 CY Emb	18,118.40	362.37

SUBTOTAL	$270,300.00
Clearing and Grubbing	3,300.00
Seeding	23,500.00
Monitoring & Evaluation	25,000.00
Relocate Borrow Site	11,600.00
Supervision and Administration	15,000.00
Engineering and Design	27,000.00
TOTAL COST	$376,000.00

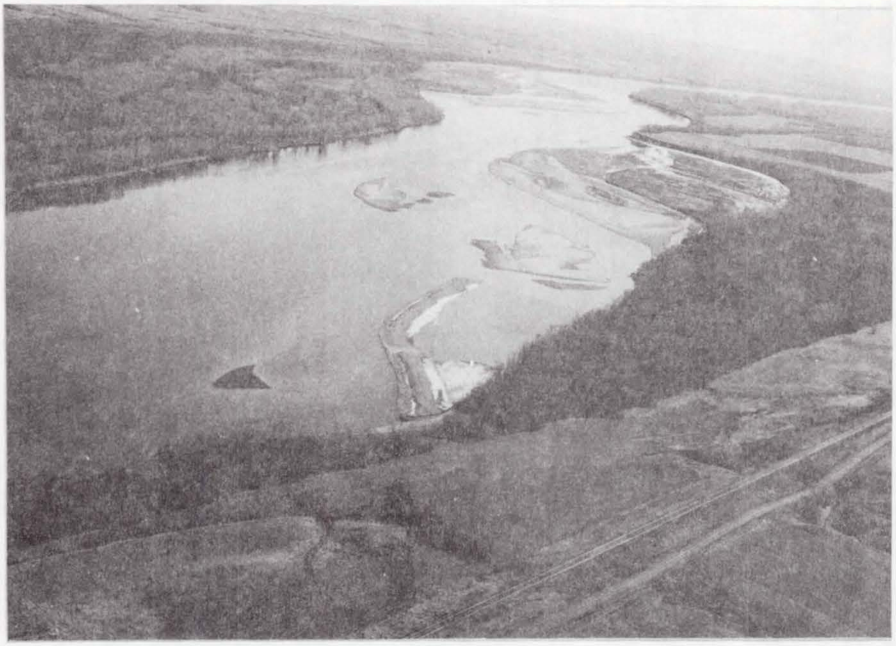


Photo 13. Aerial View of Earth Core Dike 1345.5 loading downstream (Photo taken 15 April 1980)

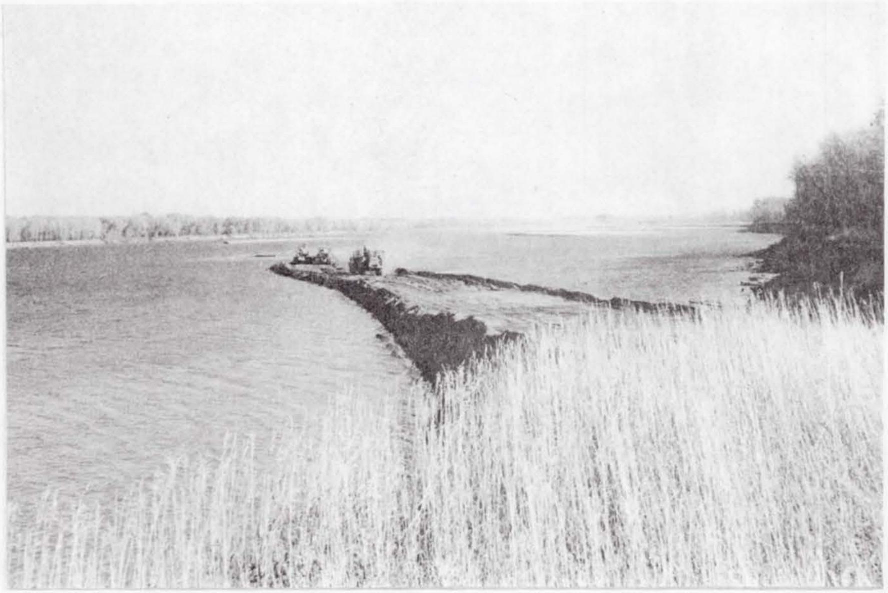


Photo 14. Construction View of Earth Core Dike 1345.5 loading downstream (Photo taken 4 October 1979)

Sanger Area
Photos 13 and 14

Photo 15. Earth Core Dike 1345.5 immediately after completion and prior to planting of crown vegetation. (Photo taken 16 November 1979)

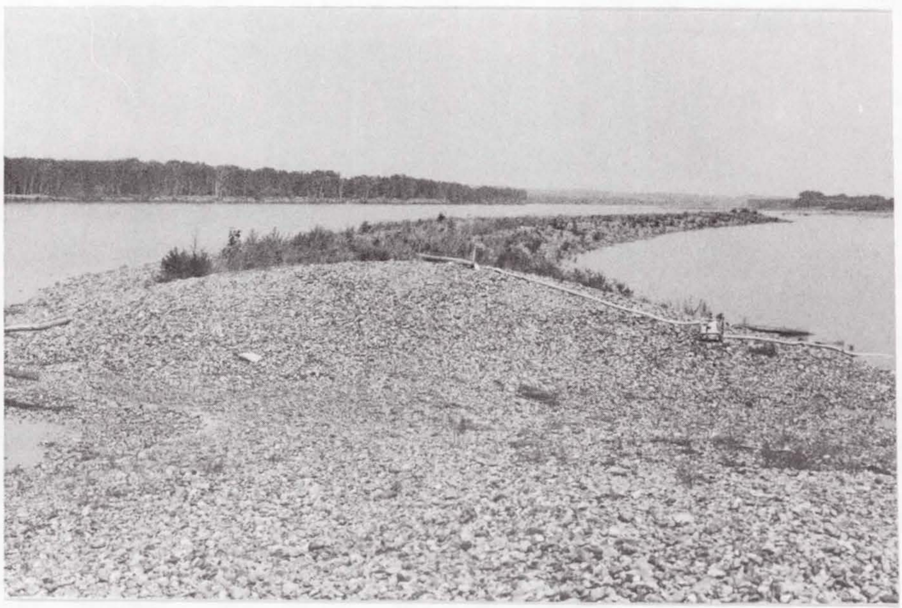


Photo 16. Environmental notch in foreground and downstream portion of earth core dike. The vegetation on the dike was planted in May 1980, two months before this photograph was taken. (Photo taken 17 July 1980)

Sanger Area
Photos 15 and 16

Photo 17. Looking downstream along downstream site of earth core. Dike 1345.5, 2 months after vegetation planting in May 1980

Photo 18. Looking upstream along upstream side of Earth Core Dike 1345.5, 2 months after vegetation planting in May 1980. (Photo taken 17 July 1980)

Sanger Area
Photos 17 and 18

4. **EAGLE PARK PROJECT**. The general plan for this project is shown on Plate 13-1. The initial demonstration area consisted of approximately 2½ miles of bankline protected by 2,200 linear feet of composite revetment in three segments, 2,200 linear feet of windrow revetment in five segments, eight windrow stonefill refusals with a total of 650 linear feet, 800 linear feet of tree retards in two segments, and 7 hardpoint structures totaling 540 linear feet. The project required several modifications to the original contract to correct severe erosion problems located in the project area. These modifications resulted in the additional construction of 2350 linear feet of bankline revetment, five windrow stone fill refusals with a total of 250 linear feet and 6 hardpoint structures totalling 540 linear feet. Reconstruction was required in 1,320 linear feet of windrow revetment, 300 linear feet of composite revetment, 150 linear feet of windrow refusal and 2 hardpoint structures. The 800 linear feet of tree retards were destroyed by ice and replaced by two hardpoint structures. More detail concerning the reconstruction are discussed in the Reconstruction portion of this appendix, Section IV, paragraph C.

Typical sections of the structure types used in this project are shown on Plate 13-2. One composite revetment is Type A and consists of a uniform blanket of gravel placed on a IV to 3H slope. Three composite revetments are Type B and consist of a blanket of upper bank paving of stone, cobbles, spalls or low-grade material, placed on a IV to 2H slope. Three composite revetments are Type D and consist of a filter cloth, such as Mirafi 140 or equivalent, placed on a IV to 3H slope and anchored and armored by a 6-inch (minimum) layer of gravel, cobbles or spalls. One composite revetment is Type E and consists of a layer of stone (3 feet below CRP) up to 3 feet above CRP at a slope of IV to 3H. The stone fill refusal consists of stone fill to the same section indicated for Windrow Revetment, Type I. The windrow revetment are Type I and Type II, which are described in detail in Section III.B. paragraph 1.c., and shown on Plate 13-2. The average stone material application rate for each structure constructed at Eagle Park is shown in Table 1-19.

Table 1-19

Structure Type	Average Stone Material Application Rate (tons/linear feet)
Composite Revetment	4.3
Windrow Revetment	9.5
Windrow Refusal	4.7
Bankline Revetment	3.0
Tree Retards	0.2
Hardpoints	8.9

Table 1-21 provides a construction program of the Eagle Park project area which includes material quantities and costs by structure. Table 1-20 displays the specific stone and gravel gradations. Stone used in the project construction was required to meet the following standards bulk specific gravity, saturated surface dry basis, Method CRD-C107-69, required not less than 2.40; soundness in magnesium sulfate, ASTM Standard C88-73, required a loss at 5 cycles of not more than 12 percent; soundness in freezing and thawing, AASHO Designation T103-42, required a loss at 12 cycles not to exceed 10 percent.

Table 1-20

STONE AND GRAVEL GRADATIONS

SMALL STONE GRADATION

Weight Per Stone	Percent of Total Weight Lighter Than or Passing
200 lbs	100
50 lbs	35 - 60
2-inch screen	0 - 15

LARGE STONE GRADATION

Weight Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

Before, during, and after construction photographs at the Eagle Park Area are shown on Photos 19 through 25. Hardpoint systems are shown in Photo 16. Tree retards, during and after construction, are shown in Photos 27 and 28.

Table 1-21
EAGLE PARK CONSTRUCTION PROGRAM

Structure No.	Type*	Total Length (ft)	Date Start	Date End	Total Stone (tons)	Total LGM (tons)	Total Exc (CY)	Total Gravel (tons)	Other	Total Cost	Cost/Ft. of Structure
1324.51	WRF	30	11/4/77	11/4/77	180		179			2,220.65	74.02
1324.5											
0+00-4+00	BR	400	11/2/77	11/3/77	1000		516			11,212.60	28.03
0+00-1+10	BR	110	8/16/78	8/16/78					60 T. C&S	720.00	6.55
4+00-6+50	BR	250	8/1/78	8/10/78	900				1300 CY Emb 130 T. C&S	13,615.00	54.46
6+50-8+50	BR	200	11/4/77	11/10/77	1015		298			10,850.30	54.25
8+50-8+90	BR	40	8/4/78	8/11/78	200				250 CY Emb 30 T. C&S	2,947.50	73.69
10+45-11+45	BR	100	8/14/78	8/15/78	600		72			6,169.20	61.69
1324.32	WRF	20	8/3/78	8/3/78	79					790.00	39.50
1324.3	HP	60	10/27/77	10/28/77	290		148			3,247.80	54.13
1324.2	HP	80	8/27/77	9/2/77	521		381			5,917.85	73.97
1324.19											
0+00-4+00	TR	400	8/30/77	9/3/77	103		325		9 tree elements 1 deadman	5,693.75	14.23
12+00-16+00	TR	400	8/29/77	8/29/77	58		209		5 tree elements 1 deadman	3,571.15	8.93
1324.0	HP	60	8/29/77	9/1/77	487		111			5,130.85	85.51
1323.81	WRF	100	4/21/77	5/16/77	451		438			5,539.30	55.39
1323.8											
0+00-4+40	WR	440	4/15/77	4/20/77	1926		1391			20,603.85	46.83
6+40-10+80	WR	440	4/15/77	4/21/77	1277		901			13,787.35	31.33
12+80-17+20	WR	440	5/24/77	6/10/77	1925		1406			20,629.10	46.88
19+20-23+60	WR	440	4/6/77	4/13/77	1282		1341			14,871.35	33.80
25+60-30+00	WR	440	3/21/77	3/31/77	1921		1794			21,500.90	48.87
0+00-4+40	WR	440	8/78	8/78					220 CY Earth Cover	517.00	1.18
6+40-10+80	WR	440	8/78	8/78					220 CY Earth Cover	517.00	1.18
12+80-17+20	WR	440	8/78	8/78					220 CY Earth Cover	517.00	1.18
19+20-23+60	WR	440	8/78	8/78					240 CY Earth Cover	564.00	1.28

Table 1-21 contd.
EAGLE PARK CONSTRUCTION PROGRAM

Structure No.	Type*	Total Length (ft)	Date Start	Date End	Total Stone (tons)	Total LGM (tons)	Total Exc (CY)	Total Gravel (tons)	Other	Total Cost	Cost/Ft. of Structure
1323.75	WRF	50	3/31/77	4/1/77	228		231			2,822.85	56.46
1323.65	WRF	50	4/4/77	4/5/77	225		212			2,748.20	54.96
1323.55	WRF	50	3/31/77	4/1/77	225		227			2,783.45	55.67
1323.45	WRF	50	3/22/77	3/22/77	224		207			2,726.45	54.53
1323.4	HP	80	4/5/77	4/6/77	522		212			5,405.70	67.57
1323.2	HP	80	4/13/77	4/15/77	450		191			4,761.35	59.52
1323.06	WRF	100	7/1/77	7/1/77	448		940			6,689.00	66.89
1323.05											
0+00-7+50	CR	750	9/6/77	10/24/77	3249		5766	801		50,789.85	67.72
10+50-18+00	CR	750	9/12/77	10/31/77	3258		4203		340 T. C&S 1325 S.Y. FC	46,744.55	62.33
21+00-28+00	CR	700	7/14/77	10/20/77	3040		2117	198	610 T. clay	39,242.95	56.06
1322.85	WRF	100	6/30/77	6/30/77	657		418			7,552.30	75.52
1322.65	WRF	100	6/22/77	6/22/77	449		1027			6,903.45	69.03
1322.4	HP	100	6/16/77	6/21/77	600		531			6,935.35	69.35
1322.2	HP	60	6/14/77	6/16/77	609		173			6,309.05	105.15
1322.0	HP	80	6/13/77	6/15/77	514		185			5,262.25	65.78

SUBTOTAL	$369,000.00
Clearing and Grubbing	5,000.00
Seeding	7,000.00
Monitoring and Documentation	52,000.00
Supervision & Administration	38,000.00
Engineering & Design	30,000.00
TOTAL COST	$501,000.00

*HP = Hardpoint; TR = Tree Retards; WRF = Windrow Refusal;
CR = Composite Revetment, WR = Windrow Revetment;
BR = Bankline Revetment
EC = Earth Cover
Emb = Embankment
C&S = Cobbles & Spalls

Table 1-21a
EAGLE PARK CONSTRUCTION PROGRAM
REHABILITATION

Structure No.	Type*	Total Length (ft)	Date Start	Date End	Total Stone (tons)	Total LGM (tons)	Total Exc (CY)	Total Gravel (tons)	Other	Total Cost	Cost/Ft. of Structure
1324.15	HP	60	8/4/78	8/8/78	374		194			4,284.10	71.40
1324.1	HP	60	8/4/78	8/8/78	364		194			4,174.10	69.57
1323.9	WRF	50	8/8/78	8/8/78	233		94			2,718.10	54.36
1323.89											
0+00-4+00	BR	400	7/27/78	7/31/78	1553				2315 CY Emb 232 T. C&S	26,001.75	65.00
6+50-10+50	BR	400	7/21/78	7/27/78	1558				2315 CY Emb 231 T. C&S	26,044.75	65.11
1323.85	WRF	50	7/21/78	7/21/78	228		94			2,663.10	53.26
1323.8											
12+80-17+20	WR	440	10/4/79	10/4/79	880					11,440.00	26.00
19+20-23+60	WR	440	10/4/79	10/4/79	1320					17,160.00	39.00
25+60-30+00	WR	440	10/4/79	10/4/79	880					11,440.00	26.00
1323.65	WRF	50	10/4/79	10/4/79	150					1,950.00	39.00
1323.55	WRF	50	10/4/79	10/4/79	150					1,950.00	39.00
1323.45	WRF	50	10/4/79	10/4/79	150					1,950.00	39.00
1323.2	HP	200	10/4/79	10/4/79	1000					13,000.00	65.00
1323.05	CR	300	10/4/79	10/4/79					600 T. C&S	8,100.00	27.00
1322.4	HP	50	10/4/79	10/4/79	100					1,300.00	26.00
1322.3	HP	80	7/19/78	7/19/78	512		194			5,702.10	71.28
1322.2	HP	80	7/18/78	7/18/78	673		194			7,473.10	93.41
1322.1	HP	80	7/19/78	7/20/78	530		194			5,900.10	73.75

SUBTOTAL	$153,000.00
Clearing and Grubbing	2,000.00
Seeding	2,250.00
Excavation	5,500.00
Monitoring	5,000.00
Supervision & Administration	9,000.00
Engineering & Design	18,000.00
TOTAL COST	$195,000.00

*HP = Hardpoint; TR = Tree Retards; WRF = Windrow Refusal;
CR = Composite Revetment, WR = Windrow Revetment;
BR = Bankline Revetment
EC = Earth Cover
Emb = Embankment
C&S = Cobbles & Spalls

Photo 19. Composite Revetment Site - Type E 323.05, prior to construction. (Photo taken 14 July 1977)

Photo 20. Composite Revetment - Type E 1323.05, station 26+50, prior to bank slope shaping. (Photo taken 22 August 1977)

Eagle Park Area
Photos 19 and 20

Photo 21. Bank slope shaping and clay placement on Composite Revetment Type E 1323.05, Station 26+50. (Photo taken 29 September 1977)

Photo 22. Clay placement on Composite Revetment Type E 1323.05, Station 26+50. (Photo taken 29 September 1977)

Eagle Park Area
Photos 21 and 22

Photo 23. Composite Revetment - Type A 1323.05, Station 0+00 to 7+50, with gravel cover. (Photo taken June 1978)

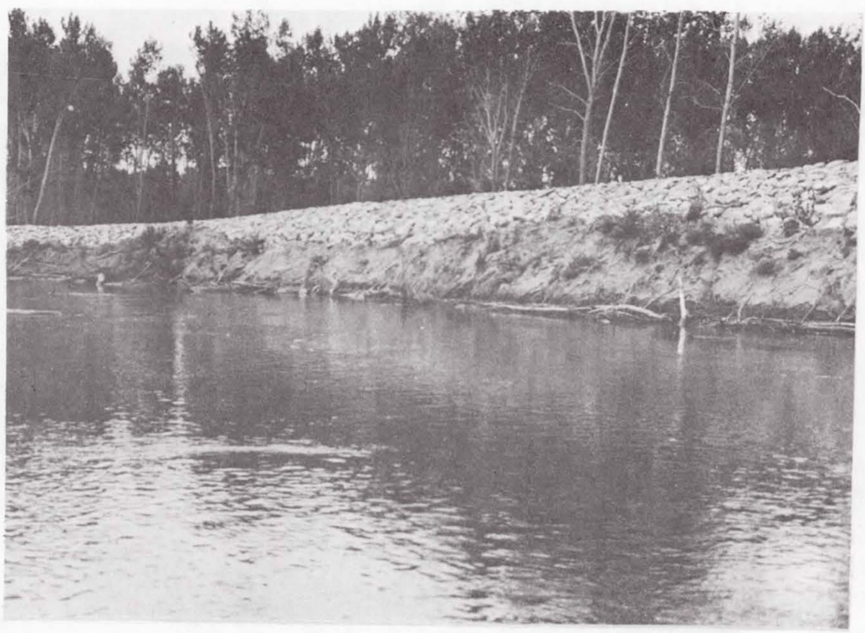


Photo 24. Windrow Revetment 1323.8, Station 12+80 to 17+20, approximately 6 months after completion. (Photo taken September 1977)

Eagle Park Area
Photos 23 and 24

Photo 25. Windrow Revetment 1323.8, Station 0+00 to 4+40, approximately 15 months after completion. (Photo taken June 1978)

Photo 26. Looking upstream along the Hardpoint System at the downstream end of the project. (Photo taken July 1979)

Eagle Park Area
Photos 25 and 26

Photo 27. Tree Retard 1324.19 during construction. (Photo taken September 1977)

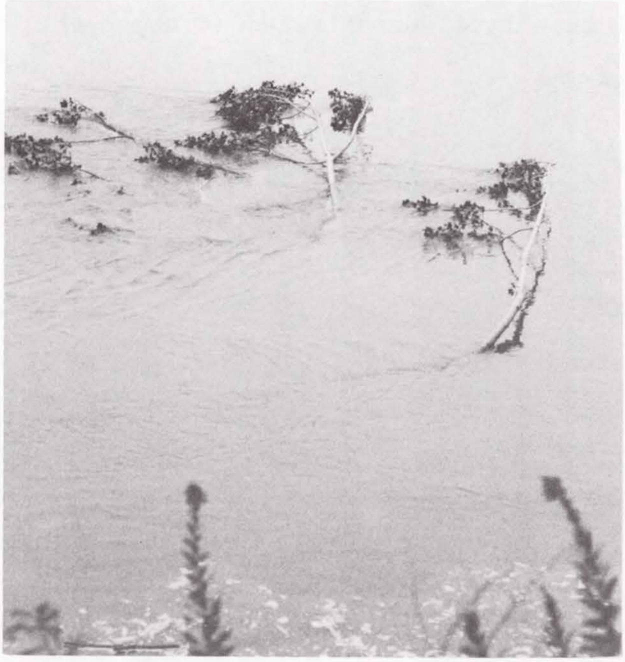


Photo 28. Tree Retard Structure 1324.19. (Photo taken September 1977)

Eagle Park Area
Photos 27 and 28

5. **BURNT CREEK PROJECT.** The general plan for this project is shown on Plate 14-1. The initial demonstration project consisted of approximately 2,100 linear feet of reinforced revetment in four segments, 400 linear feet of windrow revetment, six windrow refusals totalling 325 linear feet, 1,350 linear feet of composite revetment in two segments, three hardpoints totalling 220 linear feet, two earth core dikes totalling 1,100 linear feet, and two environmental gaps. The initial contract for the project was modified by adding 250 linear feet of composite revetment and 80 linear feet of windrow stone fill refusal. Typical sections of the structure types used in this project are shown on Plates 14-2, 14-3, 14-4 and 14-5. The reinforced revetments are Type II and consist of toe fill (stone or low grade material) placed a short distance riverward of the high bank; stone fill tiebacks, extending from the toe fill to or into the high banks; and cut/fill slopes, between and landward ends of the tiebacks, which form the lower, upper, and highback bank zones. The average stone material application rate for each structure type demonstrated at the Burnt Creek Area is shown in Table 1-22.

Table 1-22

Structure Type	Average Stone Material Application Rate (tons/linear feet)
Reinforced Revetment	4.8
Composite Revetment	4.9
Windrow Revetment	4.1
Windrow Refusal	4.4
Earth Core Dike	8.6
Hardpoints	6.5

Table 1-25 provides a construction program of the Burnt Creek project which includes material quantities and costs by structure.

Tables 1-23 and 1-24 display the specified stone gradations.

Table 1-23

STONE GRADATION FOR COMPOSITE REVETMENT TOE (UPPER), REINFORCED REVETMENT TIEBACKS, WINDROW REVETMENT AND REFUSALS, HARDPOINT UPPER PAVING FILL AND ROOT AND UPPER SEGMENTS OF EARTH CORE DIKES (UPPER BANK TREATMENT)

Weight or Size of Stone	Percent of Total Weight Lighter Than or Passing
200 lbs	100
50 lbs	35 - 60
2-inch screen	0 - 15

Table 1-24

STONE GRADATION FOR COMPOSITE REVETMENT TOE (LOWER), REINFORCED REVETMENT TOE, HARDPOINT CORE AND TOE REVETMENT OF EARTH CORE DIKES AND OTHER STONE FILL STRUCTURES

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

The stone material used in the construction of this project was required to meet the following standards: bulk specific gravity, saturated surface - dry basis, Method CRD-C 107-69, required not less than 2.35; soundness in magnesium sulfate, ASTM Standard C88-76, required a loss of 5 cycles of not more than 12 percent; soundness in freezing and thawing for Ledge Rock Method Modified Designation T103-62, required a loss at 12 cycles not to exceed 10 percent.

An aerial photograph of completed Earth Core Dikes 1321.15 and 1320.8 is shown on Photo 29. A typical photograph of a reinforced revetment is shown on Photo 30. Photo 31 shows vegetation cover on Dike 1321.15. The environmental notch of Dike 1320.8 is shown on Photo 32.

Table 1-25

BURNT CREEK CONSTRUCTION PROGRAM

Structure*	Type*	Total Length (Ft)	Date Start	Date End	Total Stone (tons)	Total Exc (CY)	Total Gravel (tons)	Other	Total Cost	Cost/ft. of Structure
1321.95	HP	100	10/25/79	10/25/79	604	300	25		8,324.00	83.24
1321.92	HP	60	6/80	6/80	360	180	25		5,095.00	84.92
1321.89	HP	60	10/25/79	10/25/79	367	180	26		5,193.75	86.56
1321.81	WRF	75	6/21/80	6/23/80	460	340			6,315.00	84.20
1321.80										
0+00 to 6+00	RR	600	6/23/80	6/23/80	2928	2311	361		45,183.00	75.30
9+00 to 15+00	RR	600	6/10/80	6/28/80	2927	1800	360		44,135.75	73.56
18+00 to 22+00	RR	400	6/17/80	6/28/80	1948	1200	240		29,383.00	73.46
25+00 to 27+50	CR	250	10/23/79	10/29/79	1693		158		22,793.25	91.17
1321.60	WRF	50	6/09/80	6/10/80	303	225			4,161.75	83.24
1321.40	WRF	50	6/10/80	6/10/80	301	225			4,137.25	82.75
1321.15	Dike									
0+75 to 6+75		600			3925		800	5700 CY Emb 300 SY FC	72,506.25	120.84
1320.8	Dike									
0+80 to 1+30		50	10/09/79	10/16/79	200	200			2,850.00	57.00
1+30 to 2+30		100	10/09/79	10/16/79	1125	200	200	475 CY Emb 300 SY FC	19,050.00	190.50
2+30 to 5+30		300	10/08/79	10/16/79	2100		350	3600 CY Emb	38,375.00	127.92
5+30 to 5+80		50	10/09/79	10/16/79	865		220	510 CY Emb	14,603.75	292.08
1320.71	WRF	50	10/04/79	10/05/79	301	225			4,137.25	82.75
1320.70										
0+00 to 5+00	RR	500	10/06/79	10/09/79	2150	1500			29,337.50	58.68
5+00 to 9+00	WR	400	10/12/79	10/13/79	1629	2400			24,755.25	61.89
11+70 to 22+70	CR	1100	10/01/79	10/22/79	5396		666		74,759.00	67.96
1320.53	WRF	50	10/01/79	10/03/79	304	225			4,174.00	83.48
Rehab bankline and construct refusal 1320.56									$6,311.00	
Relocate Dike 1321.2, delete stone root, add refusal 1321.31									$1,234.00	

SUBTOTAL	$466,800.00
Clearing and Grubbing	28,000.00
Seeding	23,250.00
Monitoring & Evaluation	54,000.00
Remove Car Bodies	1,500.00
Supervision and Administration	24,000.00
Engineering and Design	33,000.00
TOTAL COST	$631,000.00

*HP = Hardpoints; WRF = Windrow Refusal;
RR = Reinforced Revetment; CR = Composite Revetment
Emb = Embankment
FC = Filter Cloth
Dike = Earth Core Dike; WR = Windrow Revetment

Photo 29. Aerial View of Completed Dikes 1321.15 and 1320.8. (Photo taken 15 April 1980)

Photo 30. Reinforced Revetment 1321.8, looking downstream at Station 20+00. (Photo taken 6 August 1980)

Burnt Creek Area
Photos 29 and 30

Photo 31. Vegetation cover on Dike 1321.15. (Photo taken 15 April 1980)

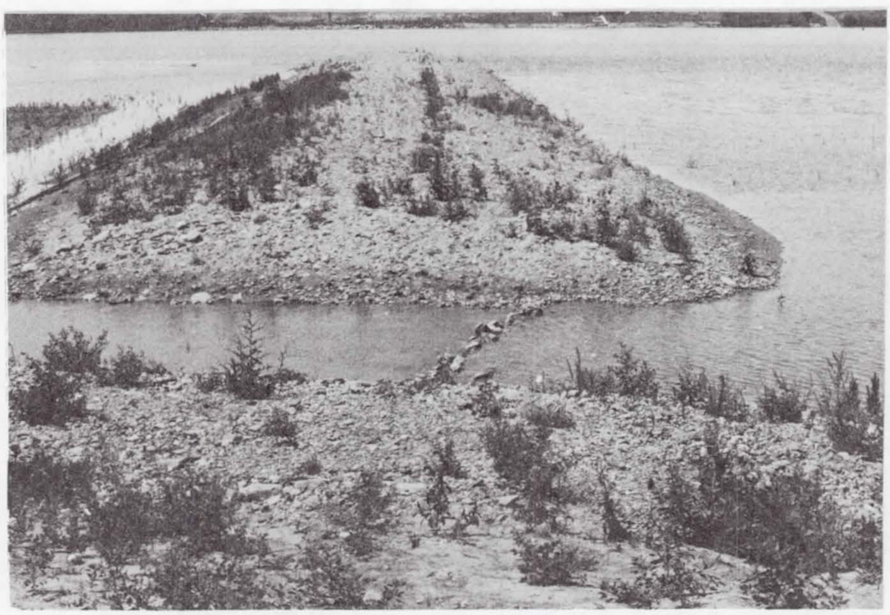


Photo 32. Dike 1320.8, with environmental gap shown in the foreground, approximately 9 months after completion. (Photo taken 18 July 1960)

Burnt Creek Area
Photos 31 and 32

6. **I-94 HIGHWAY PROJECT.** The general plan for this project is shown on Plates 15-1 and 15-2. The demonstration project consists of approximately 400 linear feet of reinforced revetment, Type I, 856 linear feet for 17 windrow refusals, 350 linear feet of windrow revetment, 5,825 linear feet of composite revetment divided into 14 segments, 1,820 linear feet of rehabilitated revetment in five segments, 150 linear feet of four existing concrete hardpoints, and 100 linear feet of hardpoint.

As a result of the increasing difficulty in locating quality stone material from nearby sources, the cost of stone has risen drastically in recent years. For this reason, an alternate type of material was fabricated and utilized to replace the low grade material in the lower toe zones of composite revetment which would still maintain structure stability.

Of the 5,825 linear feet of composite revetment, 4,100 linear feet is composed of a lower toe zone of broken soil-cement covered by high quality stone and a thin layer of gravel. The soil-cement material was designed to be used exclusively in the lower toe zones of composite revetment, as shown on the typical sections, Plate 15-4. The entire composite revetment consists of 1.5 cubic yards per linear foot of graded soil-cement covered by 2 tons per linear foot of stone material which is topped by a thin cover layer of gravel.

The entire fabrication process was done on a large vegetated sandbar near the project area. The soil-cement was fabricated utilizing the insitu material off the sandbar as the soil base. The sieve analysis run on this sandy material, shown in Table 1-26, showed a very compatible soil material for soil-cement. A mix design was determined resulting in a required cement content of 13% by weight of soil. A portable continuous central plant method of mixing the material was established on the sandbar. The soil, water, and cement were systematically added in their appropriate quantities to a pug mill for mixing which resulted in a production rate of approximately 100 cubic yards per hour. The mixed material was then hauled by a front end loader to the curing site and then leveled in one foot thick layers on the compacted curing site by a small dozer. The material was then compacted by a rubber-tired roller to at least 96% of the maximum dry density of 108.1 pounds per cubic foot. The in-place soil cement was then sliced both lengthwise and crosswise along the surface by four heavy duty plow cutters mounted on a beam attached to a small crawler loader bucket that allowed height variation hydraulically. The material was not recompacted after cutting to avoid resealing the joints and to reduce unnecessary vibration on the new curing material. The mixing, placing and cutting process took 7 days to complete the required 6,150 cubic yards of soil-cement. The soil-cement was then covered with sand and wet cured for 7 days. After curing, the soil-cement material was broken along the fracture lines to the specified gradation, shown on Plate 15-5, and transported by floating plant equipment to the construction site for placement in the toe of the composite revetment structures. This placement procedure took a total of 1-1/2 weeks.

Table 1-26

SOIL-CEMENT TEST RESULTS

Sieve Analysis of Soil Material -	Percent Passing	Total Sample
	#10 sieve (2.00mm)	100%
	#20 sieve (0.84mm)	99.4%
	#40 sieve (0.42mm)	95.8%
	#80 sieve (0.177mm)	42.4%
	#200 sieve (0.074mm)	5.0%
	0.05mm	4.0%
	0.02mm	2.0%
	0.005mm	0

Soil Classification - Unified - Poorly graded sand, SP
AASHO - A-3

Optimum Moisture Content - 13.8%

Maximum Dry Density - 108.1 pounds per cubic foot

Cement Content by weight of dry soil material - 13%

The reinforced revetment Type I consists of the "toe" fill (stone or low grade material) placed adjacent to the high bank, and the "tie-back" stone fills placed in trenches excavated into the high bank. The existing concrete hardpoints were covered with gravel.

Table 1-29 displays the construction program at the I-94 Highway area.

Tables 1-27 and 1-28 display the specified stone gradations.

Table 1-27

STONE GRADATION FOR COMPOSITE REVETMENT TOE (UPPER), REHABILITATED REVETMENT, REINFORCED REVETMENT TIEBACKS, WINDROW REVETMENT AND REFUSALS, HARDPOINT UPPER PAVING FILL AND ROOT

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
200 lbs	100
50 lbs	35 - 60
2-inch screen	0 - 15

Table 1-28

STONE GRADATION FOR COMPOSITE REVETMENT TOE (LOWER), REINFORCED REVETMENT TOE AND HARDPOINT CORE

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

Photos 38 and 39 show 500 lb. and 200 lb. gradation tests. The stone material used in the construction of this project was required tc meet the following standards: bulk specific gravity, saturated surface-dry basis, Method CRD-C 107-69, required not less than 2.35. Soundness in magnesium sulfate, ASTM Standard C88-76, required a loss of 5 cycles of not more than 12 percent; soundness in freezing and thawing for Ledge Rock Method Modified Designation T103-62, required a loss at 12 cycles not to exceed 10 percent.

Photographs of the soil-cement fabrication site and the soil-cement material placed in the tow of a composite revetment are shown on Photos 33 and 34.

Photographs of representative erosion areas and structures during and after construction are shown on Photos 35, 36 and 37.

Photos 40 and 41 show the cobbles and spalls gradation test and the gravel stockpile.

Table 1-29

I-94 CONSTRUCTION PROGRAM

Structure*	Type*	Total Length	Date Start	Date End	Total Stone (tons)	Total LGM (tons)	Total Exc (CY)	Total Gravel (tons)	Other	Total Cost	Cost/ft. of Structure
1318.21	WRF	75	7/21/80	7/22/80	447		335			11,004.08	110.04
1318.2											
0+00 to 1+50	ReR	150	6/17/80	7/18/80	302				76 T C&S	7,981.88	53.21
1+50 to 5+50	CR	400	6/9/80	7/15/80	1810			246		44,182.95	110.46
7+50 to 11+75	CR	425	6/11/80	7/16/80	1919			262		46,872.46	110.29
13+25 to 15+00	CR	175	6/16/80	7/17/80	788			104		19,180.62	109.60
16+25 to 18+00	CR	175	6/16/80	7/17/80	804			107		19,575.54	111.86
20+00 to 22+50	CR	250	6/17/80	7/17/80	1143			158		27,969.22	111.88
1318.12	WRF	50	7/21/80	7/22/80	300		225			7,395.20	147.90
1318.10	HP	40	7/18/80	7/18/80				35		623.00	15.58
1318.08	HP	40	7/18/80	7/18/80				35		623.00	15.58
1318.06	HP	40	7/18/80	7/18/80				32		571.02	14.28
1318.04	WRF	40	7/21/80	7/22/80	238		180			5,867.54	146.69
1318.01	WRF	30	7/22/80	7/23/80	190		135			4,660.20	155.34
1317.97	WRF	50	7/22/80	7/23/80	318		225			7,783.50	155.67
1317.95	HP	30	7/18/80	7/18/80				32		569.60	18.99
1317.90	WRF	50	7/7/80	7/7/80	311		225			7,846.20	156.92
1317.89	WR	350	6/10/80	7/3/80	1586		2100			42,248.16	120.71
1317.79	WRF	50	7/3/80	7/7/80	321		225			7,846.20	156.92
1317.78											
0+00 to 3+00	CR	300	6/19/80	8/28/80	1355			178		32,990.75	109.97
6+00 to 11+00	CR	500	6/19/80	8/28/80	1007			299	750 CY S-C	51,467.34	
11+00 to 12+50	ReR	150	6/19/80	8/28/80	299				70 T C&S	7,826.59	52.18
12+50 to 14+00	CR	150	6/19/80	8/28/80	312			92	225 CY S-C	15,699.45	104.66
14+00 to 16+00	ReR	200	6/19/80	8/28/80	603					13,267.76	66.34
21+50 to 27+00	CR	550	6/19/80	8/28/80	1100			331	825 CY S-C	56,488.23	102.71
1317.71	WRF	50	7/25/80	8/19/80	314		225			7,696.60	153.93
1317.43	WRF	61	7/28/80	8/15/80	301		225			7,413.02	121.52
1317.31	WRF	50	7/28/80	8/18/80	311		225			7,620.92	152.42
1317.3											
0+00 to 3+50	ReR	350	6/30/80	9/3/80	739				164 T C&S	19,172.89	54.78
4+90 to 12+60	ReR	770	6/30/80	9/3/80	1543				369 T C&S	40,525.54	52.02
1317.19	WRF	50	7/28/80	8/12/80	305		225			7,488.26	149.77

Table 1-29 contd.

I-94 CONSTRUCTION PROGRAM

Structure*	Type*	Total Length	Date Start	Date End	Total Stone (tons)	Total LGM (tons)	Total Exc (CY)	Total Gravel (tons)	Other	Total Cost	Cost/ft. of Structure
1317.11	WRF	50	7/28/80	8/12/80	327		225			7,974.24	159.48
1317.1	RR	400	6/18/80	8/28/80	2315		83	240		55,479.48	138.70
1316.93	WRF	50	7/30/80	8/13/80	302		225			7,428.20	148.56
1316.92											
0+00 to 2+00	ReR	200	7/3/80	8/27/80	603			392	100 T C&S 975 CY S-C	81,954.67	96.42
2+00 to 8+50	CR	650	7/3/80	8/27/80	1307						
11+50 to 16+50	CR	500	7/3/80	8/27/80	1147			311	750 CY S-C	54,775.07	109.55
19+50 to 25+50	CR	600	7/3/80	8/27/80	1310			358	900 CY S-C	69,988.78	106.65
28+50 to 34+50	CR	600	7/3/80	8/27/80	1208			356	900 CY S-C	61,789.48	102.98
37+50 to 43+00	CR	550	7/3/80	8/27/80	1115			333	825 CY S-C	56,867.79	103.40
1316.76	WRF	50	7/30/80	8/19/80	291		225			7,184.22	143.68
1316.66	WRF	50	7/30/80	8/19/80	307		225			7,534.68	150.69
1316.46	WRF	50	7/31/80	8/19/80	308		225			7,562.84	151.26
1316.27	WRF	50	7/31/80	8/21/80	304		225			7,465.38	149.31
1316.06	HP	100	9/2/80	9/2/80	609		300	34		15,048.04	150.48

SUBTOTAL	$ 971,500.00
Clearing and Grubbing	16,500.00
Seeding	2,200.00
Monitoring & Evaluation	69,000.00
Supervision and Administration	65,000.00
Engineering and Design	104,000.00
TOTAL COST	$1,228,000.00

*WRF = Windrow Refusal; ReR = Rehabilitated Revetment;
CR = Composite Revetment; HP = Hardpoint; RR = Reinforced Revetment;
WR = Windrow Revetment
C&S = Cobbles & Spalls
S-C = Soil-Cement

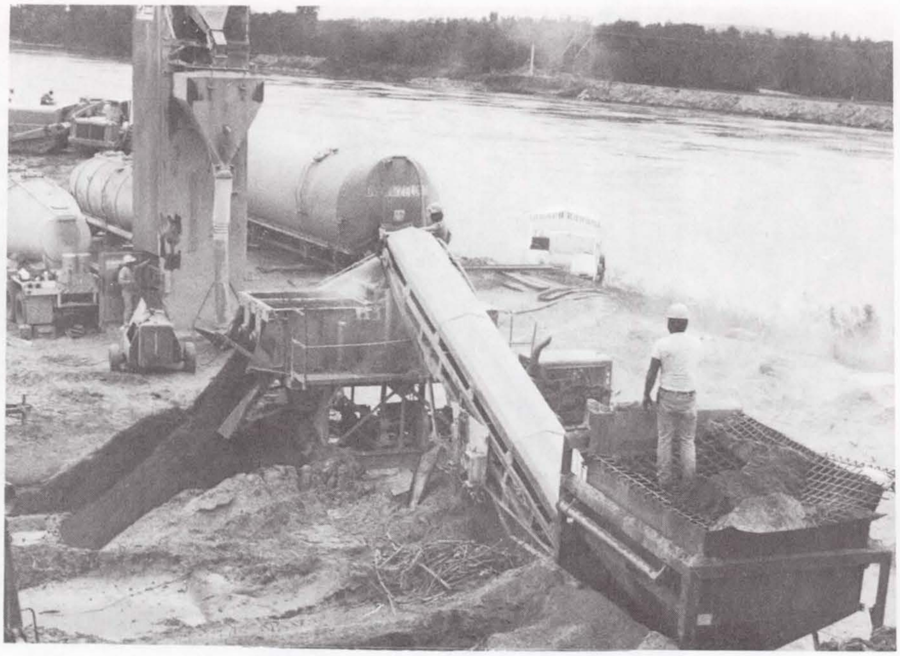


Photo 33. Soil-Cement Fabrication Site located on a high vegetated island near the project site. (Photo taken 17 July 1980)

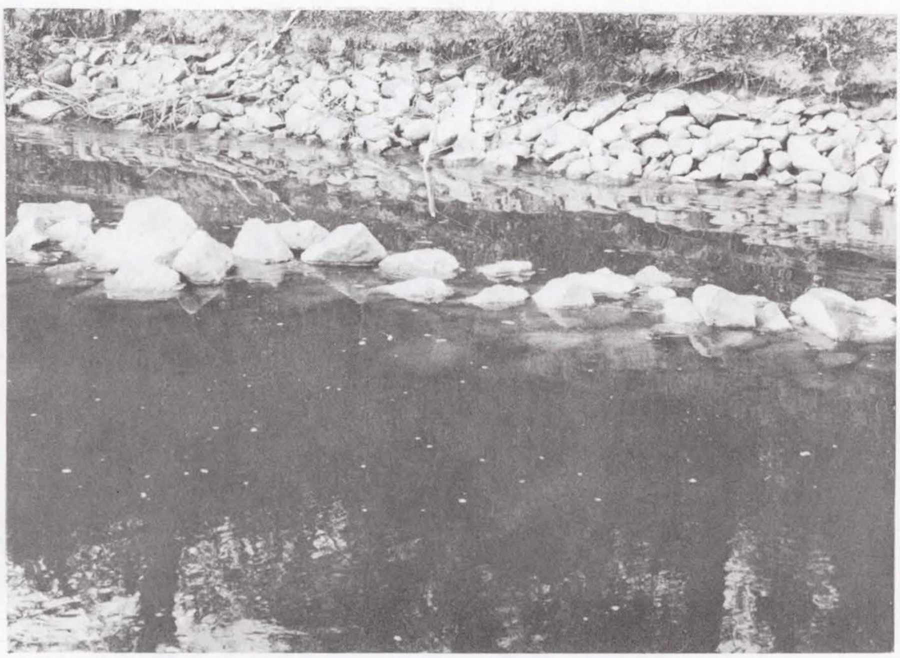


Photo 34. Soil-Cement toe prior to stone cover. (Photo taken 15 August 1980)

Photo 35. Composite Revetment during placement of gravel cover at Stations 7+50 to 11+75. (Photo taken 26 August 1980)

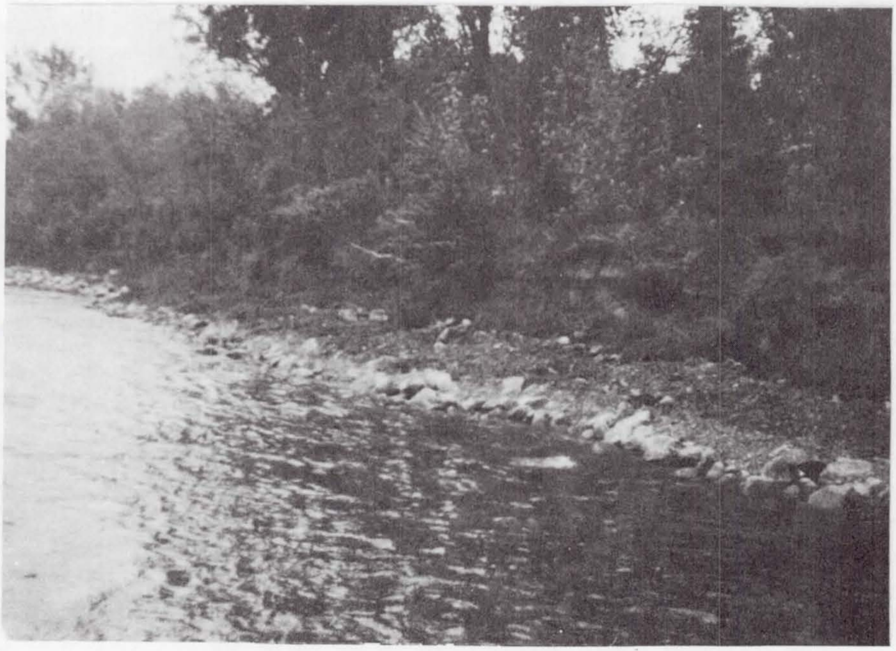


Photo 36. Composite Revetment 1317.78 approximately 3 months after completion. (Photo taken 2 September 1980)

I-94 Area
Photos 35 and 36

Photo 37. Composite Revetment 1318.2 approximately 4 months after completion. (Photo taken 9 October 1980)

Photo 38. 500 pound gradation test. (Photo taken 12 May 1980)

I-94 Area
Photos 37 and 38

Photo 39. 200 pound gradation test. (Photo taken 12 May 1980)

Photo 40. Cobbles and spalls gradation test. (Photo taken 12 May 1980)

I-94 Area
Photos 39 and 40

Photo 41. Gravel stockpile. (Photo taken 12 May 1980)

I-94 Area
Photo 41

7. **PRETTY POINT (PHASE I) PROJECT.** The general plan for this project is shown on Plate 9-1. This demonstration project is currently under construction and consists of approximately 500 linear feet of reinforc revetment, five 50 linear feet of windrow refusals, two segments totalling 900 linear feet of windrow revetment, and 1,100 linear feet of composite revetment in two segments. The reinforced revetments are Type II and the windrow revetments are Type A, which are discussed in detail in Section III.B., paragraph 1.a., of this appendix.

The demonstration aspects of the project incorporate revetment structural variations including different windrow material application rates, and alternate reinforced revetment tieback intervals and stone toe designs. The average stone material application rate for each structure type is shown in Table 1-30.

Table 1-30

Structure Type	Average Stone Material Application Rate (tons/linear feet)
Reinforced Revetment	5.6
Windrow Revetment	3.9
Windrow Refusal	6.0
Composite Revetment	4.5

Table 1-33 shows the construction schedule for the Pretty Point (Phase I) project.

Tables 1-31 and 1-32 indicate the specific stone gradation for the various structural components.

Table 1-31

STONE GRADATION FOR COMPOSITE REVETMENT TOE, SMALL GRADATION (UPPER ZONE), REINFORCED REVETMENT TIEBACKS, WINDROW REVETMENT AND REFUSALS, HARDPOINT UPPER PAVING FILL AND ROOT

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
GRADATION A	
150 lbs	100
40 lbs	30 - 55
2-inch screen	0 - 15
GRADATION B	
200 lbs	100
50 lbs	35 - 60
2-inch screen	0 - 15
GRADATION C	
250 lbs	100
60 lbs	30 - 55
2-inch screen	0 - 15

Table 1-32

STONE FOR COMPOSITE REVETMENT TOE, LARGE GRADATION (LOWER ZONE), REINFORCED REVETMENT TOE

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

Photographs of typical bankline prior to construction are shown on Photos 42 and 43.

Table 1-33
PRETTY POINT (PHASE I)
CONSTRUCTION SCHEDULE

ESTIMATED QUANTITIES

STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	C.R.P. ELEV.	STONE (TONS)	STONE GRADATION	STONE OR LOW GRADE MATRL. (TONS)	EXCAVATION (C.Y.)	GRAVEL (TONS)
REF. 1343.72	R	50	2+30 to 2+80	Windrow Refusal	1674.3	300	C	---	225	---
REF. 1343.71	R	500	0+00 to 5+00	Reinforced Revetment -Type II (Tieback interval @ 100')	1647.3	550	C	2250	1500	300
REF. 1343.60	R	50	3+70 to 4+20	Windrow Refusal	1647.2	300	C	---	225	---
REV. 1343.59	R	400	0+00 to 4+00	Windrow Revetment -Type A (4.5 t/lf)	1647.2	1800	C	---	1600	---
	R	500	7+00 to 12+00	Windrow Revetment -Type A (3.5 t/f)	1647.1	1750	C	---	1500	---
REF. 1343.46	R	50	3+05 to 3+55	Windrow Refusal	1647.1	300	C	---	225	---
REF. 1343.34	R	50	4+75 to 5+25	Windrow Refusal	1647.0	300	B	---	225	---
REV. 1343.33	R	500	0+00 to 5+00	Composite Revetment	1647.0	1000	B	1250	---	300
	R	600	8+00 to 14+00	Composite Revetment	1646.9	1200	B	1500	---	300
REF. 1343.26	R	50	1+80 to 2+30	Windrow Refusal	1646.9	300	B	---	225	---

NOTES: (1) CRP refers to the Construction Reference Plane elevation as defined in Section II.B.1.b.

(2) Stone Gradations A, B, and C refer to stone sizes and weights as defined in Table 1-25.

Photo 42. Aerial view of upstream portion of Pretty Point-Phase I Area prior to construction. (Photo taken 15 April 1980)

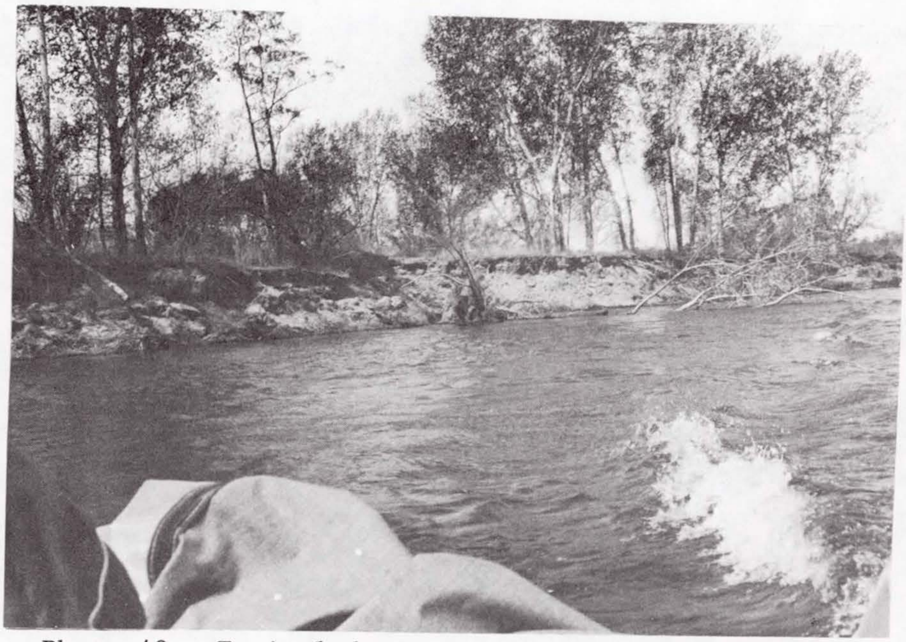


Photo 43. Typical downstream bankline along Pretty Point-Phase I Area prior to construction. (Photo taken 22 May 1980)

Pretty Point-Phase I Area
Photos 42 and 43

8. **PRICE PART I (PHASE I) PROJECT.** The general plan for the project is shown on Plates 10-1 and 10-2. This demonstration project consists of five segments totalling approximately 2,225 linear feet of reinforced revetment, 1,950 linear feet of composite revetment in five segments, two segments of windrow revetment totalling 750 linear feet, and 12 windrow refusals totalling 650 linear feet. The reinforced revetments are Types I, II and IV, and the windrow revetment is Type A. Typical sections of these structure types used in this project are shown on Plates 1-2, 1-3 and 1-4. The demonstration aspects of the project incorporate revetment structural variations including different windrow material application rates and alternative revetment tieback and stone toe designs. The average stone material application rate for the structures constructed at this project is shown in Table 1-34.

Table 1-34

Structure Type	Average Stone Application Rate (tons/linear feet)
Reinforced Revetment	5.6
Composite Revetment	4.5
Windrow Revetment	4.5
Windrow Refusal	6.0

Table 1-37 shows the construction schedule for the Price-Part I (Phase I) project.

Tables 1-35 and 1-36 display the specific stone gradations for the various structural components.

Table 1-35

STONE GRADATION FOR COMPOSITE REVETMENT TOE, SMALL GRADATION (UPPER ZONE), REINFORCED REVETMENT TIEBACKS, WINDROW REVETMENT AND REFUSALS

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
GRADATION A	
150 lbs	100
40 lbs	30 - 55
2-inch screen	0 - 15
GRADATION B	
200 lbs	100
50 lbs	35 - 60
2-inch screen	0 - 15
GRADATION C	
250 lbs	100
60 lbs	30 - 55
2-inch screen	0 - 15

Table 1-36

STONE FOR COMPOSITE REVETMENT TOE, LARGE GRADATION (LOWER ZONE), REINFORCED REVETMENT TOE

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

Photos 44 and 45 show typical eroding banklines along the Price-Part I (Phase I) project area.

Table 1-37
PRICE-PART I (PHASE I)
CONSTRUCTION SCHEDULE

ESTIMATED QUANTITIES

STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	C.R.P. ELEV.	STONE (TONS)	STONE GRADATION	STONE OR LOW-GRADE MATRL. (TONS)	EXCAVATION (C.Y.)	GRAVEL (TONS)
REF. 1342.38	R	50	1+80 to 2+30	WINDROW REFUSAL	1646.3	300	A	---	300	---
REV. 1342.37	R	800	0+00 to 8+00	Reinforced Revetment -Type II (Tieback intervals @ 100')	1646.3	880	A	3600	2400	480
REF. 1342.17	R	50	2+45 to 2+95	Windrow Refusal	1646.1	300	B	---	300	---
REV. 1342.16	R	450	0+00 to 4+50	Composite Revetment	1646.1	900	B	1125	---	210
REF. 1342.04	R	100	6+15 to 7+15	Windrow Refusal	1646.0	600	B	---	600	---
REV. 1342.03	R	350	0+00 to 3+50	Reinforced Revetment -Type I (tieback intervals @ 70')	1646.0	550	B	1575	1050	210
	R	400	7+00 to 11+00	Reinforced Revetment -Type I (tieback intervals @ 200')	1645.9	220	B	1800	1200	240
REF. 1341.84	R	50	4+30 to 4+80	Windrow Refusal	1645.9	300	B	---	300	---
REF. 1341.68	R	50	2+80 to 3+30	Windrow Refusal	1645.8	300	C	---	300	---
REV. 1341.67	R	650	0+00 to 6+50	Composite Revetment	1645.8	1300	C	1625	---	
REV. 1341.67	R	150	9+00 to 10+50	Composite Revetment	1645.6	300	C	375	---	90
REF. 1341.47	R	50	0+50 to 1+00	Windrow Refusal	1645.6	300	C	---	300	---
REF. 1341.36	R	50	0+15 to 0+65	Windrow Refusal	1645.5	300	B	---	300	---
REV. 1341.35	R	400	0+00 to 4+00	Windrow Revetment Type A (4.5 t/lf)	1645.5	1800	B	---	2400	---

NOTES: (1) CRP refers to the Construction Reference Plane elevation as defined in Section II.B.1.b.

(2) Stone Gradations A, B, and C refer to stone sizes and weights as defined in Table 1-28.

Table 1-37 contd.
PRICE-PART I (PHASE I)
CONSTRUCTION SCHEDULF

								ESTIMATED QUANTITIES		
STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	C.R.P. ELEV.	STONE (TONS)	STONE GRADATION	STONE OR LOW-GRADE MATRL. (TONS)	EXCAVATION (C.Y.)	GRAVEL (TONS)
REV. 1341.35	R	350	6+50 to 10+00	Windrow Revetment Type A)4.5 t/lf)	1645.4	1575	B	---	2100	---
REF. 1341.24	R	50	0+25 to 0+75	Windrow Refusal	1645.4	300	B	---	300	---
REF. 1341.14	R	50	0+80 to 1+30	Windrow Refusal	1645.3	300	B	---	300	---
REV. 1341.13	R	350	0+00 to 3+50	Composite Revetment	1645.3	700	A	875		210
	R	350	0+50 to 9+00	Composite Revetment	1645.25	700	A	875	210	
REF. 1341.04	R	50	0+70 to 1+20	Windrow Refusal	1645.25	300	A	---	300	---
REF. 1340.89	R	50	-0+20 to 0+30	Windrow Refusal	1645.2	300	B	---	300	---
REV. 1340.88	R	375	0+00 to 3+75	Reinforced Revetment[1] Type IV (tieback interval @ 75')	1645.2	550	B	1690	1125	225
	R	300	6+25 to 9+25	Reinforced Revetment[1] Type IV (tieback interval @ 100')	1645.1	220	B	1350	900	180
REF. 1340.78	R	50	0+50 to 1+00	Windrow Refusal	1645.1	300	B	---	300	---

NOTES: (1) CRP refers to the Construction Reference Plane elevation as defined in Section II.B.1.b.

(2) Stone Gradations A, B, and C refer to stone sizes and weights as defined in Table 1-28.

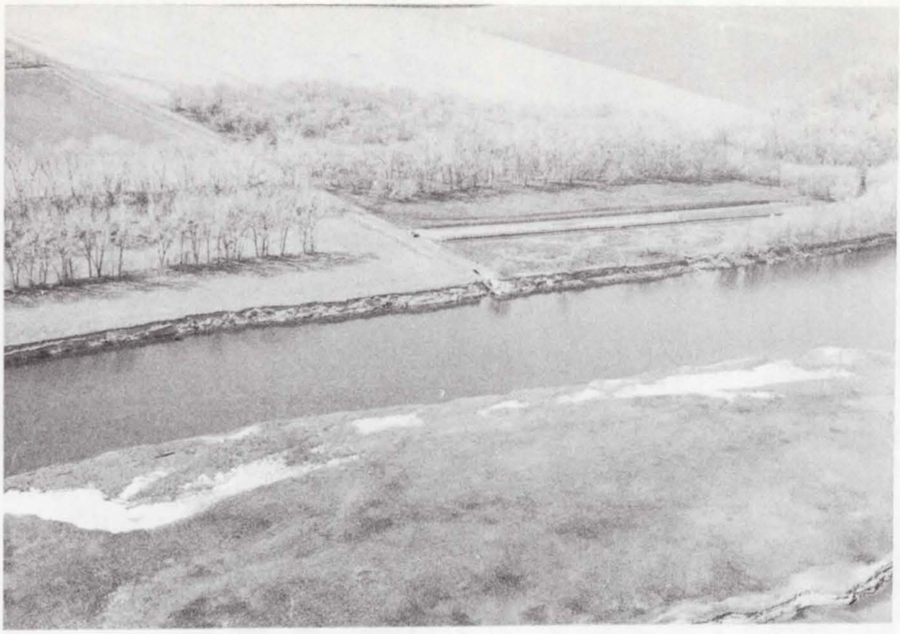


Photo 44. Aerial view of Price-Part I Phase I area, prior to construction. (Photo taken 15 April 1980)

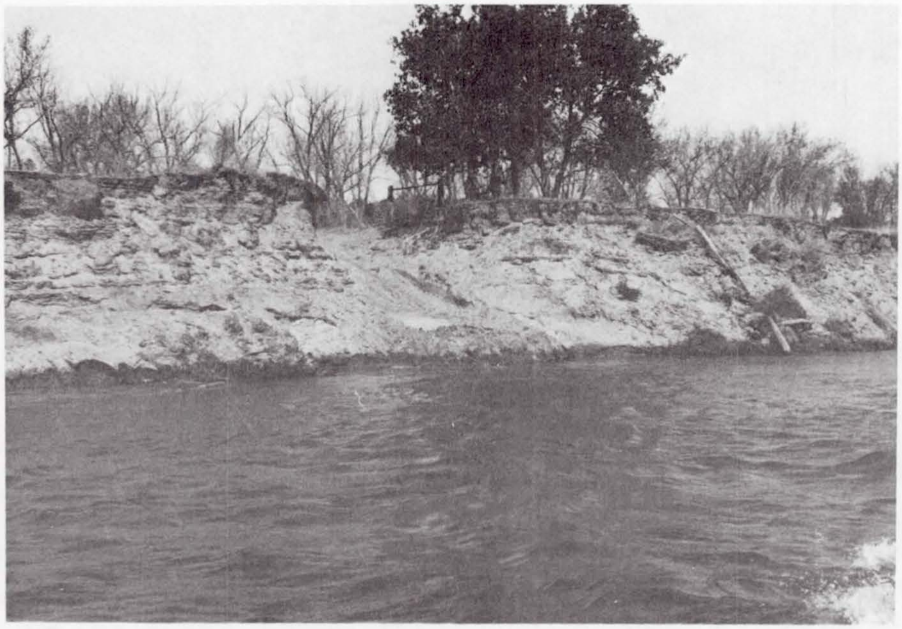


Photo 45. Typical eroding bankline. (Photo taken 22 May 1980)

Price-Part I - Phase I Area
Photos 44 and 45

9. **COAL LAKE COULEE (PHASE I) PROJECT.** The general plan for this project is shown on Plate 5-1. This demonstration project was completed in June 1981 and consists of approximately 300 linear feet of reinforced revetment, 700 linear feet of windrow revetment, two segments totalling 1,300 linear feet of composite revetment, and four 50 linear feet windrow refusals. The reinforced revetment is Type I and the windrow revetment is Type A. Typical sections of the structural types used in this project are shown on Plates 1-2, 1-3 and 1-4. The demonstration aspects of the project incorporate revetment structural variations including different windrow material application rates and alternative revetment tieback intervals and stone toe designs. The average stone material application rate for each structure type at this project is shown in Table 1-38.

Table 1-38

Structure Type	Average Stone Application Rate (tons/linear feet)
Reinforced Revetment	5.6
Composite Revetment	4.5
Windrow Revetment	3.5
Windrow Refusal	6.0

Table 1-41 shows the construction schedule for the Coal Lake Coulee (Phase I) project.

Tables 1-39 and 1-40 indicate the specific stone gradations for various structural components.

Table 1-39

STONE GRADATION FOR COMPOSITE REVETMENT TOE, SMALL GRADATION UPPER ZONE), REINFORCED REVETMENT, TIEBACKS, WINDROW REVETMENT AND REFUSALS

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
	GRADATION A
150 lbs	100
40 lbs	30 - 55
2-inch screen	0 - 15
	GRADATION B
200 lbs	100
50 lbs	35 - 60
2-Inch screen	0 - 15
	GRADATION C
250 lbs	100
60 lbs	30 - 55
2-inch screen	0 - 15

Table 1-40

STONE FOR COMPOSITE REVETMENT TOE, LARGE GRADATION (LOWER ZONE), REINFORCED REVETMENT TOE

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

Photo 46 shows the typical eroding bankline along the Coal Lake Coulee (Phase I) project area.

Table 1-41
COAL LAKE COULEE (PHASE I)
CONSTRUCTION SCHEDULE

								ESTIMATED QUANTITIES		
STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	C.R.P. ELEV.	STONE (TONS)	STONE GRADATION	STONE OR LOW-GRADE MATRL. (TONS)	EXCAVATION (C.Y.)	GRAVEL (TONS)
REF. 1359.14	L	50'	0+40 to 0+90	Windrow Refusal	1658.6	300	B	---	300	---
REV. 1359.13	L	700'	0+00 to 7+00	Windrow Revetment -Type A (3.5 T/LF)	1658.6	2450	B	---	2100	---
REF. 1358.98	L	50'	1+90 to 2+40	Windrow Refusal	1685.5	300	B	---	300	---
REV. 1358.97	L	300	0+00 to 3+00	Reinforced Revetment -Type I (Tieback intervals @ 100')	1658.5	330	B	1350	900	180
REF. 1358.87	L	50'	1+80 to 2+30	Windrow Refusal	1658.4	300	C	---	300	---
REV. 1358.86	L	600'	0+00 to 6+00	Composite Revetment	1658.4	1200	C	1500	---	360
	L	700'	9+00 to 16+00	Composite Revetment	1658.3	1400	A	1750	---	420
REF. 1358.70	L	50'	1+90 to 2+40	Windrow Refusal	1658.3	300	A	---	300	---

NOTES: (1) CRP refers to the Construction Reference Plane elevation as defined in Section II.B.1.b.

(2) Stone Gradations A, B, and C refer to stone sizes and weights as defined in Table 1-31.

Photo 46. Typical severely eroding bankline along the Coal Lake Coulee - Phase I project area. (Photo taken 23 May 1980)

Coal Lake Coulee - Phase I Area
Photo 46

10. KNIFE POINT I (PHASE I) PROJECT.

The general plan for this project is shown on Plate 3-1. The demonstration project was completed in June 1981 and consists of approximately 750 linear feet of reinforced revetment in two segments, 850 linear feet of composite revetment in two segments, 850 linear feet of windrow revetment, and five 50 linear feet windrow refusals. The reinforced revetment is Type II and IV. The windrow revetment is Type A. Typical sections of the structural types used in this project are shown on Plates 1-2, 1-3 and 1-4. The demonstration aspects of the project incorporate revetment structural variations including different windrow material application rates and alternative revetment tieback and stone toe designs. The average stone application rate for each structure at this project is shown in Table 1-42.

Table 1-42

Structure Type	Average Stone Application Rate (tons/linear feet)
Windrow Revetment	4.5
Reinforced Revetment	5.6
Composite Revetment	4.5
Windrow Refusals	6.0

Table 1-45 shows the construction schedule for the Knife Point I (Phase I) project.

Tables 1-43 and 1-44 display the specific stone gradations for the various structural components of this project.

Table 1-43

STONE GRADATION FOR COMPOSITE REVETMENT TOE, SMALL GRADATION UPPER ZONE), REINFORCED REVETMENT TIEBACKS, WINDROW REVETMENT AND REFUSALS

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
GRADATION A	
150 lbs	100
40 lbs	30 - 55
2-inch screen	0 - 15
GRADATION B	
200 lbs	100
50 lbs	35 - 60
2-inch screen	0 - 15
GRADATION C	
250 lbs	100
60 lbs	30 - 55
2-inch screen	0 - 15

Table 1-44

STONE FOR COMPOSITE REVETMENT TOE, LARGE GRADATION (LOWER ZONE), REINFORCED REVETMENT TOE

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

A photograph of the typical eroding bankline at the Knife Point - Part I (Phase I) project area is shown on Photo 47.

Table 1-45
KNIFE POINT-PART I (PHASE I)
CONSTRUCTION SCHEDULE

						ESTIMATED QUANTITIES				
STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	C.R.P. ELEV.	STONE (TONS)	STONE GRADATION	STONE OR LOW-GRADE MATRL. (TONS)	EXCAVATION (C.Y.)	GRAVEL (TONS)
REF. 1374.06	L	50'	2+40 to 2+90	Windrow Refusal	1667.8	.00	A	---	300	---
REV. 1374.05	L	850'	0+00 to 8+50	Windrow Revetment -Type A (4.5 T/LF	1667.8	3325	A	---	3400	---
REF. 1373.86	L	50'	0+80 to 1+30	Windrow Refusal	1667.7	300	A	---	300	---
REV. 1373.85	L	400'	0+00 to 4+00	Composite Revetment	1667.7	800	A	1000	---	240
		450'	6+50 to 11+00	Composite Revetment	1667.6	900	C	1125	---	270
REF. 1373.70	L	50'	1+40 to 1+90	Windrow Refusal	1667.6	300	C	---	300	---
REF. 1373.45	L	50'	0+90 to 1+40	Windrow Refusal	1667.5	300	C	---	300	---
REV. 1373.44	L	400'	0+00 to 4+00	Reinforced Revetment - Type IV (Tieback Intervals @ 100')	1667.5	440	C	1800	1200	240
	L	350	7+00 to 10+50	Reinforced Revetment - Type II (Tieback Intervals @ 70')	1667.5	385	B	1575	1050	210
REF. 1373.37	L	50'	0+60 to 1+10	Windrow Refusal	1667.5	300	B	---	300	---

NOTES: (1) CRP refers to the Construction Reference Plane elevation as defined in Section II.B.1.b.

(2) Stone Gradations A, B, and C refer to stone sizes and weights as defined in Table 1-34.

Photo 47. Typical eroding bankline along the Knife Point - Part I - project area. (Photo taken 23 May 1980)

Knife Point - Part I - Phase I Area
Photo 47

11. **WILDWOOD (PHASE I) PROJECT.** The general plan for this project is shown on Plate 8-1. The demonstration project is currently under construction and consists of approximately 300 linear feet of reinforced revetment, two segments totalling 1,150 linear feet of composite revetment, 700 linear feet of windrow revetment and four linear feet 50 windrow refusals. The reinforced revetment is Type II and IV. The windrow revetment is Type A and B. Typical sections of the structural types used in this project are shown on Plates 1-2, 1-3 and 1-4. Table 1-49 shows the construction schedule at the Wildwood (Phase I) project. The demonstration aspects of the project incorporate revetment structural variations including different windrow material application rates, and alternative revetment tieback and stone toe designs. The average stone application rates for the various structure types are shown in Table 1-46.

Table 1-46

Structure Type	Average Stone Application Rate (tons/linear feet)
Reinforced Revetment	6.0
Composite Revetment	4.5
Windrow Revetment	4.0
Windrow Refusal	6.0

Tables 1-47 and 1-48 display the specific stone gradations for the various structural components of this project.

Table 1-47

STONE GRADATION FOR COMPOSITE REVETMENT TOE, SMALL GRADATION (UPPER ZONE), REINFORCED REVETMENT TIEBACK, WINDROW REVETMENT AND REFUSALS

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
	GRADATION A
150 lbs	100
40 lbs	30 - 55
2-inch screen	0 - 15
	GRADATION B
200 lbs	100
50 lbs	35 - 55
2-inch screen	0 - 15
	GRADATION C
250 lbs	100
60 lbs	30 - 55
2-inch screen	0 - 15

Table 1-48

STONE FOR COMPOSITE REVETMENT TOE, LARGE GRADATION (LOWER ZONE), REINFORCED REVETMENT TOE

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

A photograph of the typical eroding bankline along the Wildwood (Phase I) Project area is shown on Photo 48.

Table 1-49

WILDWOOD (PHASE I)
CONSTRUCTION SCHEDULE

STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	C.R.P. ELEV.	STONE (TONS)	STONE GRADATION	ESTIMATED QUANTITIES STONE OR LOW-GRADE MATRL. (TONS)	EXCAVATION (C.Y.)	GRAVEL (TONS)
REF. 1344.96	L	50'	0+40 to 0+90	Windrow Refusal	1648.2	300	B	---	250	---
REV. 1344.95	L	150'	0+00 to 1+50	Reinforced Revetment Type II (Tieback interval at 75')	1648.2	220	B	675	450	90
	L	150'	1+50 to 3+00	Reinforced Revetment Type IV (Tieback interval at 75')	1648.2	220	B	675	450	90
REF. 1344.83	L	50'	0+30 to 0+80	Windrow Refusal	1648.1	300	C	---	250	---
REV. 1344.82	L	500'	0+00 to 5+00	Composite Revetment	1648.1	1000	C	1250	---	300
	L	650'	8+00 tc 14+50	Composite Revetment	1648.0	1300	C	1625	---	390
REF. 1344.72	L	50'	0+00 to 0+50	Windrow Refusal	1648.0	300	B	---	250	---
	L	50'	0+30 to 0+80	Windrow Refusal	1647.8	300	B	---	250	
REV. 1344.50	L	350'	0+00 to 3+50	Windrow Revetment Type A - 4.5 T/LF	1647.8	1575	B	---	1400	---
	L	350	3+50 to 7+00	Windrow Revetment Type B - 3.5 T/LF	1647.8	1225	B	---	1225	---

NOTES: (1) CRP refers to the Construction Reference Plane elevation as defined in Section II.B.1.b.

(2) Stone Gradations A, B, and C refer to stone sizes and weights as defined in Table 1-37.

Photo 48. Typical eroding bankline along Wildwood - Phase I project area. (Photos taken 22 May 1980)

Wildwood - Phase I Area
Photo 48

12. **PRICE II (PHASE I) PROJECT.** The general plan for the project is shown on Plate 11-1. This demonstration project is currently under construction and consists of approximately 400 linear feet of reinforced revetment, 1,400 linear feet of composite revetment in three segments, and four 50 linear feet windrow refusals. The reinforced revetments are types III and V. Typical sections of the structural types used in this project are shown on Plates 1-2, 1-3 and 1-4. The demonstration aspects of the project incorporate revetment structural variations including alternative revetment tieback and stone toe designs. The average stone application rates for the structure types at this project are shown in Table 1-50.

Table 1-50

Structure Type	Average Stone Application Rate (tons/linear feet)
Reinforced Revetment	6.3
Composite Revetment	4.5
Windrow Refusal	6.0

Tables 1-51 and 1-52 display the specific stone gradations.

Table 1-51

STONE GRADATION FOR COMPOSITE REVETMENT TOE, SMALL GRADATION (UPPER ZONE), REINFORCED REVETMENT TIEBACKS, WINDROW REFUSALS

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
GRADATION A	
150 lbs	100
40 lbs	30 - 55
2-inch screen	0 - 15

Table 1-51 (Cont'd)

STONE GRADATION FOR COMPOSITE REVETMENT TOE, SMALL GRADATION (UPPER ZONE), REINFORCED REVETMENT TIEBACKS, WINDROW REFUSALS

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
GRADATION B	
200 lbs	100
50 lbs	35 - 60
2-inch screen	0 - 15
GRADATION C	
250 lbs	100
60 lbs	30 - 55
2-inch screen	0 - 15

Table 1-52

STONE FOR COMPOSITE REVETMENT TOE, LARGE GRADATION (LOWER ZONE), REINFORCED REVETMENT TOE

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

The construction schedule for this project is shown in Table 1-53.

Table 1-53
PRICE-PART II (PHASE I)
CONSTRUCTION SCHEDULE

STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	C.R.P. ELEV.	STONE (TONS)	STONE GRADATION	ESTIMATED QUANTITIES STONE OR LOW-GRADE MATRL. (TONS)	EXCAVATION (C.Y.)	GRAVEL (TONS)
REF. 1388.71	L	50'	1+70 to 2+20	Windrow Refusal	1643.6	300	A	---	250	---
REV. 1338.70	L	400'	0+00 to 4+00	Composite Revetment	1643.6	800	A	1000	---	240
	L	500'	7+00 to 12+00	Composite Revetment	1643.4	1000	A	1250	---	300
	L	500'	15+00 to 20+00	Composite Revetment	1643.3	1000	A	1250	---	300
REF. 1338.53	L	50'	1+35 to 1+85	Windrow Refusal	1643.4	300	A	---	250	---
REF. 1338.3	L	50'	1+65 to 2+15	Windrow Refusal	1643.3	300	A	---	250	
REF. 1338.22	L	50'	2+10 to 2+60	Windrow Refusal	1643.2	300	B	---	250	---
REV. 1338.21	L	200'	0+00 to 2+00	Reinforced Revetment Type III (Tieback Interval at 100')	1643.2	350	B	900	600	120
		200'	2+00 to 4+00	Reinforced Revetment Type V (Tieback Interval at 100')	1643.2	350	B	900	600	120

NOTES: (1) CRP refers to the Construction Reference Plane elevation as defined in Section II.B.1.b.

(2) Stone Gradations A, B, and C refer to stone sizes and weights as defined in Table 1-40.

13. **FORT LINCOLN (PHASE I) PROJECT.** The general plan for the project is shown on Plate 16-1. This demonstration project was completed in June 1981 and consists of approximately 900 linear feet of rehabilitated revetment in two segments, 1,250 linear feet of composite revetment in three segments, four 50 linear feet windrow refusals and 5 hardpoint structures totalling 500 linear feet. Typical sections used at this project are shown on Plates 1-2, 1-3 and 1-4. Tables 1-57 show the construction schedule at the Fort Lincoln (Phase I) Project. All construction at this project was constructed by floating plant to reduce any upper bank disturbance of the State Park Area in a National Historic Site.

The rehabilitated revetment consisted of adding 1.0 tons of stone per linear foot to the crown of the existing minor protection constructed early in this century. Table 1-54 and 1-55 indicates the specific stone gradations for the various structural components.

Table 1-54

STONE GRADATION FOR COMPOSITE REVETMENT TOE, SMALL GRADATION (UPPER ZONE), WINDROW REFUSALS, HARDPOINT UPPER PAVING FILL AND ROOT, AND REHABILITATED REVETMENT

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
GRADATION A	
150 lbs	100
40 lbs	30 - 55
2-inch screen	0 - 15
GRADATION B	
200 lbs	100
50 lbs	35 - 60
2-inch screen	0 - 15
GRADATION C	
250 lbs	100
60 lbs	30 - 55
2-inch screen	0 - 15

Table 1-55

STONE FOR COMPOSITE REVETMENT TOE, LARGE GRADATION (LOWER ZONE)

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

A photograph of the typical eroding bankline along the Fort Lincoln (Phase I) project area is shown on Photo 49.

The average stone material application rate for each structure type constructed at this project is shown in Table 1-56.

Table 1-56

Structure Type	Average Stone Material Application Rate (tons/linear feet)
Windrow Refusal	6.0
Composite Revetment	4.7
Hardpoints	6.0

Table 1-57
FORT LINCOLN (PHASE I)
CONSTRUCTION SCHEDULE

ESTIMATED QUANTITIES

STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	C.R.P. ELEV.	STONE (TONS)	STONE GRADATION	STONE OR LOW-GRADE MATRL. (TONS)	EXCAVATION (C.Y.)	GRAVEL (TONS)
REF. 1311.01	R	50'	3+20 to 3+70	Windrow Refusal	1625.9	300	B	---	300	---
REV. 1311.0	R	550	0+00 to 5+50	Composite Revetment	1625.9	1100	B	1375	---	330
REF. 1310.77	R	50'	2+20 to 2+70	Windrow Refusal	1625.7	300	A	---	---	
REV. 1310.76	R	300'	0+00 to 3+00	Composite Revetment	1625.7	600	A	750	---	180
		250'	3+00 to 5+50	Rehabilitated Revet.	1625.7	250	A	---	---	100
REF. 1310.57		50'	0+00 to 0+50	Windrow Refusal	1625.5	300	B	---	---	
REV. 1310.56	R	650'	0+00 to 6+50	Rehabilitation Revet.	1625.5	650	B	---	---	260
REF. 1310.42	R	50'	1+00 to 1+50	Windrow Refusal	1625.5	300	B	---	300	---
REV. 1310.41	R	400'	0+00 to 4+00	Composite Revetment	1625.5	800	B	1200	---	240
HP 1310.25	R	50'	1+00 to 1+50	Stone Root (Type B)	1625.4	225	C	---	250	---
	R	50'	1+50 to 2+00	Hardpoint		125	C	250	---	30

NOTES: (1) CRP refers to the Construction Reference Plane elevation as defined in Section II.B.1.b.

(2) Stone Gradations A, B, and C refer to stone sizes and weights as defined in Table 1-43.

(3) The Floating Plant was utilized at all Fort Lincoln construction sites.

Table 1-57 contd.
FORT LINCOLN (PHASE I)
CONSTRUCTION SCHEDULE

ESTIMATED QUANTITIES

STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	C.R.P. ELEV.	STONE (TONS)	STONE GRADATION	STONE OR LOW-GRADE MATRL. (TONS)	EXCAVATION (C.Y.)	GRAVEL (TONS)
HP 1310.19	R	50'	0+85 to 1+35	Stone Root (Type B)	1625.4	225	C	---	250	---
	R	50'	1+35 to 1+85	Hardpoint		125	C	250	---	30
HP 1310.13	R	50'	1+15 to 1+65	Stone Root (Type B)	1625.3	225	C	---	250	---
	R	50'	1+65 to 2+15	Hardpoint		125	C	250	---	30
HP 1310.09	R	50'	1+00 to 1+50	Stone Root (Type B)	1625.3	225	C	---	250	---
	R	50'	1+50 to 2+00	Hardpoint		125	C	250	---	30
HP 1309.94	R	50'	1+00 to 0+50	Stone Root (Type B)	1625.2	225	C	---	250	---
	R	50'	1+50 to 1+00	Hardpoint		125	C	250	---	30

NOTES: (1) CRP refers to the Construction Reference Plane elevation as defined in Section II.B.1.b.

(2) Stone Gradations A, B, and C refer to stone sizes and weights as defined in Table 1-43.

(3) The Floating Plant was utilized at all Fort Lincoln construction sites.

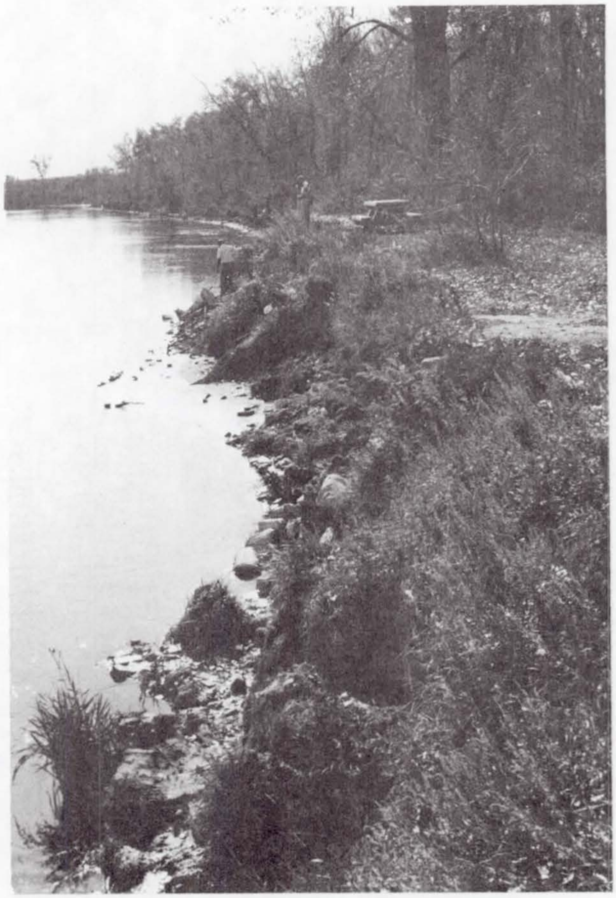


Photo 49. Typical eroding bankline along the Fort Lincoln - Phase I project area. (Photo taken 9 October 1980)

Fort Lincoln - Phase I Area
Photo 49

14. **HORSESHOE BUTTE (PHASE I) PROJECT**. The general plan for the project is shown on Plate 12-1. This demonstration project was completed in June 1981 and consists of approximately 450 linear feet of reinforced revetment, four segments totalling 1,450 linear feet of composite revetment, 600 linear feet of windrow revetment and six 50 linear feet windrow refusals. The reinforced revetment is Type I and the windrow revetment is Type B. Typical section demonstration aspects of the project incorporate revetment structural variations including different windrow material application rates and alternative revetment tieback and stone toe designs, as shown on Plates 1-2, 1-3 and 1-4. The construction schedule for this project is shown in Table 1-61. The specific stone gradations used at this site are shown in Tables 1-58 and 1-59.

Table 1-58

STONE GRADATION FOR COMPOSITE REVETMENT TOE, SMALL GRADATION (UPPER ZONE), REINFORCED REVETMENT TIEBACKS, WINDROW REVETMENT AND REFUSALS

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
GRADATION A	
150 lbs	100
40 lbs	30 - 55
2-inch screen	0 - 15
GRADATION B	
200 lbs	100
50 lbs	35 - 60
2-inch screen	0 - 15
GRADATION C	
250 lbs	100
60 lbs	30 - 55
2-inch screen	0 - 15

Table 1-59

STONE FOR COMPOSITE REVETMENT TOE, LARGE GRADATION (LOWER ZONE), REINFORCED REVETMENT TOE

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

Photos 50 and 51 show typical eroding bankline along the Horseshoe Butte (Phase I) project area.

The average stone material application rate for each structure type constructed at the project is shown in Table 1-60.

Table 1-60

Structure Type	Average Store Material Application Rate (tons/linear feet)
Composite Revetment	4.5
Reinforced Revetment	5.9
Windrow Revetment	6.0
Windrow Refusal	6.0

Table 1-61
HORSESHOE BUTTE (PHASE I)
CONSTRUCTION SCHEDULE

STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	C.R.P. ELEV.	STONE (TONS)	STONE GRADATION	STONE OR LOW-GRADE MATRL. (TONS)	EXCAVATION (C.Y.)	GRAVEL (TONS)
								ESTIMATED QUANTITIES		
REF. 1335.60	R	50'		Windrow Refusal	1641.4	300	B	---	300	---
REV. 1335.59	R	450'	0+00 to 4+50	Reinforced Revetment Type I (Tieback interval at 75')	1641.4	660	B	2000	1350	270
REF. 1335.47	R	50'	1+20 to 1+70	Windrow Refusal	1641.3	300	B	---	300	---
REV. 1335.46	R	400'	0+00 to 4+00	Composite Revetment	1641.3	800	B	1000	---	240
	R	300'	7+00 to 10+00	Composite Revetment	1641.2	600	B	750	---	180
	R	350'	13+00 to 16+50	Composite Revetment	1641.1	700	B	875	---	210
	R	400'	19+50 to 23+50	Composite Revetment	1641.0	800	B	1000	---	240
REF. 1335.34	R	50'	1+60 to 2+10	Windrow Refusal	1641.2	300	B	---	300	---
REF. 1335.22	R	50'	1+50 to 2+00	Windrow Refusal	1641.1	300	B	---	300	
REF. 1335.10	R	50'	1+20 to 1+70	Windrow Refusal	1641.0	300	B	---	300	---
REF. 1334.18	R	50'	2+40 to 2+90	Windrow Refusal	1640.4	300	B	---	300	---
REV. 1334.17	R	100'	0+00 to 3+00	Windrow Revetment	1640.4	1350	B	---	1200	---
		300'	3+00 to 6+00	Windrow Revetment	1640.4	1050	B	---	1050	

NOTES: (1) CRP refers to the Construction Reference Plane elevation as defined in Section II.B.1.b.

(2) Stone Gradations A, B, and C refer to stone sizes and weights as defined in Table 1-46.

Photo 50. Typical eroded bankline along upstream portion of the Horseshoe Butte-Phase project area. (Photo taken 9 October 1980)

Photo 51. Typical eroding bankline along Horseshoe Butte-Phase I project area. (Photo taken 9 October 1980)

Horseshoe Butte-Phase I Area
Photos 50 and 51

15. **KNIFE POINT II (PHASE I) PROJECT**. The general plan for the project is shown on Plate 2-1. This demonstration project was completed in June 1981 and consists of approximately 1,000 linear feet of reinforced revetment in two segments, 600 linear feet of windrow revetment, three 50 linear feet windrow refusals, and three hardpoint structures totalling 300 linear feet. Typical sections of the structural types used in this project are shown on Plates 1-2, 1-3 and 1-4. The reinforced revetments are Types II and IV, and the windrow revetment structural variations include different windrow material application rates and alternative revetment tieback and stone toe designs. Hardpoints are constructed at varying spacing intervals. The average stone application rates for the various structure types at this project are shown in Table 1-62.

Table 1-62

Structure Types	Average Stone Application Rates (tons/linear feet)
Reinforced Revetment	5.6
Windrow Revetment	6.0
Hardpoints	6.0
Windrow Refusal	6.0

The project area was extended by Modification #1 because of the severity of the erosion downstream of the original construction area. Table 1-65 shows the initial construction schedule at the Knife Point II (Phase I) Project and Table 1-65a shows the modification extending the scope of this project.

Table 1-63

STONE GRADATION FOR REINFORCED REVETMENT TIEBACKS, WINDROW REVETMENT AND REFUSALS, HARDPOINT UPPER PAVING FILL AND ROOT

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
GRADATION A	
150 lbs	100
40 lbs	30 - 55
2-inch screen	0 - 15
GRADATION B	
200 lbs	100
50 lbs	35 - 60
2-inch screen	0 - 15
GRADATION C	
250 lbs	100
60 lbs	30 - 55
2-inch screen	0 - 15

Table 1-64

STONE FOR REINFORCED REVETMENT TOE

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

Photos 52 and 53 show typical eroding bankline along the Knife Point - Part II (Phase I) project area.

Table 1-65
KNIFE POINT-PART II (PHASE I)
CONSTRUCTION SCHEDULE

STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	C.R.P. ELEV.	STONE (TONS)	STONE GRADATION	ESTIMATED QUANTITIES: STONE OR LOW-GRADE MATRL. (TONS)	ESTIMATED QUANTITIES: EXCAVATION (C.Y.)	ESTIMATED QUANTITIES: GRAVEL (TONS)
REF. 1380.28	R	50'	1+00 to 1+50	Windrow Refusal	1671.7	300	B	---	300	---
REV. 1380.27	R	500'	0+00 to 5+00	Reinforced Revetment Type II (Tieback interval at 100')	1671.7	550	B	2250	1500	300
REV. 1380.27	R	500'	8+00 to 13+00	Reinforced Revetment Type IV (Tieback interval at 100')	1671.6	550	B	2250	1500	300
REF. 1380.13	R	50'	0+10 to 0+60	Windrow Refusal	1671.6	300	B	---	300	---
REF. 1379.97	R	50'	-0+40 to 0+10	Windrow Refusal	1671.5	300	C	---	300	
REV. 1379.96	R	300'	0+00 to 3+00	Windrow Revetment Type A 4.5 tons / Ln. Ft	1671.5	1350	C	---	1200	---
	R	300'	3+00 to 6+00	Windrow Revetment Type B 3.5 tons / Ln. Ft.	1671.5	1050	C	---	1050	
HP 1379.81	R	50'	-0+10 to 0+40	Stone Root (Type A)	1671.4	225	C	---	250	---
		50'	0+40 to 0+90	Hardpoint	1671.4	125	C	250	---	30
HP 1379.78	R	50'	-0+50 to 0+00	Stone Root (Type A)	1671.4	225	A	---	250	---
		50'	0+00 to 50+00	Hardpoint	1671.4	125	A	250	30	
HP 1379.75	R	50'	-0+20 to 0+30	Stone Root (Type A)	1671.3	225	B	---	250	---
		50'	0+30 to 0+80	Hardpoint	1671.3	125	B	250	---	30

NOTES: (1) CRP refers to the Construction Reference Plane elevation as defined in Section II.B.1.b.

(2) Stone Gradations A, B, and C refer to stone sizes and weights as defined in Table 1-49.

Table 1-65a
KNIFE POINT-PART II (PHASE I)
MODIFICATION NO. 1

STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	C.R.P. ELEV.	STONE (TONS)	STONE GRADATION	ESTIMATED QUANTITIES STONE OR LOW-GRADE MATRL. (TONS)	EXCAVATION (C.Y.)	GRAVEL (TONS)
HP 1379.72	R	50'	-0+10 to 0+40	Stone Root (Type A)	1671.3	225	B	---	250	---
		75'	0+40 to 1+15	Hardpoint	1671.3	190	B	375	---	40
HP 1379.69	R	50'	0+00 to 0+50	Stone Root (Type A)	1671.2	225	C	---	250	---
		100'	0+50 to 1+50	Hardpoint	1671.2	250	C	500	---	50
REF. 1379.08	R	50'	0+20 to 0+70	Windrow Refusal	1670.6	300	B	---	300	---
REV. 1379.07	R	250'	0+00 to 2+50	Reinforced Revetment (Type IV) (Tieback interval at 125')	1670.6	220	C	1125	750	175
	R	250'	2+50 to 5+00	Reinforced Revetment (Type II) (Tieback interval at 125')	1670.6	220	C	1125	750	175
REF. 1378.96	R	50'	0+15 to 0+65	Windrow Refusal	1670.5	300	B	---	300	---
REV. 1378.95	R	600'	0+00 to 6+00	Composite Revetment	1670.5	1200	C	1500	---	320

NOTES: (1) CRP refers to the Construction Reference Plane elevation as defined in Section II.B.1.b.

(2) Stone Gradations A, B, and C refer to stone sizes and weights as defined in Table 1-49.

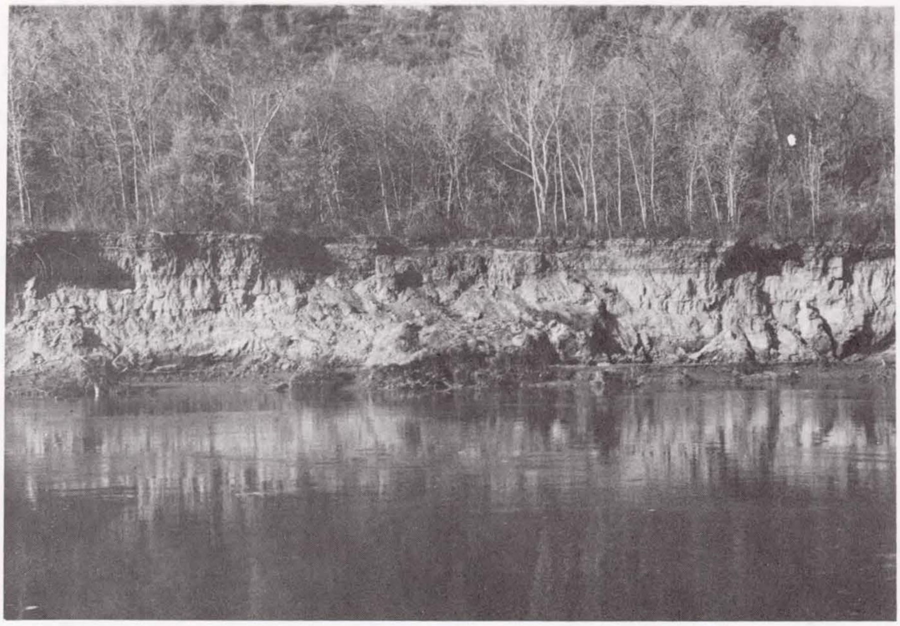


Photo 52. Typical eroding bankline along upstream portion of the project area. (Photo taken 8 October 1980)

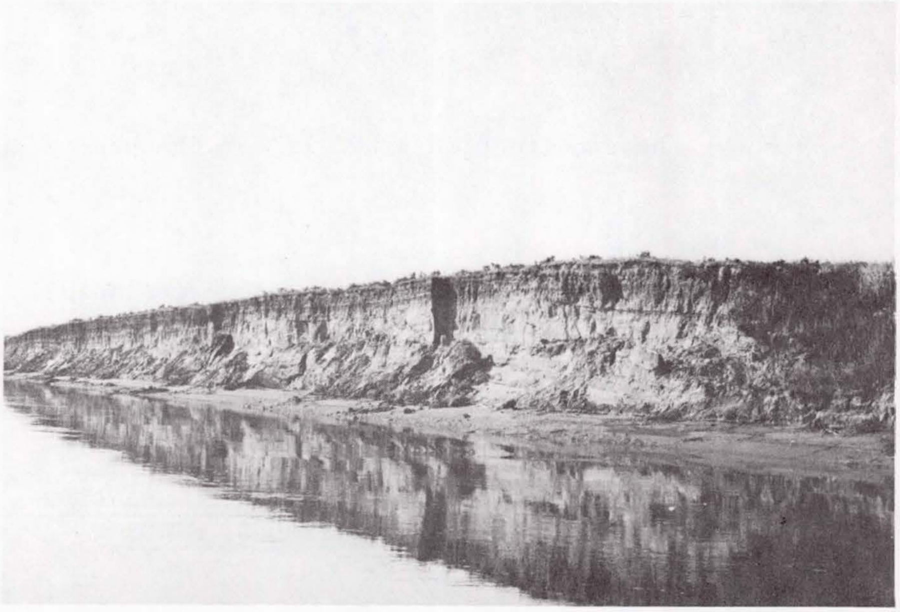


Photo 53. Typical eroding bankline along downstream portion of the project area. (Photo taken 18 July 1980)

Knife Point-Part II-Phase I Area
Photos 52 and 53

16. **HANCOCK (PHASE I) PROJECT.** The general plan for the project is shown on Plate 1-1. This demonstration project was completed in August 1981 and consists of two segments totalling approximately 900 linear feet of reinforced revetment, 900 linear feet of composite revetment in two segments, and four 50 linear feet windrow refusals. The reinforced revetments are Types II and IV. Typical sections of the structured types used in this project are shown on Plates 1-2, 1-3 and 1-4. The demonstration aspects of the project incorporate revetment structural variations including alternative revetment tieback and stone toe designs. The average stone material application rate for the various structure types constructed at this project are shown in Table 1-66.

Table 1-66

Structure Type	Average Stone Application Rate (tons/linear feet)
Reinforced Revetment	2.8
Composite Revetment	4.5
Windrow Refusal	6.0

Table 1-69 shows the construction schedule for the Hancock (Phase I) Project.

Tables 1-67 and 1-68 display the specific stone gradations for various structural components of this project.

Table 1-67

STONE GRADATION FOR COMPOSITE REVETMENT TOE, SMALL GRADATION (UPPER ZONE), REINFORCED REVETMENT TIEBACKS, WINDROW AND REFUSALS

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
GRADATION A	
150 lbs	100
40 lbs	30 - 55
2-inch screen	0 - 15

Table 1-67 (Cont'd)

STONE GRADATION FOR COMPOSITE REVETMENT TOE, SMALL GRADATION (UPPER ZONE), REINFORCED REVETMENT TIEBACKS, WINDROW AND REFUSALS

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
GRADATION B	
200 lbs	100
50 lbs	35 - 60
2-inch screen	0 - 15
GRADATION C	
250 lbs	100
60 lbs	30 - 55
2-inch screen	0 - 15

Table 1-68

STONE FOR COMPOSITE REVETMENT TOE, LARGE GRADATION (LOWER ZONE), REINFORCED REVETMENT TOE

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35 - 60
3-inch screen	0 - 15

A photograph of a typical eroding bankline along the Hancock (Phase I) project area is shown on Photo 54.

Table 1-69
HANCOCK (PHASE I)
CONSTRUCTION SCHEDULE

STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	C.R.P. ELEV.	ESTIMATED QUANTITIES STONE (TONS)	STONE GRADATION	STONE OR LOW GRADE MATRL. (TONS)	EXCAVATION (C.Y.)	GRAVEL (TONS)
REF. 1385.73	R	50'	1+75 to 2+25	Windrow Refusal	1674.2	300	A	---	300	---
REV. 1385.72	R	200'	0+00 to 2+00	Reinforced Revetment Type II (Tieback interval at 100')	1674.2	220	A	900	600	120
	R	200'	2+00 to 4+00	Type IV (Tieback interval at 100')						
REF. 1385.58	R	50'	1+75 to 2+25	Windrow Refusal	1674.1	300	A	---	300	---
REV. 1385.57	R	400'	0+00 to 4+00	Composite Revetment	1674.1	800	A	1000	---	240
REF. 1384.60	R	50'	5+90 to 6+40	Windrow Refusal	1673.7	300	B	---	300	---
REV. 1384.59	R	500'	0+00 to 5+00	Composite Revetment	1673.7	1000	B	1250	---	300
REF. 1384.45	R	50'	5+50 to 6+00	Windrow Refusal	1673.6	300	C	---	300	---
REV. 1384.44	R	250'	0+00 to 2+50	Reinforced Revetment[1] Type IV (Tieback interval at 125')	1673.6	220	C	1125	750	150
	R	250'	2+50 to 5+00	Reinforced Revetment[1] Type II (Tieback interval at 125')	1673.6	220	C	1125	750	150

NOTES: (1) CRP refers to the Construction Reference Plane elevation as defined in Section II.B.1.b.

(2) Stone Gradations A, B, and C refer to stone sizes and weights as defined in Table 1-52.

Photo 54. Typical severely eroding bankline along Hancock-Phase I project. (Photo taken 18 July 1980)

Hancock-Phase I Area
Photo 54

D. COSTS. A summary of the total costs (including Construction, Engineering and Design, Supervision and Administration, Monitoring and Rehabilitation) at each project site between Garrison Dam and Lake Oahe is as follows:

Project Area	Costs ($000)
Sandstone Bluff I and II	$1,128
Lewis and Clark 4-H Camp	278
Sanger	376
Eagle Park	696
Burnt Creek	631
I-94 Highway	1,228
Pretty Point (Phase I)	305*
Price I (Phase I)	559*
Coal Lake Couler (Phase I)	310*
Knife Point I (Phase I)	369*
Wildwood (Phase I)	307*
Price II (Phase I)	238*
Fort Lincoln (Phase I)	319*
Horseshoe Butte (Phase I)	407*
Knief Point II (Phase I)	332*
Hancock (Phase I)	209*

*Pre-Construction Estimate

IV-PERFORMANCE OF PROTECTION

A. MONITORING PROGRAM

The monitoring program for all projects in this reach contain several common items: bankline location surveys; overbank/streambank cross sections; velocity measurements; controlled aerial photography; ground level photographs; and qualitative structural changes. The specific monitoring schedules for each site were developed immediately after the contracts were awarded. The site specific monitoring data obtained is discussed in paragraph 3 of this section.

A lump sum bid item, "Monitoring and Documentation", was included in the construction contracts and consisted of special cross sections and photography taken before, during, and after construction.

1. CROSS SECTIONS.

a. Eagle Park demonstration area cross sections were obtained at intervals described below for each structure type.

(1) Hardpoints: Root sections, 25 feet or less (three minimum) oriented perpendicular to the root alignment; and one along the structure alignment or centerline from the landward end of the root and extending riverward past the terminus of the hardpoint spur.

(2) Composite and Windrow Revetment: Fifty feet intervals or less (with 1 at each end), oriented perpendicular to the river bank.

(3) Tree Retard Roots: One parallel and one perpendicular to the bankline.

b. Cross sections were obtained at the intervals described below for each structure type where applicable at the following listed demonstration sites:

Sandstone Bluff I & II
Lewis and Clark 4-H Camp

(1) Hardpoints: Root sections, 25 feet or less (2 minimum) oriented perpendicular to the root alignment; and one following the structure alignment or centerline from the landward end of the root and extending riverward past the terminus of the hardpoint spur.

(2) Reinforced Revetment: Two hundred feet or less and a minimum of one section at the upstream and downstream ends and the midpoint of any segment ordered on the construction schedule. Sections were oriented perpendicular to the structure alignment.

(3) Windrow Revetment: Two hundred feet, oriented perpendicular to the structure alignment.

(4) Windrow Refusals: One oriented along the refusal alignment; and two located at the one-third points, oriented perpendicular to the refusal.

c. Cross sections were obtained at the intervals described below for each structure type where applicable at the following listed demonstration sites:

Sanger
I-94
Burnt Creek
Pretty Point (Phase I)
Price I (Phase I)

Coal Lake Coulee (Phase I)
Knife Point I (Phase I)
Wildwood (Phase I)
Price II (Phase I)
Fort Lincoln (Phase I)
Horseshoe Butte (Phase I)
Knife Point II (Phase I)
Hancock (Phase I)

(1) **Hardpoints:** One section following the structure alignment or centerline from the landward end of the structure and extending riverward to the terminus of the hardpoint spur.

(2) **Windrow Revetment:** Two hundred feet or less and a minimum of one section at the upstream and downstream ends and the midpoint of any segment ordered on the Construction Schedule. Each section was oriented perpendicular to the structure alignment.

(3) **Reinforced Revetment:** Two hundred feet or less and a minimum of one section at the upstream and downstream ends and the midpoint of any segment ordered on the Construction Schedule. Each cross section shall coincide with the centerline of the nearest tie-back consistent with the above criteria.

(4) **Windrow Refusals:** One section oriented along the refusal centerline.

(5) **Composite Revetment:** Two hundred feet or less and a minimum of one section at the upstream and downstream ends and the midpoint of any segment ordered on the Construction Schedule and oriented perpendicular to the structure alignment.

(6) **Inter-Structure Gap:** Two hundred feet or less and a minimum of one section located at the midpoint of the gap. Each section was oriented approximately perpendicular to the flow.

(7) **Rehabilitated Revetment:** Two hundred feet or less and a minimum of one section at the upstream and downstream ends and the midpoint of any segment ordered on the Construction Schedule. Each section shall be oriented perpendicular to the structure alignment.

(8) **Earth Core Dikes:** One hundred feet or less oriented perpendicular to the structure centerline from the landward end of the root extending riverward to the terminus of the dike. (This type structure used at Burnt Creek and Sanger Projects only.)

Each cross-section was monumented by the contractor to allow single re-establishment of the cross-section location to within two feet of its original position at any time within five years after construction has been completed. A recording sonic sounder which produced a continuous strip chart recording was required by the contract specifications to complete cross-sections across water areas. A set of complete cross-sections was taken prior to any construction activity. Partial or complete sections were obtained to accurately document the following construction activities.

2. PHOTOGRAPHY.

a. Photography requirements as described below were required at the Eagle Park Project.

(1) **Windrow Revetment:** Photographs were obtained of the upstream end and at 500-foot intervals for each revetment segment longer than 1,000 feet. For revetment segments less than 1,000 feet in length, photographs were obtained for the upstream and downstream ends and at the midpoint of the segment. All photographs, except at the downstream end, are oriented in the downstream direction; and at the downstream end, they are oriented upstream. The photographs were

taken prior to any clearing, excavation, stone placement and backfilling; and after backfilling and grading.

(2) **Composite Revetment:** The location of photography for Composite Revetment is the same as specified in "Windrow Revetment." The photographs were taken before any clearing, before and after excavation of the upper bank slope, and after placement of stone and upper bank paving. A photograph of the upper bank paving was obtained at each location with the detail and dimensional reference as specified in "Material Acquisition Sites."

(3) **Hardpoints:** Photographs were obtained at each hardpoint location. The photographs include the bankline prior to construction; the root trench after excavation; the completed structure, taken along the structure azimuth line; and the structure and downstream bankline, taken parallel to the bankline.

(4) **Tree Retards:** Photographs were obtained for each tree retard system. Photos included the bankline prior to any clearing; each "tree" and root and adjacent bankline immediately after placement; and the retard system and downstream bankline, taken parallel to the bank.

(5) **Material Acquisition Sites:** Photographs were obtained of the rock and gravel when stockpiled for each gradation test, at the quarry site and the jobsite. The photographs provide sufficient detail to permit differentiation of the individual stone sizes. The field of view shall include a 1-foot (minimum) interval of a rod, graduated to tenths-of-feet, or smaller, for dimensional reference.

b. Photography requirements as described below were required at the following demonstration sites.

Sandstone Bluff I and II
Lewis and Clark 4-H Camp Area
Sanger

(1) **Hardpoints:** Photographs were obtained at each hardpoint location. The photographs include the bankline prior to construction; the completed structure, taken along the structure alignment; and the structure and the downstream bankline, taken parallel to the bankline.

(2) **Reinforced Revetment:** Photographs were obtained of the upstream end and at 500-foot intervals for each revetment segment longer than 1,000 feet. For revetment segments between 1,000 and 500 feet in length, photographs shall be obtained for the upstream end and at the midpoint of the segment. For revetment segments 500 feet, or less in length, photographs were obtained at the upstream end and all photographs were oriented in the downstream direction. The photographs were taken prior to any construction; prior to application of the bank zone treatments; and after structure completion. Photos were taken from the same vantage point for each series of photos.

(3) **Earth Core Dikes:** Photographs were obtained at each earth core dike location. The photographs include the bankline prior to construction; the completed structure, taken along the structure baseline; the structure and downstream bankline taken parallel to the bankline; and the structure and upstream bankline, taken parallel to the bankline.

(4) **Windrow Revetment:** Photographs were obtained of the upstream end and at 500-foot intervals for each revetment segment longer than 1,000 feet. For revetment segments between 1,000 and 500 feet in length, photographs were obtained for the upstream end and at the midpoint of the segment. For revetment segments 500 feet or less in length, photographs were obtained at the upstream end and all photographs were oriented in the downstream direction. The photographs were taken prior

to any construction; then prior to application of the bank zone treatments; and then after structure completion. Photos were taken from the same vantage point for each series of photos.

(5) **Material Acquisition Sites:** Photographs shall be obtained of the rock and gravel when stockpiled for each gradation test, at the quarry site and the jobsite. The photographs shall provide sufficient detail to permit differentiation of the individual stone sizes. The field of view shall include a 1-foot (minimum) interval of a rod, graduated to tenths-of-feet, or smaller, for dimensional reference.

c. Photography requirements as described below were required at the following listed demonstration sites:

I-94 Area
Burnt Creek
Pretty Point (Phase I)
Price I (Phase I)
Coal Lake Coulee (Phase I)
Knife Point I (Phase I)
Wildwood (Phase I)
Price II (Phase I)
Fort Lincoln (Phase I)
Horseshoe Butte (Phase I)
Knife Point II (Phase I)
Hancock (Phase I)

Black and white photographs of preselected, representative structures, consisted of three photographs for each selected structure: one taken prior to construction work, one taken during construction, and one taken after construction is complete.

(1) **Material Acquisition Sites:** Photographs were obtained of the rock and gravel when stockpiled for each gradation test, at the quarry site and the jobsite. The photographs shall provide sufficient

detail to permit differentiation of the individual particles. The field of view included a 1-foot (minimum) interval of a rod, graduated to tenths-of-feet, or smaller, for dimensional reference.

(2) **Revetment:** Each revetment had photographs taken from a station 100 feet upstream from the upstream end of the segment. Also, photographs were obtained at the upstream end and at 500-foot intervals for each revetment segment longer than 1,000 feet. For revetment segments between 1,000 and 500 feet in length, photographs were obtained at the upstream end and at the midpoint of the segment. For revetment segments 500 feet or less in length, photographs were obtained at the upstream end. The photographs were taken prior to any construction and after structure completion. Photos were taken from the same vantage point for each pair of photos and all photos were be obtained in the downstream direction.

(3) **Hardpoints and Earth Core Dikes:** Photographs were obtained at each hardpoint and earth core dike location. The photographs included the bankline prior to construction; the completed structure, taken along the structure azimuth line; the structure and downstream bankline, taken parallel to the bankline; and the structure and upstream bankline, taken parallel to the bankline.

3. SITE SPECIFIC MONITORING DATA OBTAINED.

The following project areas have been individually monitored with the listed items for each project area obtained to assist in site and structure evaluations.

a. Eagle Park

- Bankline location surveys were obtained in June 1976, May 1979 and July 1980.
- Overbank/Streambank cross sections were obtained in June 1976 and May 1979.

- Velocity measurements were obtained in April 1977, October 1977, May 1978 and July 1979.
- Controlled black and white aerial photography was taken in May 1978, April 1980 and colored photography in October 1980.
- Ground level photographs were taken and qualitative structural changes were noted during each field reconnaissance in the project vicinity.
- Present bankline location is shown on Plate 13-1.
- Comparative average velocity profiles are shown on Plates 13-9 and 13-10.
- An evaluation of Eagle Park Area near bank soils was completed in December 1976, and the results of the analysis are shown in Table 1-6.

b. Sandstone Bluff I and II

- Bankline location survey was obtained in May 1978.
- Overbank/Streambank cross sections were obtained in September 1976 and May 1978.
- Velocity measurements were obtained in October 1977.
- Controlled black and white aerial photography was taken in May 1978, April 1980 and colored photography in October 1980.
- Ground level photographs were taken and qualitative structural changes were noted during each field reconnaissance in the project vicinity.
- Preconstruction bankline and present bankline location are shown on Plates 4-1 and 4-2.
- Comparative average velocity profiles are shown on Plates 4-12 and 4-13.
- An evaluation of Sandstone Bluff near bank soils was completed in December 1976, and the results of the analysis are shown in figure 1-6.

c. Lewis and Clark 4-H Camp Area

- Bankline location surveys were obtained in July 1976 and May 1978.
- Overbank/Streambank cross sections were obtained in May and November 1978.
- Velocity measurements were obtained in May 1978.
- Preconstruction bankline and present bankline location is shown on Plate 6-1.

•Comparative average velocity profiles are shown on Plate 6-4.

•An evaluation of Lewis and Clark 4-H Camp Area near bank soils was done in December 1976. The results are shown in Table 1-6.

d. Sanger

•Bankline location surveys were obtained in August 1978 and February 1980.

•Overbank/Streambank cross sections were obtained in August 1978.

•Controlled black and white aerial photography was taken in May 1978, April 1980 and colored photography in October 1980.

•Ground level photographs were taken and qualitative structural changes were noted during each field reconnaissance in the project vicinity.

•Present bankline location is on Plate 7-1.

e. Burnt Creek

•Bankline location survey was obtained in June 1979.

•Overbank/Streambank cross sections were obtained in August 1978 and July 1980.

•Controlled black and white aerial photography was taken in May 1978, April 1980, with colored photography in October 1980.

•Ground level photographs were taken and qualitative structural changes were noted during each field reconnaissance in the project vicinity.

•Present bankline location is shown on Plate 14-1.

f. I-94

•Bankline location surveys were obtained in August 1978, April 1979 and January 1981.

•Overbank/Streambank cross sections were obtained in August 1978 and April 1979.

•Controlled black and white aerial photography was taken in May 1978, April 1980, with colored photography in October 1980.

•Ground level photographs were taken and qualitative structural changes were noted during each field reconnaissance in the project vicinity.

•Present bankline location is shown on Plates 15-1 and 15-2.

g. Pretty Point (Phase I)

- Bankline location survey was obtained in November 1979.
- Overbank/Streambank cross sections were obtained in November 1979.
- Controlled black and white aerial photography was taken in May 1978, April 1980, with colored photography in October 1980.
- Ground level photographs were taken and qualitative structural changes were noted during each field reconnaissance in the project vicinity.
- Preconstruction bankline is shown on Plate 9-1.

h. Price I (Phase I)

- Bankline location survey was obtained in November 1979.
- Overbank/Streambank cross sections were obtained in November 1979.
- Controlled black and white aerial photography was taken in May 1978, April 1980, with colored photography in October 1980.
- Ground level photographs were taken and qualitative structural changes were noted during each field reconnaissance in the project vicinity.
- Present bankline location is shown on Plates 10-1 and 10-2.

i. Coal Lake Coulee (Phase I)

- Bankline location survey was completed in March 1980.
- Overbank/Streambank cross sections were obtained in November 1979.
- Controlled black and white aerial photography was taken in May 1978, April 1980 and colored photography in October 1980.
- Ground level photographs were taken and qualitative structural changes were noted during each field reconnaissance in the project vicinity.
- Present bankline locations are shown on Plate 5-1.

j. Knife Point I (Phase I)

- Bankline location survey was completed in April 1980.
- Overbank/Streambank cross sections were obtained in April 1980.
- Controlled black and white aerial photography was taken in May 1978, April 1980, with colored photographs taken in October 1980.
- Ground level photographs were taken and qualitative structural changes noted during each field reconnaissance in the project vicinity.

•Preconstruction bankline location is shown on Plate 3-1.

k. Wildwood (Phase I)

•Bankline location survey was completed in March 1980.

•Overbank/Streambank cross sections were obtained in March 1980.

•Controlled black and white aerial photography was taken in May 1978, April 1980, with colored photography taken in October 1980.

•Ground level photographs were taken and qualitative structural changes noted during each field reconnaissance in the project vicinity.

•Preconstruction bankline location is shown on Plate 8-1.

l. Price II (Phase I)

•Bankline location survey was completed in April 1980.

•Overbank/Streambank cross sections were obtained in March 1980.

•Controlled black and white aerial photography was taken in May 1978, April 1980, and colored photography in October 1980.

•Ground level photographs were taken and qualitative structural changes noted during each field reconnaissance in the project vicinity.

•Preconstruction bankline location is shown on Plate 11-1.

m. Fort Lincoln (Phase I)

•Bankline location survey was completed in March 1980.

•Overbank/Streambank cross sections were completed in March 1980.

•Controlled black and white aerial photography was taken in May 1978, April 1980, and colored photography in October 1980.

•Ground level photographs were taken and qualitative structural changes noted during each field reconnaissance in the project vicinity.

•Preconstruction bankline location is shown on Plate 16-1.

n. Horseshoe Butte (Phase I)

•Bankline location survey was completed in April 1980.

•Overbank/Streambank cross sections were completed in April 1980.

•Controlled black and white aerial photography was taken in May 1978, April 1980, with colored photographs taken in October 1980.

•Ground level photographs were taken and qualitative structural changes noted during each field reconnaissance in the project vicinity.

•Preconstruction bankline location is shown on Plate 12-1.

o. Knife Point II (Phase I)

•Bankline location survey was completed in December 1979.

•Overbank/Streambank cross sections were completed in December 1979.

•Controlled black and white aerial photography was taken in May 1978, April 1980, with colored photography in October 1980.

•Ground level photographs were taken and qualitative structural changes noted during each field reconnaissance in the project vicinity.

•Preconstruction bankline location is shown on Plate 2-1.

p. Hancock (Phase I)

•Bankline location survey was completed in February 1979.

•Overbank/Streambank cross sections were obtained in December 1979.

•Controlled black and white aerial photography was taken in May 1978, April 1980 and October 1980 when colored photographs were taken.

•Ground level photographs were taken and qualitative structural changes noted during each field reconnaissance in the project vicinity.

•Preconstruction bankline location is shown on Plate 1-1.

B. EVALUATION OF PROTECTION PERFORMANCE

1. <u>SANDSTONE BLUFF I AND II PROJECT</u>. This project is composed of 32 segments of reinforced revetment of various designs, one segment of windrow revetment and five hardpoints, all completed by December 1978, shown on general plan Plates 4-1 and 4-2.

a. Channel Characteristics. All revetment segments at this area are performing excellently along a portion of the river characterized by split channel flows. The flows through the left bank channel are concentrated along the bankline in the downstream portion of the project area as shown on Plates 4-1 and 4-2. The channel bed character within 25 feet of water's edge along the left bank is very irregular with depths ranging from 3 feet to 11 feet. The underwater bank slope in May 1978 varied considerably from 1V on 2H up to 1V on 14H.

b. Significant Observations.

(1) The concentration of flows along the project area has resulted in erosion of the unprotected bankline between revetment segments as shown on Plates 4-1 and 4-2. The interstructure erosion has developed to such an extent that several windrow refusal structures are in danger of being flanked. Rehabilitation to extend the length of these refusals will be completed in the summer of 1981.

(2) The tieback spacings on the reinforced revetment segments vary at 50 feet, 80 feet and 100 feet intervals. However, the structures have not experienced sufficiently high flows to adequately test the tieback spacing.

(3) The single windrow revetment segment has begun to function as designed and it appears the material application rate of 4.5 tons of stone per linear foot should be adequate for the structure to reach a stable condition.

c. Recommendations.

(1) The crown elevation of the segmented reinforced revetment toefills could be lowered 2 feet allowing better utilization of the tieback portion of the structure. Since the tiebacks have not as yet been tested, a recommendation on the spacing interval cannot be determined.

(2) The lengths of the unprotected bankline between structure segments is dependent upon river conditions but should not exceed 350 feet or be smaller than 200 feet.

(3) The required length of the windrow refusal located at the upstream end of each revetment segment varies between 30 and 75 feet and is dependent on channel conditions and the length of the designed unprotected bankline between segments.

2. **LEWIS AND CLARK 4-H CAMP PROJECT**. This project consists of three reinforced revetment segments and three hardpoint structures which were completed in November 1978 as shown on the Construction Program Table 1-15.

a. Significant Observations.

(1) All structures at this area have performed excellently. The large gap in the middle of the project area, as shown on Plate 6-1, where a construction easement right-of-way could not be obtained, has not suffered significant erosion since completion.

(2) Overall, the entire project area has experienced only minor flow attack since structure completion and therefore the structures have not been adequately tested.

b. Recommendations.

(1) The toe fill crown elevation of each reinforced revetment segment is too high and could be lowered 2 feet allowing tiebacks to function under normal flows.

(2) No recommendations on the tieback spacing can be made due to their lack of direct exposure to channel flows.

(3) Project areas where a very large unprotected bankline area is necessary, as at the Lewis and Clark 4-H Camp, should be avoided because erosion in the unprotected area could ultimately destroy the integrity of the entire project as an erosion protection system.

3. **SANGER PROJECT.** This project consists of an earth core dike approximately 1,500 feet in length, constructed in November, 1979. The design of the lone earth core dike structure incorporated riverine habitat enhancement which has been widely accepted by State and Federal Fish and Wildlife agencies. The structure has halted the erosion along 4,000 linear feet of bankline previously experiencing relatively severe erosion. Minimal disturbance to the entire 4,000 linear feet of upper bank area adjacent to the bankline was an integral part in the design of this project to avoid an adverse impact of timber clearing along the bankline where "Smith Grove" is located. This grove of timber contains a significant number of very large trees, including the largest cottonwood tree in North Dakota; therefore, the area is considered a significant historic site by local interests in North Dakota.

a. Sanger Area Vegetation Program.

(1) The revegetation planting at this site was undertaken on a portion of the 1,500 foot earth core dike structure 1345.5, as shown on Plate 7-7. There were 2,600 woody plantings placed on the earth core dike, riverward of the environmental gap, and on the downstream side of the dike. The original plan called for approximately 4,700 individual woody plants but was reduced because of lack of suitable planting area left by the contractor who constructed the dike. Conditions also precluded any planting of herbaceous material.

The woody species used were:

COMMON NAME	SCIENTIFIC NAME
Green Ash	*Fraxinus pennsylvanica*
Goldentop Willow	*Salix lutea var. vitellina*
Peachleaf Willow	*Salix amygdaloides*
Cottonwood	*Populus deltoides*
Russian Olive	*Elaeagnus angustifolia*
Buffaloberry	*Shepherdia argentea*

In addition, 8,000 containerized plugs of reed-canary grass (Phalaris arundinacea) were planted at the land-water interface of the downstream side of the bank.

(2) Each woody plant was planted in the zone of the earth core and the hole filled with soil obtained from the riverbank. Each plant was fertilized with slow release fertilizer pellets and each plant was hand watered. In addition, a 4-inch irrigation pipe and gasoline powered pump were also installed for periodic watering of the plantings.

(3) A combination of woody species and herbaceous species were chosen for site selection and hardiness for the North Dakota climate. The woody materials were of bare root stock and were procured from the North Dakota Forest Service Nursery at Towner, North Dakota and from the Lincoln-Oakes Nursery at Bismarck, North Dakota. The herbaceous materials were of 1" x 6" plugs grown in the greenhouse of the North Dakota Forest Service Nursery at Towner, North Dakota. In addition, grass seed mixtures were broadcast over selected planting sites.

b. Significant Observations.

(1) The earth core dike, 1345.5, constructed at the Sanger Area has functioned exceptionally well in eliminating the erosion along 4,000 linear feet of bankline at a very reasonable cost.

(2) Construction required only upper bank disturbance to 3 acres of a nearby brushy hillside, where the borrow material was obtained. Clearing to provide access to the structure location was not required due to an existing clearing through the timbered bankline.

(3) The low section in the structure was designed to allow limited flow through and behind the structure supporting the creation of a riverine habitat backwater area. This low elevation notch has functioned reasonably well.

(4) The vegetation planted on the dike has definitely improved the aesthetics. It is too soon to determine if the vegetation will provide erosion control on the structure area above the normal water surface. Final survival counts taken on third week of August, 1980, 3 months after planting, showed a survival count of 82%. The woody species showed growth heights up to 3 feet. The grass mixture covered the entire top of the dike. The reed-canary grass containerized plugs showed promise with laterals beginning to develop by the first week of August. The downstream bank was planted quite heavily with a mixture of woody species and showed a survival count of 86%.

(5) Overall, this earth core dike structure has been a tremendous success and has been very well accepted. It is the most economical structure type per foot of bankline protected, demonstrated by the Omaha District at Sanger at a cost of $60 per linear foot of bankline protected.

c. Recommendations.

(1) The use of an earth core dike is only appropriate for particular situations, and therefore each area must be carefully evaluated to determine the possible detrimental effects to other bankline areas prior to construction. The structure type is recommended for

use only when channel depths are less than 7 feet below the normal water surface (50% flow elevation) and should be constructed during average to low flows. Deeper conditions will require a greater volume of materials and significantly increases the difficulty of construction.

(2) A low elevation notch (constructed at the normal water surface elevation) can be used to mitigate the environmental effects of the earth core dike.

(3) The crown of the dike should be constructed 5 feet above normal water surface on a major river to withstand very high discharges and possible ice damage. The landward end of the structure should contain a stone root (50 to 70 feet) extending into the bank to protect the structure against outflanking. The landward end of the dike should also contain some type of barrier (fence, large stone boulders, etc.) to restrict public vehicular traffic which could damage the structure. Vegetation treatment is also recommended for the crown of the dike, to provide future wildlife habitat cover, and to provide erosion control for the structure.

4. EAGLE PARK PROJECT.

a. Detailed Channel Characteristics (by ranges as shown on Plate 13-1).

(1) Range 1 through 15: This area had experienced severe erosion for several years prior to initial construction in 1977. The large sandbars near the center of the channel had directed the majority of the channel floors along the left bank. The average channel depth within 50 feet of the bank has remained at about 9 feet since the initial hydrograph obtained in April 1977. The maximum velocities along this area range between 3 and 4 feet per second.

(2) **Range 16 through 22:** Between April 1977 and July 1979, the channel conditions along the windrow revetment segments changed considerably. The average depth within 50 feet of the water's edge along ranges 20 through 22 increased from about 10 feet in 1977 up to 16-17 feet in 1979; however, the maximum velocities remained above 4 feet per second.

(3) **Range 23 through 58:** No velocity data is available for this area prior to July 1979. However, field evaluations have shown that between ranges 23 and 30 very severe bed scour caused significant increases in channel depth which resulted in damage to completed windrow revetment structures. The remaining area downstream of range 30 remained fairly uniform with higher velocities away from the eroding bank.

b. Significant Observations.

(1) **Range 1 through 15:** The portion of the project, between range 6 and 15, was initially protected by only one hardpoint and one tree retard system. The tree retard system, as described in Section III, paragraph B.5., did not withstand one season before it totally failed and was replaced by hardpoints. Both beaver damage and ice movement appeared to cause the tree retard failure. Due to severe erosion conditions upstream of the initial construction, a large segment of bankline revetment and another hardpoint was constructed in November 1977, with an additional segment of bankline revetment constructed in August 1978. Also, in August 1978 the tree retards were replaced with hardpoints and a 300-foot segment of bankline revetment was constructed. To date, this portion of the project area composed of several different structure types has functioned very well.

(2) **Range 16 through 31:** This portion of the Eagle Park Area is protected by five segments of windrow revetment, each approximately

440 feet long. The three downstream segments completely failed due to very deep high velocity flows causing rapid bed scour along the structure toe. In addition, the stone material placed in the structure was much larger than designed with W_{50} of approximately 300 pounds instead of 50 pounds and W_{100} of up to 800 pounds instead of 200 pounds. The initial downstream three segments of windrow revetment composed of 3.8 tons/linear foot of structure were replaced in October 1979 by three segments of windrow revetment at 2.3 tons/linear foot of stone which was reasonably well graded with a W_{50} of only 50 pounds. These structures are presently functioning as designed.

(3) **Range 32 through 46:** This portion of the project area is protected by one hardpoint at the upstream end and a total of 2,200 feet of composite revetment. These structures are all functioning very well in eliminating the erosion. These composite revetment segments are unique to this reach because they contain variations to the upper bank not demonstrated anywhere else. The various upper bank treatments include: filter cloth and gravel; gravel and rolled clay; and gravel and installed vegetation.

(4) **Range 47 through 54:** Initial construction had these hardpoints constructed at 800-foot spacings. However, soon after construction it was determined that the unprotected gaps were excessively large and in July 1978, three additional hardpoints were constructed. The present condition is stable, however, they remain to be adequately tested.

c. Recommendations.

(1) Windrow revetment construction should be monitored very closely to insure placement of reasonably well graded stone material which does not exceed a W_{100} of 200 pounds, where river conditions are similar to these encountered at the Eagle Park Area.

(2) Hardpoint spacings should not exceed 250 feet where flows could directly attach the bankline area. The structure spaced at 400 feet gaps at the downstream portion of the project have functioned well to date. However, they have not been adequately demonstrated and could be damaged under an extended period of direct flow due to channel configuration changes.

(3) All types of composite have functioned equally well. The toe design appears to contain adequate quantities of stone material to maintain stability. All upper bank areas have revegetated very well.

(4) Project areas should be closely monitored both during construction and after construction to insure accurate placement of materials and that the demonstration structures perform adequately.

(5) Tree Retards, as designed and constructed at the Eagle Park Area, are not a successful method of erosion control in North Dakota or in regions susceptible to ice formation. Also, the timber used should be treated or protected in some way (i.e. chicken wire) to resist immediate damage from beavers.

5. **BURNT CREEK PROJECT**. This project site includes several different types of erosion control protection including hardpoints, reinforced revetment, composite revetment, windrow revetment and earth core dikes. Completion of this project was in June 1980 and therefore has not been in place long enough to be completely evaluated.

a. Burnt Creek Area Vegetation Program.

(1) The vegetation planting at this site was done on the two earth core dikes (Dike 1321.15 and Dike 1320.8) and on the upper bank area adjacent to a Revetment 1320.70, as shown on Plates 14-8 and 14-9.

Along these areas, 3,800 individual woody plants were planted in rows and clump type plantings.

The species planted were:

COMMON NAME	SCIENTIFIC NAME
Cottonwood	Populus deltoides
Green Ash	Fraxinus pennsylvanica
Russian Olive	Elaeagnus angustifolia
Buffaloberry	Shepherdia argentea
Red-Osier Dogwood	Cornus stolonifera
Golden Willow	Salix alba vitelina
Hackberry	Celtis occidentalis
Ponderosa Pine	Pinus ponderosa

(2) In addition to the woody materials, 8,000 containerized plugs of reed-canary grass (Phalaris arundinacea) and slender-western wheatgrass (Agropyron trachycalum and Agropyron smithil) were planted at the land/water interface and at the upper edge of the bank area itself. A grass seed mixture was also broadcast over appropriate planting sites.

b. Significant Observations.

(1) All structures at the Burnt Creek Area have functioned exceptionally well in eliminating the erosion along a previously severely eroding bankline.

(2) The low elevation notch in the two earth core dike structures designed to allow limited flow through and behind the structure to support the creation of a riverine habitat backwater area have not functioned very well with the downstream areas mainly silted-in.

(3) The vegetation planted on the dikes have significantly improved the aesthetics. Sufficiently high flows have not been experienced to determine if the vegetation will provide erosion control on the structure area above the normal water surface. Final survival counts taken on the third week of August, 1980, 3 months after planting, showed the ponderosa pine suffered extensive damage by vehicles and were not included in a survival count as no live ones were found in the August count. The two earth core dikes had a survival count in the third week of August of 76%. The upper bank area had a survival count of 78%. The grass seed mixture showed excellent growth on the upper bank area. The unprotected area between structure segments are all approximately 300 feet in length and are functioning very well.

6. <u>I-94 HIGHWAY PROJECT</u>. This very large project was completed in September 1980. To date the entire project has functioned as designed; however, the short time period since completion is insufficient to evaluate the effectiveness of individual structure segments.

The unique demonstration of using broken soil-cement in-lieu-of low grade natural material has been a success so far. The material testing following the fabrication process showed the material was of excellent quality capable of withstanding the extreme North Dakota weather conditions. However, the winter of 1980-1981 was relatively mild and therefore was not a normal field test for this material. The quality of the soil-cement is very dependent upon the percent of cement content and proper quality control. Difficulty was encountered in determining the cement content to be used because of the nonuniformity of the sand deposits on the high vegetated bar which was utilized as the soil source.

a. Significant Observations.

(1) The use of soil-cement as demonstrated at the I-94 Area appears to be a viable alternative to stone in areas where stone is not readily available. However, additional field test time is needed before the soil-cement material has properly demonstrated adequate soundness quality.

(2) Construction utilizing floating plant techniques can be used in this reach of the Missouri River channel depths permitting. Floating plant construction was found to be more readily accepted by Federal, state and local interests than land base construction along timbered areas because it requires only minimal amounts of clearing where the windrow refusals are to be constructed. However, floating plant construction techniques result in a cost increase of approximately 25% when compared to land base construction techniques.

(3) The soil-cement was constructed at a unit price of $32.00 per cubic yard which converts to approximately $21.33 per ton. This cost is very similar to the unit price for stone at the I-94 Project of $22.00 per ton. Therefore, the use of soil-cement as a partial substitute for stone is a cost effective method of protection.

b. Recommendations.

(1) The exact source of soil material to be utilized in the soil-cement mixture should be analyzed carefully to insure an adequate mix design is used. After a section of soil-cement material is mixed and placed to its designated lines and grades, it should be compacted, scored, covered with soil, and wetted within two hours. It is very important to avoid disturbing the soil-cement during the curing period (at least seven days) as any vibrations to the material may significantly reduce the bonding action, resulting in a low quality product.

(2) The existing revetment along the project, which was rehabilitated with 2 tons per linear foot of stone, should contain only angular shaped reasonably well graded stone material so the stone will

maintain the existing steep slope. For stone to stand on a steep slope it must have the ability to chink together which angular stone provides more effectively. This chinking ability is more important underwater than above normal water.

7. **PRETTY POINT (PHASE I) AND THE PRICE I (PHASE I) PROJECTS.** The contract for these project areas was not awarded until 8 September 1980 and the construction was not completed until August 1981. Therefore, the various structures have not been completed long enough to be evaluated for their effectiveness at this time.

8. **COAL LAKE COULEE (PHASE I) AND THE KNIFE POINT I (PHASE I) PROJECTS.** The contract for these project areas was not awarded until 17 September 1980 and the construction was completed in June 1981. Therefore, the structures cannot be evaluated for effectiveness at this time.

9. **WILDWOOD (PHASE I) AND THE PRICE II (PHASE I) PROJECTS.** The contract for these project areas was not awarded until 18 September 1980. The construction was not completed until May 1981. Therefore, the various structures have not been completed long enough to be evaluated for their effectiveness at this time.

10. **FORT LINCOLN (PHASE I) AND THE HORSESHOE BUTTE PROJECTS.** The contract for these project areas was not awarded until 18 September 1980 and the construction was not completed until June 1981. Therefore, the various structures cannot be evaluated for effectiveness at this time.

11. **KNIFE POINT II (PHASE I) AND THE HANCOCK (PHASE I) PROJECTS.** The contract for these project areas was not awarded until 25 September 1980 and was not completed until June 1981. Therefore, the various structures have not been completed long enough to be evaluated for their effectiveness at this time.

C. RECONSTRUCTION.

1. EAGLE PARK AREA.

a. Reconstruction was needed to replace severely damaged tree retard systems (TR 1324.19 and TR 1322.2). These systems required replacement due to damage from ice and beavers. They were replaced by the construction of Hardpoint 1324.15, Hardpoint 1324.1, Windrow Refusal 1323.9, Bankline Revetment 1323.89, Windrow Refusal 1323.85, Hardpoint 1322.3, Hardpoint 1322.2 and Hardpoint 1322.1. This reconstruction required 6,023 tons of stone; 1,064 cubic yards of excavation; 4,630 cubic yards of embankment and 463 tons of cobbles and spalls. The total cost for this modification, including photography and cross sections, was $89,000 and was completed in August of 1978.

b. Three windrow revetment segments (Rev. 1323.8, stations 12+80 to 17+20, 19+20 to 23+60, and 25+60 to 30+00) and their attendant 50-foot windrow refusals (Ref. 1323.65, Ref. 1323.55 and 1323.45) were severely degraded within 18 months after their completion in September 1977. The original windrow segments, consisting of 3.5 tons of stone per linear foot, had fallen into the river and were overtopped by flows of about 4 feet at normal river stages. The windrow refusals were reinforced by adding 3 tons of stone per linear foot. Revetment segments from stations 12+80 to 17+20 and 25+00 to 30+00 were reinforced with an additional 2 tons of stone per linear foot of bankline and the segment from station 19+20 to 23+60 with 3 tons per linear foot of bankline. This reconstruction which required 3,530 tons of stone was completed in September of 1979. The cost of this reconstruction, including excavation, seeding and monitoring and evaluation, was $51,000.

c. Two hardpoint spurs (HP 1323.2 and 1322.4) and composite revetment 1323.05 were degraded within 18 months after completion in September 1977. They were repaired with a total of 1,100 tons of stone and 600 tons of cobbles and spalls at a cost, including excavation, seeding and monitoring and documentation, of $25,000. This reconstruction was completed in September of 1979.

D. GENERAL CONCLUSIONS FOR THE GARRISON DAM TO LAKE OAHE REACH.

1. WINDROW REVETMENT.

a. Smaller gradation (200-pound top size with D_{50} of 7" to 8") stone is more effective in windrow revetment than a large gradation (500-pound top size with D_{50} of 9" to 10") stone because the smaller gradation stone forms a more dense, closely checked protective layer which is necessary to resist erosion of the underwater bank slope.

b. Windrow revetment is very effective in eliminating erosion along areas where river flows are unusually steep and swift along the toe of the bankline.

c. The amount of stone placed in the windrow that is required to achieve a stable condition is entirely dependent on site specific channel characteristics. Under normal conditions encountered on this reach of the Missouri River, 4.5 tons per linear foot of stone is adequate.

d. Construction is relatively simple and does not require special equipment or excessive construction time.

e. Minor additional land loss must be acceptable to allow the stone material to slough and function as designed.

f. Construction requires more clearing than most other structure types because the structure is excavated into the bank; therefore, more construction area is required for equipment movement.

g. The size of the unprotected bankline areas between windrow revetment segments is dependent upon flow conditions and erosion rates. The average effective unprotected gap along this reach of the Missouri River is 250 feet.

h. Construction of a 30 to 75 foot windrow refusal extending into the bank is mandatory at the upstream end of each revetment segment to eliminate the possibility of erosion flanking the structure.

i. Windrow Revetment - Type A is recommended over Type B in most cases because it requires less additional bank losses before it reaches a stable equilibrium condition.

j. After the structure reaches equilibrium, the landward face protected becomes vegetated, usually within one year.

2. **COMPOSITE REVETMENT.**

a. This type of structure is effective in all conditions, particularly deep channels with high banks along highly sensitive upper bank areas requiring immediate stabilization. Composite revetments can be constructed with no excavation and the least amount of upper bank disturbance of any revetment type structures demonstrated by this reach.

b. For this reach of the Missouri River, the optimum toe of the composite should be composed of approximately 4.5 tons per linear foot of bankline to lines and grades shown on Plate 1-2, or the necessary material required for the estimated maximum scour.

c. The landward crown elevation of the stone should be 3 feet above the CRP. The riverward crown elevation should be approximately 2 feet below CRP.

d. The crown of the stone composite should be covered by a thin layer of gravel if aesthetics are a desirable project objective. In addition to aesthetics, the gravel permits easier access to the river for wildlife and enhances vegetation growth.

e. The lengths of revetment segments and the size of the unprotected bankline between segments is determined by the specific hydraulic conditions of the project area to be protected. The minimum length of an individual segment of composite revetment should be 400 feet. The unprotected bankline between structure segments should not exceed 300 feet where the flow is parallel to the bank and should not exceed 200 feet where the flow stream lines approach the bank at an angle of 45 degrees or more to the bankline.

f. A 30-foot to 50-foot windrow refusal comprised of stone extending landward into the bank should always be constructed at the upstream end of each revetment segment to resist the possibility of flows flanking the structure.

g. The lower toe zones of the composite revetment can be constructed of a lower grade material (i.e. soil-cement) if the material is placed at a low enough elevation so that it remains underwater most of the time and is not exposed to constant wet/dry and freeze/thaw cycles.

3. REINFORCED REVETMENT.

a. Types I, II and III have all been proven effective methods in eliminating erosion. Types IV and V have been in place less than six months and therefore cannot be effectively evaluated.

b. The maximum crown elevation of the toe of the reinforced revetments were constructed at the Construction Reference Place (CRP).

Therefore, under normal daily flows the water elevation does not exceed the crown and the tiebacks are not utilized. Only under severe flows will the tiebacks be effectively utilized. Consideration should be given to lowering the maximum crown elevation 2 feet.

c. The optimum tieback placement interval cannot be determined yet. The recently completed projects demonstrating the various tieback spacings have not experienced high flows and therefore, have not been adequately tested.

d. Reinforced Revetment is most effective along banklines containing an underwater bench adjacent to the highbank. In this case, the stone toe can be constructed riverward of the bank with less material requirements than most other structure types.

4. **HARDPOINTS.**

a. Hardpoints are a very cost effective method of erosion protection. However, they do not supply the degree of protection that segmented revetment does.

b. Hardpoints should only be utilized along straight or convex shaped banklines where the stream flow lines are parallel to the bankline.

c. The minimum length of each hardpoint should be 100 feet (50-foot spur and 50-foot root) with an unprotected spacing between structures of approximately 250 feet.

d. Hardpoint construction should be limited to areas where channel depths are no greater than 10 feet within 50 feet of the bankline to avoid very large stone material quantity requirements.

e. The entire hardpoint structure should be aligned 10° to 20° in the downstream direction from the normal to the bankline to reduce the formation of a back eddy downstream of the structure which could increase the erosion in the downstream unprotected bankline.

5. **EARTH CORE DIKES.**

a. Earth core dikes should only be constructed along channel areas where existing sandbars can be incorporated into the structure alignment to reduce the amount of necessary embankment fill.

b. Earth core dikes are a very cost effective method of immediately stopping erosion along large areas of bankline while only requiring minimal disturbance at the landward end of the dike during construction.

c. The crown elevation of the structure should be approximately 3.25 feet above the Construction Reference Plane. The crown should be covered by a thin layer of gravel if aesthetics is of concern and a more rapid revegetation is desired.

d. The construction of a functional environmental low elevation notch is an important part of the earth core dike design of improvement if riverine habitat is desired.

e. A vegetation planting program is recommended for the above water surface areas of the structure to improve the natural cover and structure appearance.

f. The landward end of the dike should have a vehicle traffic barricade (i.e., fence or large boulders) to restrict public vehicular access over the dike after construction.

g. An earth core dike should not be considered if the channel flow width would be adversely affected by the structure placement within the normal water level flow-way.

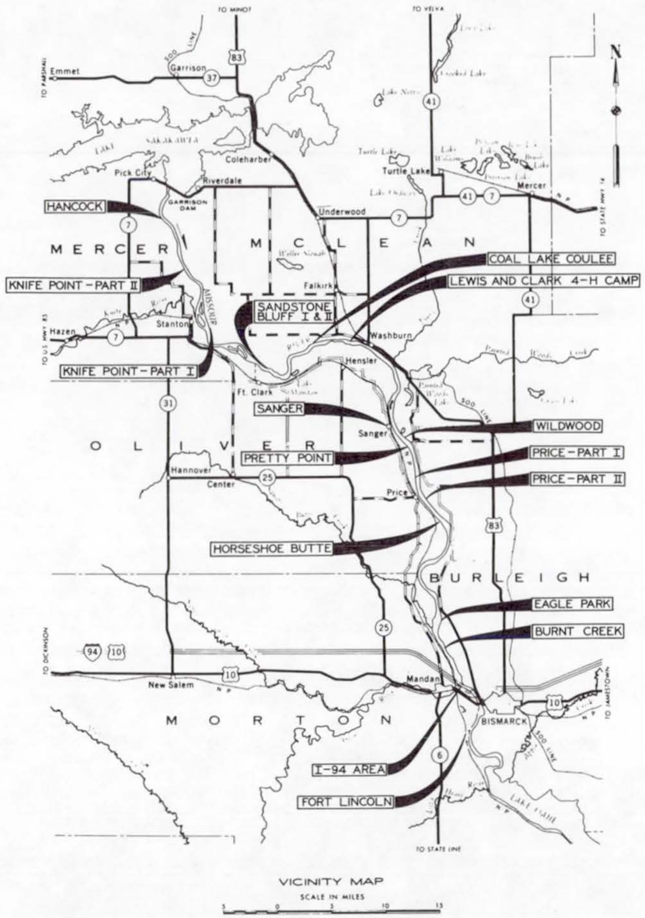
6. TREE RETARDS.

a. Tree Retards are not an effective method of erosion protection as designed, constructed and demonstrated at the Eagle Park Project Area. Both the flow and beaver damage have severely destroyed the structures within one year after completion.

b. If used, the trees should be large with the majority of the tree limbs extending above the Construction Reference Plane (CRP) to assist in the development of a shoal area downstream of the retard.

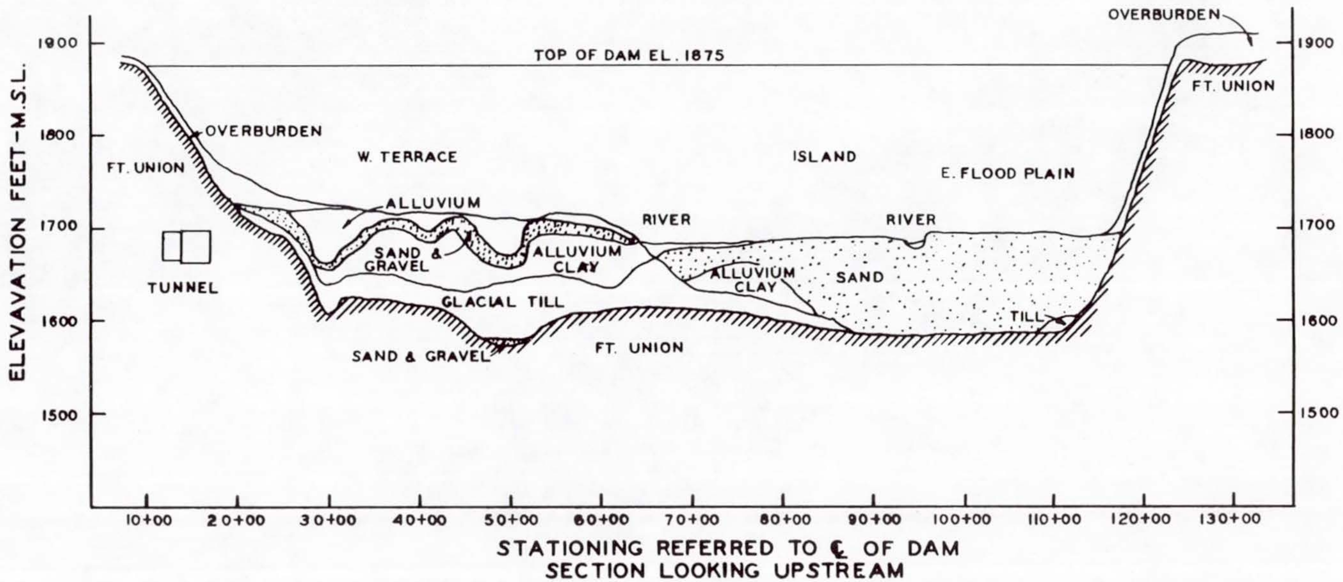
c. Beaver damage could be resisted by applying a treatment to the trees which would resist beavers.

PLATE 0-1



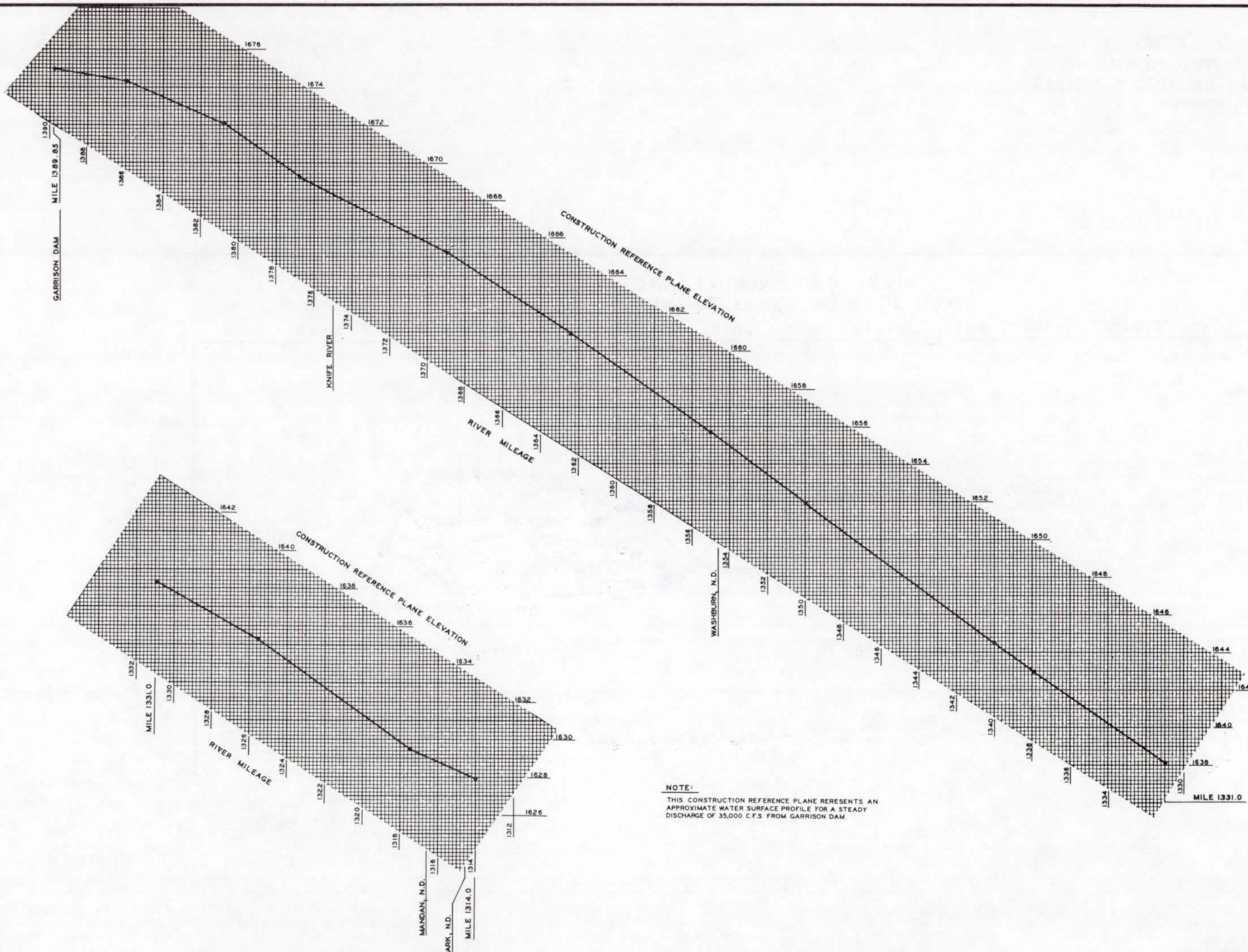
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
LOCATION AND VICINITY MAP

E-1-150



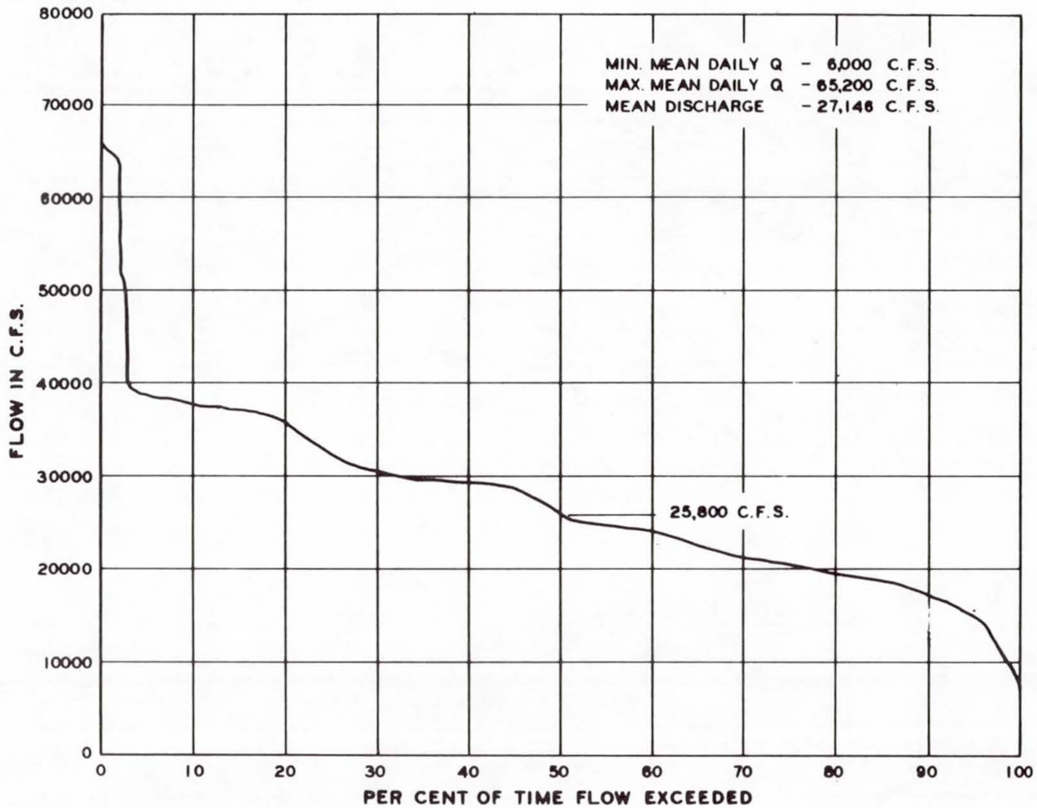
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
GEOLOGIC PROFILE

PLATE 0-3



NOTE:
THIS CONSTRUCTION REFERENCE PLANE RERESENTS AN APPROXIMATE WATER SURFACE PROFILE FOR A STEADY DISCHARGE OF 35,000 C.F.S. FROM GARRISON DAM.

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
WATER SURFACE PROFILES
MILE 1389.85 TO MILE 1314.00

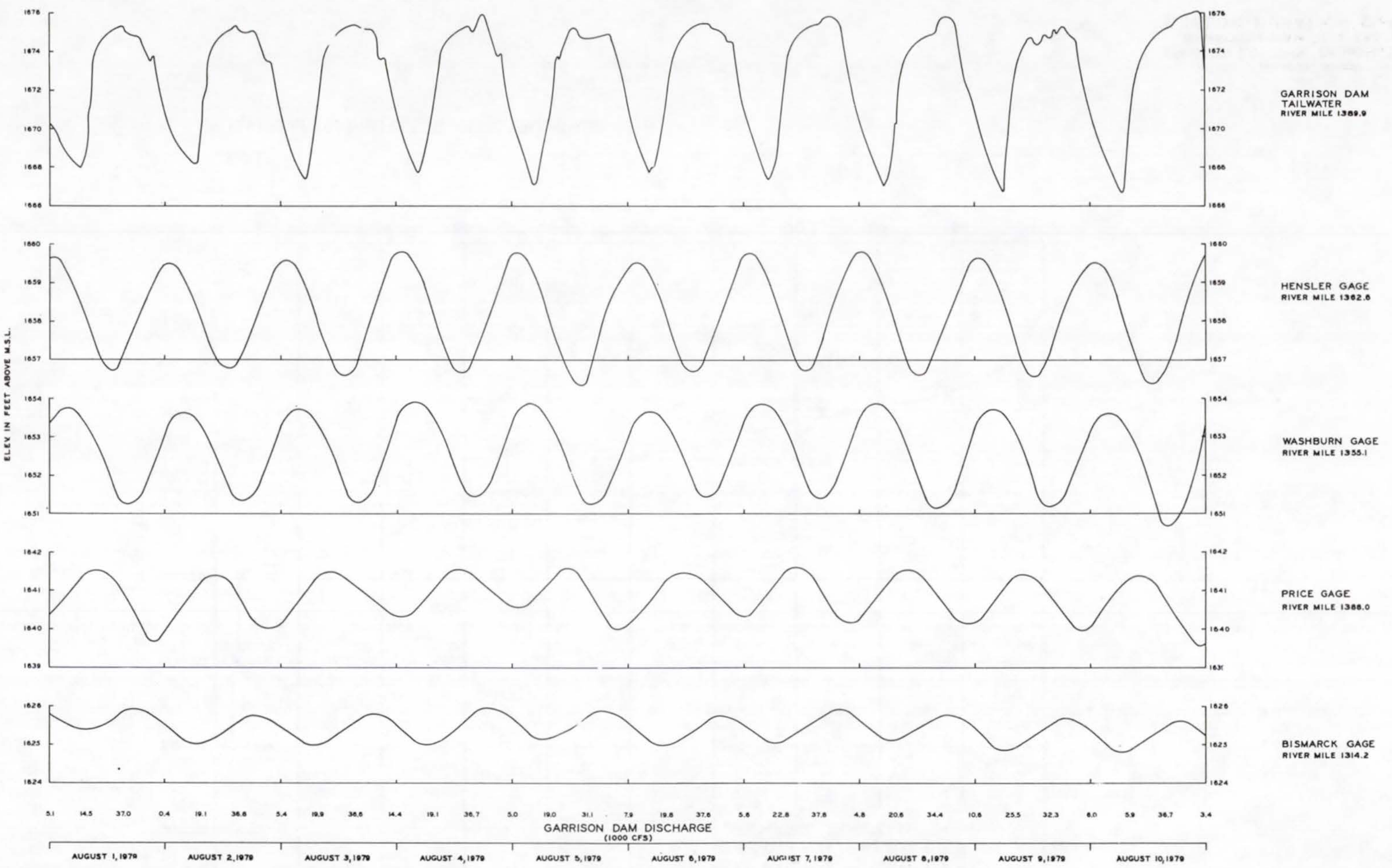


NOTE:

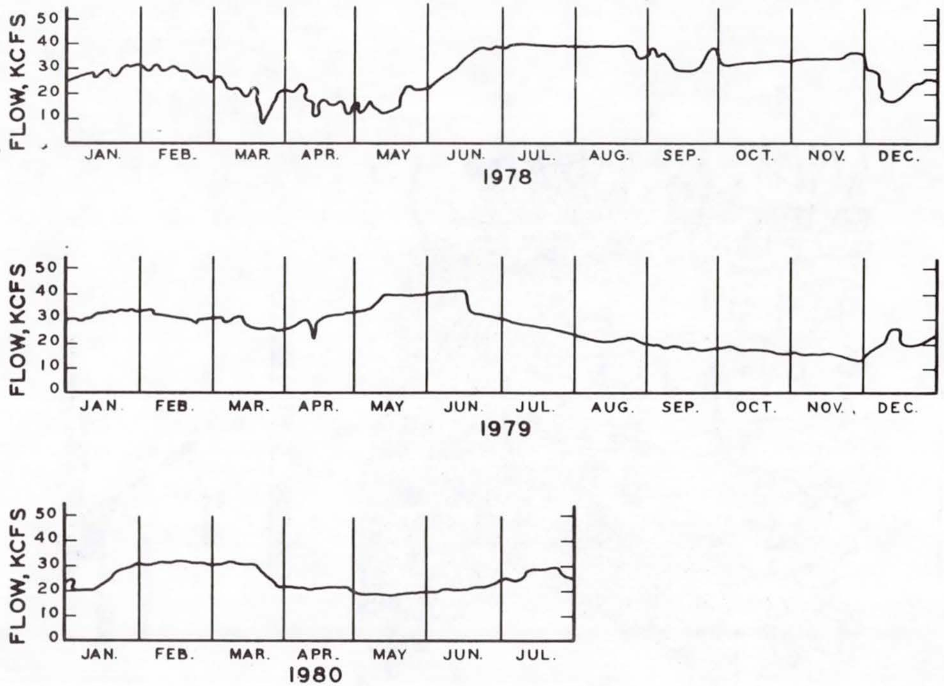
PERIOD APR 01 THRU OCT 31, YEARS 1967 THRU OCT 1976

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
FLOW DURATION CURVE

PLATE 0-5



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
STAGE FLUCTUATIONS AT SELECTED GAGES



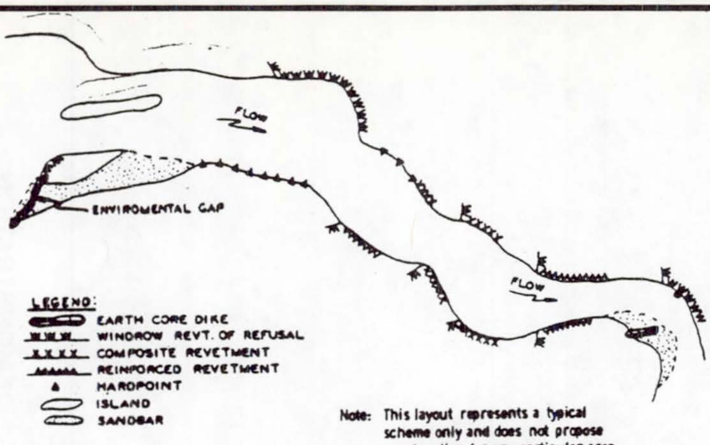
MISSOURI RIVER

EROSION CONTROL DEMONSTRATION

GARRISON DAM TO LAKE OAHE

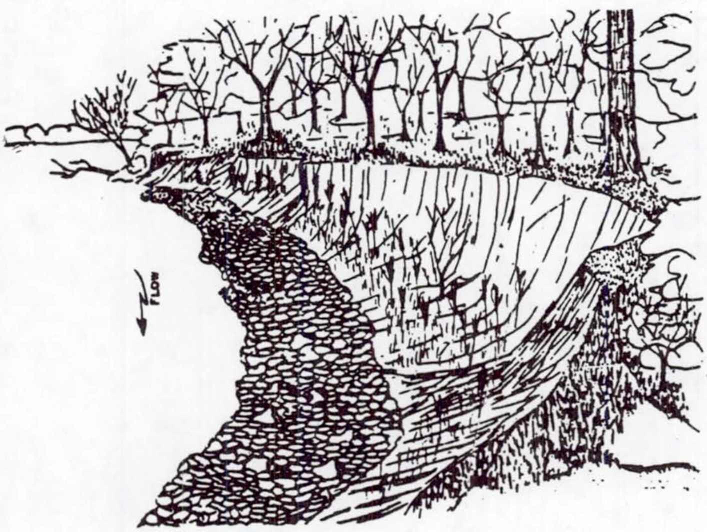
AVERAGE DAILY GARRISON DAM RELEASES

PLATE 0-6

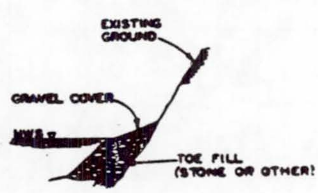


Note: This layout represents a typical scheme only and does not propose construction for any particular area.

TYPICAL BANK PROTECTION SCHEMES FOR EROSION CONTROL



COMPOSITE REVETMENT



TYPICAL SECTION

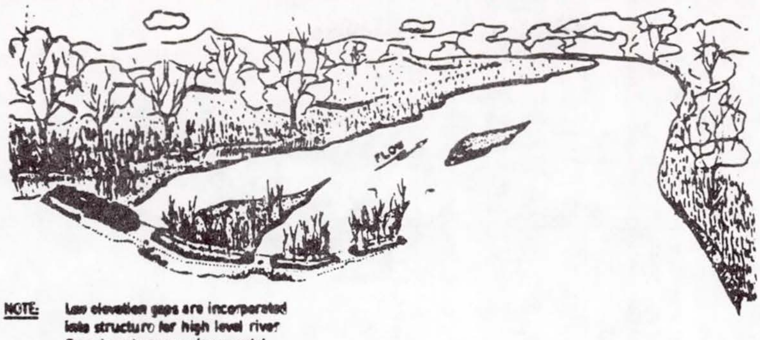
MISSOURI RIVER

EROSION CONTROL DEMONSTRATION

GARRISON DAM TO LAKE OAHE

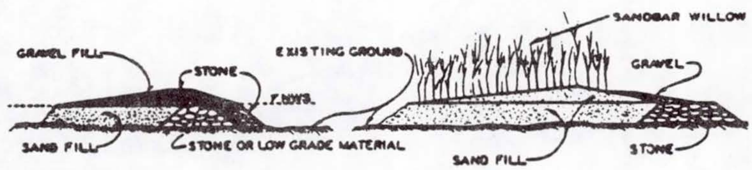
TYPICAL BANK PROTECTION SCHEMES

PLATE 0-7

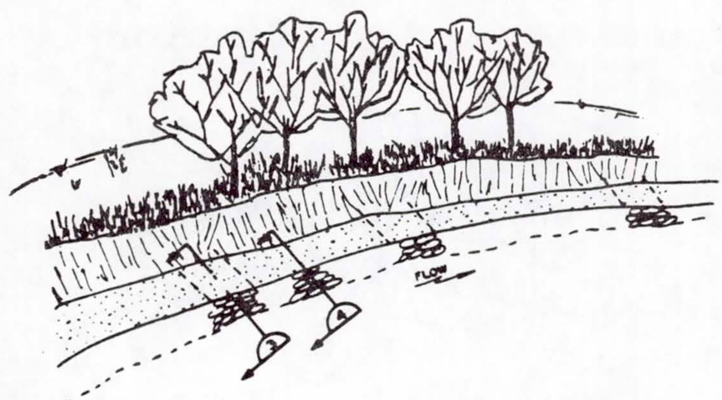


NOTE: Low elevation gaps are incorporated into structure for high level river flows to enhance environmental area downstream.

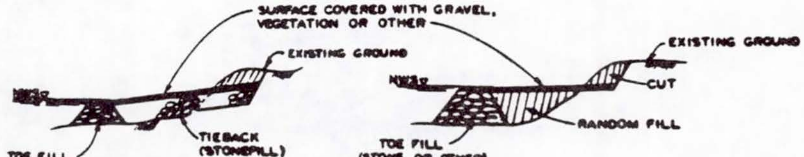
EARTH CORE DIKE



TYPICAL SECTIONS



REINFORCED REVETMENT



SECTION 3 SECTION 4

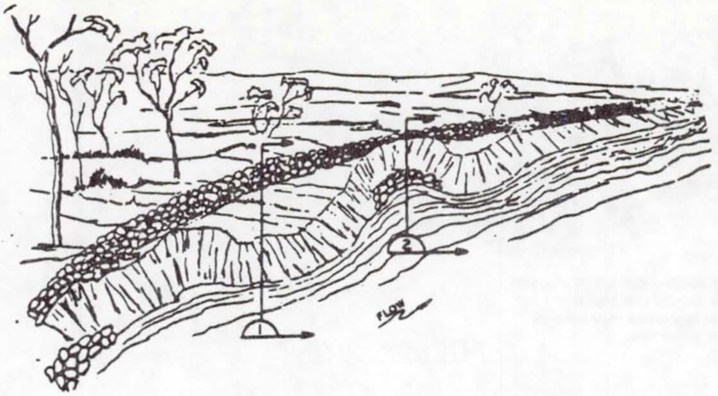
MISSOURI RIVER

EROSION CONTROL DEMONSTRATION

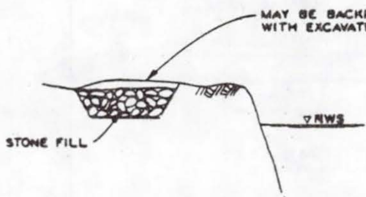
GARRISON DAM TO LAKE OAHE

TYPICAL BANK PROTECTION SCHEMES

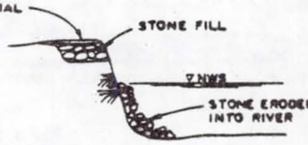
PLATE 0-8



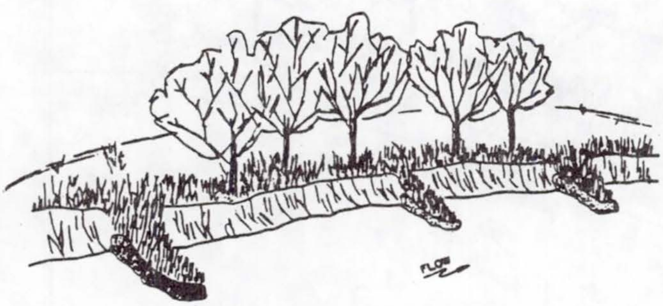
WINDROW REVETMENT



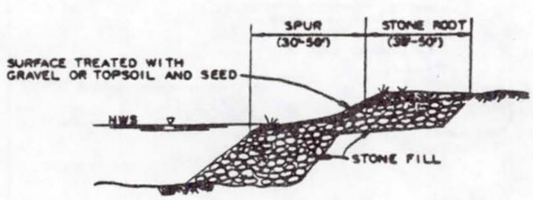
SECTION 1



SECTION 2



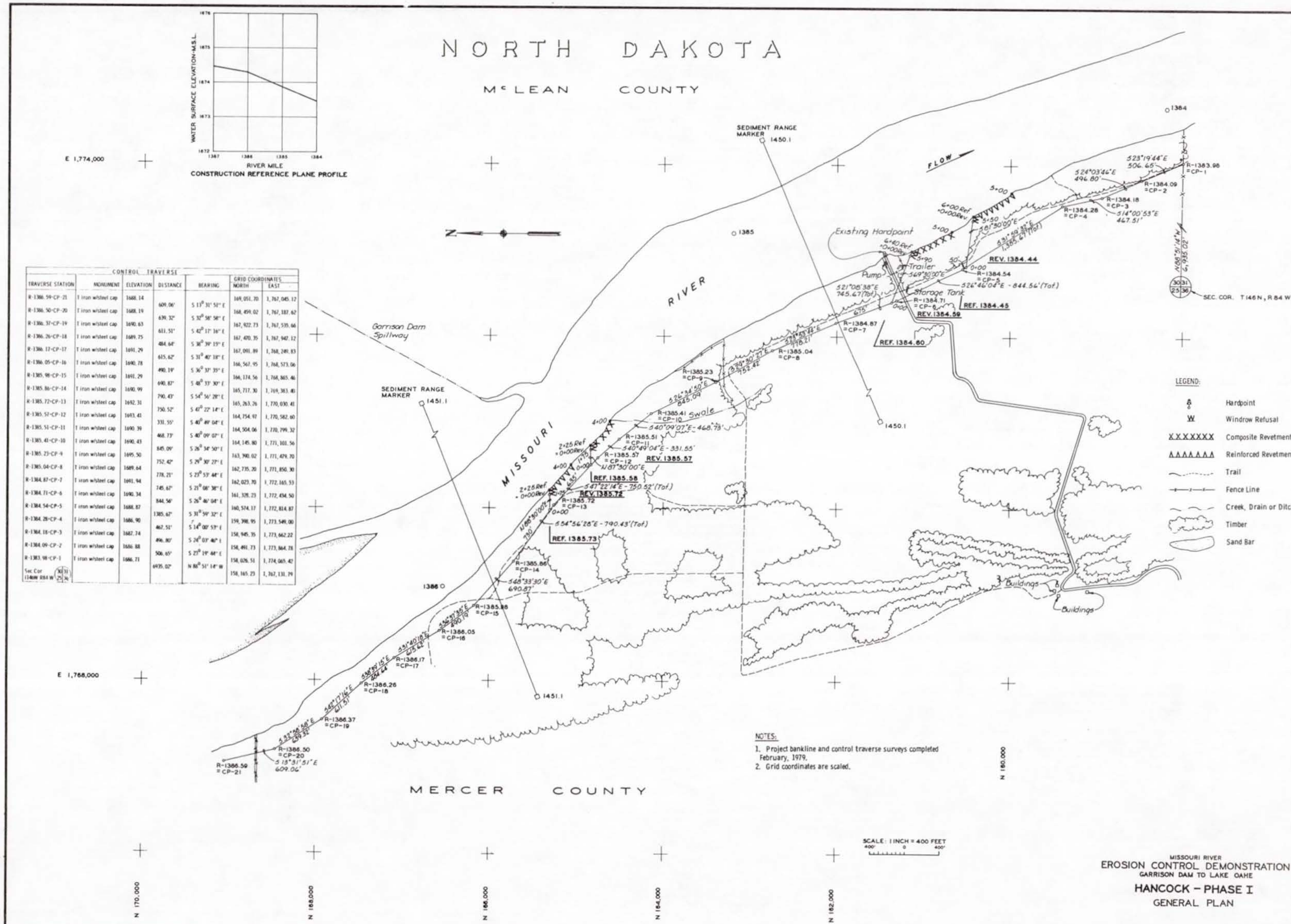
HARD POINT SYSTEM



TYPICAL SECTION

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
TYPICAL BANK PROTECTION SCHEMES

PLATE 0-9



CONTROL TRAVERSE						
TRAVERSE STATION	MONUMENT	ELEVATION	DISTANCE	BEARING	GRID COORDINATES NORTH	EAST
R-1386.59-CP-21	T iron w/steel cap	1688.14	609.06'	S 13° 31' 51" E	169,051.70	1,767,045.12
R-1386.50-CP-20	T iron w/steel cap	1688.19	639.32'	S 32° 58' 58" E	168,459.02	1,767,187.62
R-1386.37-CP-19	T iron w/steel cap	1690.63	611.51'	S 42° 17' 16" E	167,922.73	1,767,535.66
R-1386.26-CP-18	T iron w/steel cap	1689.75	484.64'	S 38° 39' 15" E	167,470.35	1,767,947.12
R-1386.17-CP-17	T iron w/steel cap	1691.29	615.62'	S 31° 40' 18" E	167,091.89	1,768,249.83
R-1386.05-CP-16	T iron w/steel cap	1690.78	490.19'	S 36° 37' 35" E	166,567.95	1,768,573.06
R-1385.98-CP-15	T iron w/steel cap	1691.29	690.87'	S 48° 33' 30" E	166,174.56	1,768,865.46
R-1385.86-CP-14	T iron w/steel cap	1690.99	790.43'	S 54° 56' 28" E	165,717.30	1,769,383.40
R-1385.72-CP-13	T iron w/steel cap	1692.31	750.52'	S 47° 22' 14" E	165,263.26	1,770,030.41
R-1385.57-CP-12	T iron w/steel cap	1693.41	331.55'	S 40° 49' 04" E	164,754.97	1,770,582.60
R-1385.51-CP-11	T iron w/steel cap	1690.39	468.73'	S 40° 09' 07" E	164,504.06	1,770,799.32
R-1385.41-CP-10	T iron w/steel cap	1690.43	845.09'	S 26° 34' 50" E	164,145.80	1,771,101.56
R-1385.23-CP-9	T iron w/steel cap	1695.50	752.42'	S 29° 30' 27" E	163,390.02	1,771,479.70
R-1385.04-CP-8	T iron w/steel cap	1689.64	778.21'	S 23° 53' 44" E	162,735.20	1,771,850.30
R-1384.87-CP-7	T iron w/steel cap	1691.94	745.67'	S 21° 08' 38" E	162,023.70	1,772,165.53
R-1384.71-CP-6	T iron w/steel cap	1690.34	844.56'	S 26° 46' 04" E	161,328.23	1,772,434.50
R-1384.54-CP-5	T iron w/steel cap	1688.87	1385.67'	S 31° 59' 32" E	160,574.17	1,772,814.87
R-1384.28-CP-4	T iron w/steel cap	1686.90	467.51'	S 14° 00' 53" E	159,398.95	1,773,549.00
R-1384.18-CP-3	T iron w/steel cap	1687.74	496.80'	S 24° 03' 46" E	158,945.35	1,773,662.22
R-1384.09-CP-2	T iron w/steel cap	1686.88	506.65'	S 23° 19' 44" E	158,491.73	1,773,864.78
R-1383.98-CP-1	T iron w/steel cap	1686.71	6935.02'	N 88° 51' 14" W	158,026.51	1,774,065.42
Sec Cor T146N R84 W (30 31 / 25 36)					158,165.23	1,767,131.79

NOTES:

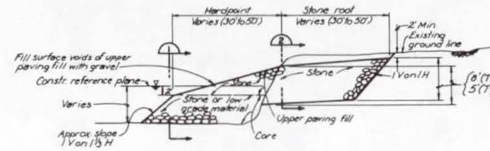
1. Project bankline and control traverse surveys completed February, 1979.
2. Grid coordinates are scaled.

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
HANCOCK - PHASE I
GENERAL PLAN

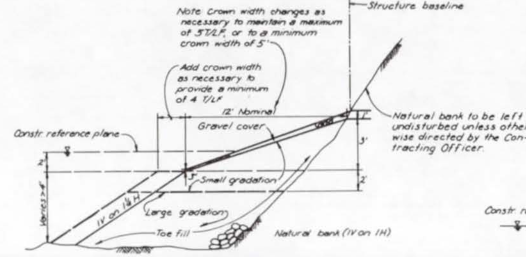
E-1-159

PLATE 1-1

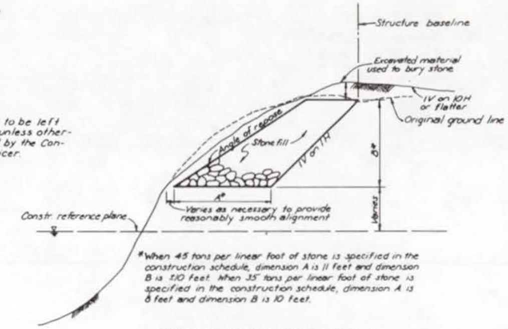
PLATE 1-2



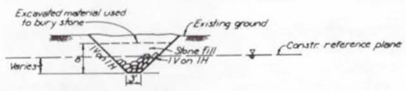
HARD POINT
NO SCALE



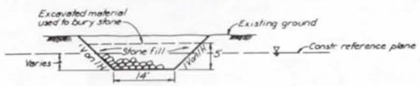
COMPOSITE REVETMENT
CASE I - Water depths deeper than 6 feet below C.R.P.
NO SCALE



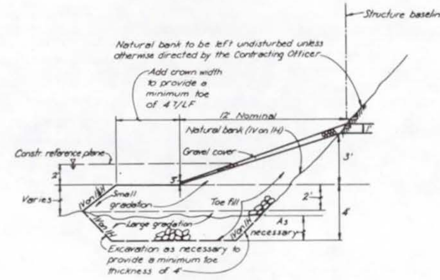
WINDROW REVETMENT - TYPE A
NO SCALE



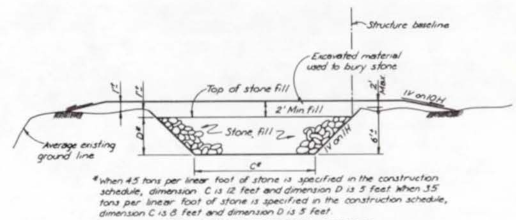
SECTION 2
STONE ROOT - TYPE A
NO SCALE



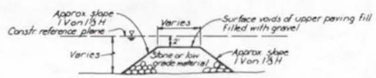
SECTION 2
STONE ROOT - TYPE B
NO SCALE



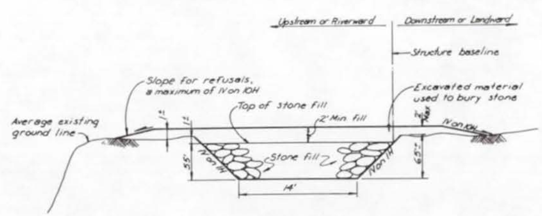
COMPOSITE REVETMENT
CASE II - Water depths shallower than 6 feet below C.R.P.
NO SCALE



WINDROW REVETMENT - TYPE B
NO SCALE

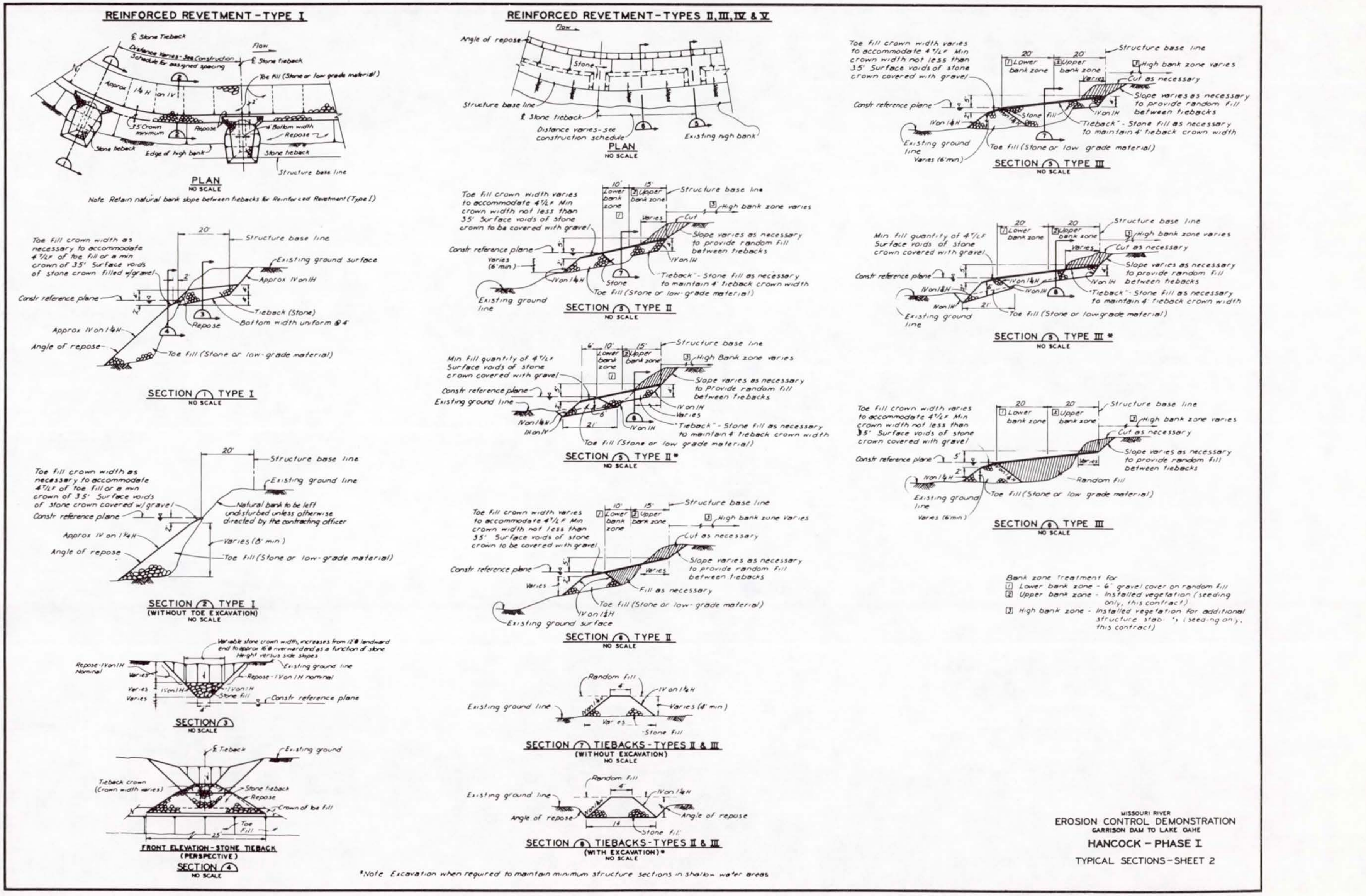


SECTION 1
HARD POINT
NO SCALE



WINDROW REFUSAL
NO SCALE

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
HANCOCK - PHASE I
TYPICAL SECTIONS - SHEET 1

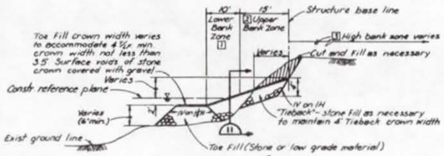


E-1-161

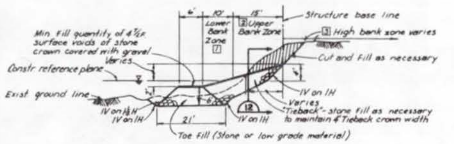
PLATE 1-3

PLATE 1-4

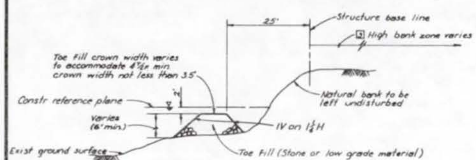
REINFORCED REVETMENT



SECTION 5 TYPE IV
NO SCALE

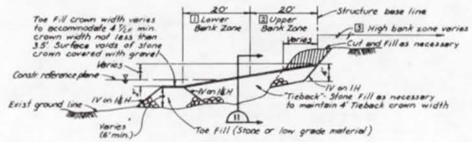


SECTION 5 TYPE IV *
NO SCALE

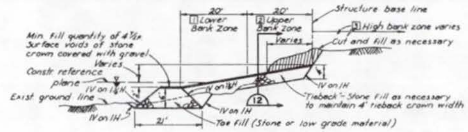


SECTION 6 TYPE IV
NO SCALE

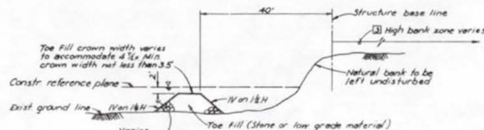
REINFORCED REVETMENT



SECTION 5 TYPE V
NO SCALE

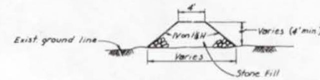


SECTION 5 TYPE V *
NO SCALE

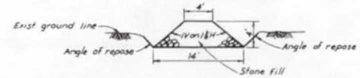


SECTION 6 TYPE V
NO SCALE

REINFORCED REVETMENT



SECTION 11 TIEBACKS - TYPES IV & V
(WITHOUT EXCAVATION)
NO SCALE

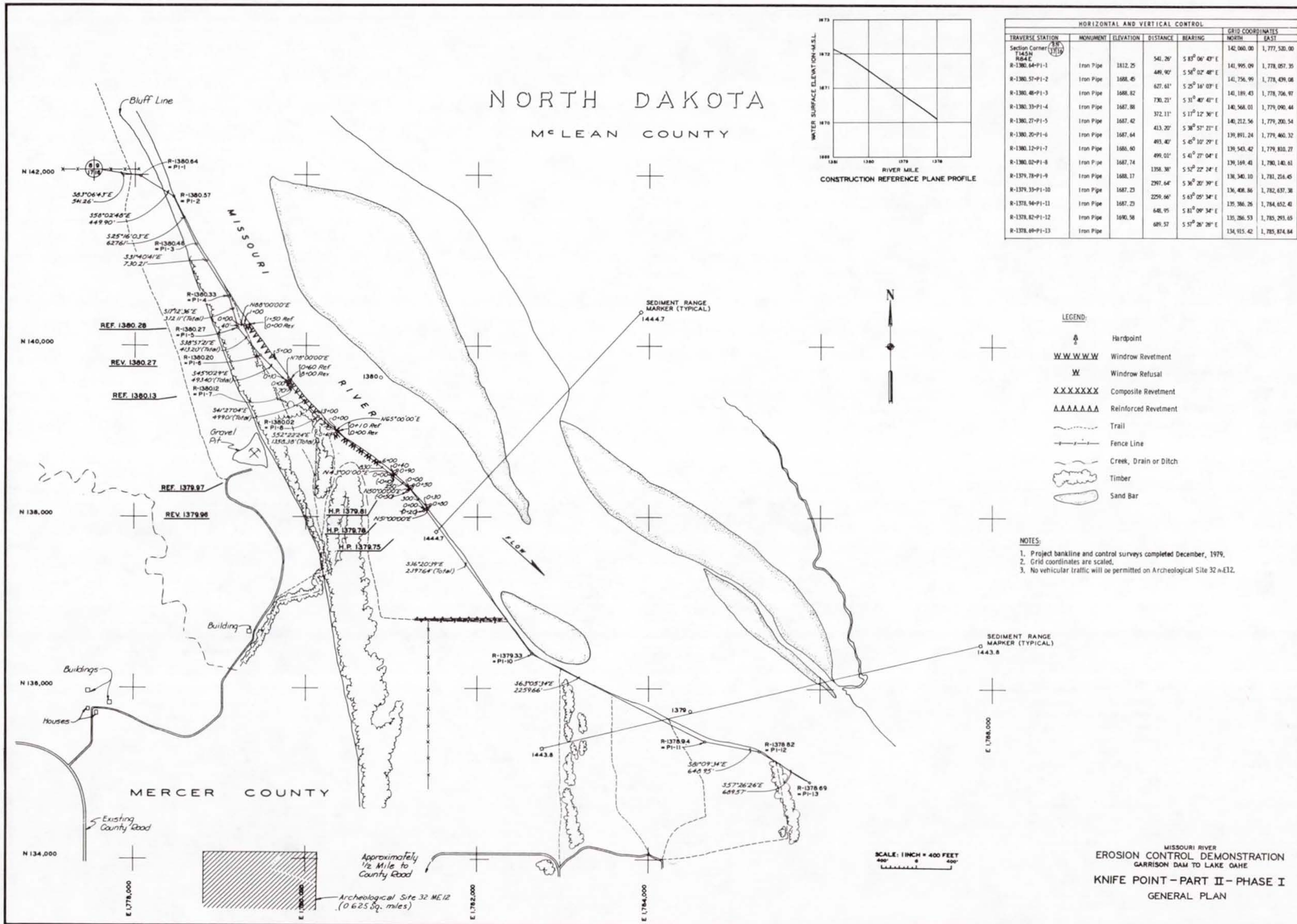


SECTION 12 TIEBACKS - TYPES IV & V
(WITH EXCAVATION) *
NO SCALE

* Excavation when required to maintain minimum structure sections in shallow water areas.

Bank zone treatment for:
1 Lower bank zone - 6" gravel cover on random fill
2 Upper bank zone - Installed vegetation (seeding only this contract)
3 High bank zone - Installed vegetation for additional structure stability (seeding only, this contract)

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
HANCOCK - PHASE I
TYPICAL SECTIONS - SHEET 3



HORIZONTAL AND VERTICAL CONTROL						
					GRID COORDINATES	
TRAVERSE STATION	MONUMENT	ELEVATION	DISTANCE	BEARING	NORTH	EAST
Section Corner (8/9, 17/16) T145N R84E			541.26'	S 83° 06' 43" E	142,060.00	1,777,520.00
R-1380.64+PI-1	Iron Pipe	1812.25	449.90'	S 58° 02' 48" E	141,995.09	1,778,057.35
R-1380.57+PI-2	Iron Pipe	1688.45	627.61'	S 25° 16' 03" E	141,756.99	1,778,439.08
R-1380.48+PI-3	Iron Pipe	1688.82	730.21'	S 31° 40' 41" E	141,189.43	1,778,706.97
R-1380.33+PI-4	Iron Pipe	1687.88	372.11'	S 17° 12' 36" E	140,568.01	1,779,090.44
R-1380.27+PI-5	Iron Pipe	1687.42	413.20'	S 38° 57' 21" E	140,212.56	1,779,200.54
R-1380.20+PI-6	Iron Pipe	1687.64	493.40'	S 45° 10' 29" E	139,891.24	1,779,460.32
R-1380.12+PI-7	Iron Pipe	1686.60	499.01'	S 41° 27' 04" E	139,543.42	1,779,810.27
R-1380.02+PI-8	Iron Pipe	1687.74	1358.38'	S 52° 22' 24" E	139,169.41	1,780,140.61
R-1379.78+PI-9	Iron Pipe	1688.17	2397.64'	S 36° 20' 39" E	138,340.10	1,781,216.45
R-1379.33+PI-10	Iron Pipe	1687.23	2259.66'	S 63° 05' 34" E	136,408.86	1,782,637.38
R-1378.94+PI-11	Iron Pipe	1687.23	648.95	S 81° 09' 34" E	135,386.26	1,784,652.41
R-1378.82+PI-12	Iron Pipe	1690.58	689.57	S 57° 26' 26" E	135,286.53	1,785,293.65
R-1378.69+PI-13	Iron Pipe				134,915.42	1,785,874.84

NOTES:

1. Project bankline and control surveys completed December, 1979.
2. Grid coordinates are scaled.
3. No vehicular traffic will be permitted on Archeological Site 32 ME12.

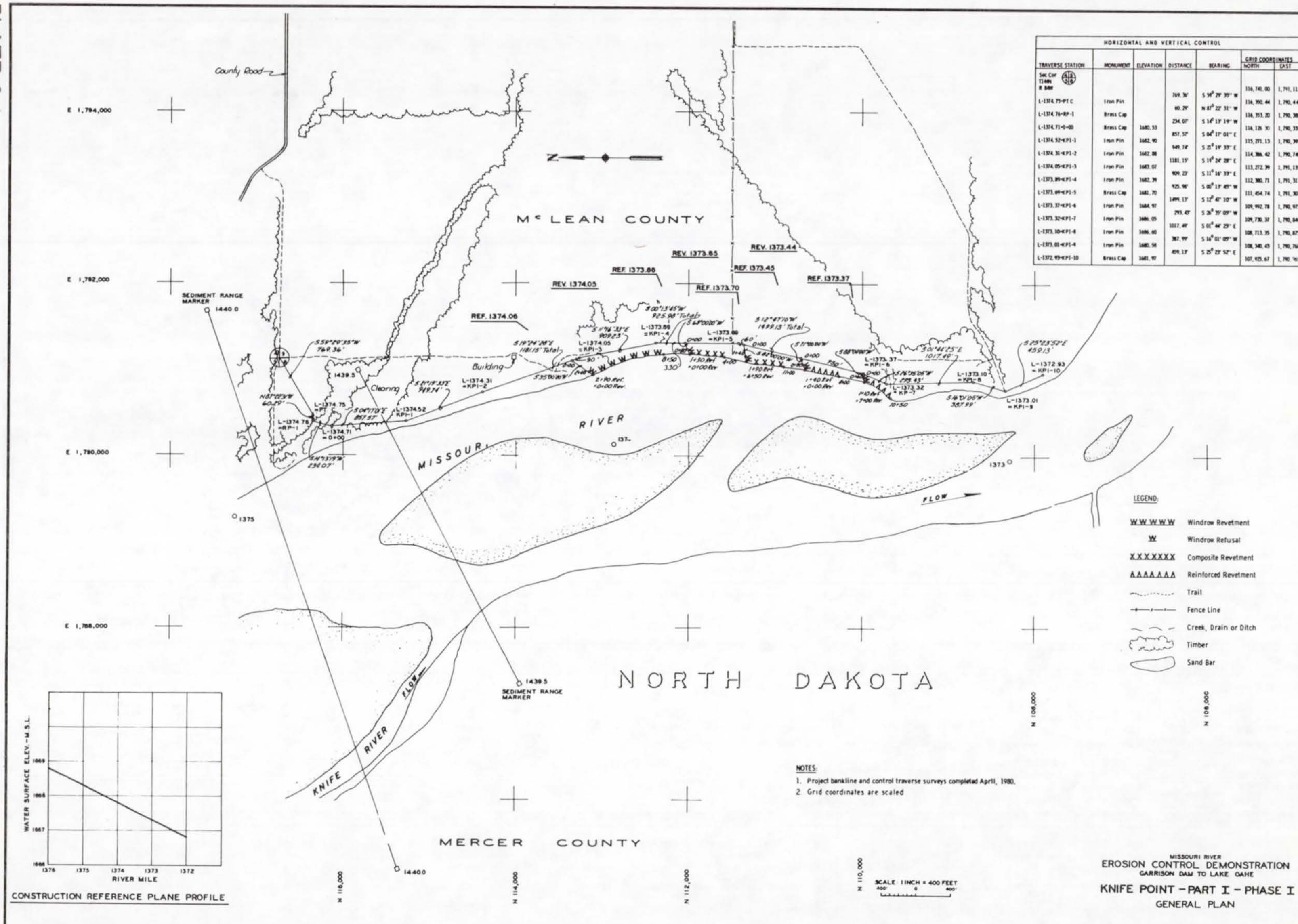
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE

KNIFE POINT – PART II – PHASE I
GENERAL PLAN

E-1-163

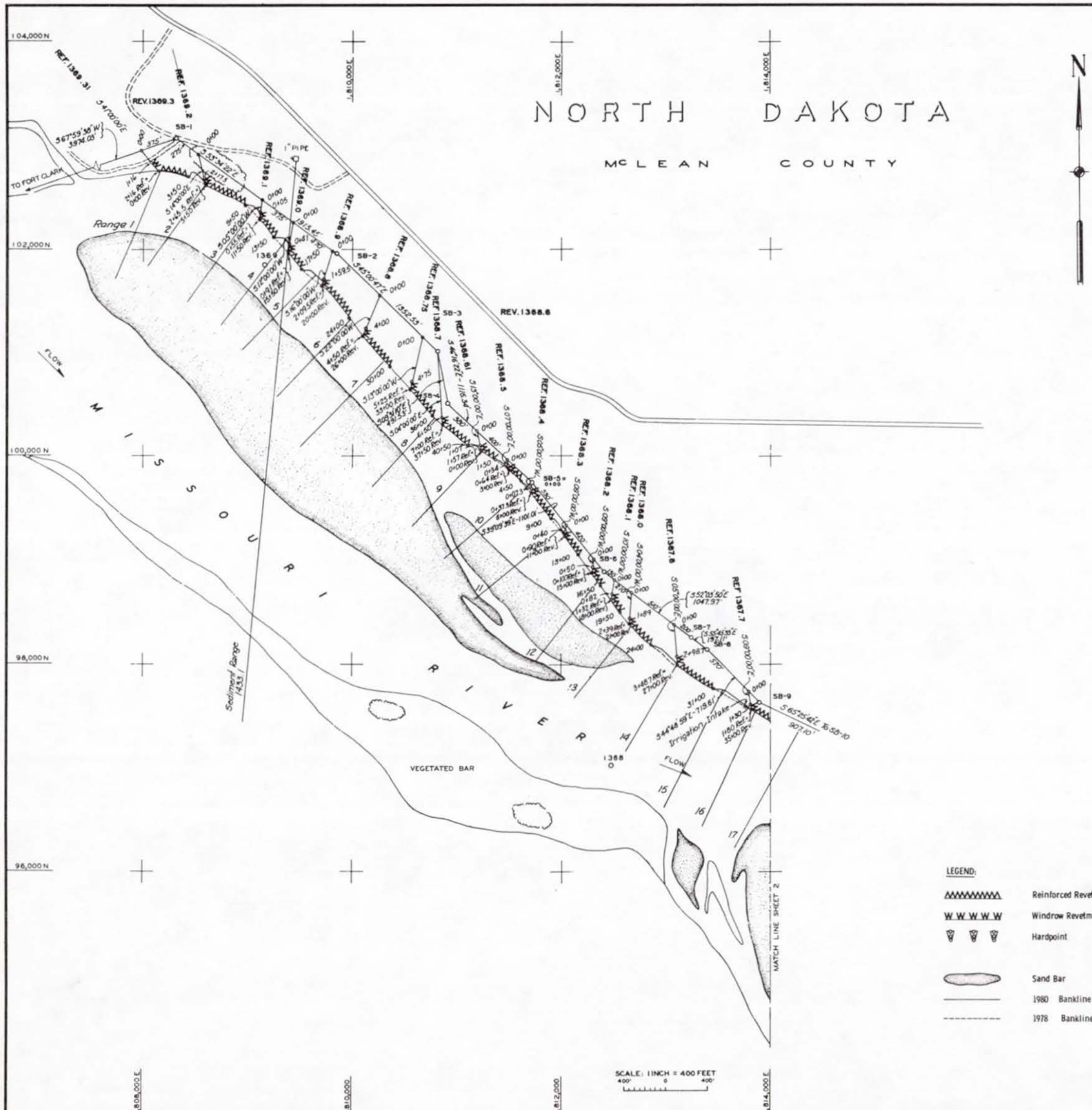
PLATE 2-1

PLATE 3-1



HORIZONTAL AND VERTICAL CONTROL

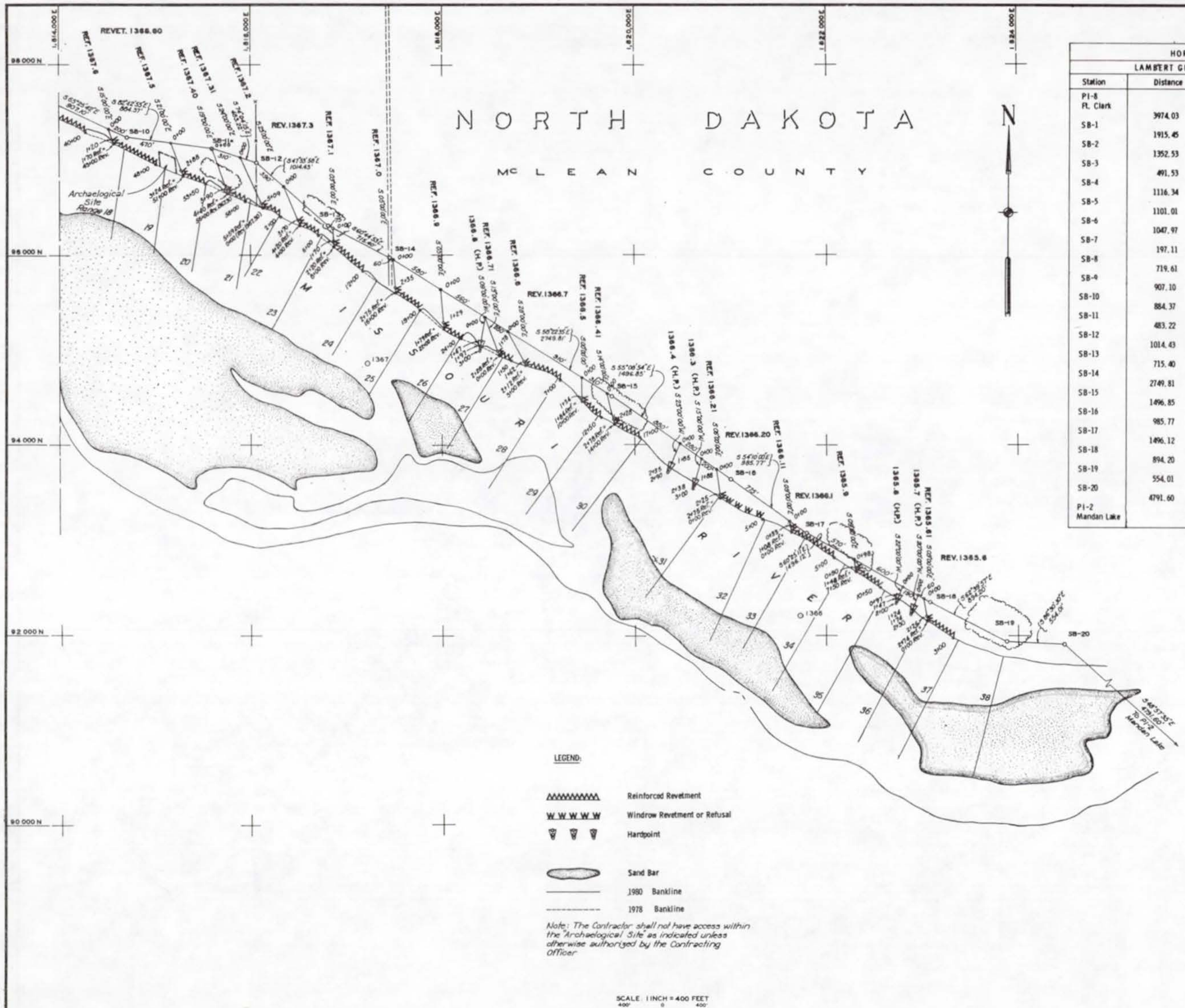
TRAVERSE STATION	MONUMENT	ELEVATION	DISTANCE	BEARING	GRID COORDINATES NORTH	GRID COORDINATES EAST
Sec Cor T144N R 84W					116,741.00	1,791,112.00
			769.36'	S 59° 29' 35" W		
L-1374.75=PT C	Iron Pin				116,350.44	1,790,449.14
			60.29'	N 87° 22' 31" W		
L-1374.76=RP-1	Brass Cap				116,353.20	1,790,388.92
			234.07'	S 14° 13' 19" W		
L-1374.71=0+00	Brass Cap	1680.53			116,126.30	1,790,331.41
			857.57'	S 04° 17' 01" E		
L-1374.52=KP1-1	Iron Pin	1682.90			115,271.13	1,790,395.47
			949.74'	S 21° 19' 33" E		
L-1374.31=KP1-2	Iron Pin	1682.88			114,386.42	1,790,740.86
			1181.15'	S 19° 24' 28" E		
L-1374.05=KP1-3	Iron Pin	1683.07			113,272.39	1,791,133.34
			909.23'	S 11° 16' 33" E		
L-1373.89=KP1-4	Iron Pin	1682.39			112,380.71	1,791,311.13
			925.96'	S 00° 13' 45" W		
L-1373.69=KP1-5	Brass Cap	1681.70			111,454.74	1,791,307.42
			1499.13'	S 12° 47' 10" W		
L-1373.37=KP1-6	Iron Pin	1684.97			109,992.78	1,790,975.65
			293.47'	S 26° 35' 09" W		
L-1373.32=KP1-7	Iron Pin	1686.05			109,730.37	1,790,844.33
			1017.49'	S 01° 44' 29" E		
L-1373.10=KP1-8	Iron Pin	1686.60			108,713.35	1,790,875.23
			387.99'	S 16° 01' 05" W		
L-1373.01=KP1-9	Iron Pin	1680.58			108,340.43	1,790,768.17
			459.13'	S 25° 23' 52" E		
L-1372.93=KP1-10	Brass Cap	1681.97			107,925.67	1,790,765.09



HORIZONTAL CONTROL LAMBERT GRID NORTH DAKOTA				
Station	Distance	Bearing	Grid Coordinates	
			Y	X
PI-8 Ft. Clark			101,596.05	1,804,625.36
	3974.03	S 67° 59' 38" W		
SB-1			103,085.14	1,808,309.86
	1915.45	S 53° 34' 22" E		
SB-2			101,947.74	1,809,851.05
	1352.53	S 45° 00' 47" E		
SB-3			100,991.58	1,810,807.65
	491.53	S 09° 31' 10" E		
SB-4			100,506.82	1,810,888.94
	1116.34	S 46° 16' 22" E		
SB-5			99,735.18	1,811,695.65
	1101.01	S 39° 09' 39" E		
SB-6			98,881.48	1,812,390.94
	1047.97	S 52° 03' 50" E		
SB-7			98,237.21	1,813,217.47
	197.11	S 55° 45' 33" E		
SB-8			98,126.30	1,813,380.42
	719.61	S 44° 48' 59" E		
SB-9			97,615.83	1,813,887.63
	907.10	S 65° 25' 42" E		
SB-10			97,238.63	1,814,712.58
	884.37	S 82° 42' 59" E		
SB-11			97,126.49	1,815,589.81
	483.22	S 74° 04' 15" E		
SB-12			96,993.87	1,816,054.48
	1014.43	S 47° 53' 58" E		
SB-13			96,313.76	1,816.807.16
	715.40	S 60° 44' 53" E		
SB-14			95,964.18	1,817,431.33
	2749.81	S 58° 11' 39" E		
SB-15			94,522.35	1,819,772.82
	1496.85	S 55° 08' 54" E		
SB-16			93,666.97	1,821,001.19
	985.77	S 54° 10' 00" E		
SB-17			93,089.87	1,821,800.38
	1496.12	S 60° 25' 11" E		
SB-18			92,351.32	1,823.101.50
	894.20	S 62° 30' 57" E		
SB-19			91,940.72	1,823,895.86
	554.01	S 86° 30' 30" E		
SB-20			91,906.98	1,824,448.84
	4791.60	S 48° 57' 35" E		
PI-2 Mandan Lake			88,760.86	1,828,062.89

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANDSTONE BLUFF PART I
AND
SANDSTONE BLUFF PART II
GENERAL PLAN - SHEET 1

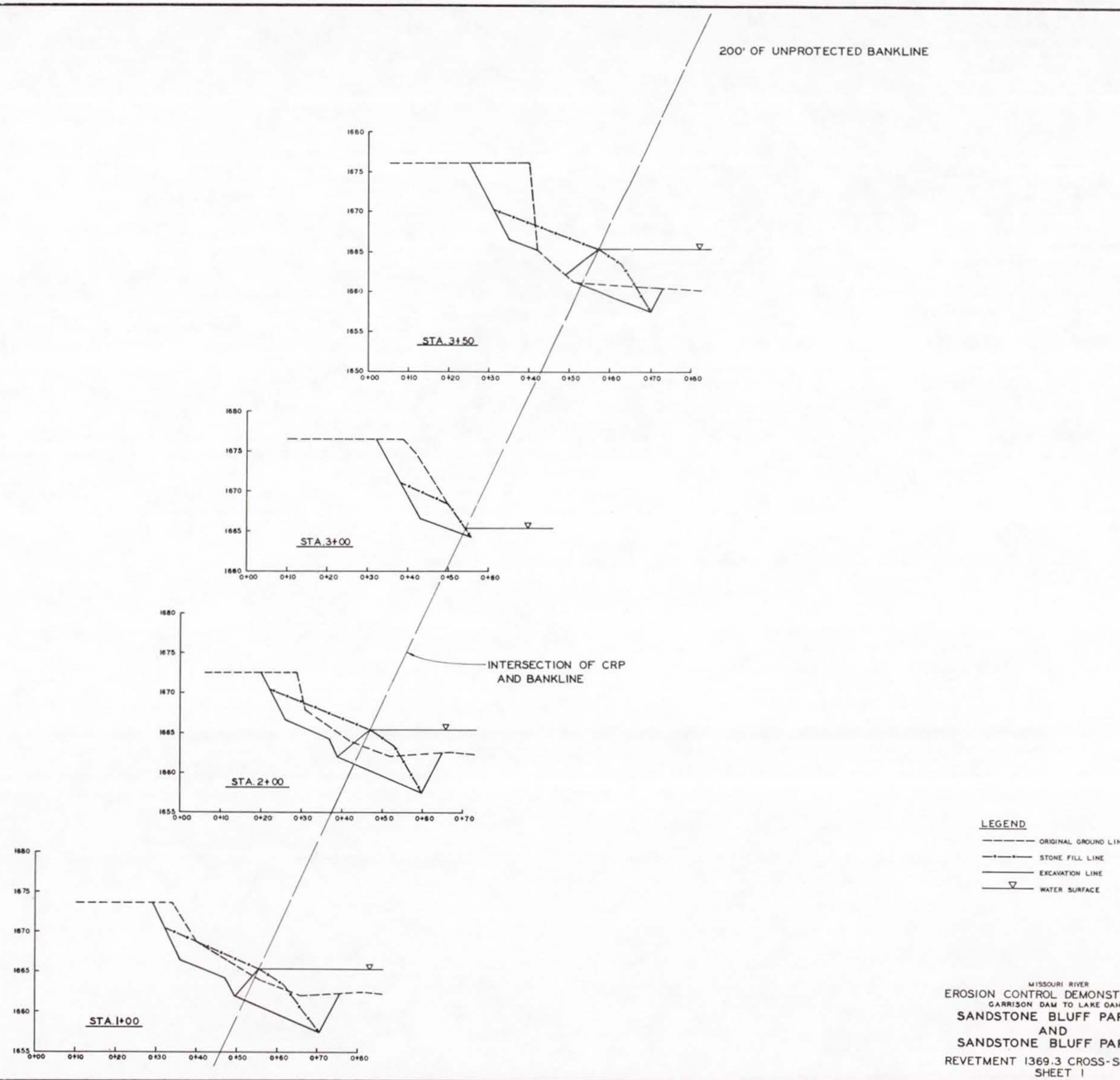
PLATE 4-1



HORIZONTAL CONTROL				
LAMBERT GRID NORTH DAKOTA				
Station	Distance	Bearing	Grid Coordinates Y	Grid Coordinates X
PI-8 Ft. Clark			101,596.05	1,804,625.36
	3974.03	S 67° 59' 38" W		
SB-1			103,085.14	1,808,309.86
	1915.45	S 53° 34' 22" E		
SB-2			101,947.74	1,809,851.05
	1352.53	S 45° 00' 47" E		
SB-3			100,991.58	1,810,807.65
	491.53	S 09° 31' 10" E		
SB-4			100,506.82	1,810,888.94
	1116.34	S 46° 16' 22" E		
SB-5			99,735.18	1,811,695.65
	1101.01	S 39° 09' 39" E		
SB-6			98,881.48	1,812,390.94
	1047.97	S 52° 03' 50" E		
SB-7			98,237.21	1,813,217.47
	197.11	S 55° 45' 33" E		
SB-8			98,126.30	1,813,380.42
	719.61	S 44° 48' 59" E		
SB-9			97,615.83	1,813,887.63
	907.10	S 65° 25' 42" E		
SB-10			97,238.63	1,814,712.58
	884.37	S 82° 42' 59" E		
SB-11			97,126.49	1,815,589.81
	483.22	S 74° 04' 19" E		
SB-12			96,993.87	1,816,054.48
	1014.43	S 47° 53' 58" E		
SB-13			96,313.76	1,816,807.16
	715.40	S 60° 44' 53" E		
SB-14			95,964.18	1,817,431.33
	2749.81	S 58° 11' 39" E		
SB-15			94,522.35	1,819,772.82
	1496.85	S 55° 08' 54" E		
SB-16			93,666.97	1,821,001.19
	985.77	S 54° 10' 00" E		
SB-17			93,089.87	1,821,800.38
	1496.12	S 60° 25' 11" E		
SB-18			92,351.32	1,823,101.50
	894.20	S 62° 30' 57" E		
SB-19			91,940.72	1,823,895.86
	554.01	S 86° 30' 30" E		
SB-20			91,906.98	1,824,448.84
	4791.60	S 48° 57' 35" E		
PI-2 Mandan Lake			88,760.86	1,828,062.89

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANDSTONE BLUFF PART I
AND
SANDSTONE BLUFF PART II
GENERAL PLAN - SHEET 2

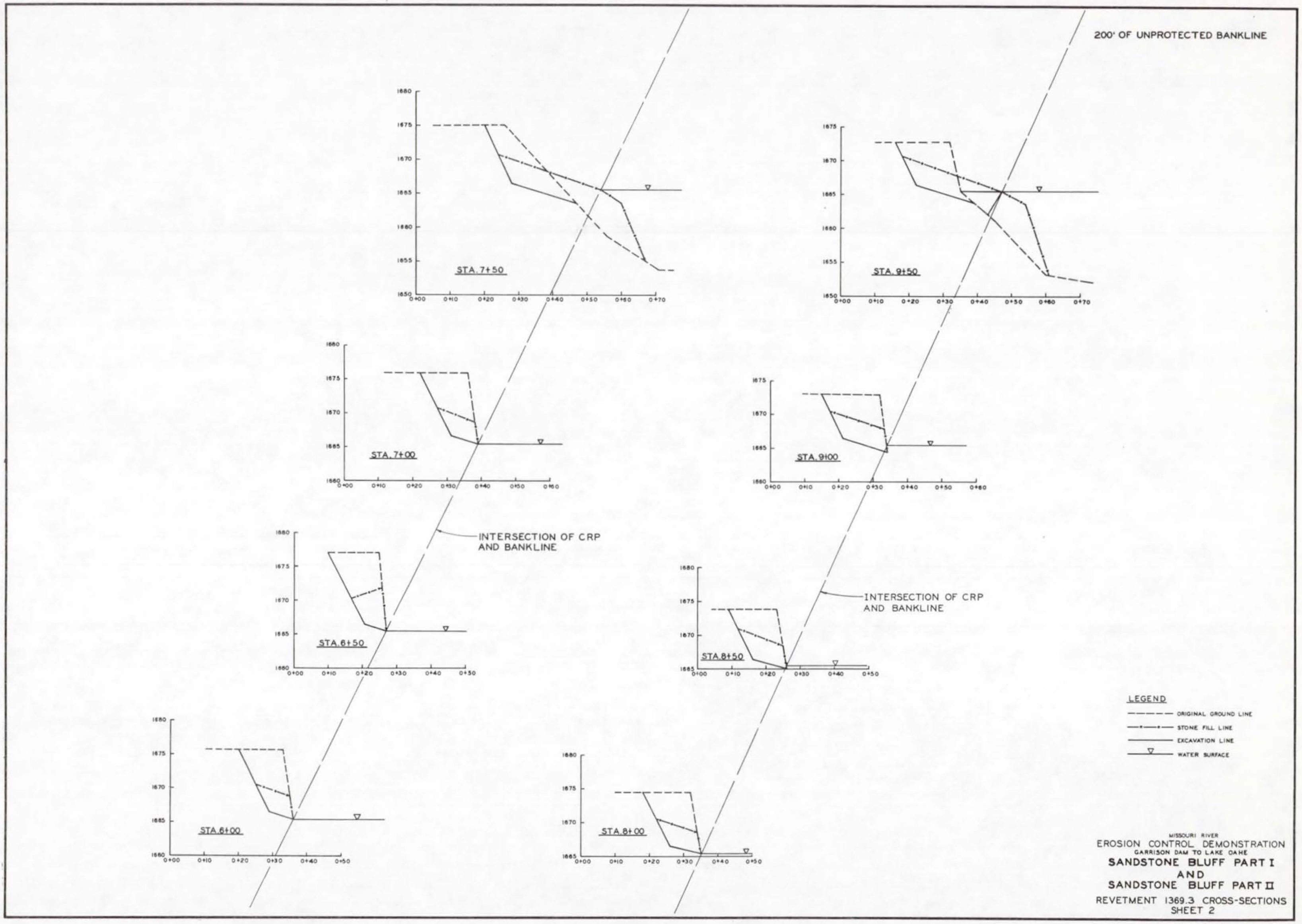
PLATE 4-2

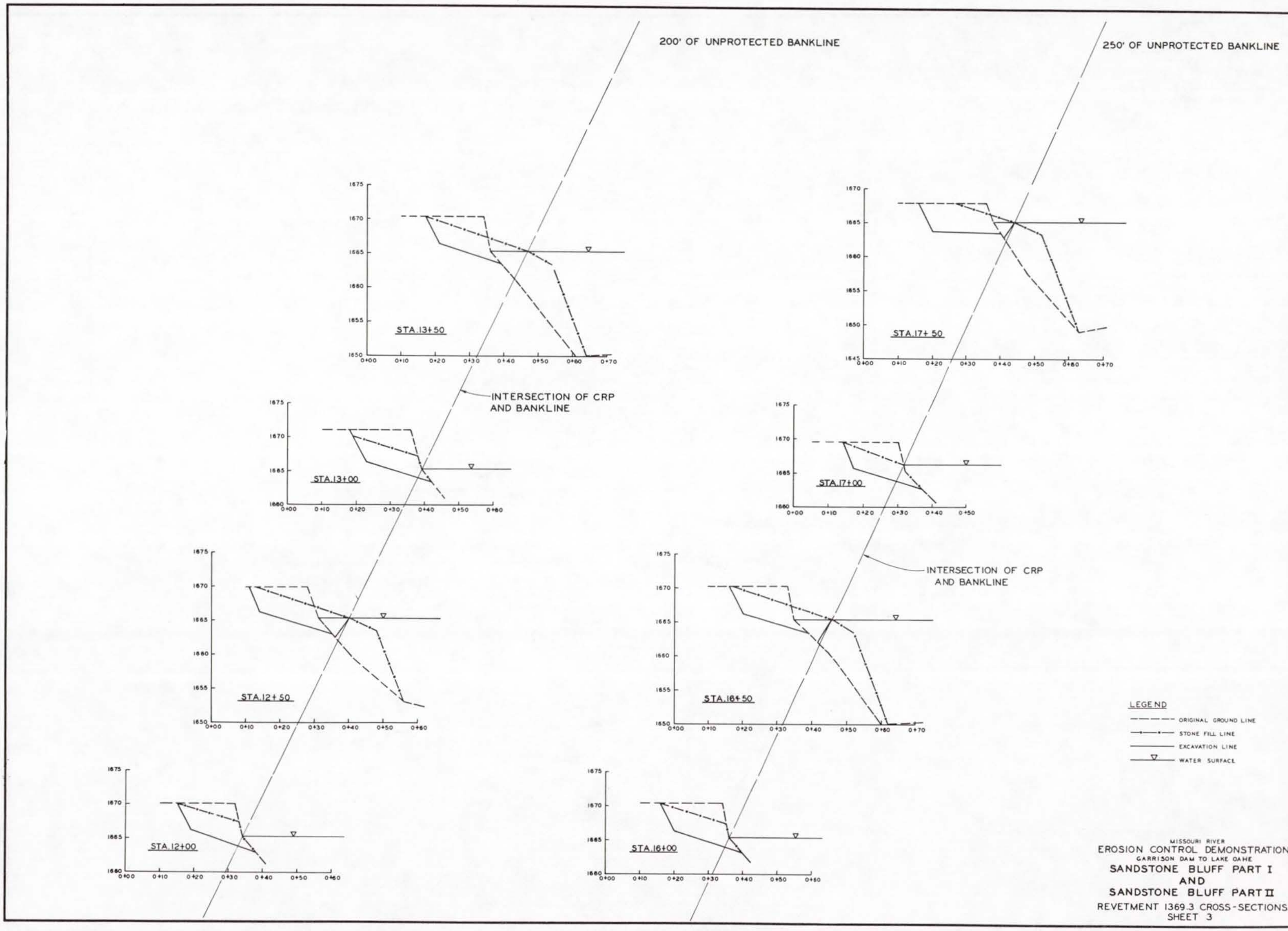


MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANDSTONE BLUFF PART I
AND
SANDSTONE BLUFF PART II
REVETMENT 1369.3 CROSS-SECTIONS
SHEET 1

PLATE 4-3

PLATE 4-4

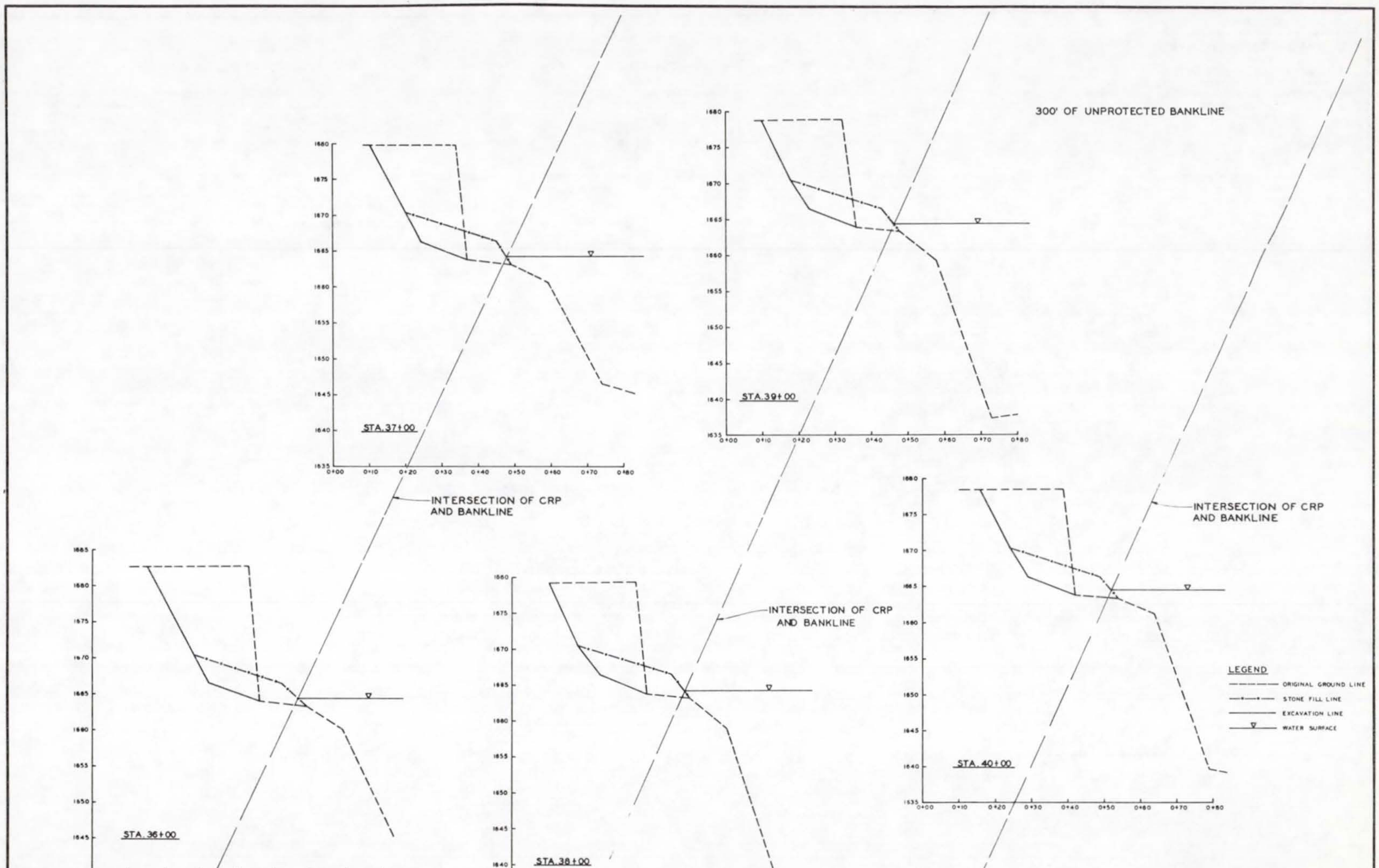

200' OF UNPROTECTED BANKLINE
STA. 7+50
STA. 9+50
STA. 7+00
STA. 9+00
STA. 6+50
STA. 8+50
STA. 6+00
STA. 8+00
INTERSECTION OF CRP AND BANKLINE
INTERSECTION OF CRP AND BANKLINE
LEGEND
ORIGINAL GROUND LINE
STONE FILL LINE
EXCAVATION LINE
WATER SURFACE
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANDSTONE BLUFF PART I
AND
SANDSTONE BLUFF PART II
REVETMENT 1369.3 CROSS-SECTIONS
SHEET 2



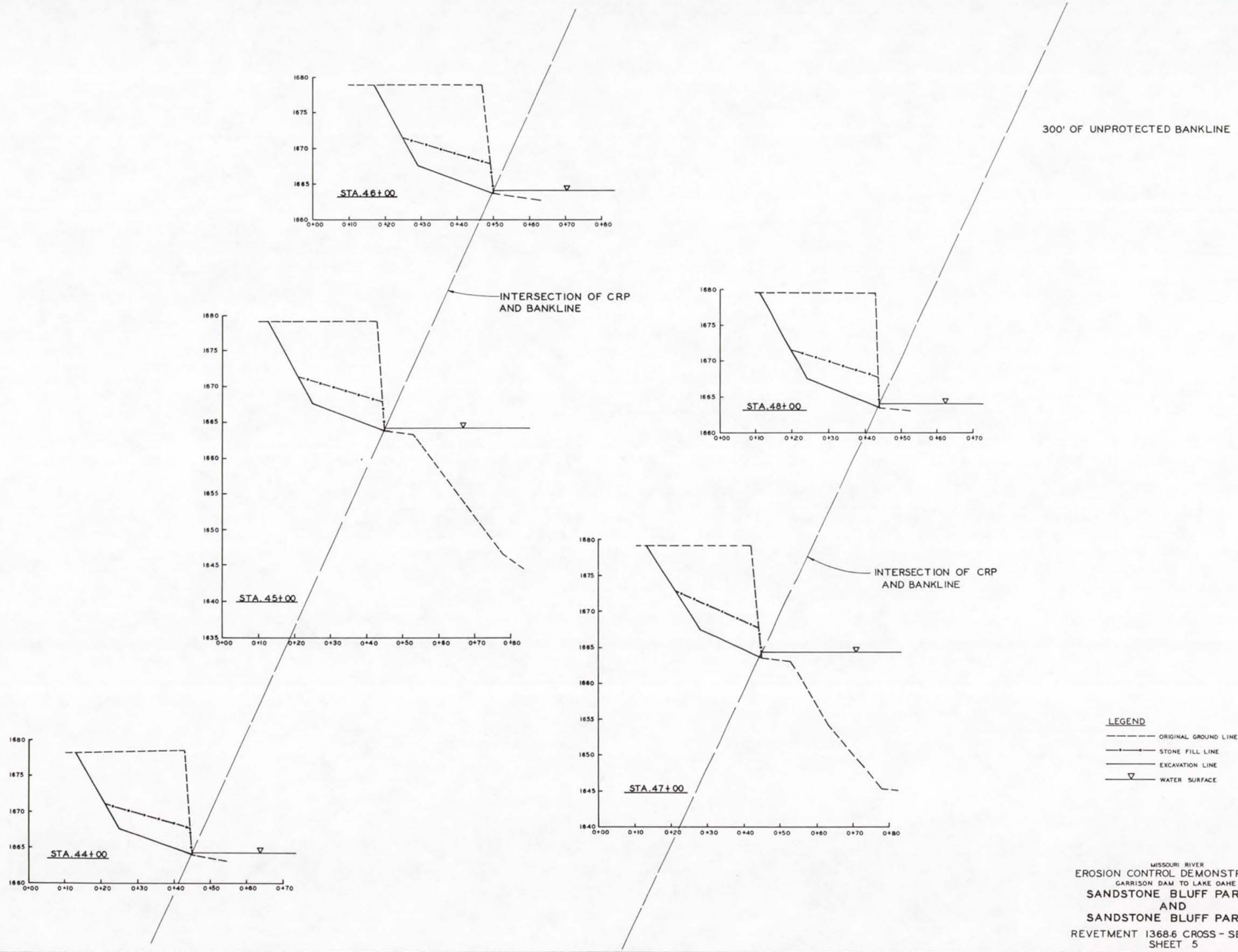
E-1-169

PLATE 4-5

PLATE 4-6



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANDSTONE BLUFF PART I
AND
SANDSTONE BLUFF PART II
REVETMENT 1368.6 CROSS - SECTIONS
SHEET 4

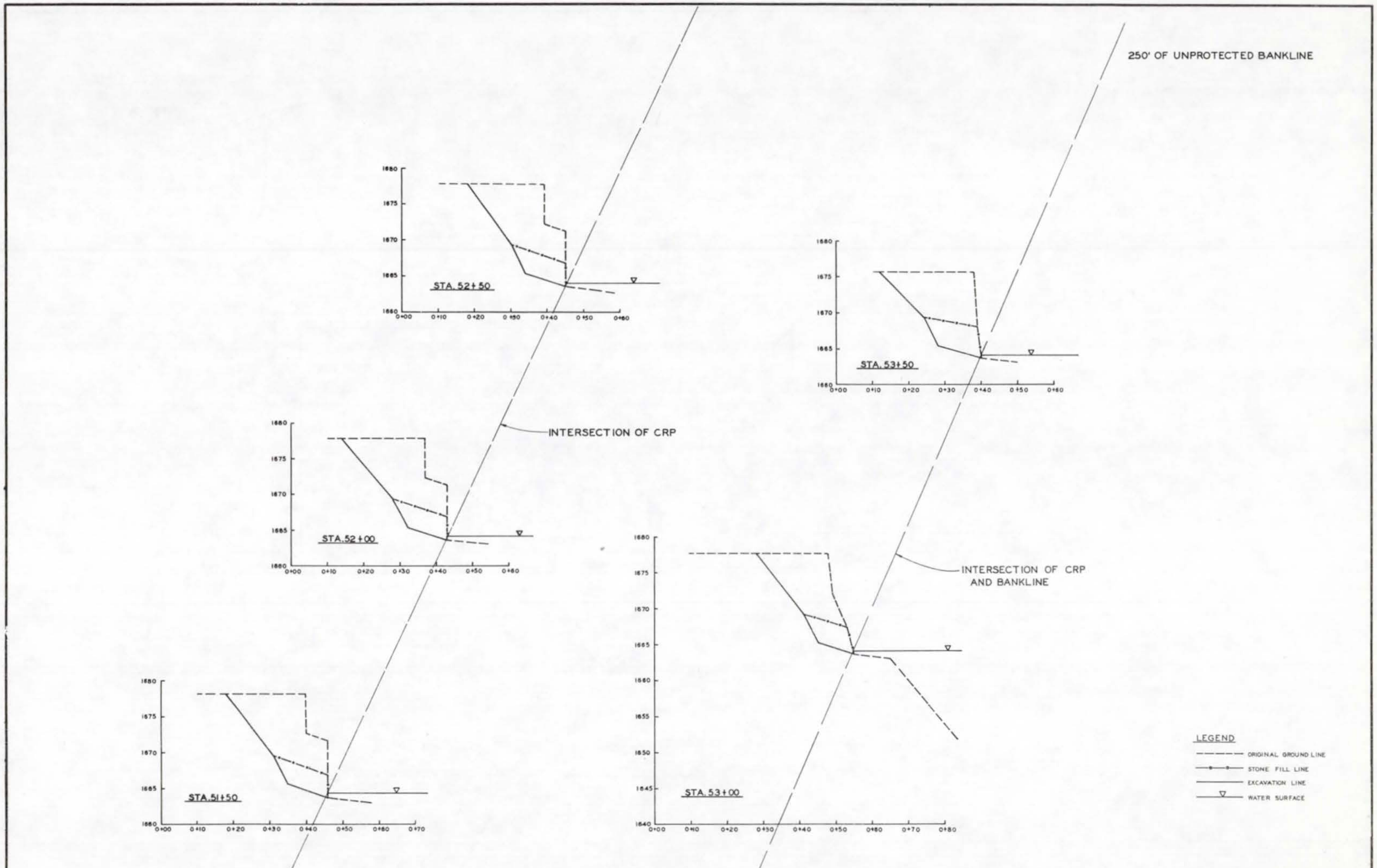


MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANDSTONE BLUFF PART I
AND
SANDSTONE BLUFF PART II
REVETMENT 1368.6 CROSS - SECTIONS
SHEET 5

E-1-171

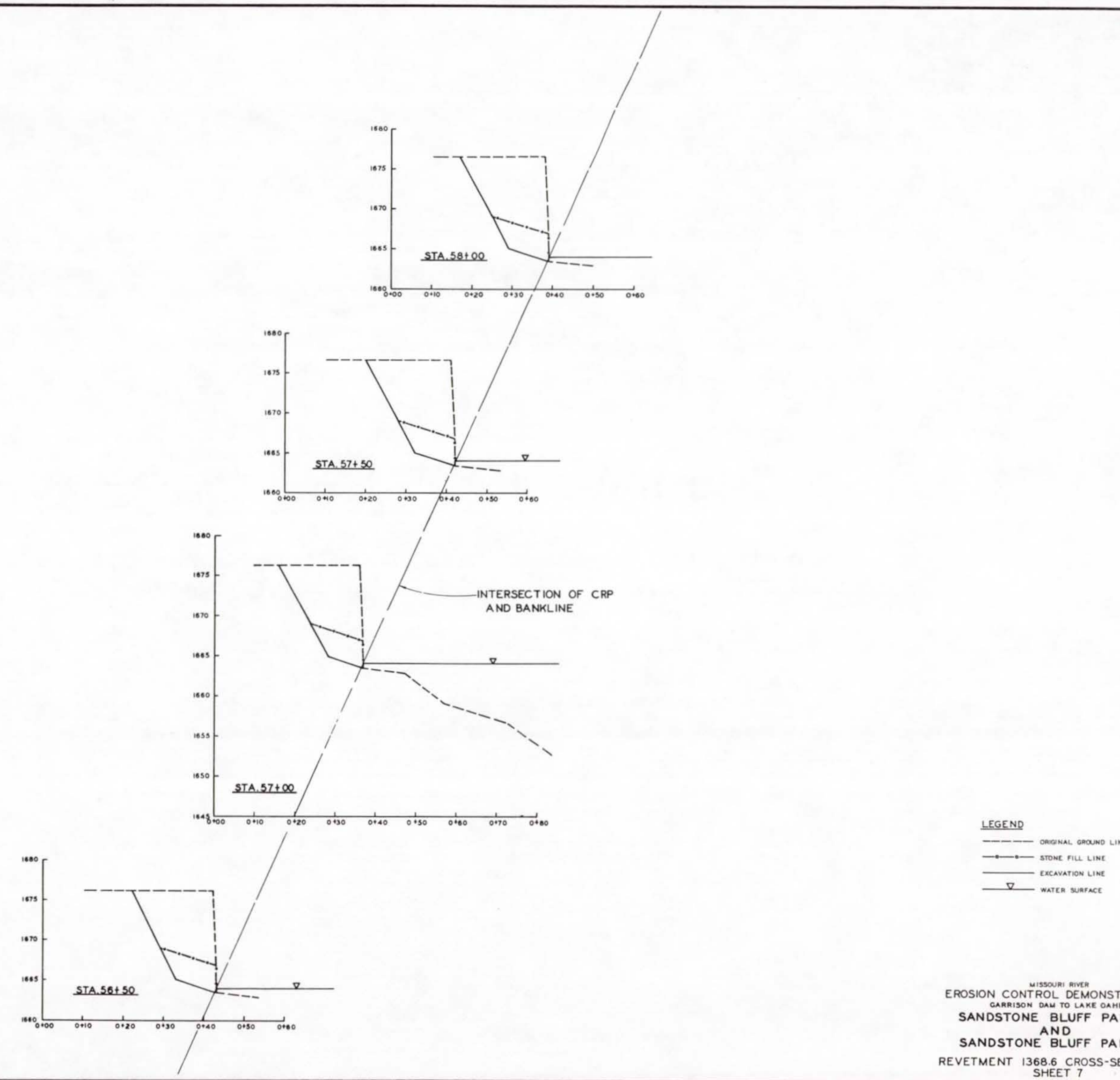
PLATE 4-7

PLATE 4-8



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANDSTONE BLUFF PART I
AND
SANDSTONE BLUFF PART II
REVETMENT 1368.6 CROSS-SECTIONS
SHEET 6

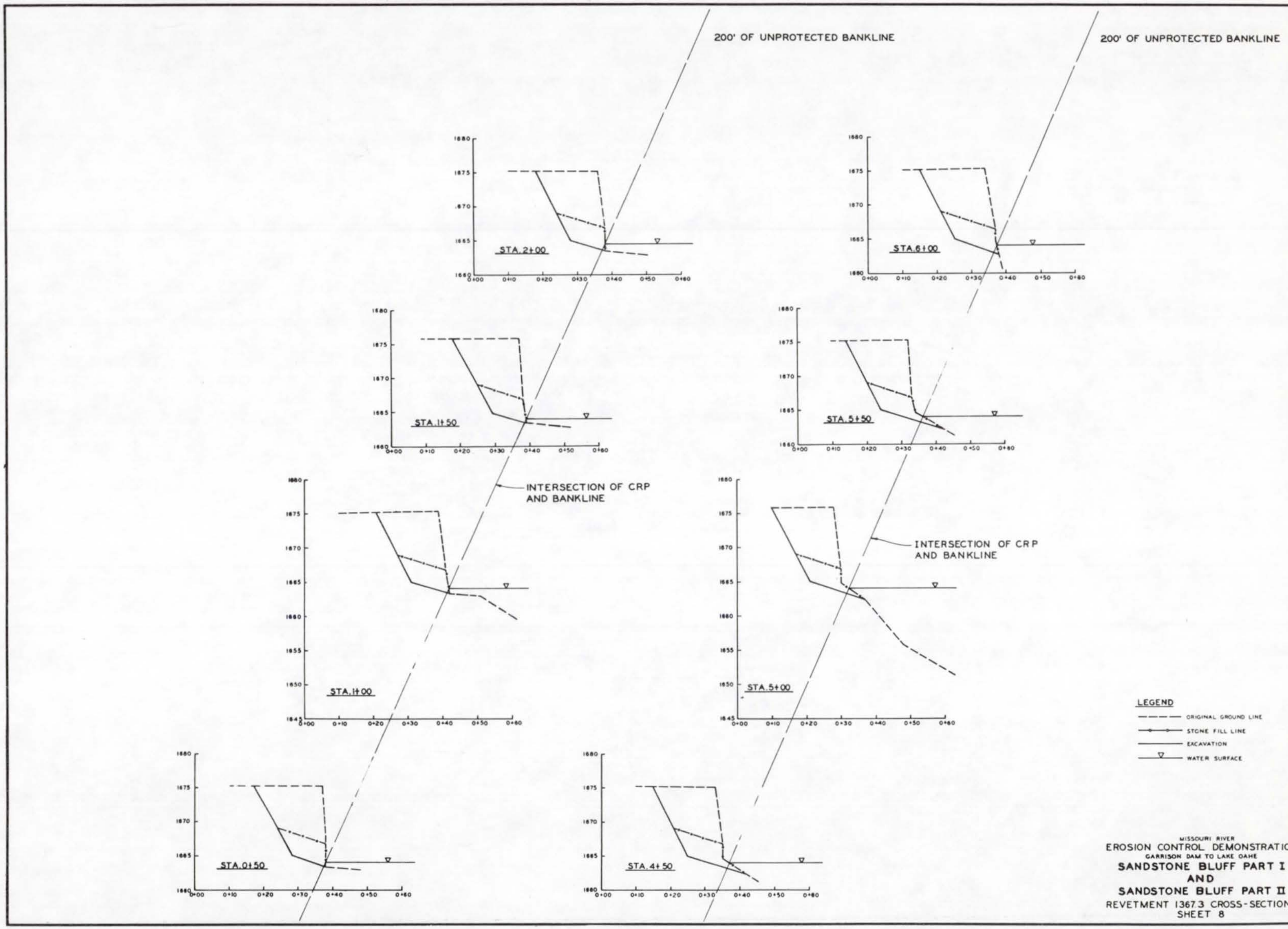
E-1-172

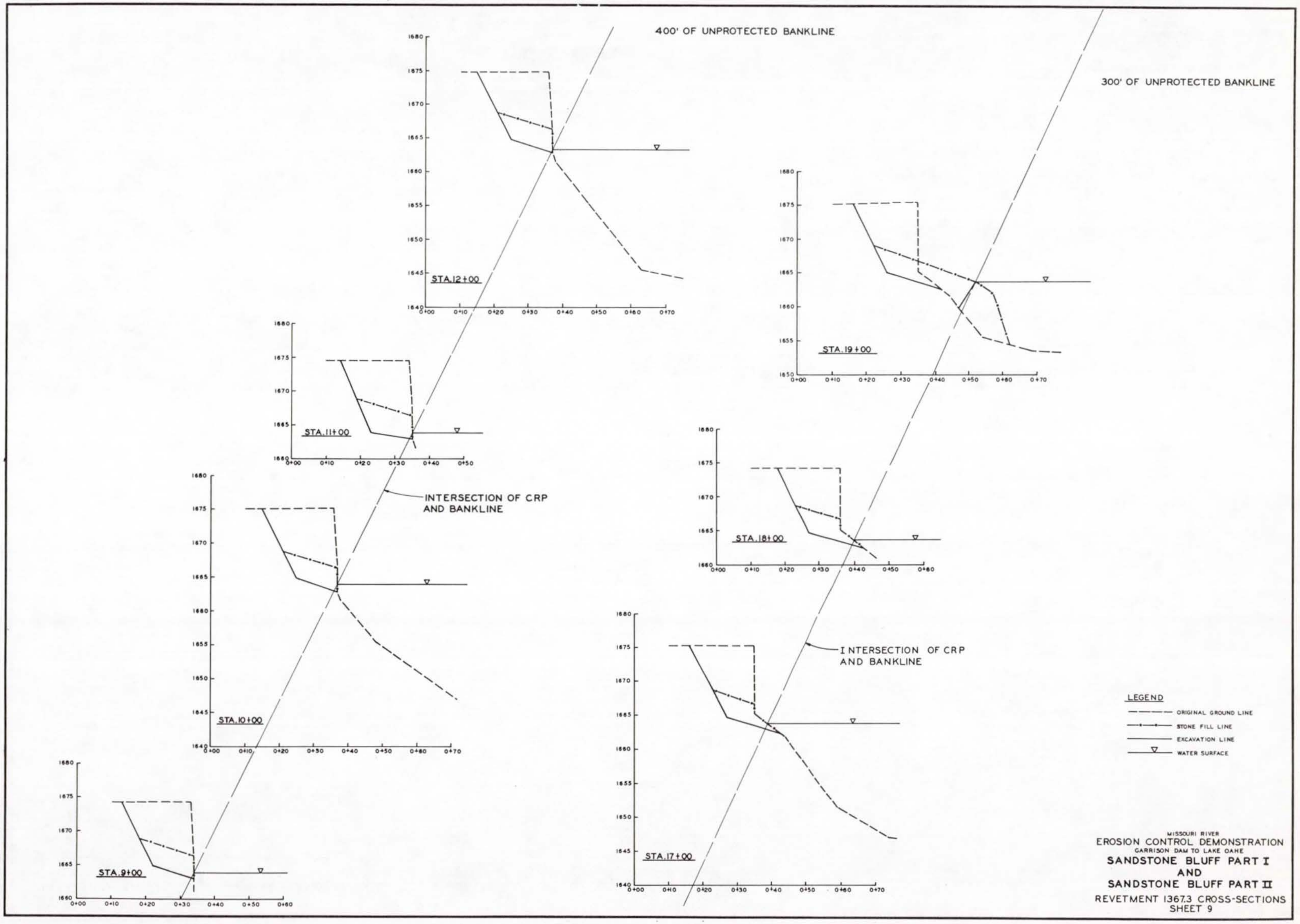


MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANDSTONE BLUFF PART I
AND
SANDSTONE BLUFF PART II
REVETMENT 1368.6 CROSS-SECTIONS
SHEET 7

PLATE 4-9

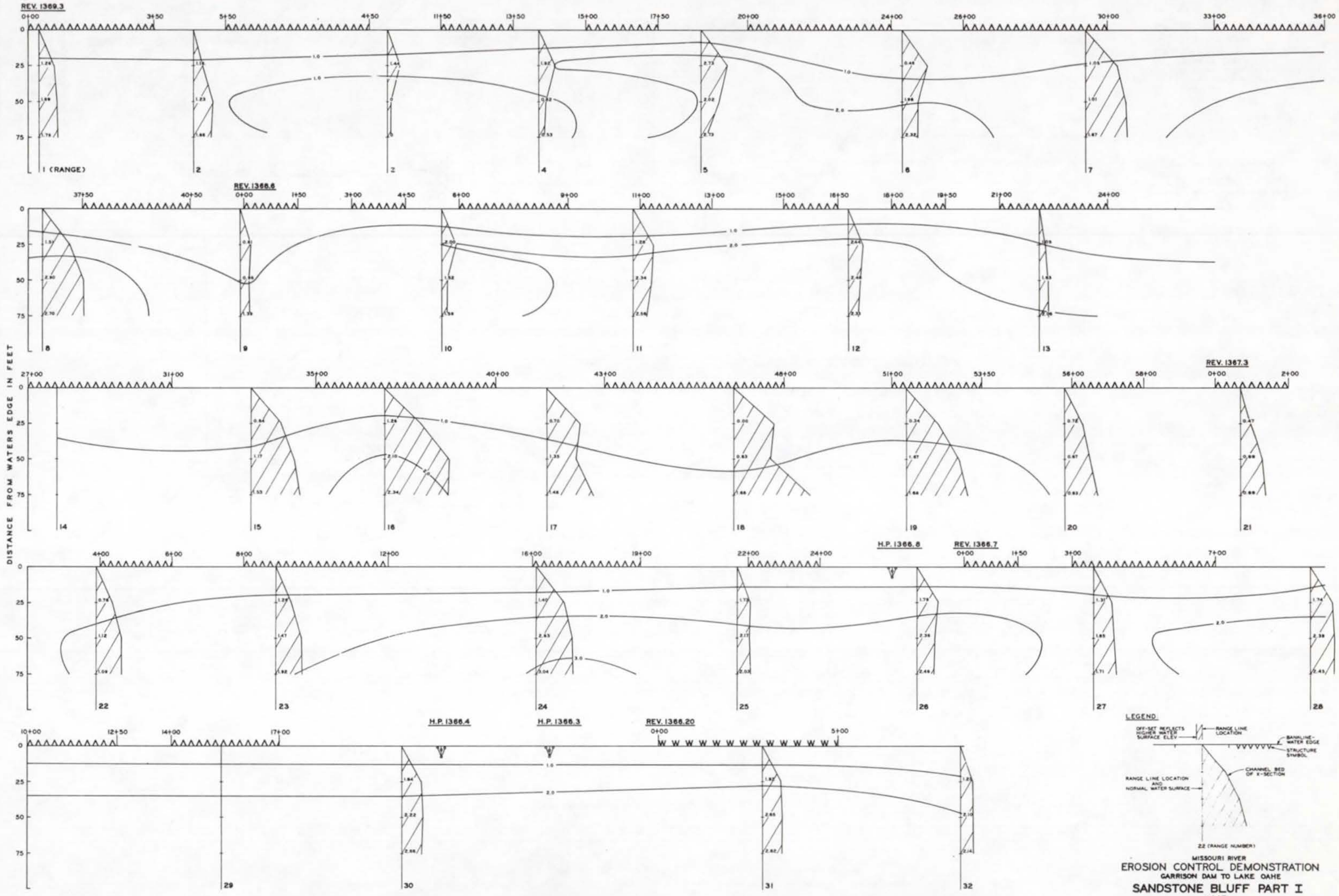
PLATE 4-10


200' OF UNPROTECTED BANKLINE
200' OF UNPROTECTED BANKLINE
STA. 2+00
STA. 6+00
STA. 1+50
STA. 5+50
INTERSECTION OF CRP AND BANKLINE
INTERSECTION OF CRP AND BANKLINE
STA. 1+00
STA. 5+00
STA. 0+50
STA. 4+50
LEGEND
ORIGINAL GROUND LINE
STONE FILL LINE
EXCAVATION
WATER SURFACE
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANDSTONE BLUFF PART I
AND
SANDSTONE BLUFF PART II
REVETMENT 1367.3 CROSS-SECTIONS
SHEET 8



E-1-175

PLATE 4-11

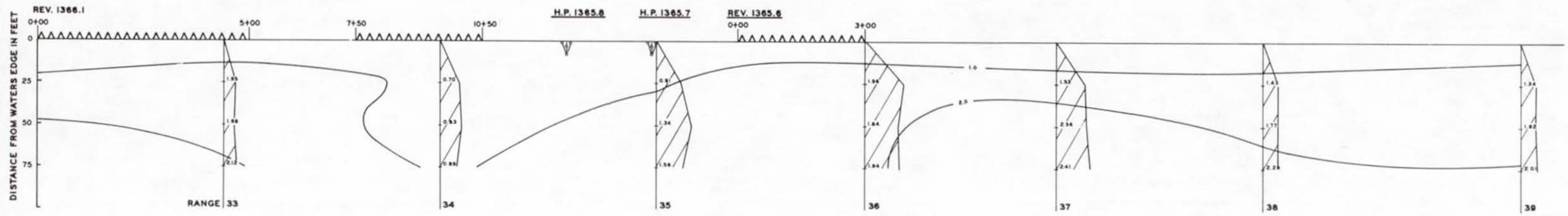


MAY 1978 Q = 5,800 C.F.S.

SCALES:
VERT. (DISTANCE FROM W.E.) 1"=25'
HORIZ. (WATER DEPTH) 1"=10'

Note: Structures were not in place at the time the velocity measurements were obtained. Construction began in August 1978.

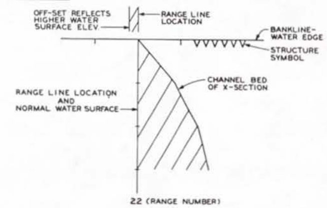
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANDSTONE BLUFF PART I
AND
SANDSTONE BLUFF PART II
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 1



MAY 1978 Q=5,800 C.F.S.

Note: Structures were not in place at the time the velocity measurements were obtained. Construction began in August 1978.

LEGEND:

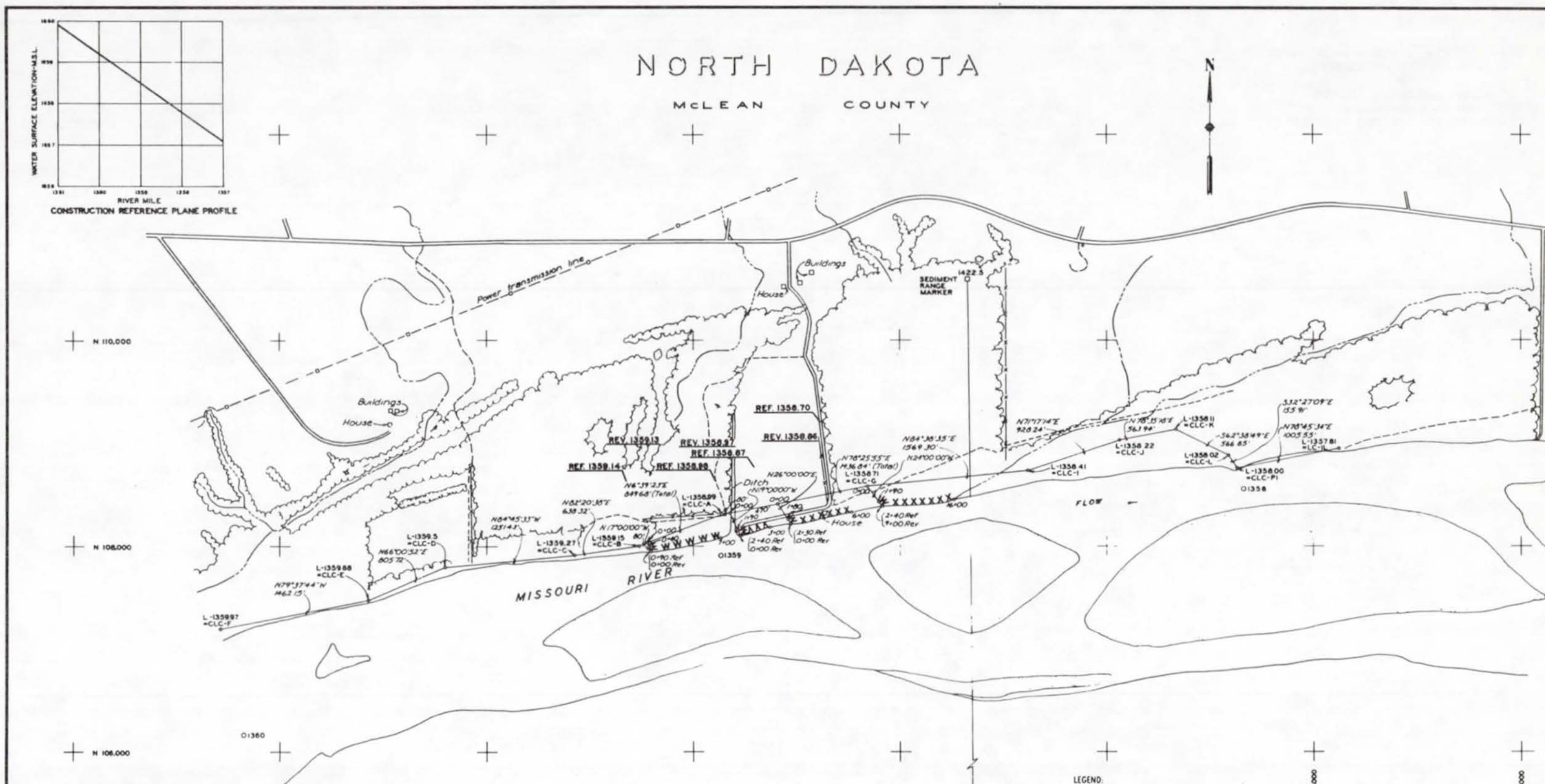


SCALES:
VERT. (DISTANCE FROM W.E.) 1"=25'
HORIZ. (WATER DEPTH) 1"=10'

Note:
Velocity Measurements Taken 20 May 1978
Q= 5,800 cfs.

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANDSTONE BLUFF PART I
AND
SANDSTONE BLUFF PART II
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 2

PLATE 5-1



HORIZTONGAL & VERTICAL CONTROL						
					GRID COORDINATES	
STATION	MONUMENT	ELEVATION	DISTANCE	BEARING	NORTH	EAST
L-1359.96-CLC-F	1/2" Rebar Brass Cap	1673.69			107,250.29	1,841,424.96
			1462.13'	N 79° 37' 44" E		
L-1359.68-CLC-E	1/2" Rebar Brass Cap	1670.37			107,473.51	1,842,863.22
			805.72'	N 66° ?' 52" E		
L-1359.5-CLC-D	1/2" Rebar Brass Cap	1669.57			107,801.04	1,843,599.36
			1251.43'	N 84° 45' 33" E		
L-1359.27-CLC-C	1/2" Rebar Brass Cap	1669.77			107,915.35	1,844,845.56
			638.32'	N 82° 20' 38" E		
L-1359.15-CLC-B	1/2" Rebar Brass Cap	1675.59			108,000.39	1,845,478.19
			849.68'	N 69° 39' 23" E		
L-1358.99-CLC-A	1/2" Rebar Brass Cap	1669.70			108,295.78	1,846,274.87
			1436.84'	N 78° 25' 55" E		
L-1358.71-CLC-G	1/2" Rebar Brass Cap	1671.71			108,583.91	1,847,682.52
			1569.30'	N 84° 38' 35" E		
L-1358.41-CLC-I	1/2" Rebar Brass Cap	1667.76			108,730.42	1,849,244.97
			928.24'	N 71° 17' 14" E		
L-1358.22-CLC-J	1/2" Rebar Brass Cap	1665.76			109,028.27	1,850,124.14
			563.94'	N 78° 35' 18" E		
L-1358.11-CLC-K	1/2" Rebar Brass Cap	1665.26			109,139.80	1,850,676.95
			566.85'	S 62° 38' 49" E		
L-1358.02-CLC-L	1/2" Rebar Brass Cap	1670.14			108,879.35	1,851,180.40
			155.91'	S 32° 27' 09" E		
L-1358.00-CLC-P1					108,747.79	1,851,264.06
			1005.55'	N 78° 45' 34" E		
L-1357.81-LC-1L	1/2" Rebar Brass Cap	1667.62			108,943.80	1,852,250.32

OLIVER COUNTY

1422.5 SEDIMENT RANGE MARKER

E 1,844,000 E 1,846,000 E 1,848,000 E 1,852,000 E 1,854,000

NOTES:

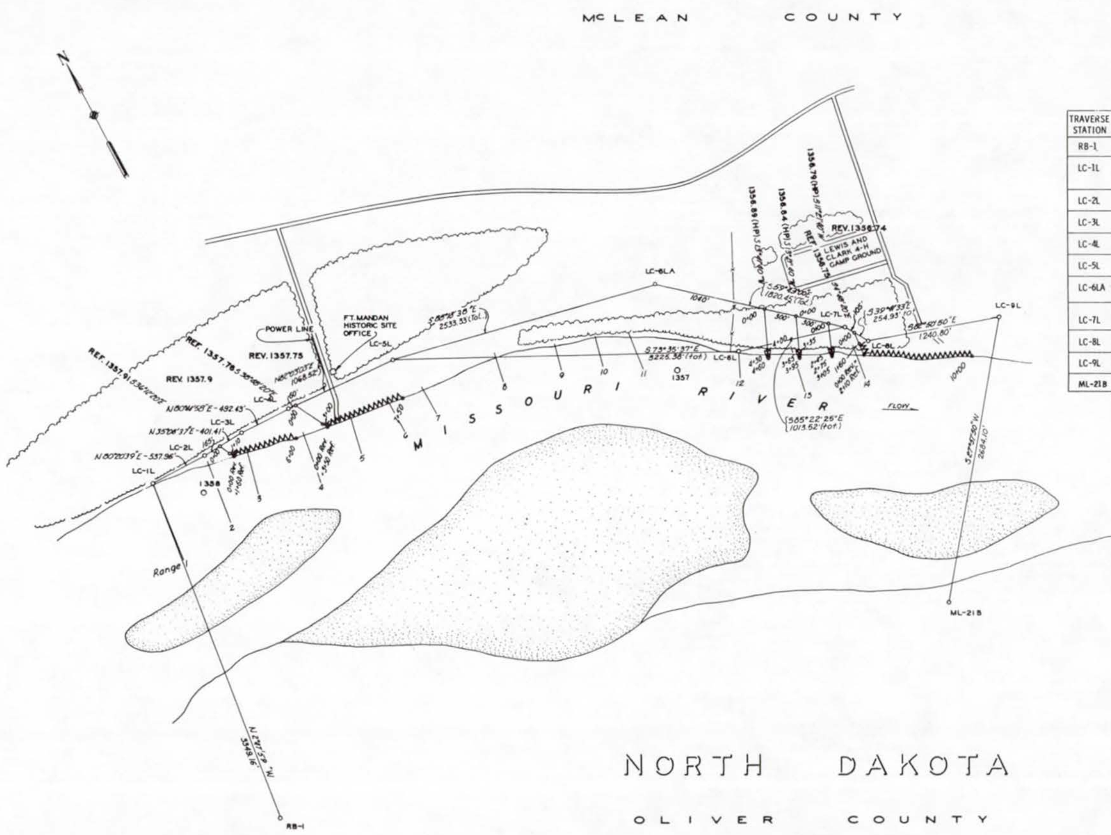
1. Project bankline and control traverse surveys completed March 1980.
2. River features are based on April 1980 aerial photography and represents an approximate discharge of 20,000 CFS.
3. Grid coordinates are scaled.
4. Control traverse point "LC-1L" is from the Lewis & Clark 4-H Camp. Project.

LEGEND:

A	Hardpoint
WWWWW	Windrow Revetment
W	Windrow Refusal
XXXXXXX	Composite Revetment
AAAAAAA	Reinforced Revetment
(symbol)	Trail
(symbol)	Fence Line
(symbol)	Creek, Drain or Ditch
(symbol)	Timber
(symbol)	Sand Bar

SCALE 1 INCH = 400 FEET
400' 0 400'

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
COAL LAKE COULEE - PHASE I
GENERAL PLAN



TRAVERSE STATION	MONUMENT	ELEVATION	DISTANCE	BEARING
RB-1	3/4" Pipe			
			3349.19'	N 02° 57' 59" W
LC-1L	1-1/2" Pipe w/plugs & tack	1667.62		
			537.95'	N 80° 20' 39" E
LC-2L	3/4" Pipe	1666.95		
			401.41'	N 75° 08' 37" E
LC-3L	3/4" Pipe	1668.69		
			492.43'	N 80° 44' 58" E
LC-4L	1-1/2" Pipe	1666.49		
			1068.52'	N 82° 03' 03" E
LC-5L		1665.85		
			2553.33'	S 88° 18' 38" E
LC-6LA	This point doesn't exist in the field.	1665.34		
			1820.45'	S 59° 43' 00" E
LC-7L	1" Pipe	1662.28		
			254.[illegible]	S 39° 41' 33" E
LC-8L	1" Pipe	1663.70		
			1240.80'	S 82° 50' 50" E
LC-9L	1" Pipe	1663.99		
			2648.08'	S 27° 51' 50" W
ML-21B	Hub			

LEGEND:

ʌʌʌʌʌʌʌʌ	Reinforced Revetment
W W W W W	Windrow Revetment or Refusal
▼ ▼ ▼	Hardpoint
(outline)	Wooded Area
(stippled)	Sand Bar

SCALE: 1 INCH = 400 FEET

MISSOURI RIVER

EROSION CONTROL DEMONSTRATION

GARRISON DAM TO LAKE OAHE

LEWIS AND CLARK 4-H CAMP AREA

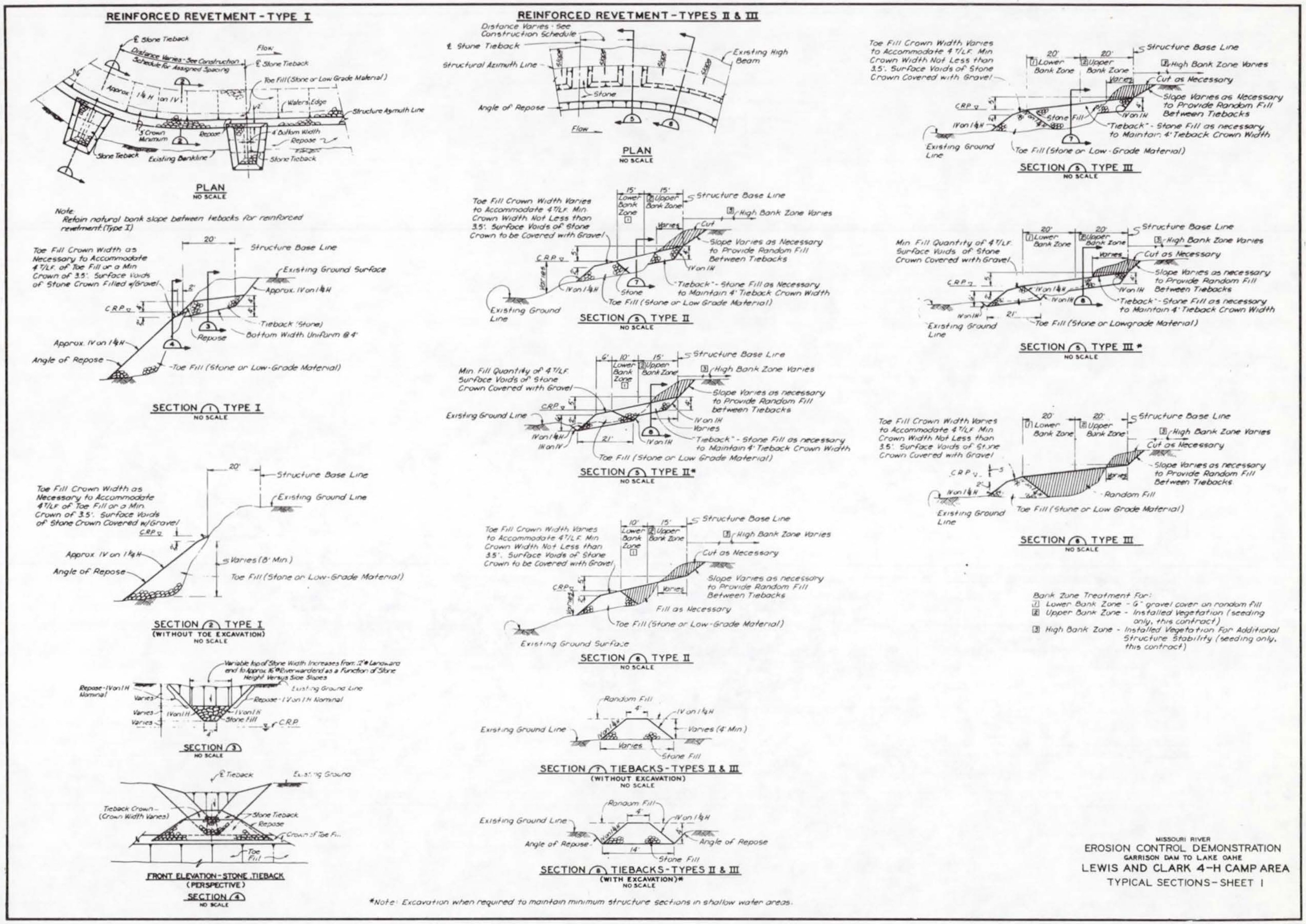
GENERAL PLAN

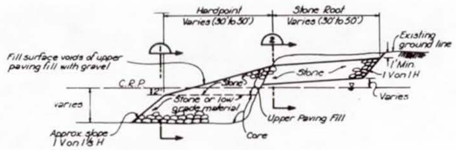
E-1-179

PLATE 6-1

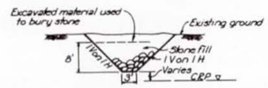
PLATE 6-2

E-1-180

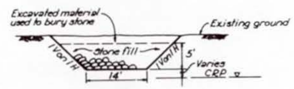




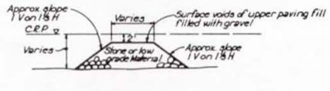
HARD POINT
NO SCALE



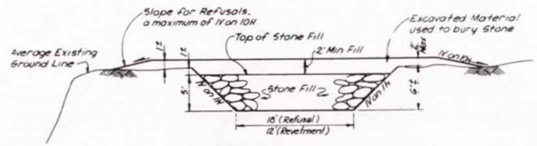
SECTION 2
STONE ROOT - TYPE A
NO SCALE



SECTION 2
STONE ROOT - TYPE B
NO SCALE



SECTION 1
HARD POINT
NO SCALE



WINDROW REVETMENT OR REFUSAL

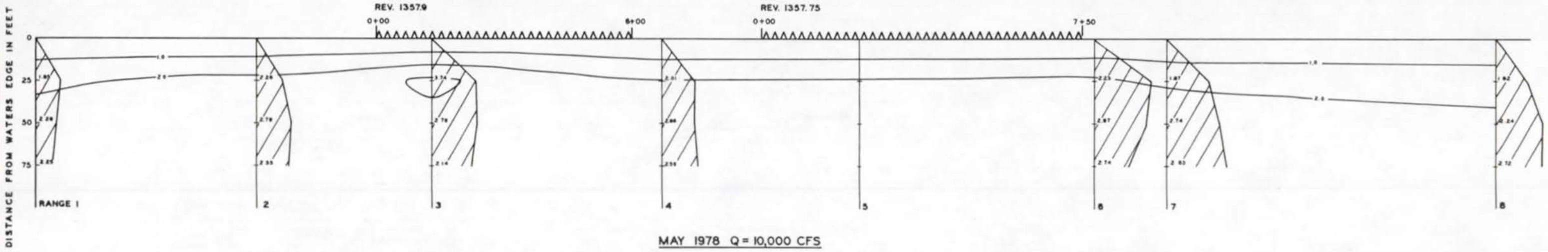
SCALE: 1 INCH = 400 FEET
400' 0 400'

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
LEWIS AND CLARK 4-H CAMP AREA
TYPICAL SECTIONS - SHEET 2

E-1-181

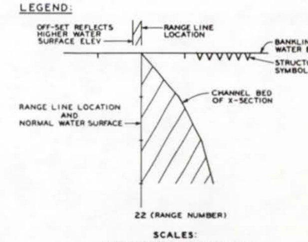
PLATE 6-3

PLATE 6-4



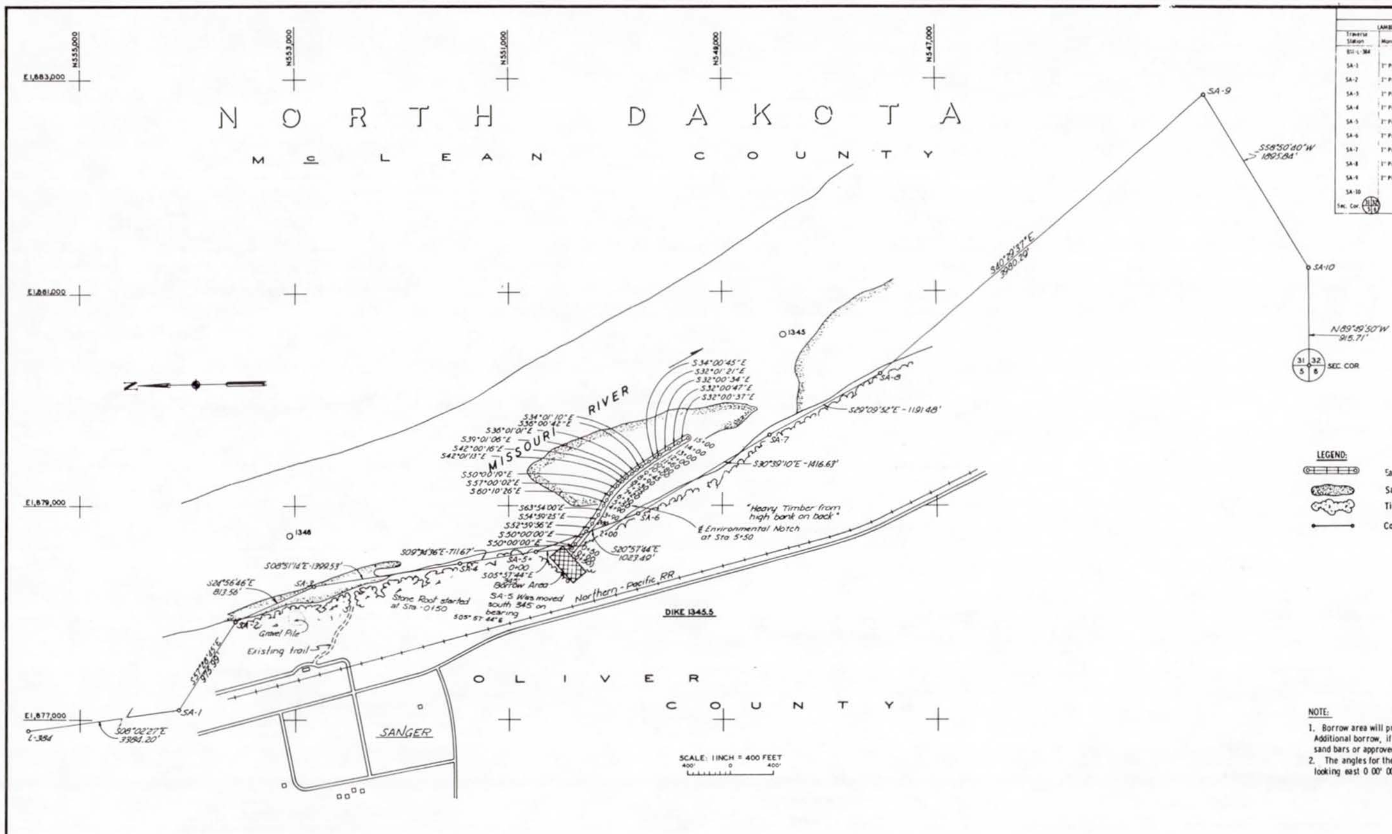
MAY 1978 Q = 10,000 CFS

LEGEND:



SCALES:
VERT (DISTANCE FROM W.E.) 1"=25'
HORIZ (WATER DEPTH) 1"=10'

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
LEWIS & CLARK 4-H CAMP AREA
AVERAGE VELOCITY PROFILE



LEGEND:

- Earth Core Dike
- Sand Bar
- Timbered Area
- Control Traverse

HORIZONTAL CONTROL						
LAMBERT GRID				NORTH DAKOTA		
Traverse Station	Monument	Elevation	Distance	Bearing	Grid Coordinates North	Grid Coordinates East
BM-L-384		1646.32			557,430.86	1,876,613.49
			3394.20'	S 08° 02' 27" E		
SA-1	1" Pipe				554,079.93	1,877,086.87
			975.99'	S 57° 28' 45" E		
SA-2	1" Pipe				553,555.23	1,877,909.82
			813.56'	S 24° 56' 46" E		
SA-3	1" Pipe	1656.21			552,817.57	1,878,252.95
			1399.53'	S 08° 51' 14" E		
SA-4	1" Pipe	1661.52			551,434.71	1,878,468.36
			711.67'	S 09° 34' 36" E		
SA-5	1" Pipe	1660.52			550,732.95	1,878,586.76
			1023.40'	S 20° 57' 44" E		
SA-6	1" Pipe	1660.79			549,777.19	1,878,952.92
			1416.63'	S 30° 39' 10" E		
SA-7	1" Pipe	1660.01			548,558.50	1,879,675.17
			1191.48'	S 29° 09' 52" E		
SA-8	1" Pipe	1658.73			547,518.07	1,880,255.80
			3980.29'	S 40° 29' 37" E		
SA-9	1" Pipe				544,491.14	1,882,840.46
			1895.84'	S 58° 50' 40" W		
SA-10					543,510.30	1,881,218.06
			915.71'	N 89° 49' 50" W		
Sec. Cor. (31 32 / 5 8)					543,513.01	1,880,302.35

NOTE:

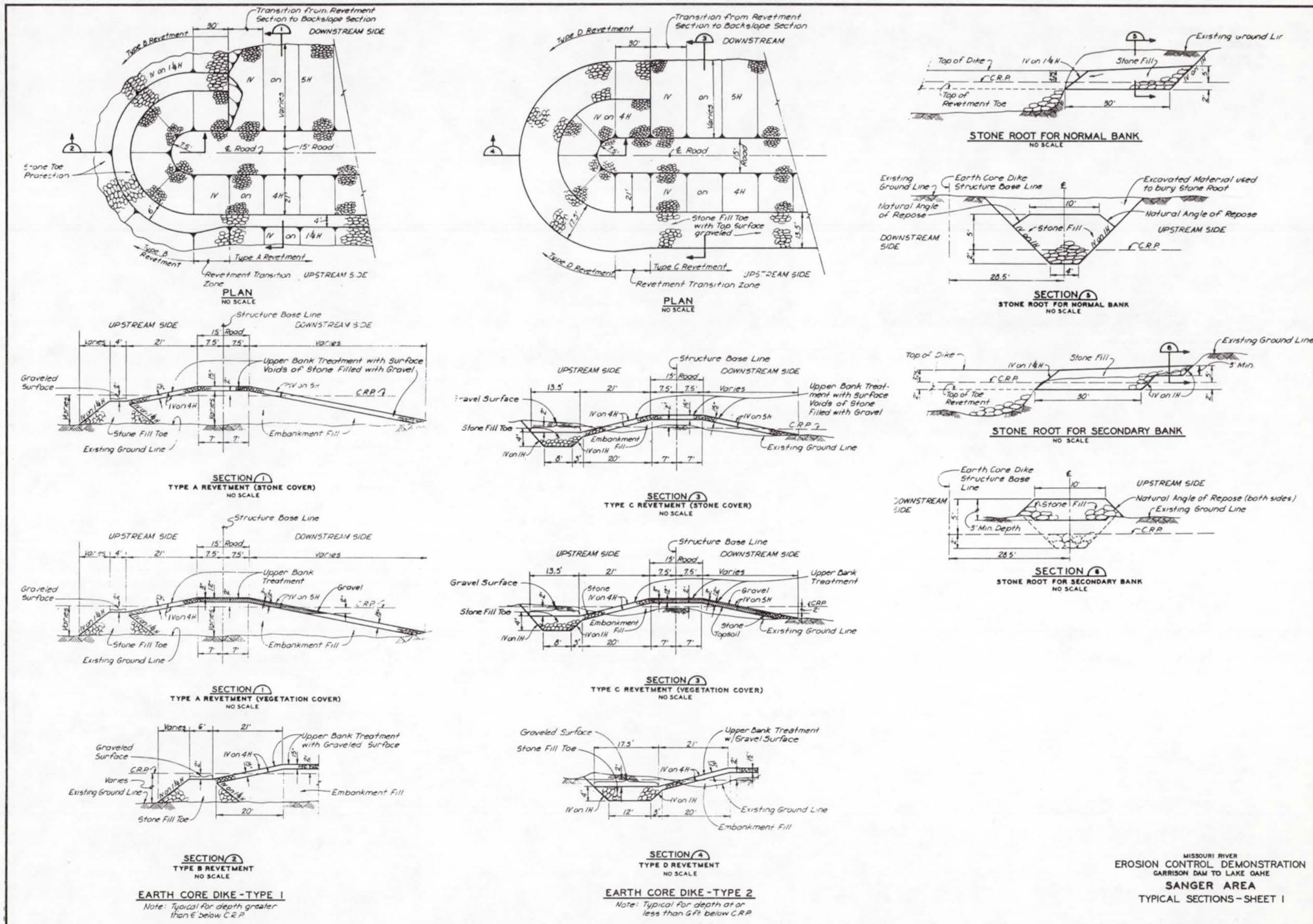
1. Borrow area will provide approximately 7500 c.y. of material. Additional borrow, if required, shall be obtained from existing sand bars or approved sites in accordance with the specifications.
2. The angles for the alignment of the dike were turned from Sta. 0 + 00 looking east 0 00' 00" degree.

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANGER AREA
GENERAL PLAN

E-1-183

PLATE 7-1

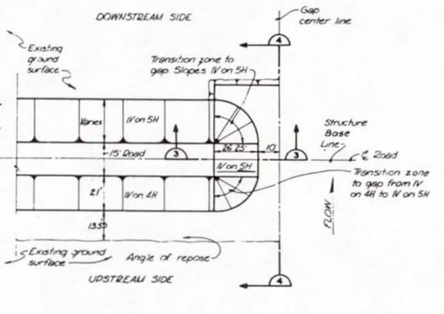
PLATE 7-2



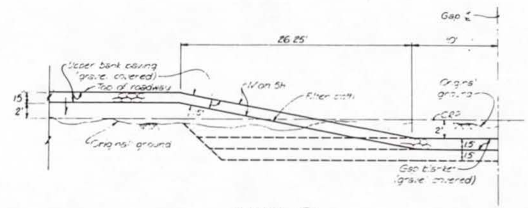
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANGER AREA
TYPICAL SECTIONS - SHEET 1

E-1-184

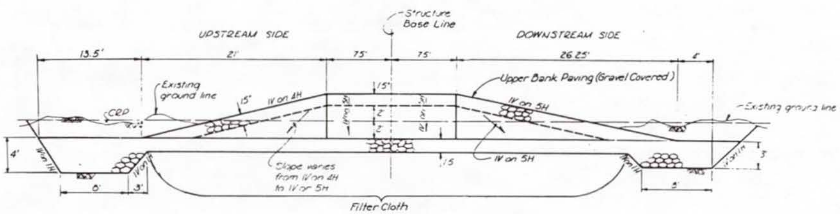
Note:
1. All environmental gap paving and transition areas to receive filter cloth.
2. Environmental gap symmetrical about ℄.



PLAN
NO SCALE



SECTION 3
NO SCALE



SECTION 4
NO SCALE

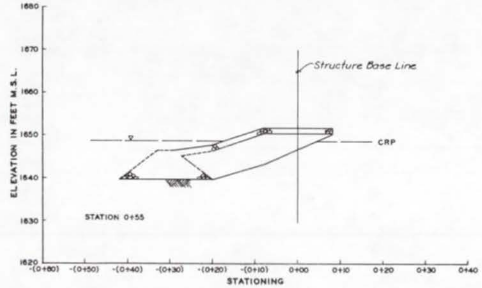
EARTH CORE DIKE
ENVIRONMENTAL GAP

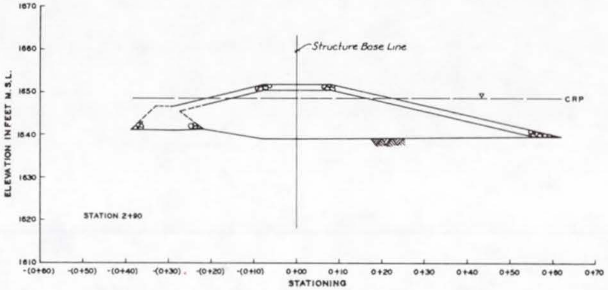
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANGER AREA
TYPICAL SECTIONS-SHEET 2

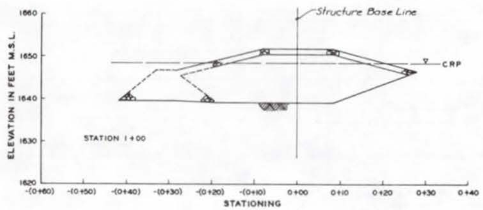
E-1-185

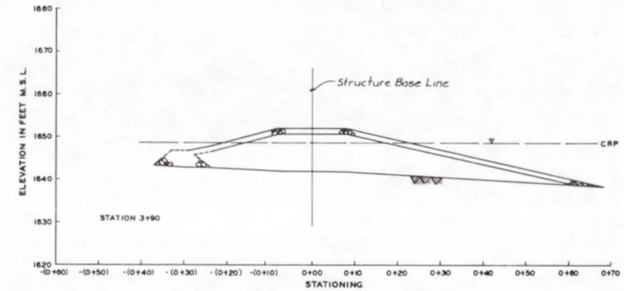
PLATE 7-3

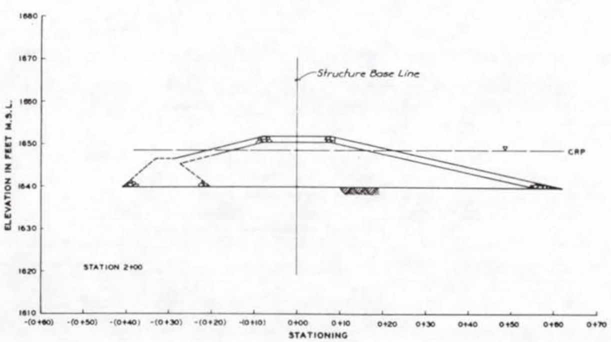
PLATE 7-4











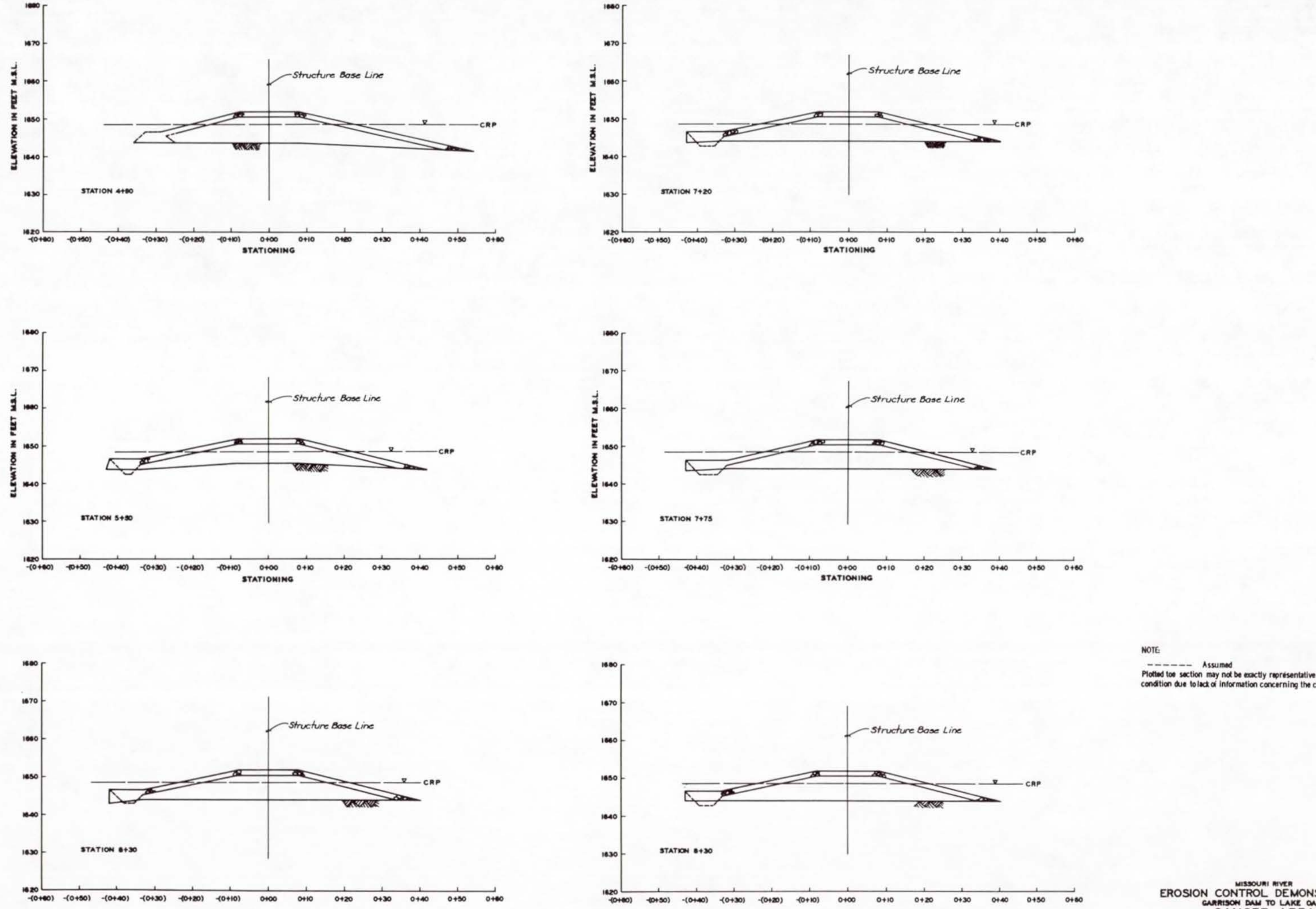
NOTE:

– – – – – – – Assumed

Plotted toe section may not be exactly representative of actual as-built condition due to lack of information concerning the crown width.

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANGER AREA
EARTH CORE DIKE - STRUCTURE NO. 1345.5
CROSS SECTIONS - SHEET 1

E-1-187



NOTE:

------- Assumed

Plotted toe section may not be exactly representative of actual as-built condition due to lack of information concerning the crown width.

MISSOURI RIVER

EROSION CONTROL DEMONSTRATION

GARRISON DAM TO LAKE OAHE

SANGER AREA

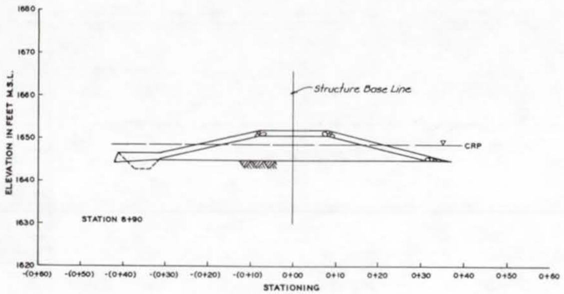
EARTH CORE DIKE - STRUCTURE NO. 1345.5

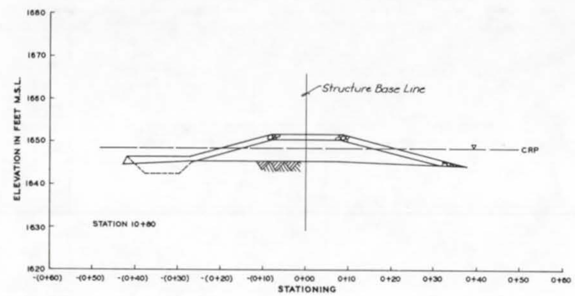
CROSS SECTIONS - SHEET 2

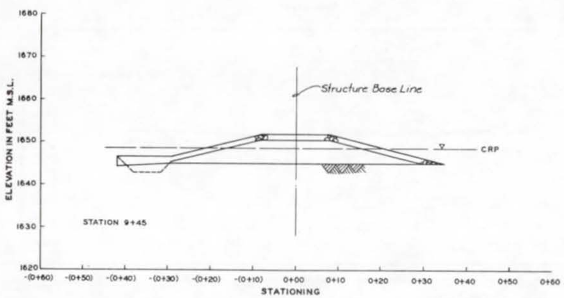
PLATE 7-5

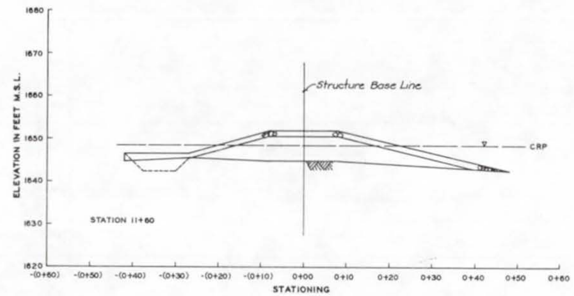
PLATE 7-6

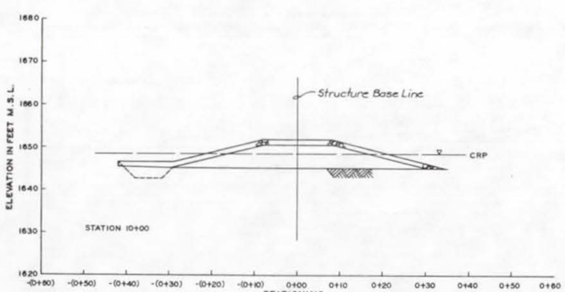
E-1-188

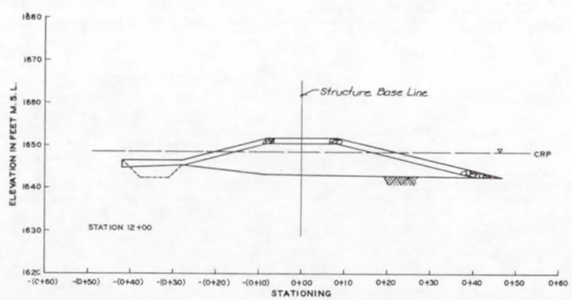










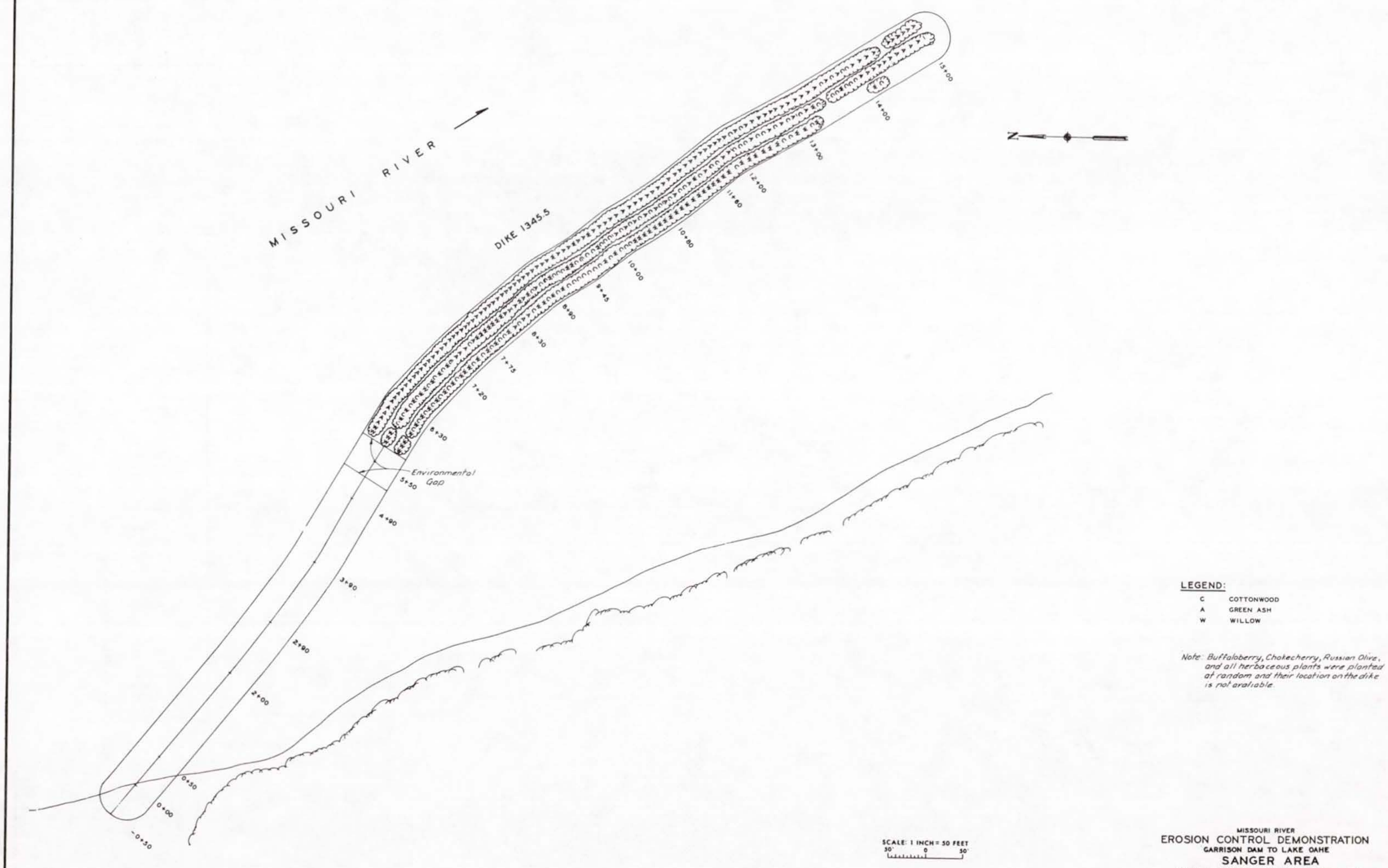


NOTE:

- - - - - - - - Assumed

Plotted toe section may not be exactly representative of actual as-built condition due to lack of information concerning the crown width.

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANGER AREA
EARTH CORE DIKE - STRUCTURE NO. 1345.5
CROSS SECTIONS - SHEET 3



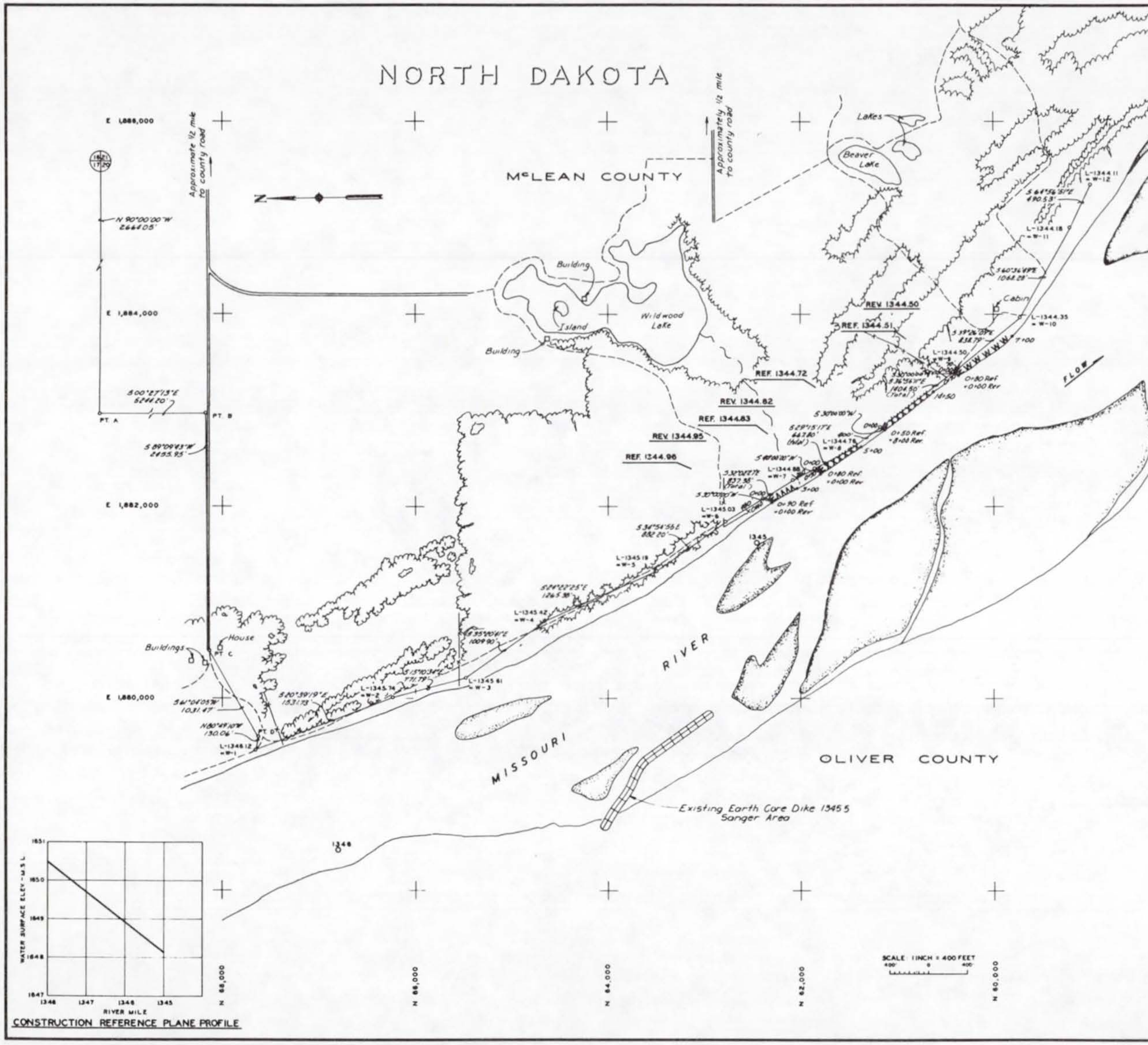
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
SANGER AREA
VEGETATION SITE LAYOUT ON
EARTH CORE DIKE 1345.5

PLATE 7-7

E-1-189

PLATE 8-1

E-1-190



HORIZONTAL & VERTICAL CONTROL						
STATION	MONUMENT	ELEVATION	DISTANCE	BEARING	GRID COORDINATES NORTH	GRID COORDINATES EAST
Sec Cor 16 21 17 20 Range 81 West Township 143 North					73,425.00	1,885,580.00
			2664.05'	N 90° 00' 00" W		
					73,425.00	1,882,915.95
			5244.20'	S 00° 27' 13" E		
PT-B					68,180.96	1,882,957.47
			2455.95'	S 89° 09' 43" W		
PT-C					68,145.04	1,880,501.78
			1031.47'	S 61° 04' 05" W		
PT-D					67,646.04	1,879,599.05
			130.06'	N 80° 49' 10" W		
L-1346.12-W-1	1/2" Rebar Brass Cap	1657.85			67,666.80	1,879,470.65
			1531.73'	S 20° 39' 19" E		
L-1345.74-W-2	1/2" Rebar Brass Cap	1659.38			66,233.53	1,880,010.96
			771.79'	S 15° 10' 34" E		
L-1345.61-W-3	1/2" Rebar Brass Cap	1662.24			65,488.66	1,880,213.00
			1009.90'	S 35° 20' 41" E		
L-1345.42-W-4	1/2" Rebar Brass Cap	1660.18			64,664.89	1,880,797.25
			1265.38'	S 24° 22' 25" E		
L-1345.19-W-5	1/2" Rebar Brass Cap	1655.02			63,512.29	1,881,319.43
			882.20'	S 34° 54' 55" E		
L-1345.03-W-6	1/2" Rebar Brass Cap	1656.54			62,788.89	1,881,824.37
			837.38'	S 32° 02' 27" E		
L-1344.88-W-7	1/2" Rebar Brass Cap	1656.46			62,079.07	1,882,268.62
			667.80'	S 29° 15' 17" E		
L-1344.76-W-8	1/2" Rebar Brass Cap	1658.98			61,496.44	1,882,594.97
			1404.50'	S 36° 56' 11" E		
L-1344.50-W-9	1/2" Rebar Brass Cap	1654.73			60,375.82	1,883,438.97
			838.79'	S 39° 26' 09" E		
L-1344.35-W-10	1/2" Rebar Brass Cap	1653.17			59,725.99	1,883,971.78
			1068.28'	S 60° 36' 49" E		
L-1344.18-W-11	1/2" Rebar Brass Cap	1654.03			59,201.79	1,884,902.63
			490.53'	S 64° 56' 51" E		
L-1344.11-W-12	1/2" Rebar Brass Cap	1653.77			58,994.08	1,885,346.99

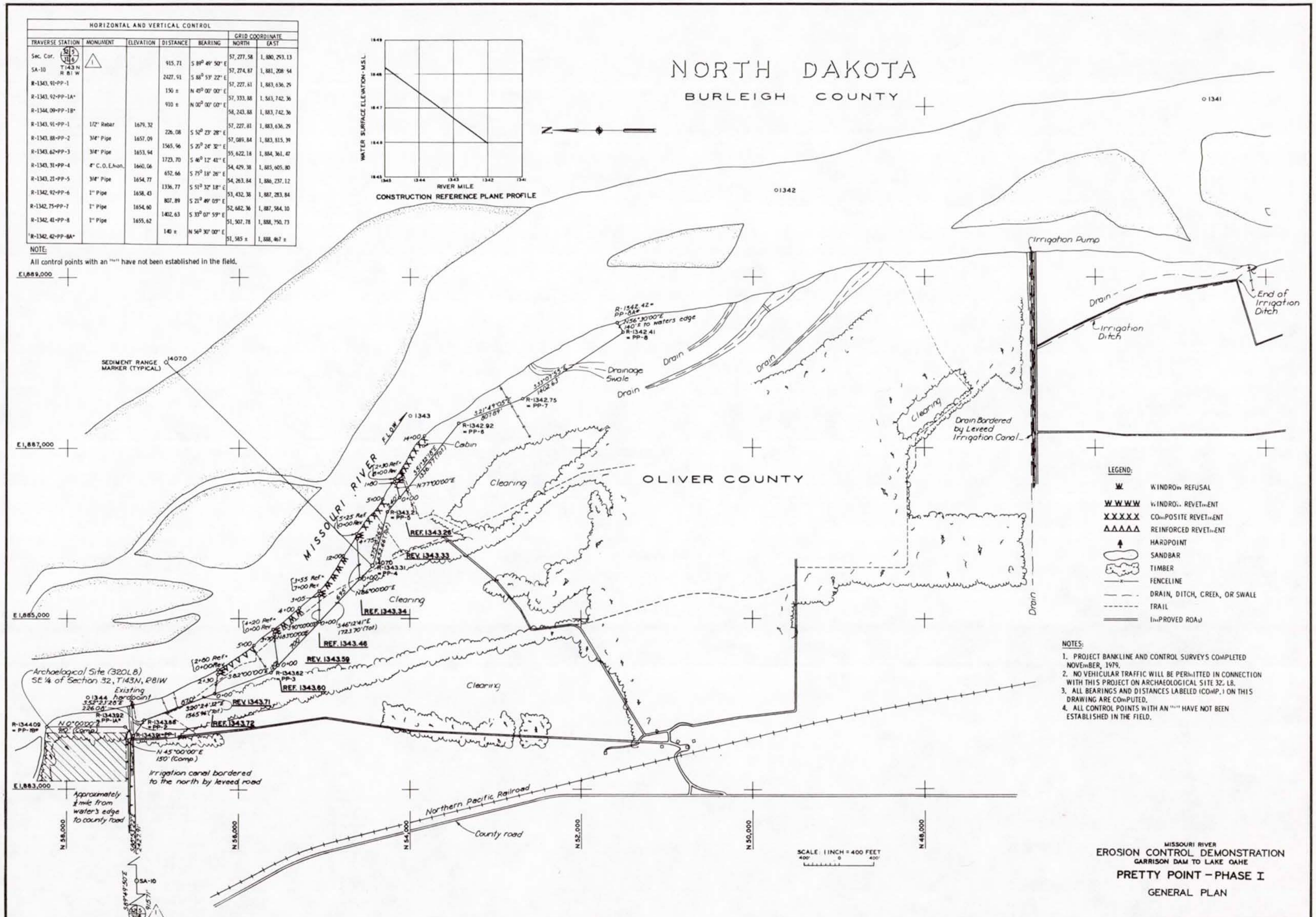
LEGEND:

- WWWWW — Windrow Revetment
- W — Windrow Refusal
- XXXXXXX — Composite Revetment
- AAAAAAA — Reinforced Revetment
- Trail
- Fence Line
- Creek, Drain or Ditch
- Timber
- Sand Bar

NOTES:

1. Project bankli e and control traverse surveys completed March, 1980.
2. Grid coordinates are scaled.

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
WILDWOOD – PHASE I
GENERAL PLAN



HORIZONTAL AND VERTICAL CONTROL

TRAVERSE STATION	MONUMENT	ELEVATION	DISTANCE	BEARING	GRID COORDINATE NORTH	GRID COORDINATE EAST
Sec. Cor. (32/5, 31/6)	△1		915.71	S 89° 49' 50" E	57, 277.58	1, 880, 293.13
SA-10 T143N R81W			2427.91	S 88° 53' 22" E	57, 274.87	1, 881, 208.54
R-1343.91=PP-1			150 ±	N 45° 00' 00" E	57, 227.61	1, 883, 636.29
R-1343.92=PP-1A*			910 ±	N 00° 00' 00" E	57, 333.88	1, 563, 742.36
R-1344.09=PP-1B*					58, 243.88	1, 883, 742.36
R-1343.91=PP-1	1/2" Rebar	1679.32	226.08	S 52° 23' 28" E	57, 227.81	1, 883, 636.29
R-1343.88=PP-2	3/4" Pipe	1657.09	1565.96	S 20° 24' 32" E	57, 089.84	1, 883, 815.39
R-1343.62=PP-3	3/4" Pipe	1653.94	1723.70	S 46° 12' 41" E	55, 622.18	1, 884, 361.47
R-1343.31=PP-4	4" C.O.E.Mon.	1660.06	652.66	S 75° 18' 26" E	54, 429.38	1, 885, 605.80
R-1343.21=PP-5	3/4" Pipe	1654.77	1336.77	S 51° 32' 18" E	54, 263.84	1, 886, 237.12
R-1342.92=PP-6	1" Pipe	1658.43	807.89	S 21° 49' 09" E	53, 432.38	1, 887, 283.84
R-1342.75=PP-7	1" Pipe	1654.60	1402.63	S 33° 07' 59" E	52, 682.36	1, 887, 584.10
R-1342.41=PP-8	1" Pipe	1655.62	140 ±	N 56° 30' 00" E	51, 507.78	1, 888, 750.73
R-1342.42=PP-8A*					51, 585 ±	1, 888, 467 ±

NOTE:
All control points with an "*" have not been established in the field.

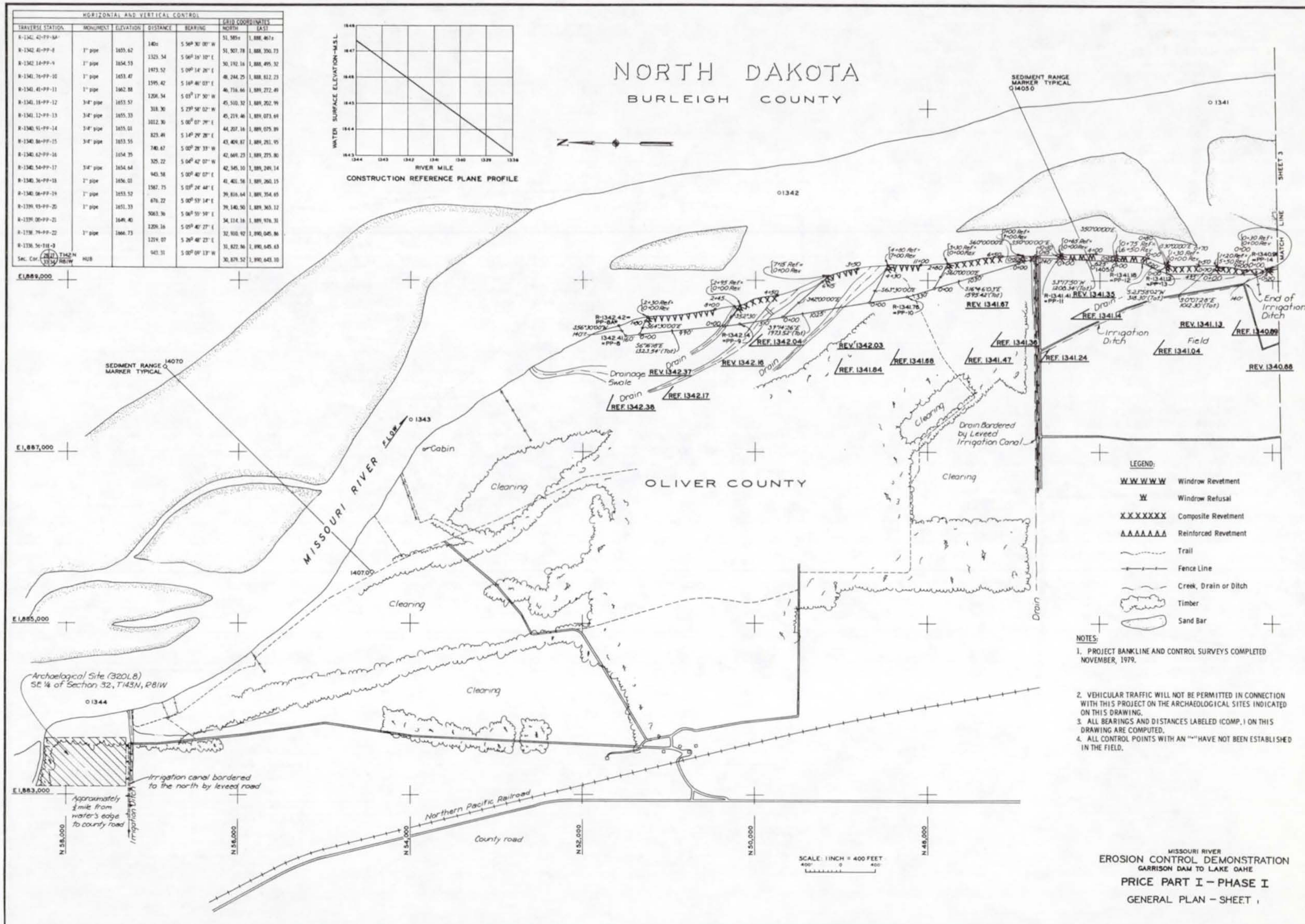
E-1-191

PLATE 9-1

PLATE 10-1

E-1-192

HORIZONTAL AND VERTICAL CONTROL					GRID COORDINATES	
TRAVERSE STATION	MONUMENT	ELEVATION	DISTANCE	BEARING	NORTH	EAST
R-1342.42+PP-8A*					51,585±	1,888,467±
			140±	S 56° 30' 00" W		
R-1342.41+PP-8	1" pipe	1655.62			51,507.78	1,888,350.73
			1325.54	S 06° 16' 10" E		
R-1342.14+PP-9	1" pipe	1654.53			50,192.16	1,888,495.32
			1973.52	S 09° 14' 26" E		
R-1341.76+PP-10	1" pipe	1653.47			48,244.25	1,888,812.23
			1595.42	S 16° 46' 03" E		
R-1341.41+PP-11	1" pipe	1662.88			46,716.66	1,889,272.49
			1208.34	S 03° 17' 50" W		
R-1341.18+PP-12	3/4" pipe	1653.57			45,510.32	1,889,202.99
			318.30	S 23° 58' 02" W		
R-1341.12+PP-13	3/4" pipe	1655.33			45,219.46	1,889,073.69
			1012.30	S 00° 07' 29" E		
R-1340.91+PP-14	3/4" pipe	1655.01			44,207.16	1,889,075.89
			823.49	S 14° 29' 28" E		
R-1340.86+PP-15	3/4" pipe	1653.55			43,409.87	1,889,281.95
			740.67	S 00° 28' 33" W		
R-1340.62+PP-16		1654.35			42,669.23	1,889,275.80
			325.22	S 04° 42' 07" W		
R-1340.54+PP-17	3/4" pipe	1654.64			42,345.10	1,889,249.14
			943.58	S 00° 40' 07" E		
R-1340.36+PP-18	1" pipe	1656.01			41,401.58	1,889,260.15
			1587.75	S 03° 24' 44" E		
R-1340.06+PP-19	1" pipe	1653.52			39,816.64	1,889,354.65
			676.22	S 00° 53' 14" E		
R-1339.93+PP-20	1" pipe	1651.33			39,140.50	1,889,365.12
			5063.36	S 06° 55' 59" E		
R-1339.00+PP-21		1649.40			34,114.16	1,889,976.31
			1209.16	S 05° 40' 27" E		
R-1338.79+PP-22	1" pipe	1666.73			32,910.92	1,890,045.86
			1219.07	S 26° 48' 23" E		
R-1338.56+TIE-3					31,822.96	1,890,645.63
			943.31	S 00° 09' 13" W		
Sec. Cor. 28 27 / 33 34 T142N R81W	HUB				30,879.52	1,890,643.10



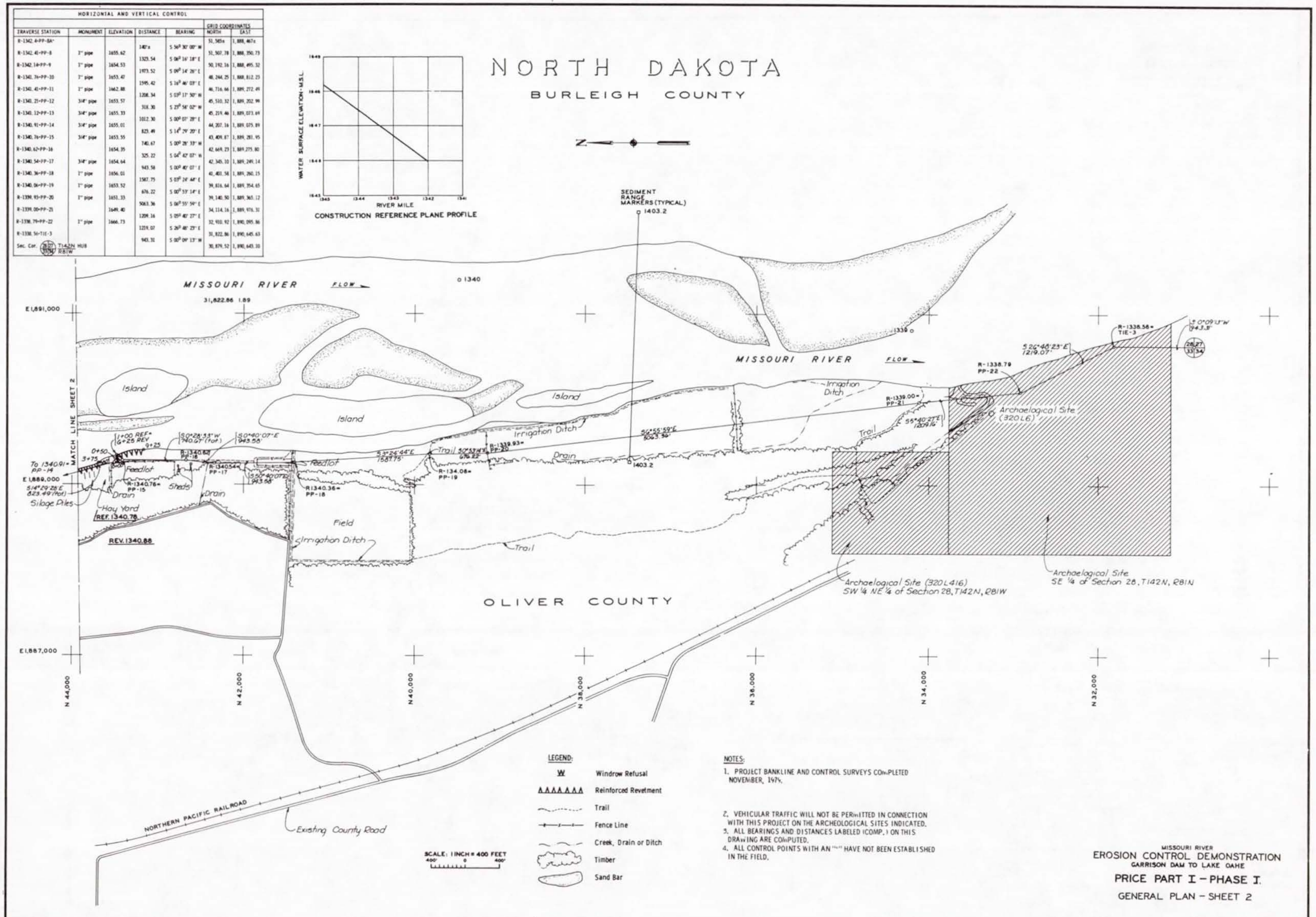
LEGEND:

W W W W W	Windrow Revetment
W	Windrow Refusal
X X X X X X X	Composite Revetment
A A A A A A A	Reinforced Revetment
	Trail
	Fence Line
	Creek, Drain or Ditch
	Timber
	Sand Bar

NOTES:

1. PROJECT BANKLINE AND CONTROL SURVEYS COMPLETED NOVEMBER, 1979.
2. VEHICULAR TRAFFIC WILL NOT BE PERMITTED IN CONNECTION WITH THIS PROJECT ON THE ARCHAEOLOGICAL SITES INDICATED ON THIS DRAWING.
3. ALL BEARINGS AND DISTANCES LABELED (COMP.) ON THIS DRAWING ARE COMPUTED.
4. ALL CONTROL POINTS WITH AN "*" HAVE NOT BEEN ESTABLISHED IN THE FIELD.

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
PRICE PART I – PHASE I
GENERAL PLAN – SHEET 1



HORIZONTAL AND VERTICAL CONTROL						
					GRID COORDINATES	
TRAVERSE STATION	MONUMENT	ELEVATION	DISTANCE	BEARING	NORTH	EAST
R-1342.4-PP-8A*					51,585±	1,888,467±
			140'±	S 56° 30' 00" W		
R-1342.41-PP-8	1" pipe	1655.62			51,507.78	1,888,350.73
			1325.54	S 06° 16' 18" E		
R-1342.14-PP-9	1" pipe	1654.53			50,192.16	1,888,495.32
			1973.52	S 09° 14' 26" E		
R-1341.76-PP-10	1" pipe	1653.47			48,244.25	1,888,812.23
			1595.42	S 16° 46' 03" E		
R-1341.41-PP-11	1" pipe	1662.88			46,716.66	1,889,272.49
			1208.34	S 03° 17' 50" W		
R-1341.21-PP-12	3/4" pipe	1653.57			45,510.32	1,889,202.99
			318.30	S 23° 56' 02" W		
R-1341.12-PP-13	3/4" pipe	1655.33			45,219.46	1,889,073.69
			1012.30	S 00° 07' 28" E		
R-1340.91-PP-14	3/4" pipe	1655.01			44,207.16	1,889,075.89
			823.49	S 14° 29' 20" E		
R-1340.76-PP-15	3/4" pipe	1653.55			43,409.87	1,889,281.95
			740.67	S 00° 28' 33" W		
R-1340.62-PP-16		1654.35			42,669.23	1,889,275.80
			325.22	S 04° 42' 07" W		
R-1340.54-PP-17	3/4" pipe	1654.64			42,345.10	1,889,249.14
			943.58	S 00° 40' 07" E		
R-1340.36-PP-18	1" pipe	1656.01			41,401.58	1,889,260.15
			1587.75	S 03° 24' 44" E		
R-1340.06-PP-19	1" pipe	1653.52			39,816.64	1,889,354.65
			676.22	S 00° 53' 14" E		
R-1339.93-PP-20	1" pipe	1651.33			39,140.50	1,889,365.12
			5063.36	S 06° 55' 59" E		
R-1339.00-PP-21		1649.40			34,114.16	1,889,976.31
			1209.16	S 05° 40' 27" E		
R-1338.79-PP-22	1" pipe	1666.73			32,910.92	1,890,095.86
			1219.07	S 26° 48' 23" E		
R-1338.56-TIE-3					31,822.86	1,890,645.63
			943.31	S 00° 09' 13" W		
Sec. Cor. 28/27 33/34 T142N R81W HUB					30,879.52	1,890,643.30

LEGEND:

- W — Windrow Refusal
- AAAAAAA — Reinforced Revetment
- Trail
- Fence Line
- Creek, Drain or Ditch
- Timber
- Sand Bar

SCALE: 1 INCH = 400 FEET

NOTES:

1. PROJECT BANKLINE AND CONTROL SURVEYS COMPLETED NOVEMBER, 1975.
2. VEHICULAR TRAFFIC WILL NOT BE PERMITTED IN CONNECTION WITH THIS PROJECT ON THE ARCHEOLOGICAL SITES INDICATED.
3. ALL BEARINGS AND DISTANCES LABELED (COMP.) ON THIS DRAWING ARE COMPUTED.
4. ALL CONTROL POINTS WITH AN "*" HAVE NOT BEEN ESTABLISHED IN THE FIELD.

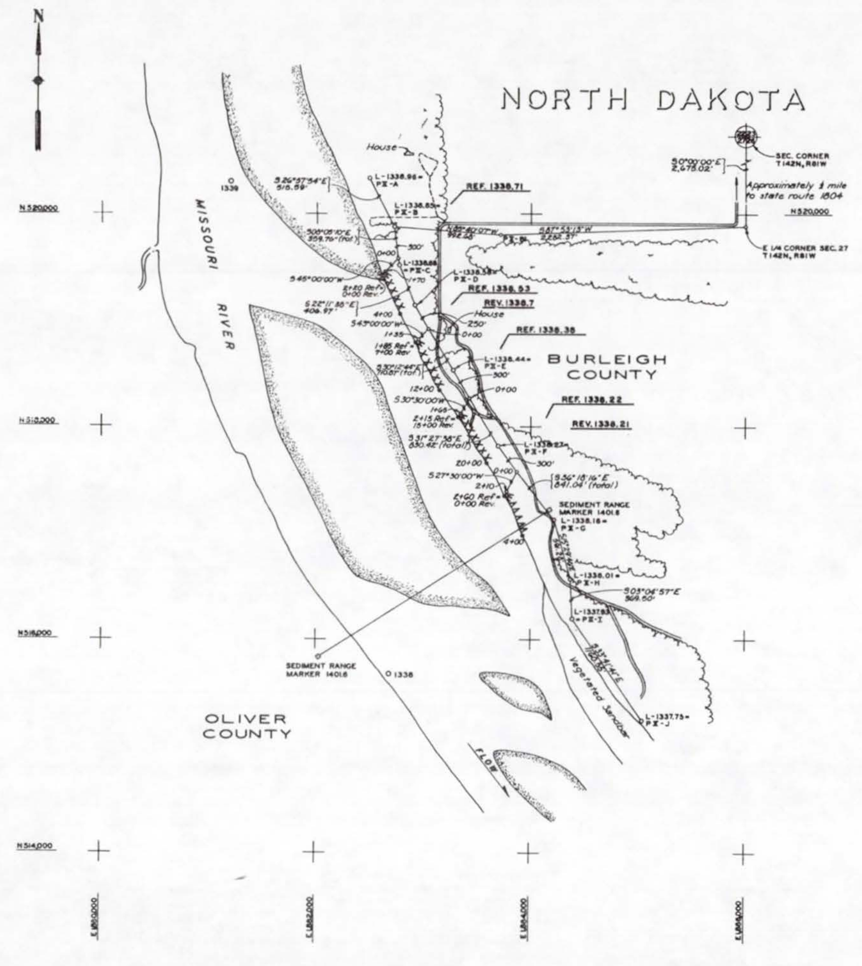
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
PRICE PART I - PHASE I
GENERAL PLAN - SHEET 2

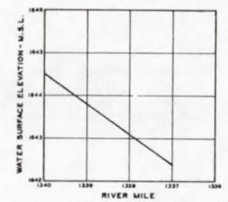
E-1-193

PLATE 10-2

PLATE 11-1

E-1-194





CONSTRUCTION REFERENCE PLANE PROFILE

CONTROL TRAVERSE						
TRAVERSE STA.	MONUMENT	ELEVATION	DISTANCE	BEARING	GRID COORDINATES NORTH	GRID COORDINATES EAST
Sec Cor 22 23 / 27 26			2675.02	S 00° 00' 00" E	522,559.90	1,886,003.02
E 1/4 Cor Sec 27			2282.37	S 87° 53' 13" W	519,884.88	1,886,003.02
PII-B1			992.68	N 85° 40' 07" W	519,800.85	1,883,222.02
L-1338.85=P11-B	Rebar w/brass cap	1659.40	515.59	N 63° 02' 06" W	519,875.40	1,882,729.34
L-1338.96=P11-A	Rebar w/brass cap	1654.47	515.59	S 26° 57' 54" E	520,335.33	1,882,495.54
L-1338.85=P11-B	Rebar w/brass cap	1659.40	359.76	S 08° 05' 10" E	519,875.80	1,882,729.34
L-1338.68=P11-C	Rebar w/brass cap	1655.11	406.97	S 22° 11' 38" E	519,519.61	1,882,779.94
L-1338.58=P11-D	Rebar w/brass cap	1654.92	730.87	S 30° 12' 44" E	519,142.80	1,882,933.67
L-1338.44=P11-E	Rebar w/brass cap	1663.49	830.42	S 31° 27' 38" E	518,528.49	1,883,291.38
L-1338.27=P11-F	Rebar w/brass cap	1658.65	841.04	S 36° 18' 16" E	517,820.14	1,883,724.79
L-1338.16=P11-G	Rebar w/brass cap	1658.13	591.28	S 15° 29' 46" E	517,142.36	1,884,222.75
L-1338.01=P11-H	Rebar w/brass cap	1662.41	369.50	S 03° 04' 57" E	516,572.57	1,884,380.72
L-1337.93=P11-I	Rebar w/brass cap	1662.83	1160.55	S 33° 41' 41" E	516,203.61	1,884,400.59
L-1337.75=P11-J	Rebar w/brass cap	1656.28			515,238.02	1,885,044.43

LEGEND:

- W — Windrow Refusal
- XXXXXXX — Composite Revetment
- ΔΔΔΔΔΔΔ — Reinforced Revetment
- Trail
- Fence Line
- Creek, Drain or Ditch
- Timber
- Sand Bar

NOTES:

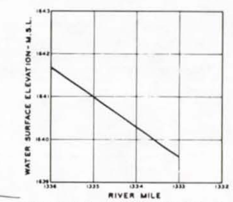
1. Project bankline and control surveys completed April, 1980.

3. Grid coordinates are scaled.

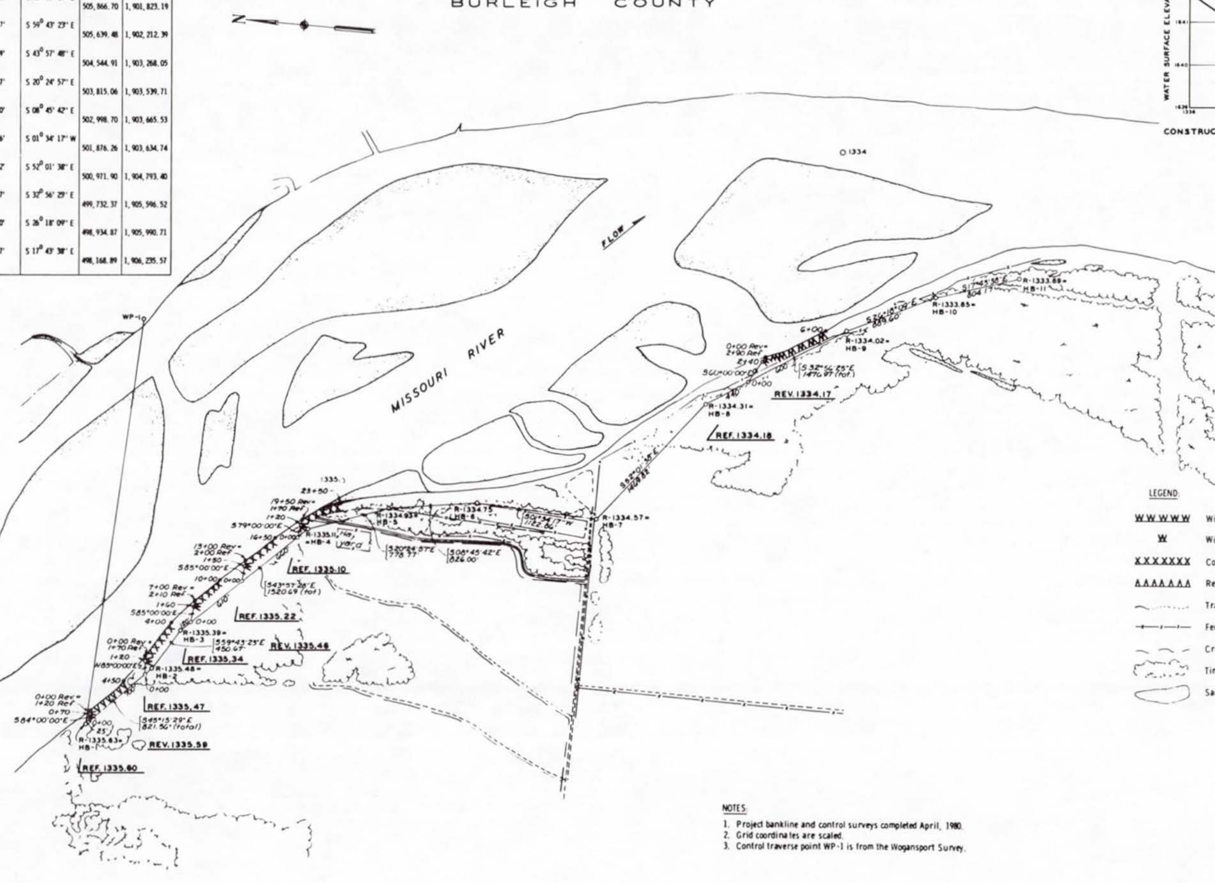
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE

PRICE PART II – PHASE I
GENERAL PLAN

RIGHT-OF-WAY TRAVERSE						
STATION	MONUMENT	ELEVATION	DISTANCE	BEARING	GRID COORDINATES NORTH	GRID COORDINATES EAST
WP-1	1" Pipe				506, 297. 22	1, 905, 069. 80
			3833.00'	N 87° 47' 25" W		
R-1335.63+HB-1	Brass Cap on 5/8" Rebar	1656.5			506, 445.01	1, 901, 239.65
			821.56'	S 45° 15' 29" E		
R-1335.48+HB-2	Brass Cap on 5/8" Rebar	1656.1			505, 866.70	1, 901, 823.19
			450.67'	S 59° 43' 23" E		
R-1335.39+HB-3	Brass Cap on 5/8" Rebar	1655.6			505, 639.48	1, 902, 212.39
			1520.69'	S 43° 57' 48" E		
R-1335.11-HB-4	Brass Cap on 5/8" Rebar	1656.8			504, 544.91	1, 903, 268.05
			778.77'	S 20° 24' 57" E		
R-1334.93+HB-5	Brass Cap on 5/8" Rebar	1655.8			503, 815.06	1, 903, 539.71
			826.00'	S 08° 45' 42" E		
R-1334.75+HB-6	Brass Cap on 5/8" Rebar	1655.9			502, 998.70	1, 903, 665.53
			1122.86'	S 01° 34' 17" W		
R-1334.57+HB-7	Brass Cap on 5/8" Rebar	1653.2			501, 876.26	1, 903, 634.74
			1469.82'	S 52° 01' 38" E		
R-1334.31+HB-8	Brass Cap on 5/8" Rebar	1654.0			500, 971.90	1, 904, 793.40
			1476.97'	S 32° 56' 29" E		
R-1334.02+HB-9	Brass Cap on 5/8" Rebar	1654.0			499, 732.37	1, 905, 596.52
			889.60'	S 26° 18' 09" E		
R-1333.85+HB-10	Brass Cap on 5/8" Rebar	1656.7			498, 934.87	1, 905, 990.71
			804.17'	S 17° 43' 38" E		
R-1333.69+HB-11	Brass Cap on 5/8" Rebar	1651.7			498, 168.89	1, 906, 235.57



CONSTRUCTION REFERENCE PLANE PROFILE



LEGEND:

WWWWW	Windrow Revetment
W	Windrow Refusal
XXXXXXX	Composite Revetment
AAAAAAA	Reinforced Revetment
	Trail
	Fence Line
	Creek, Drain or Ditch
	Timber
	Sand Bar

NOTES:

1. Project bankline and control surveys completed April, 1980.
2. Grid coordinates are scaled.
3. Control traverse point WP-1 is from the Wogansport Survey.

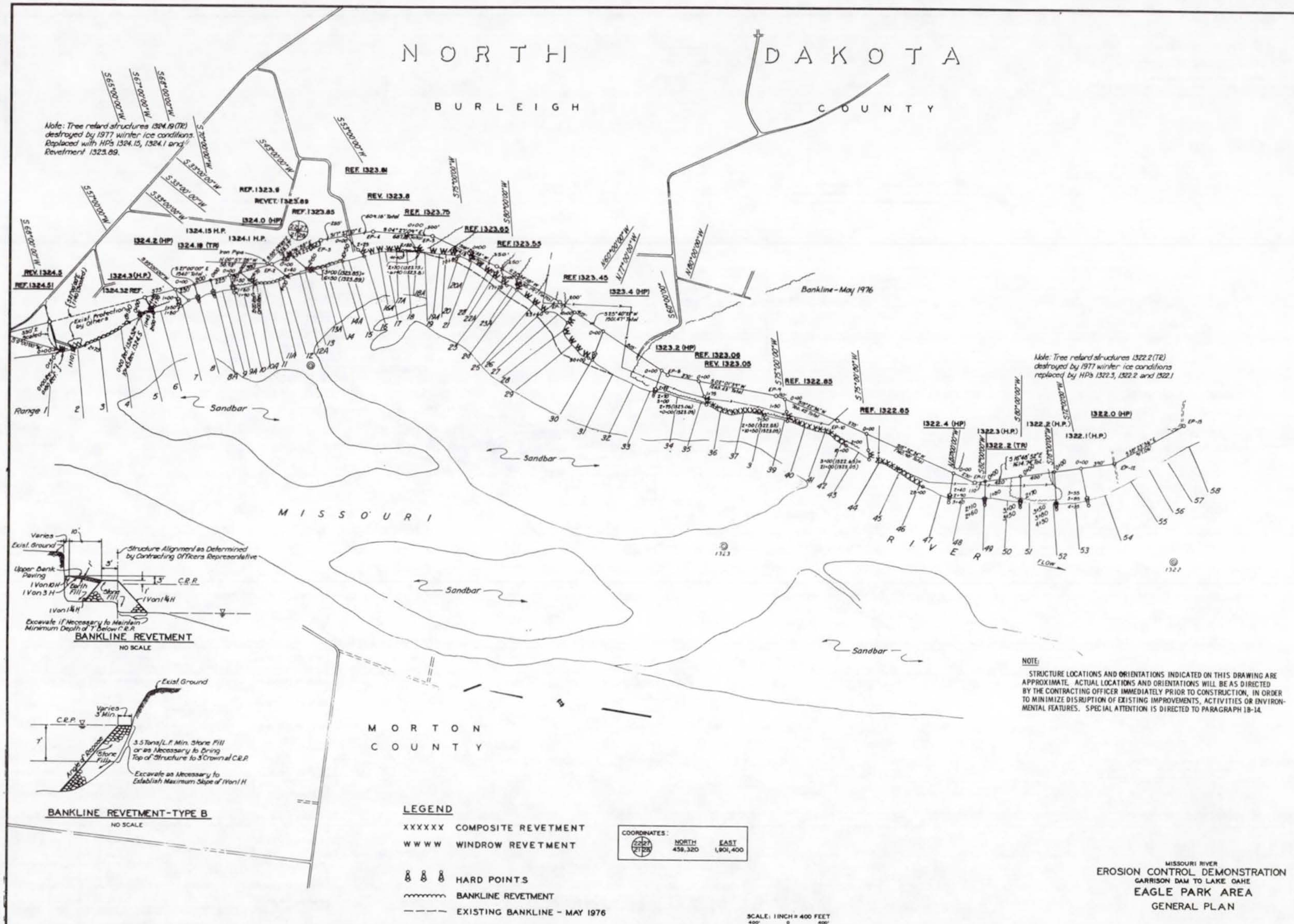
SCALE 1 INCH = 400 FEET

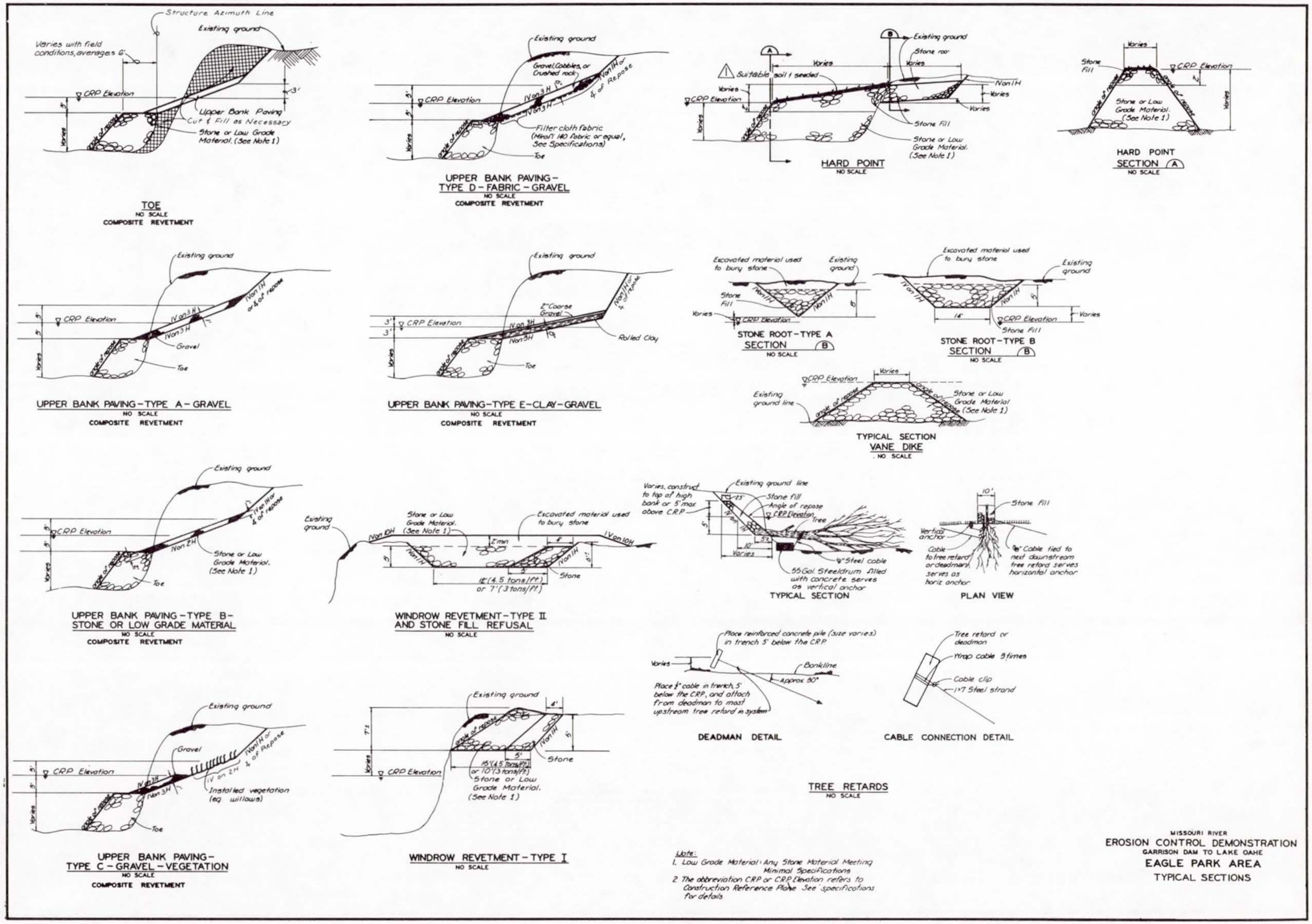
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
HORSESHOE BUTTE-PHASE I
GENERAL PLAN

E-1-195

PLATE 12-1

PLATE 13-1

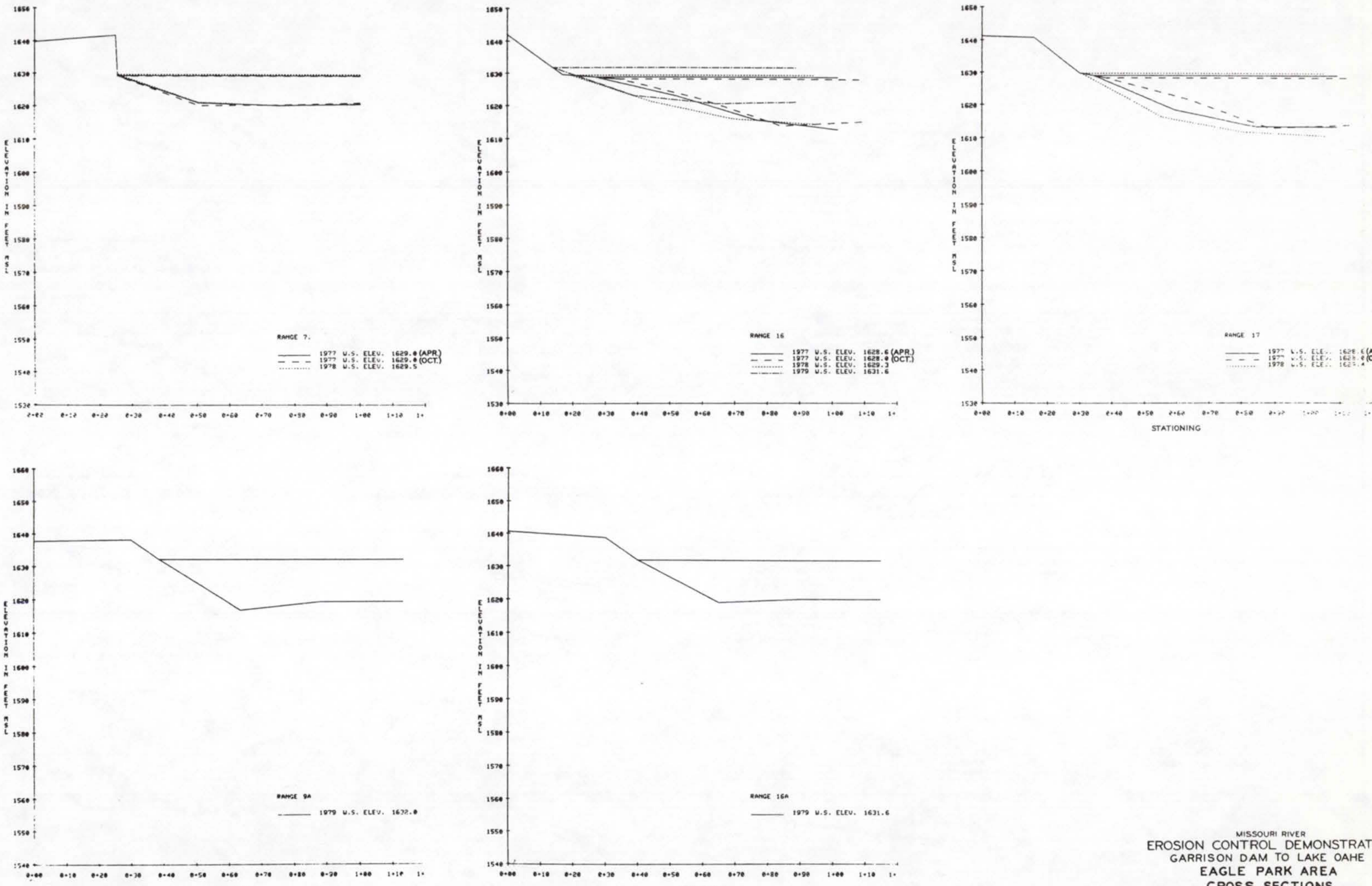

NORTH DAKOTA
BURLEIGH COUNTY
MORTON COUNTY
MISSOURI RIVER
Sandbar
Bankline - May 1976
Note: Tree retard structures 1324.19 (TR) destroyed by 1977 winter ice conditions. Replaced with HPs 1324.15, 1324.1 and Revetment 1323.89.
Note: Tree retard structures 1322.2 (TR) destroyed by 1977 winter ice conditions replaced by HPs 1322.3, 1322.2 and 1322.1
BANKLINE REVETMENT
NO SCALE
BANKLINE REVETMENT-TYPE B
NO SCALE
LEGEND
XXXXXX COMPOSITE REVETMENT
WWWW WINDROW REVETMENT
HARD POINTS
BANKLINE REVETMENT
EXISTING BANKLINE - MAY 1976
COORDINATES:
NORTH 458,320
EAST 1,901,400
SCALE: 1 INCH = 400 FEET
NOTE:
STRUCTURE LOCATIONS AND ORIENTATIONS INDICATED ON THIS DRAWING ARE APPROXIMATE. ACTUAL LOCATIONS AND ORIENTATIONS WILL BE AS DIRECTED BY THE CONTRACTING OFFICER IMMEDIATELY PRIOR TO CONSTRUCTION, IN ORDER TO MINIMIZE DISRUPTION OF EXISTING IMPROVEMENTS, ACTIVITIES OR ENVIRONMENTAL FEATURES. SPECIAL ATTENTION IS DIRECTED TO PARAGRAPH 18-14.
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
EAGLE PARK AREA
GENERAL PLAN



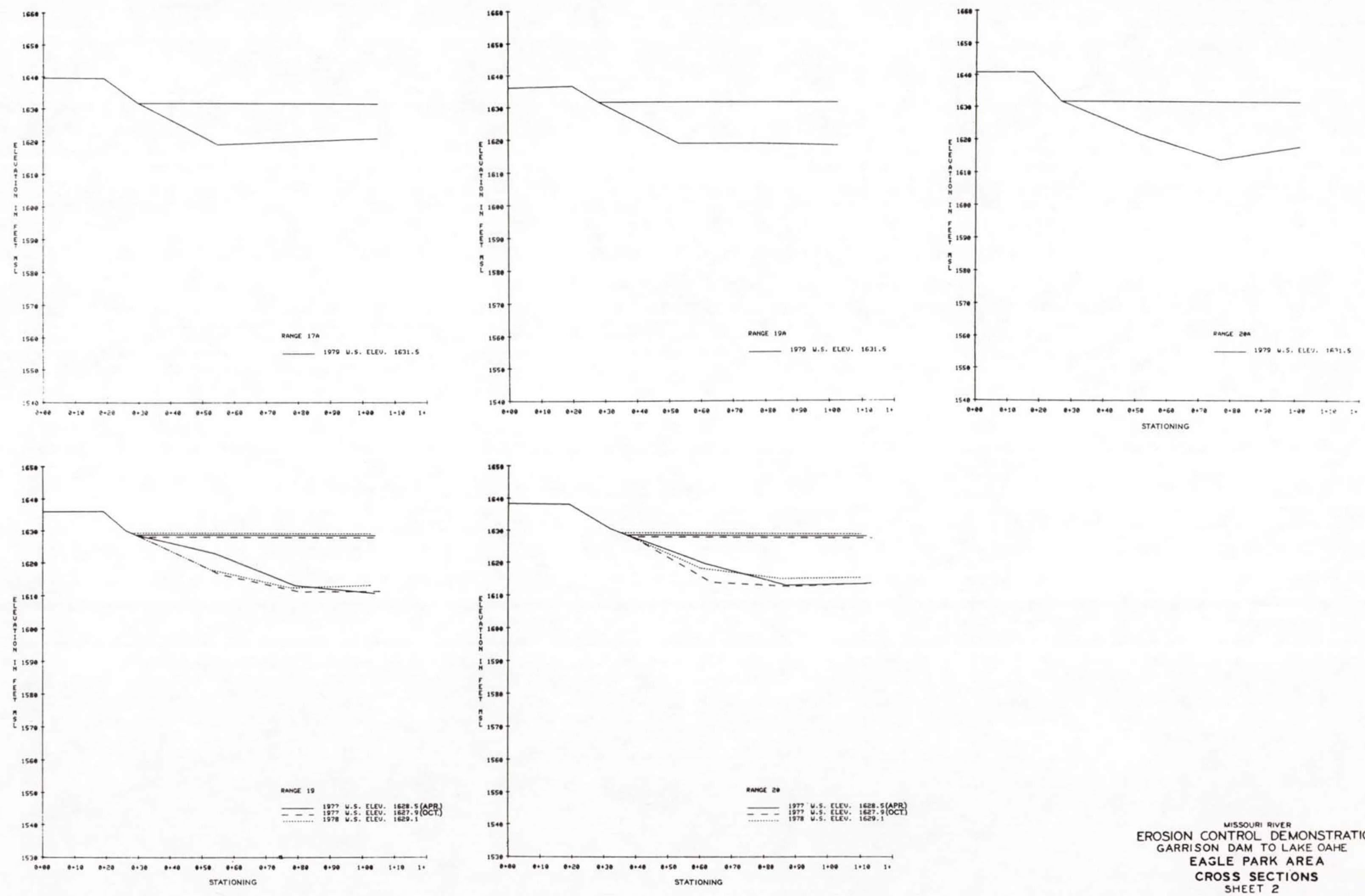
E-1-197

PLATE 13-2

PLATE 13-3



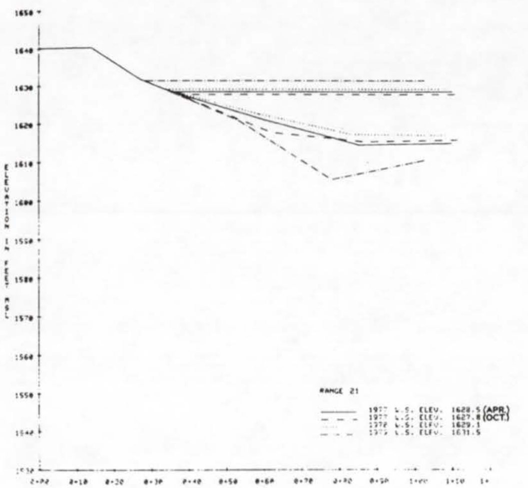
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
EAGLE PARK AREA
CROSS SECTIONS
SHEET 1

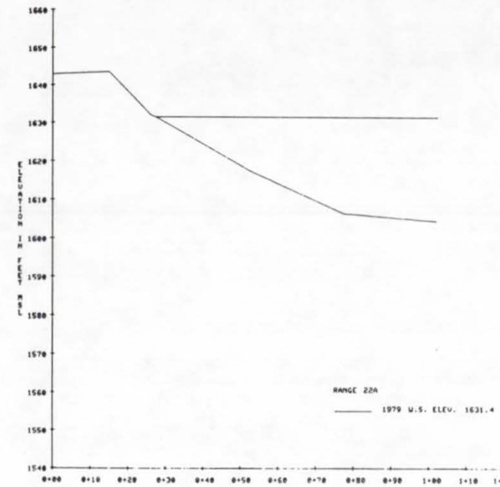


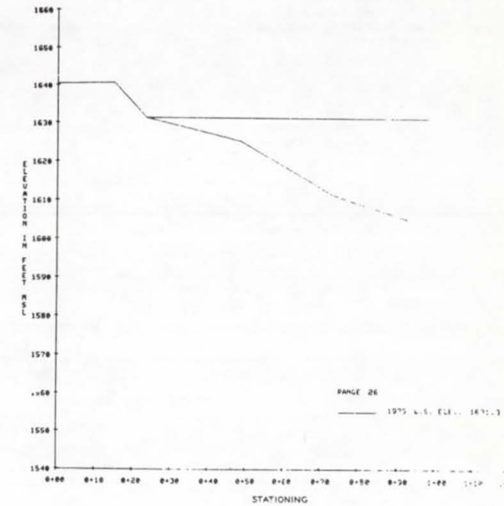
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
EAGLE PARK AREA
CROSS SECTIONS
SHEET 2

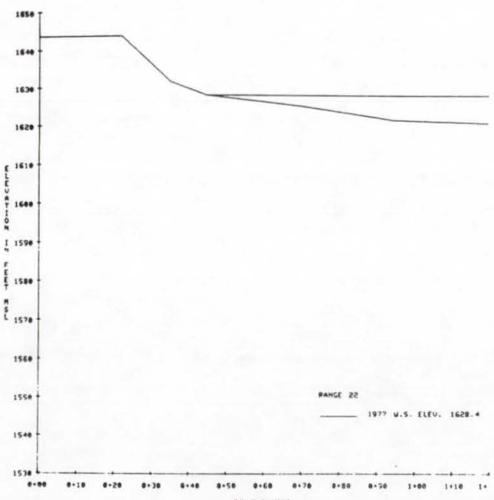
PLATE 13-4

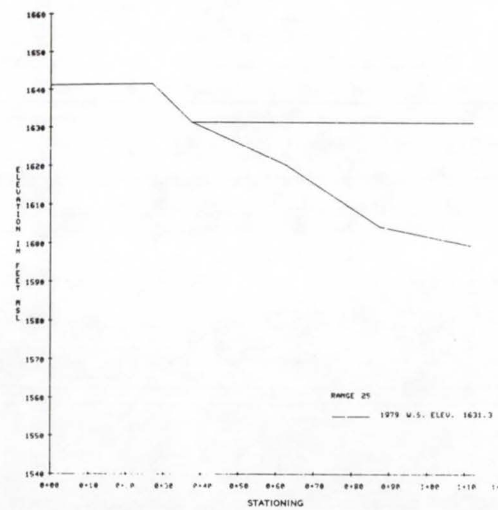
PLATE 13-5



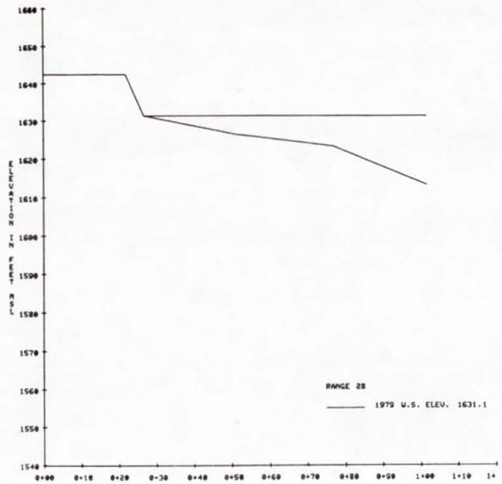


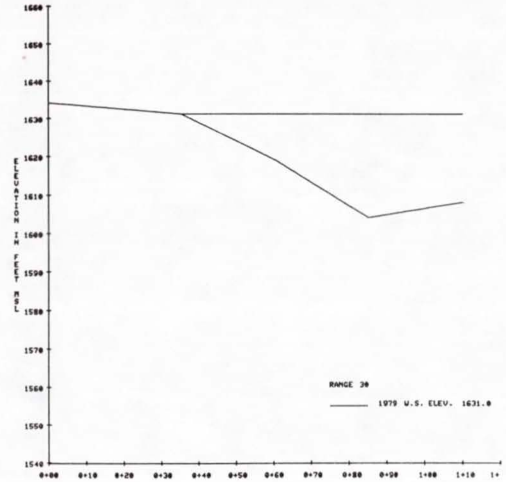


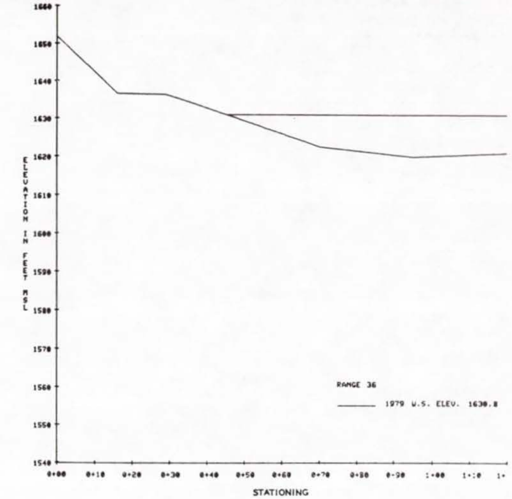


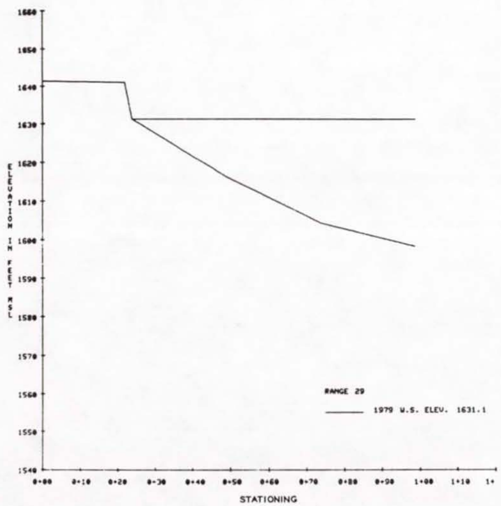


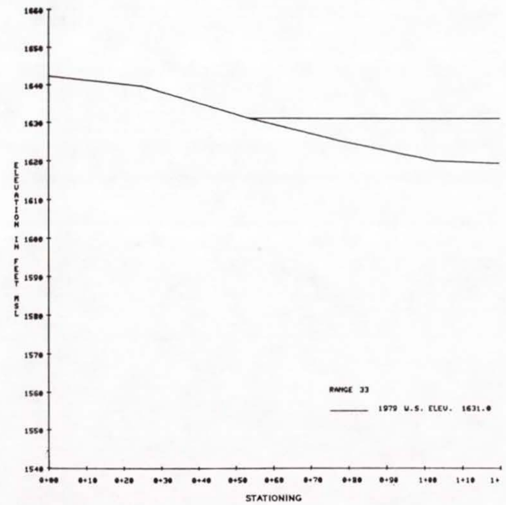
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
EAGLE PARK AREA
CROSS SECTIONS
SHEET 3





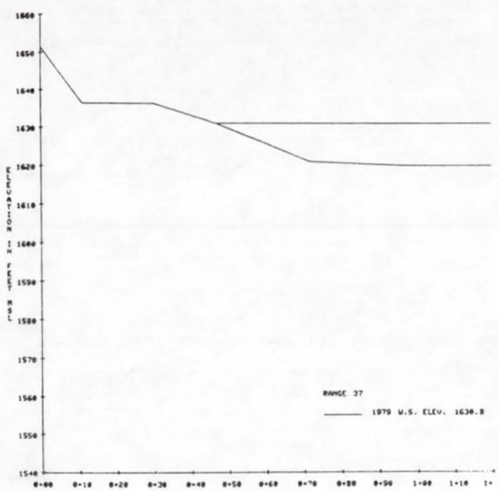


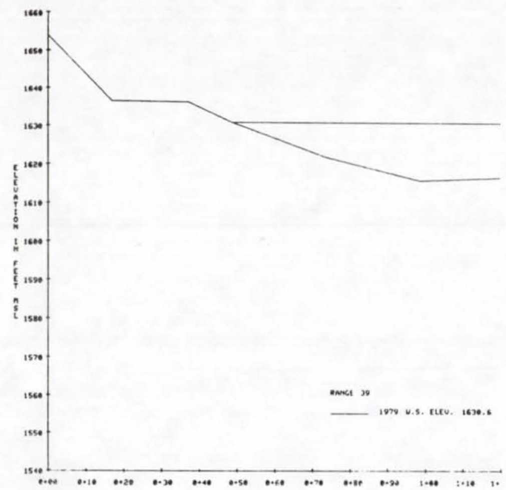


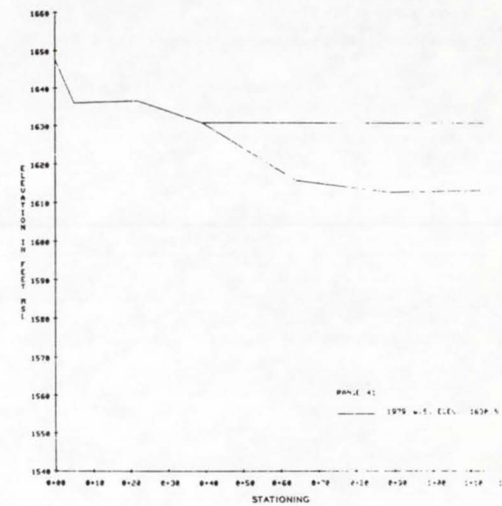


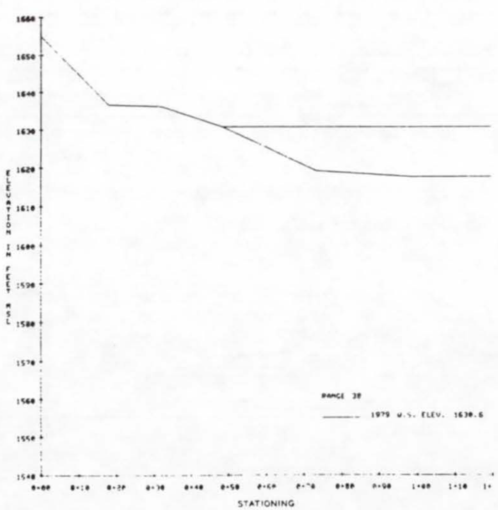
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
EAGLE PARK AREA
CROSS SECTIONS
SHEET 4

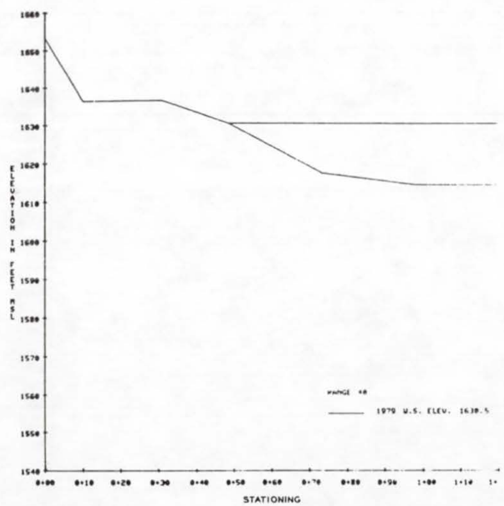
PLATE 13-7



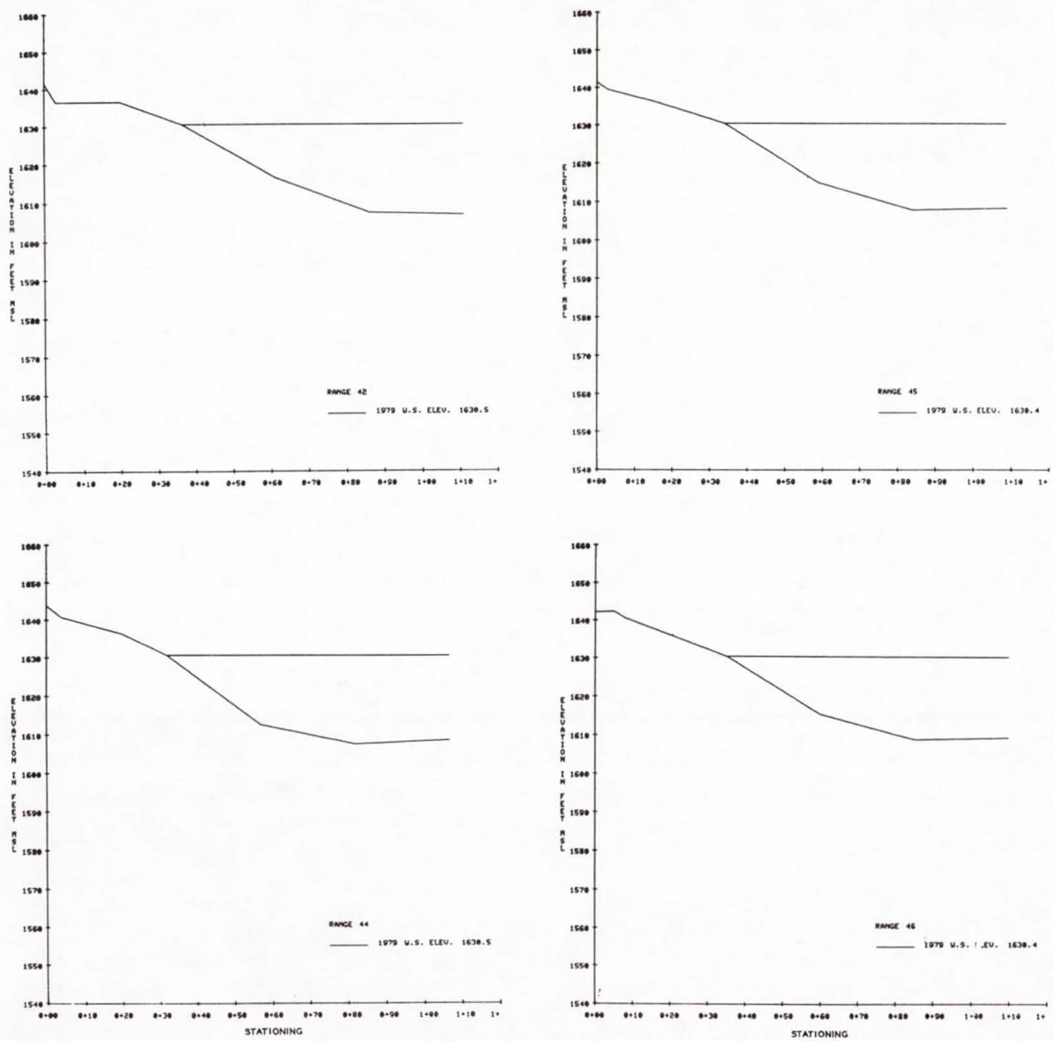








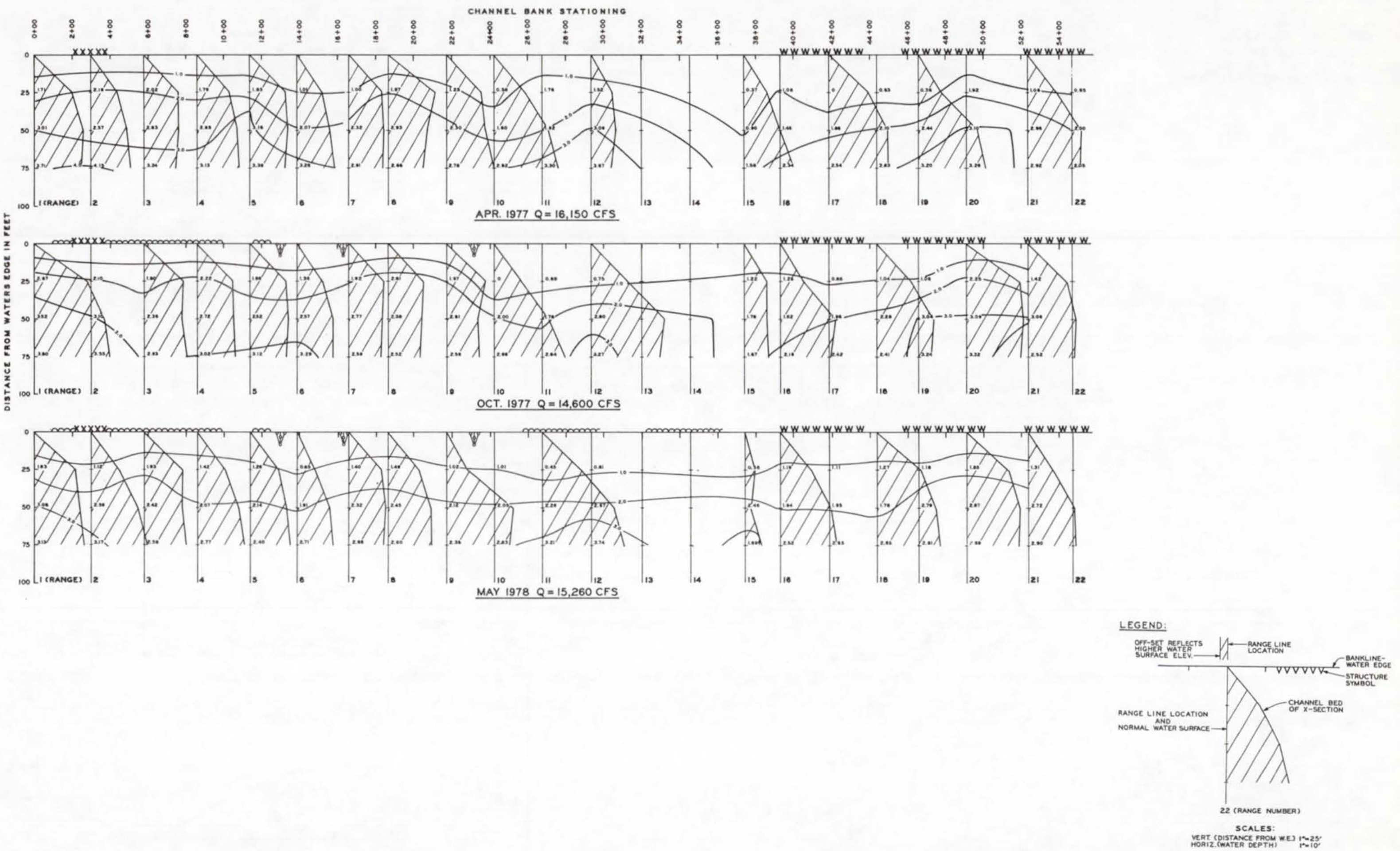
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
EAGLE PARK AREA
CROSS SECTIONS
SHEET 5



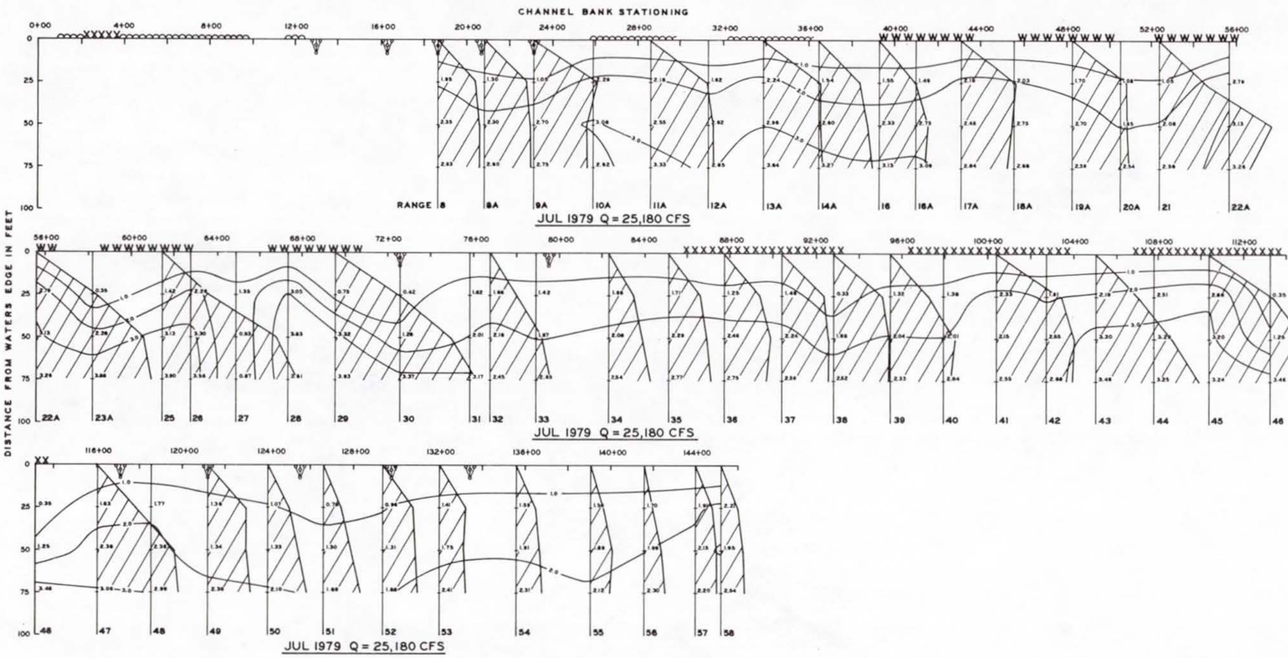
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
EAGLE PARK AREA
CROSS SECTIONS
SHEET 6

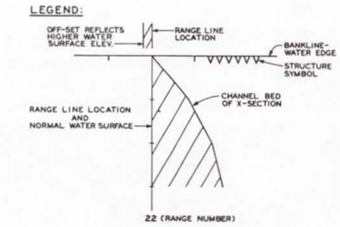
PLATE 13-8

PLATE 13-9



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
EAGLE PARK AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 1



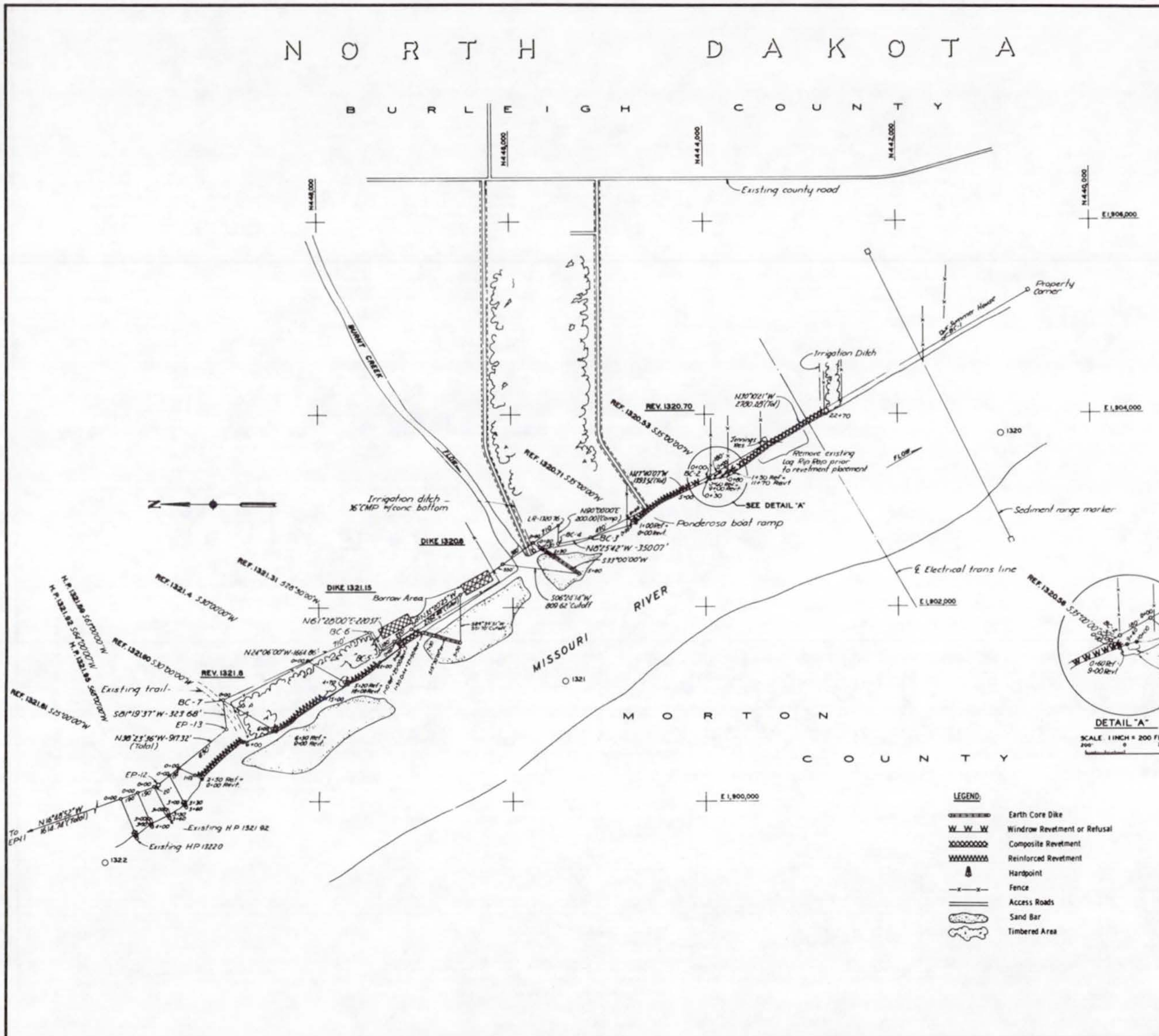


SCALES:
VERT. (DISTANCE FROM W.E.) 1"=25'
HORIZ. (WATER DEPTH) 1"=10'

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
EAGLE PARK AREA
COMPARATIVE AVERAGE VELOCITY PROFILES
SHEET 2

PLATE 13-10

PLATE 14-1

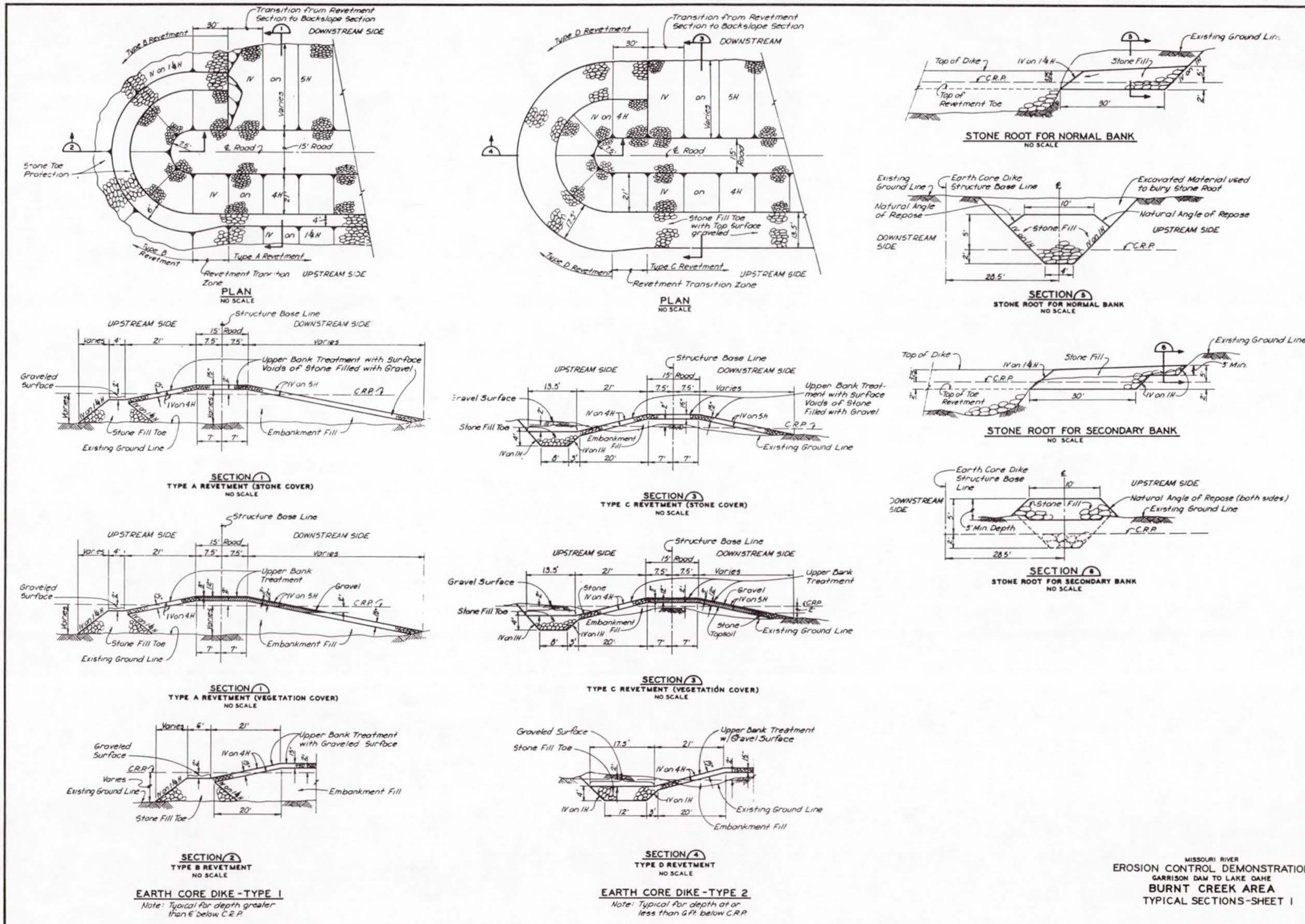


HORIZONTAL CONTROL

Traverse Station	Monument	Elevation	Distance	Bearing	North	East
		LAMBERT GRID			NORTH DAKOTA Grid Coordinates	
BC-1	1" Pipe	1638.44	2,780.28	N 30° 10' 21" W	441,529.71	1,904,753.59
BC-2	3/4" Pipe	1640.35	1,393.52	N 27° 40' 07" W	443,933.31	1,903,356.21
BC-3	1" Pipe	1639.75 *	350.07	N 58° 25' 42" W	445,167.48	1,902,709.12
BC-4	1" Pipe	1644.16	200.00	N 90° 00' 00" E	445,513.77	1,902,657.93
LR-1320.70			2,262.48	N 35° 20' 25" W	445,513.77	1,902,857.81
BC-5	1" Pipe	1637.92	220.57	N 61° 28' 00" E	447,359.35	1,901,549.12
BC-6	1" Pipe	1636.58	1,664.86	N 24° 06' 00" W	447,464.71	1,901,742.95
BC-7			323.68	S 81° 19' 37" W	448,984.65	1,901,063.52
EP-13		1639.75	917.32	N 38° 23' 36" W	448,935.64	1,900,743.54
EP-12			1,614.74	N 16° 48' 52" W	449,654.91	1,900,173.93
EP-11						

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GAVINS POINT DAM TO PONCA, NEBRASKA
BURNT CREEK AREA
GENERAL PLAN

E-1-206



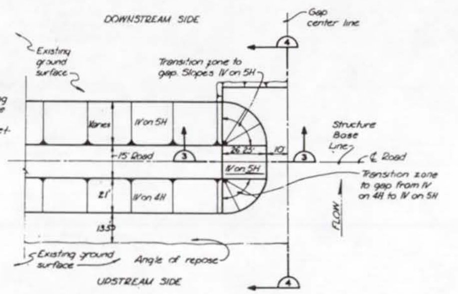
E-1-207

PLATE 14-2

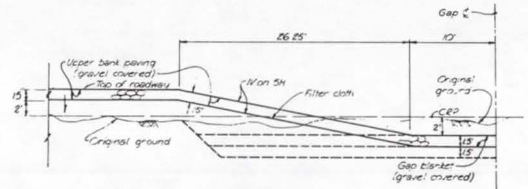
PLATE 14-3

E-1-208

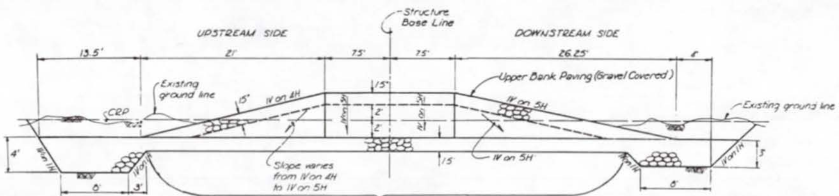
Note:
1. All environmental gap paving and transition areas to receive filter cloth.
2. Environmental gap symmetrical about ℄.



PLAN
NO SCALE



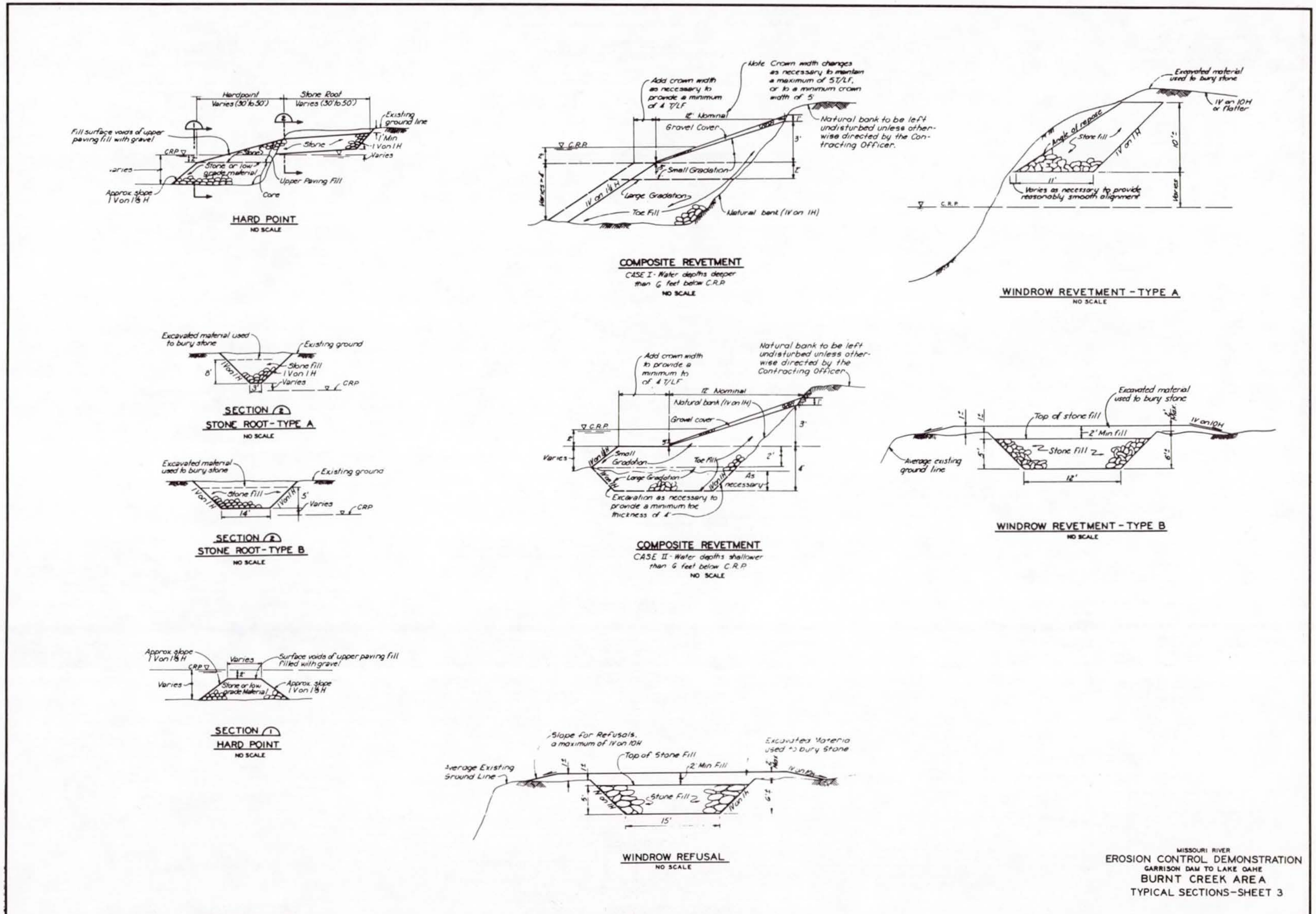
SECTION 3
NO SCALE



SECTION 4
NO SCALE

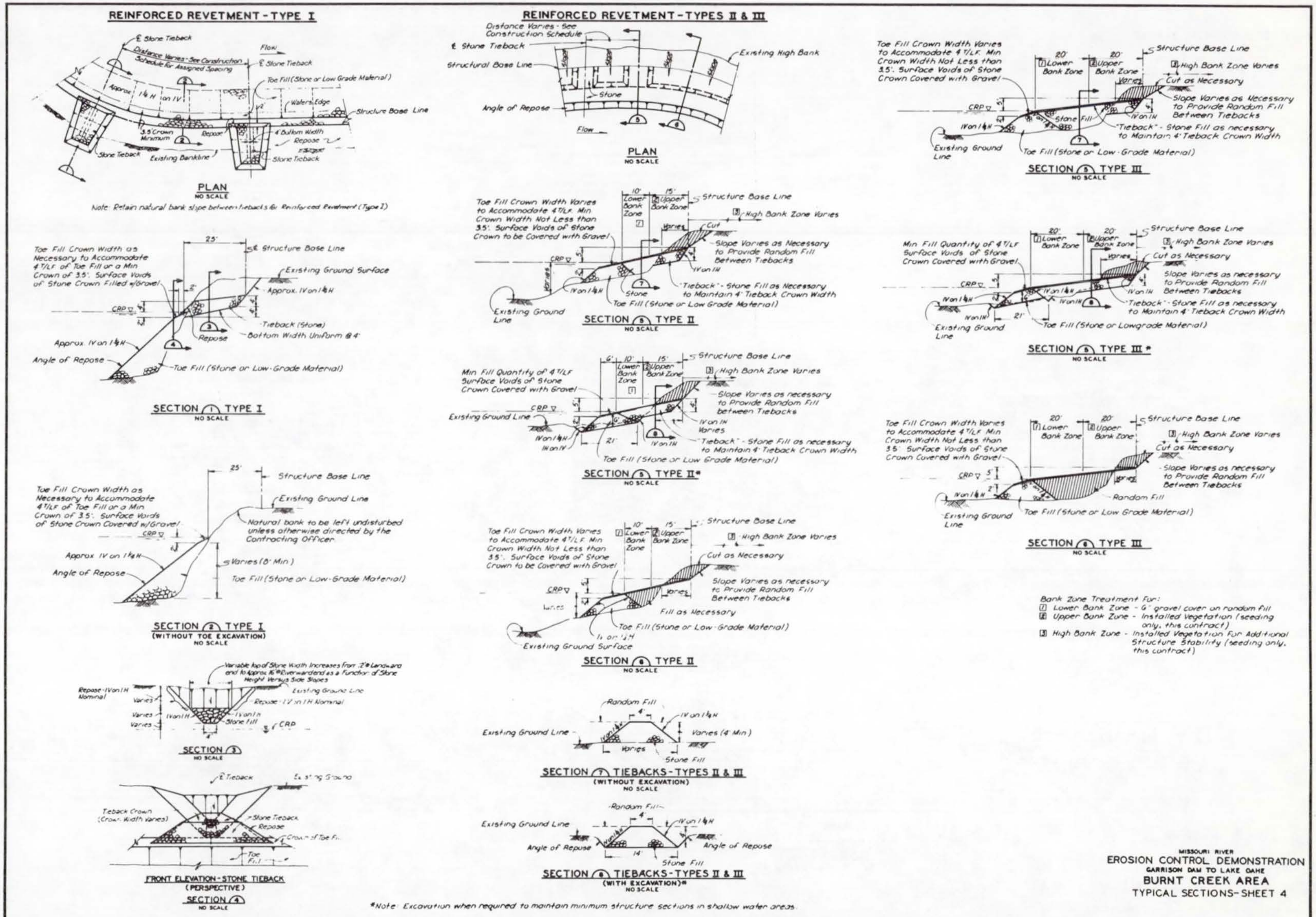
EARTH CORE DIKE
ENVIRONMENTAL GAP

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
BURNT CREEK AREA
TYPICAL SECTIONS-SHEET 2



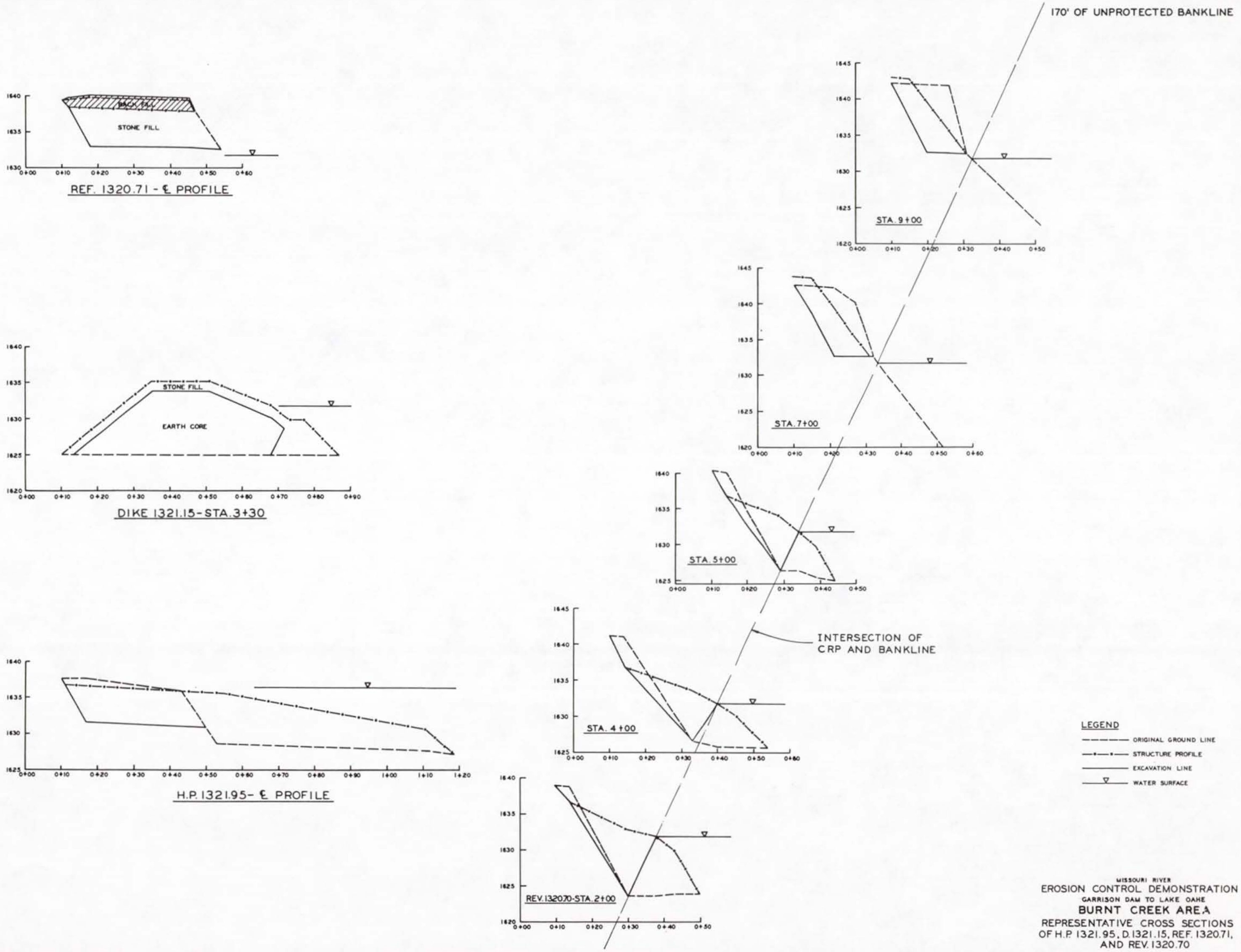
Hardpoint Varies (30' to 50')
Stone Root Varies (30' to 50')
Existing ground line
Fill surface voids of upper paving fill with gravel
CRP
Stone
Stone or low-grade material
Upper Paving Fill
Core
1' Min
1 V on 1 H
Varies
Approx. slope 1 V on 1½ H
HARD POINT
NO SCALE
Note Crown width changes as necessary to maintain a maximum of 5T/LF, or to a minimum crown width of 5'
Add crown width as necessary to provide a minimum of 4 T/LF
12' Nominal
Gravel Cover
Natural bank to be left undisturbed unless otherwise directed by the Contracting Officer.
C.R.P.
Small Gradation
Large Gradation
Toe Fill
Natural bank (1V on 1H)
1V on 1½ H
COMPOSITE REVETMENT
CASE I - Water depths deeper than 6 feet below C.R.P.
NO SCALE
Excavated material used to bury stone
1V on 10H or flatter
Angle of repose
Stone fill
1V on 1H
Varies as necessary to provide reasonably smooth alignment
C.R.P.
WINDROW REVETMENT - TYPE A
NO SCALE
Excavated material used to bury stone
Existing ground
Stone fill
1 V on 1 H
Varies
CRP
SECTION 2
STONE ROOT - TYPE A
NO SCALE
Excavated material used to bury stone
Existing ground
Stone fill
1 V on 1 H
Varies
CRP
SECTION 2
STONE ROOT - TYPE B
NO SCALE
Add crown width to provide a minimum to of 4 T/LF
Natural bank to be left undisturbed unless otherwise directed by the Contracting Officer.
12' Nominal
Natural bank (1V on 1H)
Gravel cover
C.R.P.
Varies
Small Gradation
Toe Fill
Large Gradation
As necessary
Excavation as necessary to provide a minimum toe thickness of 4'
COMPOSITE REVETMENT
CASE II - Water depths shallower than 6 feet below C.R.P.
NO SCALE
Excavated material used to bury stone
Top of stone fill
2' Min Fill
Stone Fill
1V on 10H
Average existing ground line
WINDROW REVETMENT - TYPE B
NO SCALE
Approx. slope 1 V on 1½ H
CRP
Varies
Surface voids of upper paving fill filled with gravel
Stone or low grade Material
Approx. slope 1 V on 1½ H
SECTION 1
HARD POINT
NO SCALE
Slope for Refusals, a maximum of 1V on 10H
Average Existing Ground Line
Top of Stone Fill
2' Min Fill
Excavated Material used to bury Stone
Stone Fill
1V on 1H
WINDROW REFUSAL
NO SCALE
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
BURNT CREEK AREA
TYPICAL SECTIONS-SHEET 3

PLATE 14-5



E-1-210

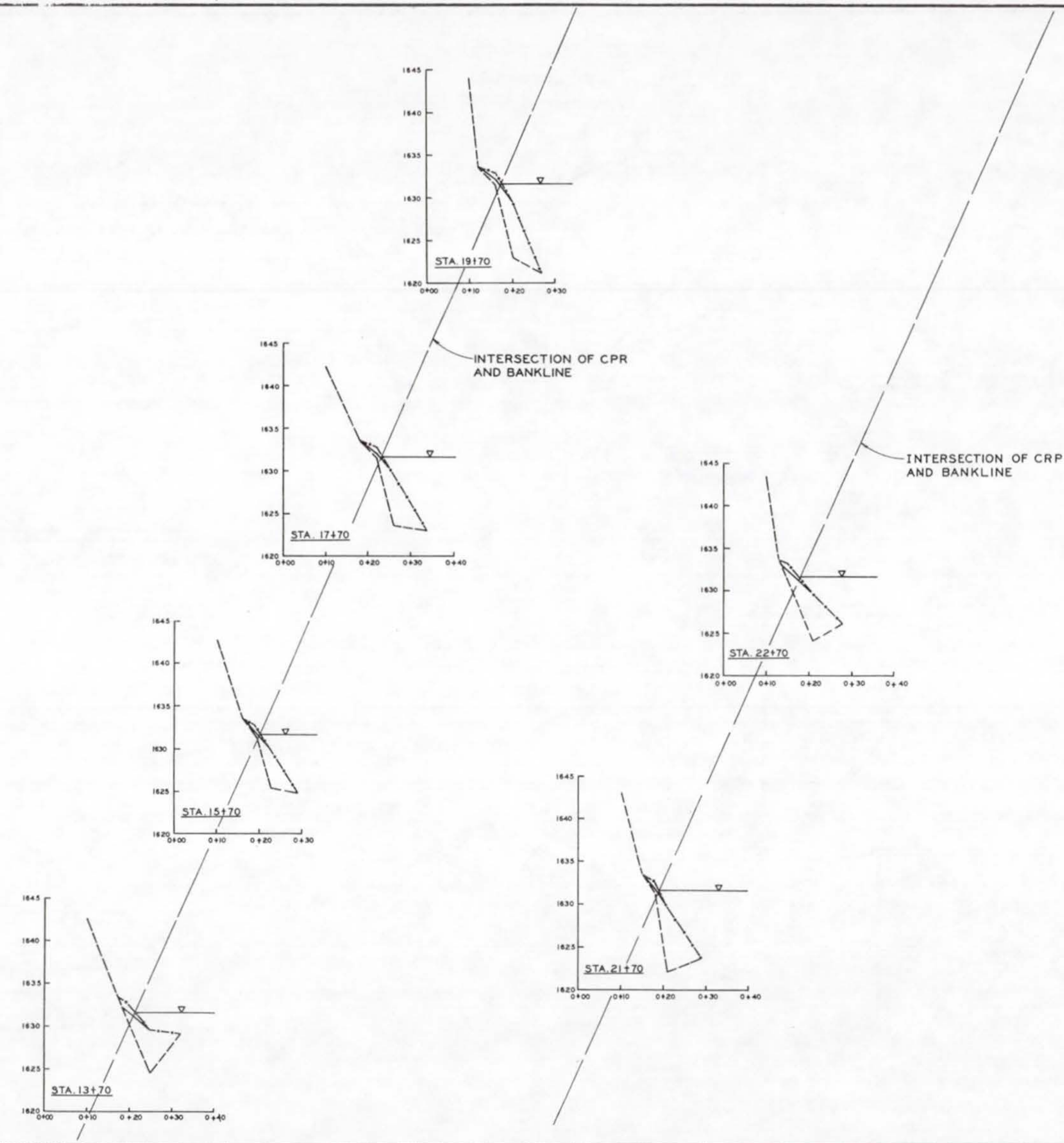
E-1-211



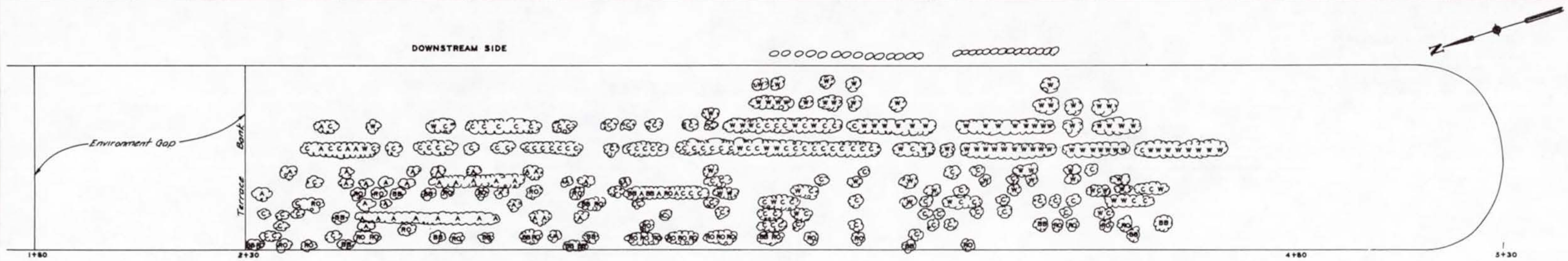
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
BURNT CREEK AREA
REPRESENTATIVE CROSS SECTIONS
OF H.P. 1321.95, D.1321.15, REF. 1320.71,
AND REV. 1320.70

PLATE 14-6

PLATE 14-7

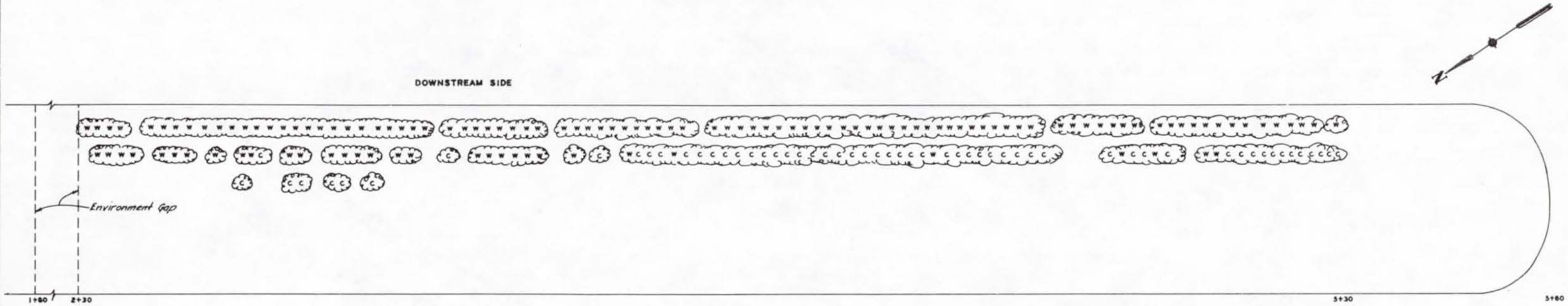


MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
BURNT CREEK AREA
REPRESENTATIVE CROSS-SECTIONS
FOR REVETMENT 1320.71



DIKE 1321.15

SCALE: 1 INCH = 10 FEET
10' 0 10'



DIKE 1320.80

SCALE: 1 INCH = 10 FEET
10' 0 10'

LEGEND:

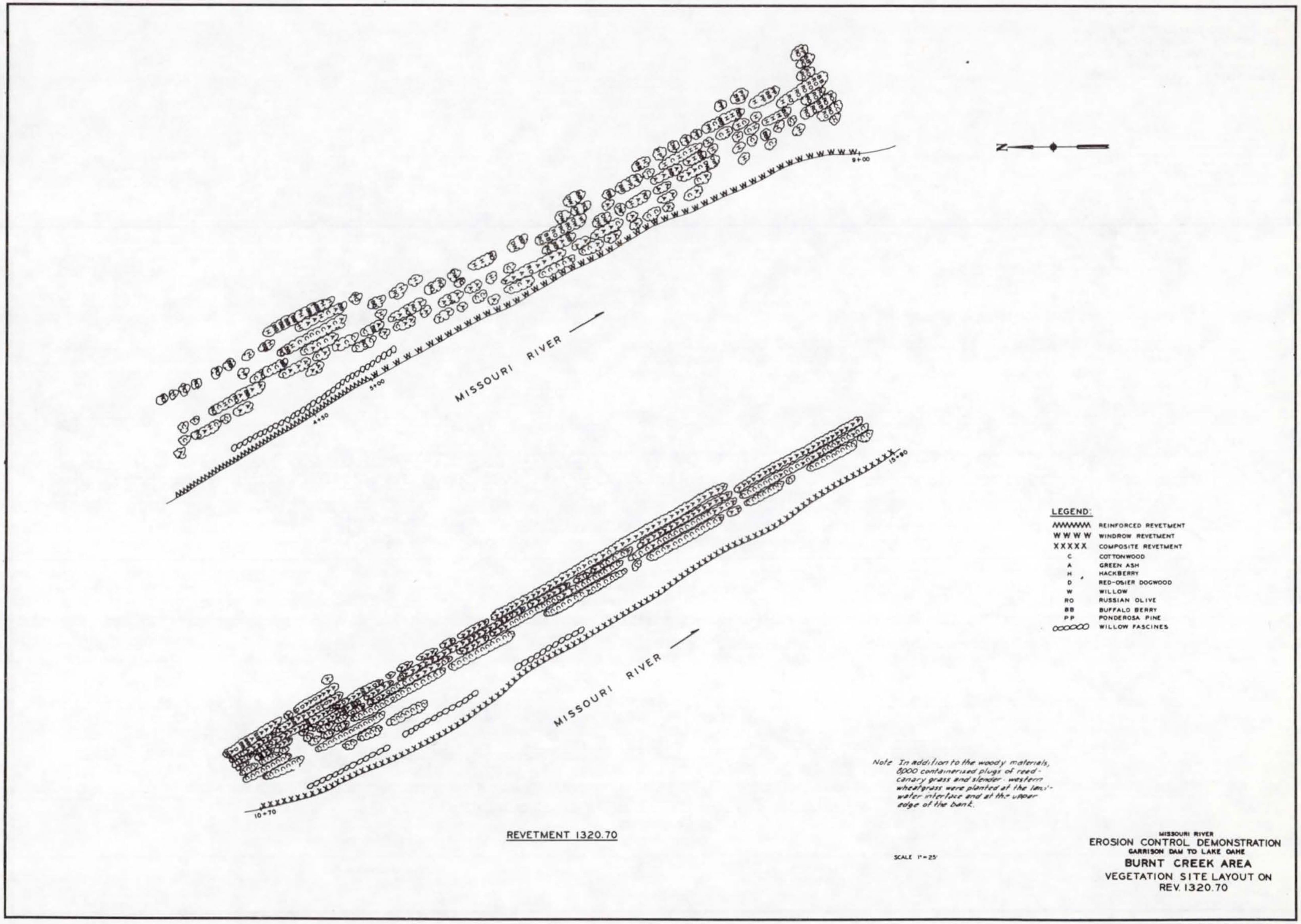
C	COTTONWOOD
A	GREEN ASH
RO	RUSSIAN OLIVE
W	WILLOW
BB	BUFFALO BERRY
(symbol)	WILLOW FASCINES

Note: The top and upstream slope of Dike 1320.80 contained a thick gravel layer which precluded planting of any trees or grasses. However, considerable natural vegetation, indegenous to the area has taken growth on the dike.

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
BURNT CREEK AREA
VEGETATION SITE LAYOUT ON
DIKE 1321.15 AND DIKE 1320.80

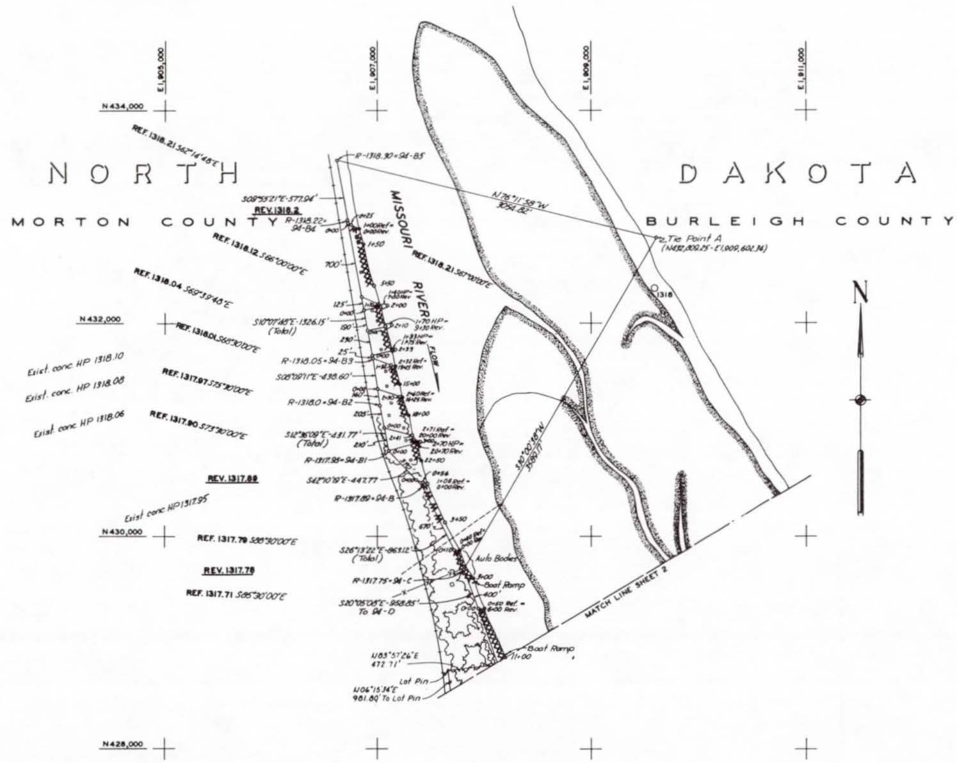
PLATE 14-8

PLATE 14-9



MISSOURI RIVER
MISSOURI RIVER
9+00
5+00
4+50
10+70
15+90
REVETMENT 1320.70
LEGEND:
REINFORCED REVETMENT
WWWW WINDROW REVETMENT
XXXXX COMPOSITE REVETMENT
C COTTONWOOD
A GREEN ASH
H HACKBERRY
D RED-OSIER DOGWOOD
W WILLOW
RO RUSSIAN OLIVE
BB BUFFALO BERRY
PP PONDEROSA PINE
WILLOW FASCINES
Note In addition to the woody materials, 8000 containerised plugs of reed-canary grass and slender western wheatgrass were planted at the land-water interface and at the upper edge of the bank.
SCALE 1"=25'
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
BURNT CREEK AREA
VEGETATION SITE LAYOUT ON
REV. 1320.70

HORIZONTAL AND VERTICAL CONTROL						
LAMBERT GRID NORTH DAKOTA						
Traverse Station	Monument	Elevation	Distance	Bearing	Grid Coordinates North	Grid Coordinates East
R-1318.30-94-B5		1640.45	577.94'	S 09° 55' 21" E	433,537.96	1,906,635.71
R-1318.22-94-B4		1640.29	1326.15'	S 10° 07' 48" E	432,968.66	1,906,735.30
R-1318.05-94-B3		1638.26	438.60'	S 08° 09' 11" E	431,663.18	1,906,968.55
R-1318.00-94-B2		1638.81	431.77'	S 12° 36' 09" E	431,299.01	1,907,030.75
R-1317.95-94-B1		1642.62	447.77'	S 42° 10' 19" E	430,807.64	1,907,124.96
R-1317.89-94-B	1/2" Pipe	1639.37	863.12'	S 26° 13' 22" E	430,475.78	1,907,425.57
R-1317.75-94-C	1" Pipe	1640.27	958.85'	S 20° 05' 08" E	429,701.49	1,907,806.95
R-1317.61-94-D	1" Pipe	1639.74	1461.45'	S 16° 38' 37" E	428,800.96	1,908,136.24
R-1317.34-94-E	1" Pipe	1642.09	707.86'	S 34° 29' 41" E	427,400.73	1,908,554.83
R-1317.21-94-F	1" Pipe	1642.31	294.71'	S 20° 11' 50" E	426,817.33	1,908,955.71
R-1317.16-94-G	1" Pipe	1642.74	1157.38'	S 30° 10' 18" E	426,540.74	1,909,057.46
R-1317.00-94-H	1" Pipe	1643.30	876.25'	S 37° 21' 36" E	425,540.16	1,909,639.15
R-1316.85-94-I	1" Pipe	1641.89	1676.04'	S 49° 53' 00" E	424,843.66	1,910,170.84
R-1316.60-94-J	1" Pipe	1642.77	1688.25'	S 67° 02' 09" E	423,763.71	1,911,452.57
R-1316.29-94-K	1" Pipe	1641.33	808.67'	S 77° 44' 09" E	423,105.00	1,913,007.01
R-1316.16-94-L	1" Pipe	1641.36	393.67'	S 63° 55' 23" E	422,878.52	1,913,783.32
R-1316.10-94-M	1" Pipe	1641.60	608.64'	S 85° 33' 49" E	422,705.47	1,914,136.92
R-1316.00-94-N	1-Bar	1641.59			422,658.39	1,914,743.74



LEGEND:

- W W W — Windrow Revetment or Refusal
- Composite Revetment
- Reinforced Revetment
- RRRRRRR — Rehabilitated Revetment
- Existing Concrete Hardpoint
- Control Traverse
- Fence Line
- Access Roads
- Sand Bar
- Timbered Area
- Railroad Tracks
- Buried Gas Line

SCALE: 1 INCH = 400 FEET

400' 0 400'

MISSOURI RIVER

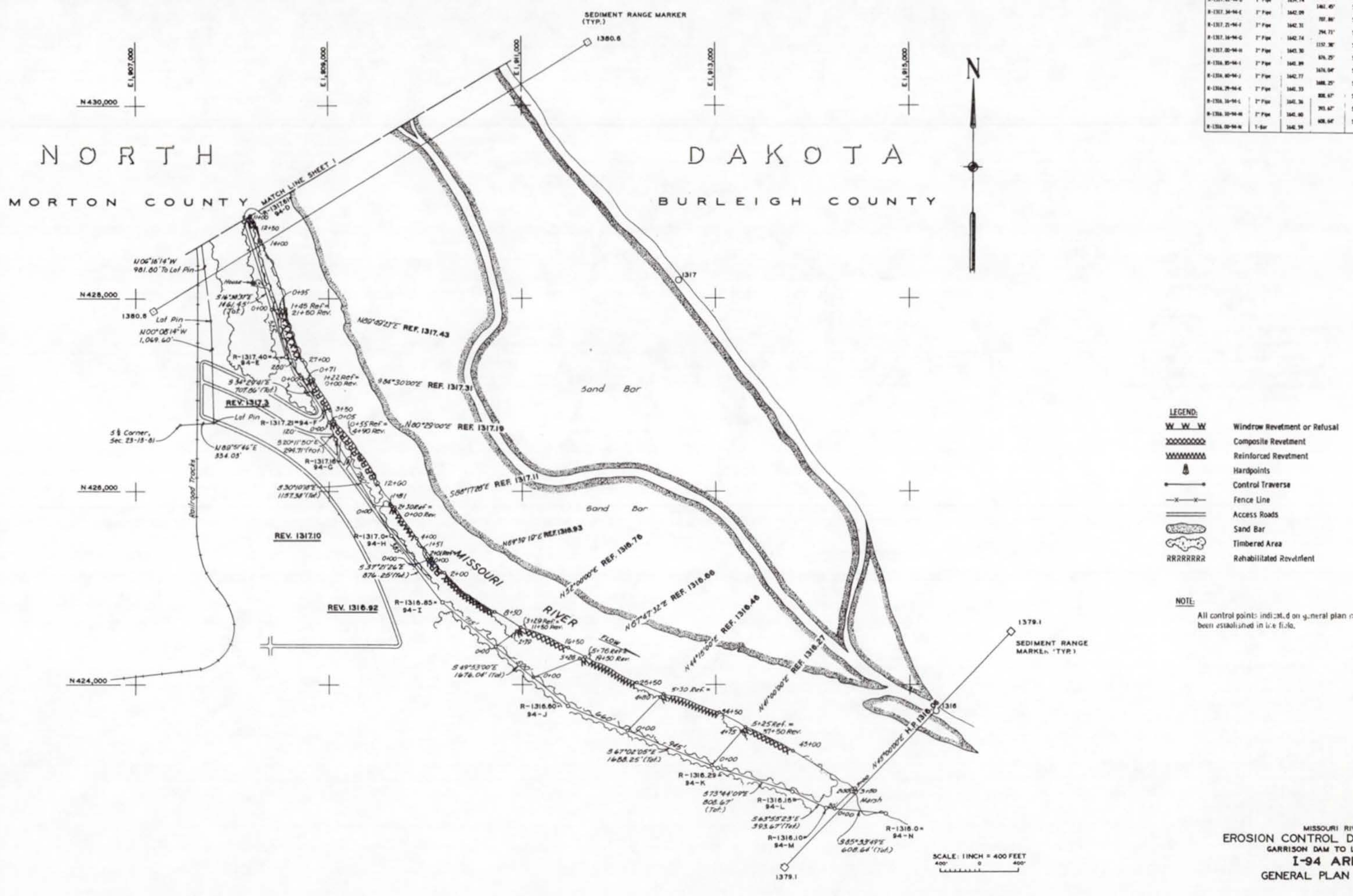
EROSION CONTROL DEMONSTRATION

GARRISON DAM TO LAKE OAHE

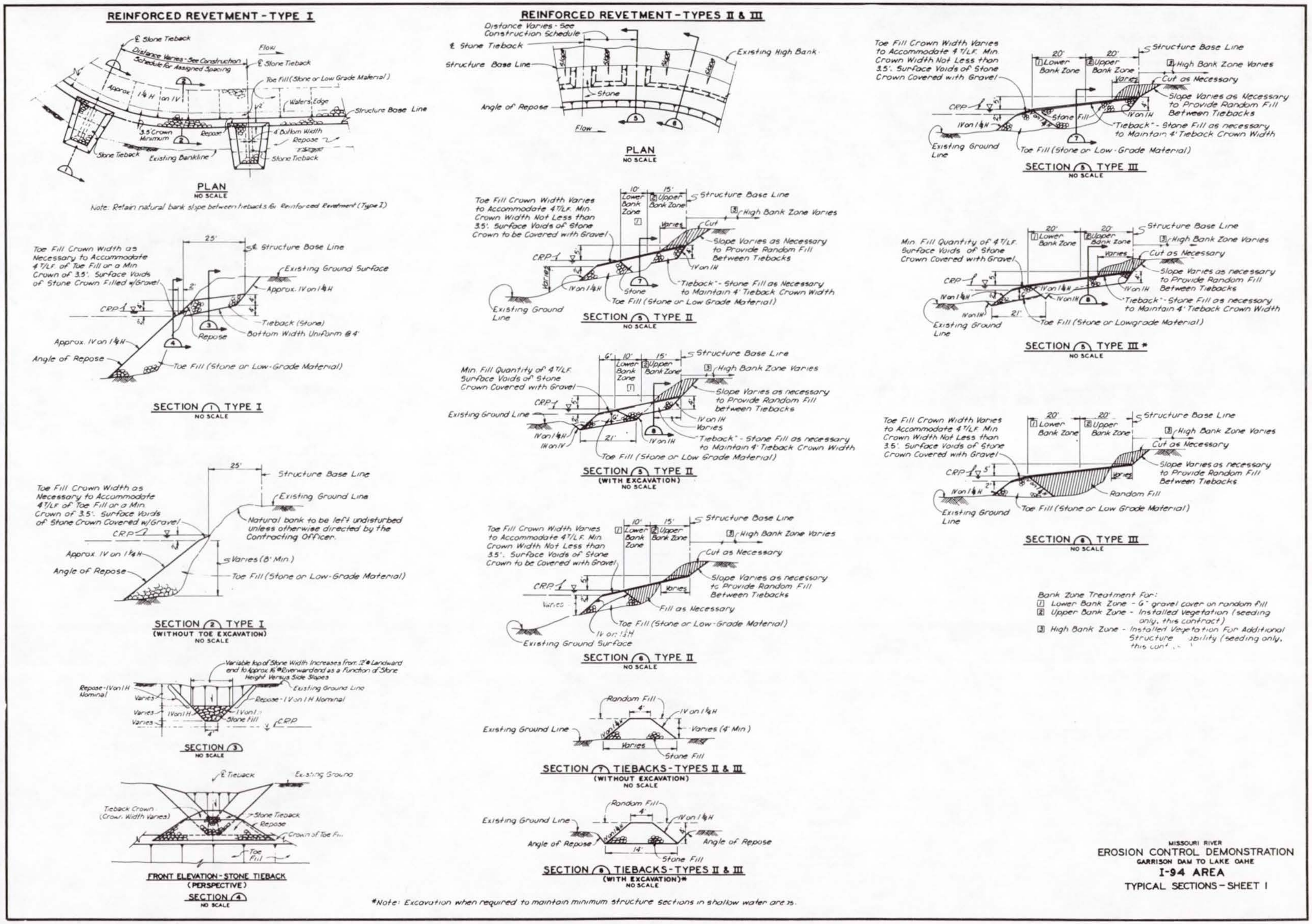
I-94 AREA

GENERAL PLAN - SHEET 1

HORIZONTAL AND VERTICAL CONTROL						
LAMBERT GRID NORTH DAKOTA						
Traverse Station	Monument	Elevation	Distance	Bearing	Grid Coordinates North	Grid Coordinates East
R-1318.30-94-B5		1640.45			433,537.96	1,906,635.71
			577.94'	S 09° 33' 21" E		
R-1318.22-94-B4		1640.29			432,966.66	1,906,730.30
			1326.15'	S 10° 07' 48" E		
R-1318.05-94-B3		1638.26			431,663.18	1,906,968.35
			438.40'	S 08° 09' 11" E		
R-1318.00-94-B2		1638.81			431,299.01	1,907,030.75
			431.77'	S 12° 36' 09" E		
R-1317.95-94-B1		1642.62			430,807.64	1,907,124.96
			447.77'	S 42° 10' 19" E		
R-1317.89-94-B	1/2" Pipe	1639.37			430,475.78	1,907,425.57
			863.12'	S 26° 13' 22" E		
R-1317.75-94-C	1" Pipe	1640.27			429,701.49	1,907,806.95
			958.85'	S 20° 05' 08" E		
R-1317.61-94-D	1" Pipe	1639.74			428,800.96	1,908,136.24
			1461.45'	S 16° 38' 37" E		
R-1317.34-94-E	1" Pipe	1642.09			427,400.73	1,908,554.83
			707.86'	S 34° 29' 41" E		
R-1317.21-94-F	1" Pipe	1642.31			426,817.33	1,908,955.71
			294.71'	S 20° 11' 50" E		
R-1317.16-94-G	1" Pipe	1642.74			426,540.74	1,909,057.46
			1157.38'	S 30° 10' 18" E		
R-1317.00-94-H	1" Pipe	1645.30			425,540.16	1,909,639.15
			876.25'	S 37° 21' 26" E		
R-1316.85-94-I	1" Pipe	1640.89			424,843.66	1,910,170.84
			1676.04'	S 49° 53' 00" E		
R-1316.60-94-J	1" Pipe	1642.77			423,763.71	1,911,452.57
			1688.25'	S 67° 02' 05" E		
R-1316.29-94-K	1" Pipe	1640.33			423,105.00	1,913,007.01
			808.67'	S 73° 44' 09" E		
R-1316.16-94-L	1" Pipe	1640.36			422,879.52	1,913,783.32
			393.67'	S 63° 55' 23" E		
R-1316.10-94-M	1" Pipe	1640.80			422,705.47	1,914,136.92
			608.64'	S 85° 33' 49" E		
R-1316.00-94-N	T-Bar	1640.59			422,658.39	1,914,743.74



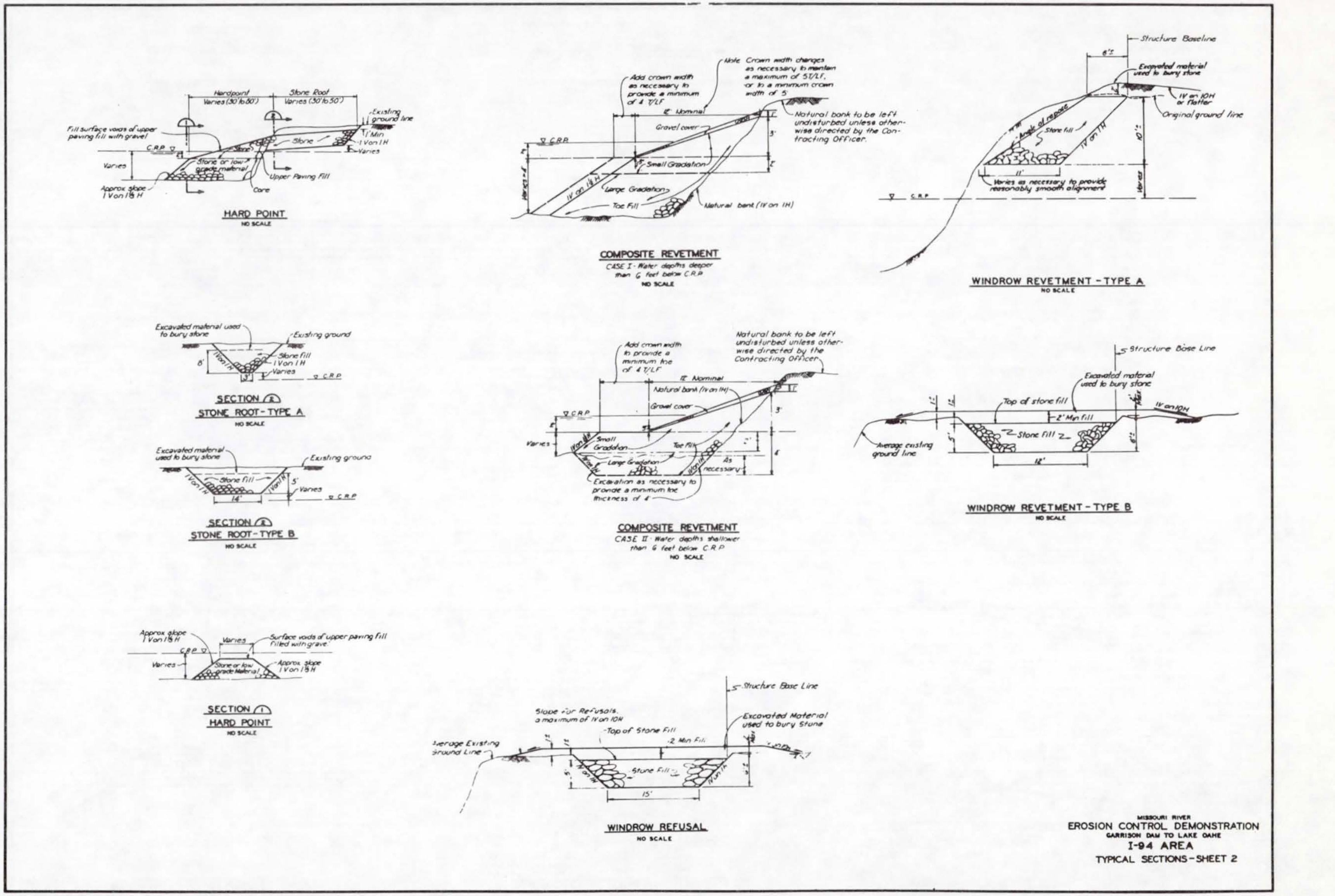
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
I-94 AREA
GENERAL PLAN – SHEET 2



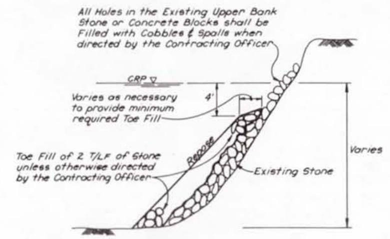
E-1-217

PLATE 15-3

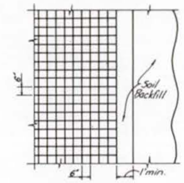
PLATE 15-4



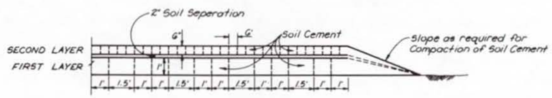
E-1-218



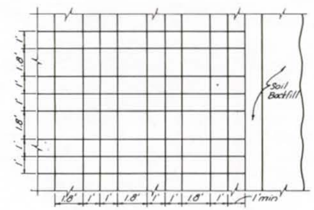
REHABILITATED REVETMENT
NO SCALE



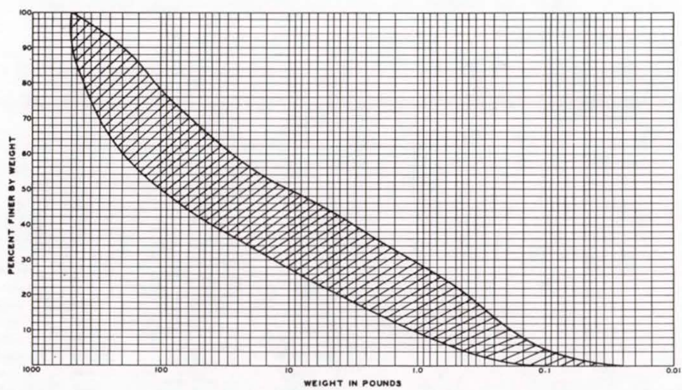
SOIL CEMENT
(CUTTING PLAN- SECOND LAYER)
NO SCALE



SOIL CEMENT
(PREPARATION)
NO SCALE



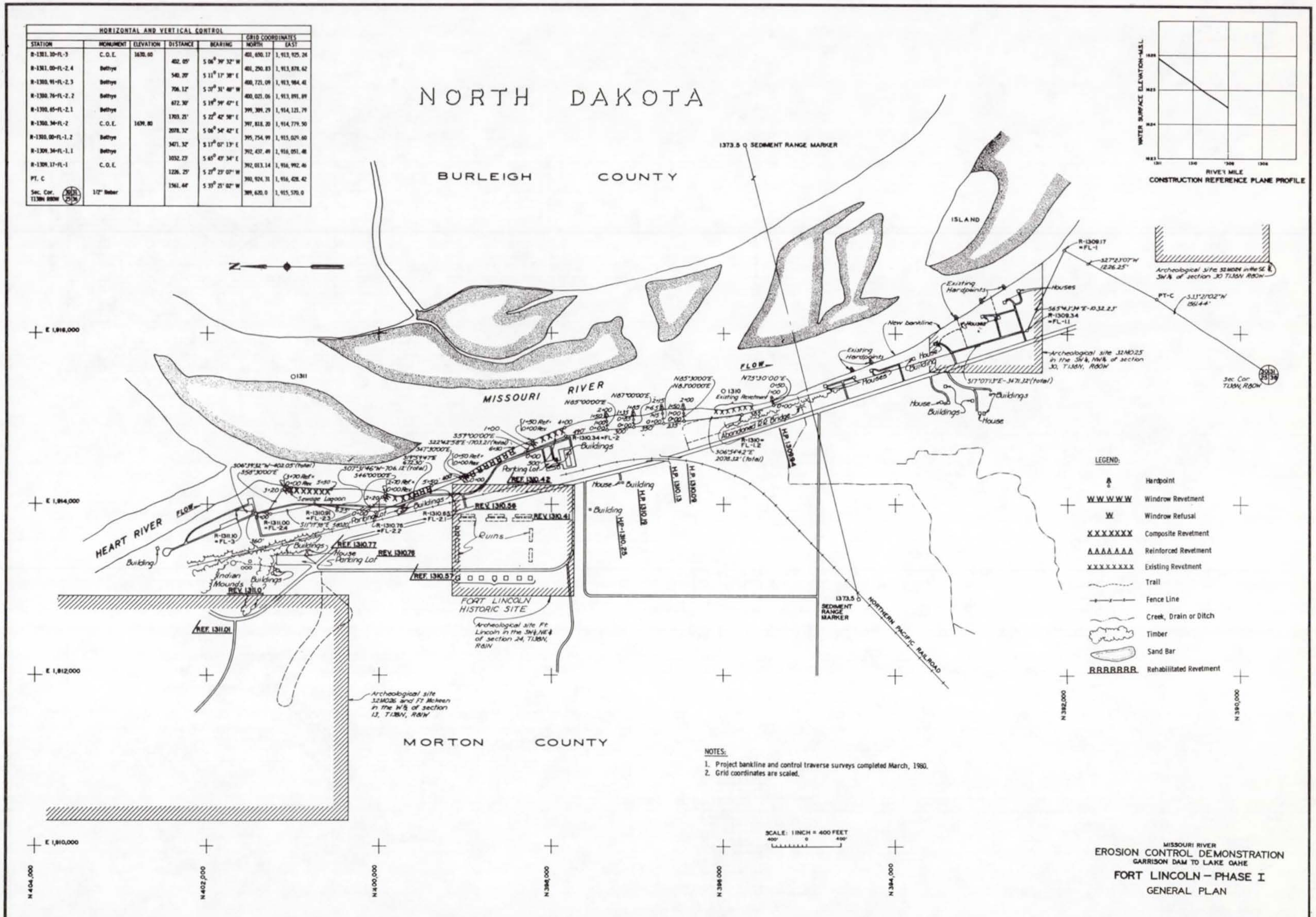
SOIL CEMENT
(CUTTING PLAN-FIRST LAYER)
NO SCALE



RANGE OF GRADATIONS FOR SOIL CEMENT WITH FINES

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
I-94 AREA
TYPICAL SECTIONS-SHEET 3

PLATE 16-1



HORIZONTAL AND VERTICAL CONTROL						
					GRID COORDINATES	
STATION	MONUMENT	ELEVATION	DISTANCE	BEARING	NORTH	EAST
R-1311.30-FL-3	C.O.E.	1630.60			401,650.17	1,913,925.24
			402.05'	S 06° 39' 32" W		
R-1311.00-FL-2.4	Bethye				401,250.83	1,913,878.62
			540.20'	S 11° 17' 38" E		
R-1310.91-FL-2.3	Bethye				400,721.09	1,913,984.41
			706.12'	S 37° 31' 40" W		
R-1310.76-FL-2.2	Bethye				400,021.06	1,913,891.89
			672.30'	S 19° 59' 47" E		
R-1310.65-FL-2.1	Bethye				399,389.29	1,914,121.79
			1703.21'	S 22° 42' 58" E		
R-1310.34-FL-2	C.O.E.	1639.80			397,818.20	1,914,779.50
			2078.32'	S 06° 54' 42" E		
R-1310.00-FL-1.2	Bethye				395,754.99	1,915,029.60
			3471.32'	S 17° 07' 13" E		
R-1309.34-FL-1.1	Bethye				392,437.49	1,916,051.48
			1032.23'	S 65° 43' 34" E		
R-1309.17-FL-1	C.O.E.				392,013.14	1,916,992.46
			1226.25'	S 27° 23' 07" W		
PT. C					390,924.31	1,916,428.42
			1561.44'	S 33° 21' 02" W		
Sec. Cor. T138N R80W	1/2" Rebar				389,620.0	1,915,570.0

NOTES:
1. Project bankline and control traverse surveys completed March, 1980.
2. Grid coordinates are scaled.

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
GARRISON DAM TO LAKE OAHE
FORT LINCOLN – PHASE I
GENERAL PLAN

UNITED STATES DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE

FISH AND WILDLIFE COORDINATION REPORT

MISSOURI RIVER

DEMONSTRATION AND EVALUATION PROGRAM

NORTH DAKOTA

FEB 11 1981

Prepared by:

BISMARCK AREA OFFICE

FISH AND WILDLIFE SERVICE

BISMARCK, NORTH DAKOTA

United States Department of the Interior
FISH AND WILDLIFE SERVICE
AREA OFFICE—NORTH DAKOTA
1500 CAPITOL AVENUE
P.O. BOX 1897
BISMARCK, NORTH DAKOTA 58501

Colonel Vito D. Stipo, District Engineer
Omaha District, Corps of Engineers
P. O. Box 5
Omaha, Nebraska 68101

Dear Colonel Stipo:

This Fish and Wildlife Report provides an assessment of the Demonstration and Evaluation Program as granted under Section 32 of the Water Resources Development Act of 1974. These comments have been prepared under the authority of and in accordance with the provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.) and other authorities mandating Department of the Interior concern for environmental values. They are also consistent with the intent of the National Environmental Policy Act. Our report addresses the effects on fish and wildlife resources of the sites already completed and the anticipated effects of future construction. We have also included comments and recommendations on ways to prevent, mitigate or compensate adverse effects of the project on fish and wildlife resources. This report is to accompany the report of the Corps of Engineers, through the Secretary of Army, to Congress. Comments on the conclusions and recommendations of this report by the North Dakota Game and Fish Department (NDGFD) are contained in the attached letter dated February 2, 1981.

Section 7(c) of the Endangered Species Act, 87 Stat. 884, as amended, requires that your agency ask the Secretary of the Interior, acting through the U.S. Fish and Wildlife Service, whether any listed or proposed endangered or threatened species may be present in the area of each Federal construction project. Prior to construction of any of the stabilization sites, the Corps initiated a Section 7 consultation with the Service that covered whooping cranes (Grus americana), peregrine falcons (Falco peregrinus) and bald eagles (Haliaeetus leucocephalus). After reviewing the Corps biological assessment of each species, the Service, in a letter dated March 10, 1980, agreed that the Section 32 program will not affect whooping cranes or the peregrine falcon but may affect the bald eagle. Our biological opinion stated "The Section 32 Streambank Erosion Control and Demonstration Program is not likely to jeopardize the continued existence of the bald eagle or adversely modify its critical habitat." However, due to scant information available on eagle use and the numerous stabilization sites identified for construction, the Service has been monitoring bald eagles along the Missouri River for the past 2 years. The additional information generated will help insure that eagles or their habitat will not be affected by the Section 32 Program.

On April 4, 1980, the Fish and Wildlife Service (FWS) transmitted maps to the Omaha District depicting the location of all the eagle sightings to date. As information is updated, it will be provided to the Corps.

In the view of the Service, the Corps of Engineers is in compliance with Executive Order 11988, Floodplain Management, for construction purposes at the project sites. While construction does take place in the Missouri River floodplain, wildlife habitat and other environmental values may be preserved by bank stabilization.

Description of the Area. The construction sites are located along the 80 miles of free flowing Missouri River in North Dakota. The project is bounded on the north by Garrison Dam and on the south by Lake Oahe. Although most of the Missouri river floodplain has been converted to agricultural use (cropland and hayland) there is still much riparian woodland left. Most exist in woodlots from 50 to 250 acres in size. While cottonwood is the dominant tree species, elm, boxelder, and green ash are also common. Except for the Game Management Areas (lands administered by the NDGFD) the woodlands are used extensively for pasture and feedlots. The river forms a series of braided channels, islands, side chutes and backwater areas (Photo No. 1). Usually the main channel is identifiable except during high flows when a continuous expanse of water extends from bank to bank.

Photo No. 1. Wilton Area
(Note the woodland pattern)

Fish and Wildlife Resources - Fish. The Missouri River provides the highest quality river fishery in the state. Primary game fish species are walleye, sauger, northern pike, rainbow and brown trout, and coho and chinook salmon. Important nongame species include channel catfish, white bass, goldeyes, carp, buffalo and shovelnose sturgeon. The river has been rated as Class I, Highest Valued Fishery Resource by the NDGFD. It provides fish species that are of high interest to area anglers. The good quality, cold water that is released at Garrison Dam helps to maintain the fishery.

Wildlife. The riparian woodlands found along the Missouri River provide some of the best wildlife habitat in the state. Two big game species, white-tailed deer and turkeys, attain their highest population levels along the Missouri River. Recent NDGFD surveys indicate that approximately 3,000 deer and 2,000-2,500 turkeys winter between Garrison Dam and Bismarck. In addition, waterfowl rest during migration on the numerous sandbars. In an average year, 2,000-4,000 mallard ducks winter on the open river below the dam.

The Missouri River also provides quality habitat for a wide range of resident nongame species including a host of songbirds and small mammals. Avian species include the red-tailed hawk, brown thrasher, least flycatcher, western meadowlark and orchard oriole. Common mammal species include beaver, muskrat, long-tailed weasel and badger. Least terns, uncommon in North Dakota, have been known to nest on the numerous sandbars on the Missouri River.

Description of the Project. When the Section 32 Program was authorized for construction, 21 sites were identified in North Dakota as having severe erosion problems. They were Eagle Park, Sanger, 4-H Camp, Sandstone Bluff I and II, Burnt Creek, I-94, Fort Lincoln, Horseshoe Butte, Price I and II, Pretty Point, Wildwood Lake, Coal Lake Coulee, Knife Point I & II, Hancock, Custer Flats, Pioneer Park, Indian Mounds and Wogansport. Of these 21 sites, only Eagle Park, Sanger, 4-H Camp, Sandstone Bluff I & II, Burnt Creek and I-94 have been completed.

The types of bankline protection may vary from site to site. Hardpoints, windrow revetment, composite revetment, tree retards, earth core dikes and vane dikes are some of the more common techniques used. Generally the type of protection used depended on the nature of the erosion problem. For example, windrow revetment may be used next to long stretches of presently eroding irregular bankline. Hardpoints are better suited for long straight sections of bankline not subject to direct attack by river currents.

Construction methods consist of two types; from land or floating plant (barge). A land based operation is used when access to the stabilization site can be accomplished with minimal clearing or using existing roads and trails in the area. A barge is used at sites where extensive tree and shrub clearing would be necessary to complete the work (Photo No. 2).

Photo No. 2. I-94 Area

Effects on Fish and Wildlife Resources - Fish. Adverse impacts to the aquatic ecosystem have been minimal. In fact, there could be some minor positive effects. The rock used in many of the revetments provides a suitable substrate for invertebrates (Photo. 3). At the I-94 site, colonization by mayflies (Ephemeroptera) and caddis flies (Trichoptera), as well as other invetebrates, were noted. These invertebrates help to increase the food base for many river fishes. It should be recognized, however, that the overall contribution to the food base is very small. With 160 miles of shoreline of the free flowing Missouri River in North Dakota, a few hundred or few thousand feet of submerged rock will not significantly increase the food base of the river.

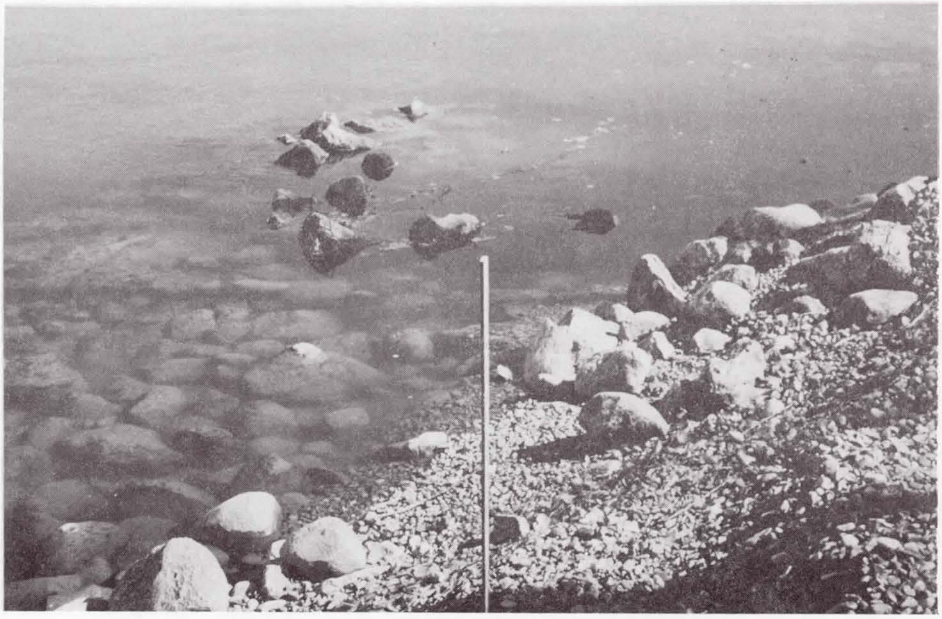


Photo No. 3. Rock Substrate, I-94 Area

At the Sanger site, a large backwater area was created behind the earth-core dike (Photo No. 4). In these backwater areas the water warms up faster and submerged aquatics have a chance to become established. This type of habitat provides a nursery area for many fishes including walleye, northern pike, crappie, white bass, white sucker and carp. Previous sampling efforts in areas similar to this one has confirmed this conclusion.

One problem with the earth-core dikes is that the area behind them has a tendency to become silted in or the lower end closes off completely. If this is combined with a decrease in the water releases from the dam, many small pools remain and the fish become stranded. The environmental notches and culverts through the dike were supposed to keep the areas behind the dikes from becoming silted in. While this is good in theory, it does not appear to have worked well in practice. At one site, instead of a large backwater area below a culvert, a narrow, shallow channel had been formed. As river levels receded, an isolated chute developed, deepest by the dike and dry at the lower end. This type of situation does little to benefit the fishery and can actually be a detriment to it. Young-of-the-year fish that might have stayed in the main river are now trapped in these isolated pools.

No. 4. - Sanger

Wildlife. Concerns over wildlife impacts were raised because of the anticipated woodland clearing that could result from the bank being stabilized. To date, this has not happened at any of the seven completed sites. Because of the present economy clearing may take years to plan and complete. The FWS has stressed the need for the project sponsor or construction agency to secure a 200 foot woodland preservation easement along the river. This would not only protect riparian habitat, but preserve eagle roost/perch trees. Unfortunately, the project sponsor has been reluctant to take such action. Thus woodland protection has not been assured.

Project construction has resulted in minimal habitat destruction. To date, we have documented approximately 3 acres of habitat lost. This all occured at the Sanger site where a brushy hillside was cleared and the area was used as a borrow site (other previously cleared areas were already available). At other sites, individual trees have also been lost either due to direct removal for a project feature or because of structure placement (Photo 5). Generally, the amount of land involved is too small to quantify or would have been lost to erosion.

No. 5 - Eagle Park

Plan of Development for Fish & Wildlife Resources. Although there is no specific language for mitigation in the authorization for the Section 32 program, habitat losses have been and will be identified. At the end of the program all habitat losses will be totalled and a mitigation plan developed. We will request that our final coordination report accompany the Corps' report to Congress and that provisions be made to mitigate all identified habitat losses. Woodland and brushy draws are the only two habitat types identified to date that would require compensation and the acreages involved have been relatively small. A standard rate of replacement for woody habitat losses will be used. After reviewing projects that involved the loss of woody vegetation, the NDGFD recommends that a 2:1 ratio be used to determine the amount of replacement habitat needed. That is, two acres of similar habitat is needed for every acre lost. Since three two acres of habitat was lost at the Sanger Site, six acres of similar habitat is needed for compensation.

An alternate approach to securing additional land would be to revegetate the project area to the pre-project conditions. As previously mentioned, habitat losses involve small acreages, this restoration is confined to a localized area. Restoration of the woody hillside at the Sanger site is a good example. With minimal effort the site could be restored to pre-project conditions.

Experimental vegetative plantings were made on the stabilization structures at the Sanger and Burnt Creek sites. It is questionable if any of the plantings will benefit wildlife. Human development and activity in the area will preclude wildlife use. It does, however, improve the aesthetics of the area. Another problem was that this summer many of the plants were under water and Missouri River water stages were about normal. It might have been better to use the plants in cleared areas on the shoreline.

At the present time, oats and wheat are seeded on the disturbed areas. These monotypic stands do little to duplicate or replace the plants that were lost to construction. A different seed mixture was described in the project specifications, but evidently the plan was not followed. If the areas were sprigged with indigenous brushy vegetation, recovery of the area would be more rapid and be of more benefit to wildlife.

The best approach we have seen to mitigate losses is to prevent habitat losses from occurring. Construction can avoid important habitat types if properly planned. Many of the sites have existing roads or trails into them, thus the need for haul roads can be eliminated.

It is our observation that positive attempts have been made to keep the impacts of construction at a minimal level. Haul roads have been routed around existing trees or where construction is necessary in a wooded area, the right-of-way is kept to a minimum. In most cases the tree loss in the right-of-way would have occurred anyway because of the rapidly eroding bank.

An alternative to constructing stabilization structures from a tree lined bank is the use of a floating plant (barge). This was used at both the I-94 and Eagle Park sites. An advantage to this construction technique is that no shoreline clearing needs to be done except for the refusals at the upper end of each revetment.

Recommendations

*Since there is no guarantee that riparian woodland will not be cleared once stabilization is completed, a woodland preservation easement is still needed. Project sponsors should be made aware of the problem and they should be strongly encouraged to take the necessary precautions against post-project clearing; particularly in areas where bald eagle use is the greatest.

*A vegetative plan should be developed and implemented to replace all identified habitat losses. This eliminates the need for a mitigation plan and improves the aesthetics of the project area.

*Tree clearing for haul roads and construction yards should be minimized as much as possible. In many cases, existing roads, trails and fields or forest openings can be used. In areas where tree clearing is necessary for haul roads, it should be kept to the absolute minimum.

*Project construction should be monitored more closely by the Corps. This will help insure that the project specifications and FWS recommendations are implemented.

*Construction activity should be halted or modified in the wintertime in those portions of the open water reaches that are used by bald eagles.

*Every effort should be made and projects modified, if necessary, to protect individual trees used for perching/hunting sites by eagles. These trees are usually large cottonwoods (50-60 feet) within 5 meters of the shoreline. The results of our winter surveys have pinpointed these trees.

*Where tree clearing is inevitable with conventional techniques, a barge should be used as an alternative construction method.

*Approximately 6 acres of compensation or a revegetation plan is needed to offset wildlife habitat losses at the Sanger site.

Overall, the Section 32 Program in North Dakota is going smoothly with only minor environmental effects observed on the seven completed sites. We have made some preliminary reviews of the 14 remaining stabilization sites and do not foresee any major environmental problems provided that project features, locations, methods or theories of construction do not change and coordination continues.

This project has been unique in that there has been excellent coordination and cooperation between the Corps and the Service. In several instances project specifications were designed to minimize environmental damage. Any problem that we could foresee with regard to wildlife habitat or bald eagles, were brought to the attention of the Corps District or site inspectors. A meeting or on-site review was immediately called and any problems or delays were alleviated. While this required extra time being spent on pre-project reviews, on-site meetings, inspections of construction activities and such, it has resulted in virtually no habitat losses.

This concludes our Interim Fish and Wildlife Coordination Report. Please contact us if you have any further questions.

Sincerely yours,

Gilbert E. Key

Gilbert E. Key
Area Manager

" VARIETY IN HUNTING AND FISHING "

NORTH DAKOTA GAME AND FISH DEPARTMENT

2121 LOVETT AVE. BISMARCK, N. DAK. 58505 PHONE 701-224-2180

February 2, 1981

Mr. Gilbert E. Key
Area Manager
US Fish and Wildlife Service
1500 Capitol Avenue
Bismarck, ND 58501

Re: Concurrence with Fish and Wildlife Service assessment of COE Demonstration and Evaluation Program

Dear Mr. Key:

We have reviewed the above referenced document and concur with your assessment of the program.

Sincerely,

Larry L. Kruckenberg
Commissioner

M:LLK:dk

Larry L. Kruckenberg
COMMISSIONER

Keith Trego
DEPUTY COMMISSIONER

MISSOURI RIVER, FORT RANDALL DAM TO NIOBRARA, NEBRASKA AND SOUTH DAKOTA

APPENDIX E-2

Section 32 Program Streambank Erosion Control
Evaluation and Demonstration Act of 1974

MISSOURI RIVER, FORT RANDALL DAM TO NIOBRARA; NEBRASKA AND SOUTH DAKOTA
DEMONSTRATION PROJECT PERFORMANCE REPORT

I - INTRODUCTION

A. PROJECT NAMES AND LOCATIONS.

The Omaha District constructed two demonstration projects in the reach of the Missouri River from Ft. Randall to Niobrara. The Sunshine Bottom project, located on the right bank of the Missouri River between river miles 869 and 866 (1960 mileage), was completed in August 1979. Construction of the White Swan project, located on the left bank between river mile 870 and 868, was initiated in September of 1980, and was completed in May 1981. Plate 0-1 shows the location of these projects.

B. AUTHORITY.

The authority for the projects in this reach is Public Law 93-251, Water Resources Development Act of 1974, Section 32 "Streambank Erosion Control Evaluation and Demonstration Act of 1974," and the House Report No. 95-1247, "Public Works for Water and Power Development and Energy Research Appropriations Bill of 1979," which specifically authorized the White Swan Area.

C. PURPOSE AND SCOPE.

The purpose and scope of this report is to describe the bank erosion problems, the types of bank protection used, and performance evaluations of the two Section 32 demonstration projects.

D. PROBLEM RESUME.

The flood plain in this reach of the Missouri River Valley has always been subject to severe erosion. Historically, however, the sediment load, combined with annual flood events, maintained a relatively constant total land area within the river meader belt through the formation of accretion lands equal in area, elevation, and fertility to the lands lost to erosion. Construction of Fort Randall Dam eliminated the upstream sediment supply and flooding in this open river reach, thereby virtually eliminating the accretion cycle. Hence, high bank areas now being eroded represent a continuing and permanent loss of a very valuable and irreplaceable resource. Flood control operation of Ft. Randall Dam results in an average daily discharge of about 30,000 c.f.s. from April through November; however, during high runoff years this may increase to 50,000 c.f.s. or more. Periods of above normal discharge required to evacuate flood storage in the reservoir may aggravate the already severe erosion problems. Certain increments within the reach have very high erosion losses, and the problem is compounded by the nonuniformity of the erosion. The valley is relatively narrow; hence, the impact of the losses is more pronounced. Site selections for installation of erosion protection were based on previously documented erosion complaints and field reconnaissances, as well as the following criteria: consideration of comparative erosion rates; land use; environmental factors (i.e., site adaptability to various potential erosion control measures); and availability of a qualified local governmental entity willing to provide sponsorship for erosion control demonstrations.

II - HISTORICAL DESCRIPTION

A. GENERAL DESCRIPTION

1. GEOMORPHOLOGY

a. Physiography. Along the Fort Randall to Niobrara reach, the Missouri River leaves the Great Plains Physiographic Province and enters the Central Lowland Physiographic Province. The Missouri River Valley through South Dakota constitutes the Missouri River Trench physical division. The Missouri River Trench trends southeastward, is 1-1/2 to 5 miles wide, and cuts to a depth of 300 to 650 feet into the Missouri Plateau. The walls of the trench have a rugged "badlands" topography. To the northeast, into South Dakota, is the gently rolling, poorly drained, glaciated terrain of the Coteau du Missouri. To the southwest, into Nebraska, is a well-integrated drainage system within the mature, moderately sloped terrain of the Pierre Hills. This drainage system has been rejuvenated by continued entrenchment of the Missouri River, and steep-sided youthful valleys are being eroded into the mature upland hills. The river valley along most of this reach is an entrenched glacial melt-water channel at the southwestern margin of glaciated eastern South Dakota. During the mid-Pleistocene Period melt water ran along the front of the Illinoian Glacier which had advanced into South Dakota. When the glacier retreated, the melt-water channel had been entrenched sufficiently to form the infant Missouri River. The river trench was partly filled during the later Wisconsin glaciation, but the river retrenched its valley in the Recent period.

b. Topography. The entrenchment of the Missouri River through relatively high, rolling plains formed the topography along this portion of the river. The river valley in this area is occasionally lined by older river terraces and often intersected by steep tributary ravines. The valley at

Fort Randall Dam is approximately 8,000 feet wide with a low flood plain elevation of about 1250. The uplands in the vicinity of the dam range from an elevation of 1450 feet in the northeast to an elevation of 2000 feet toward the southwest.

c. **Geology**. The rock formations along this reach of river are well indurated and compacted sedimentary marine deposits of the upper cretaceous period. The stratigraphic sequence in ascending order is Carlile shale, Niobrara chalk and Pierre shale. Plates 0-2 and 0-3 show the geologic profile.

The bedrock beneath the alluvial river bed is the Carlile shale formation. The entire formation is approximately 265 feet thick, but below the river channel the upper 100 feet have been eroded away and is covered by valley overburden. Carlile shale consists of silty, sandy, or sometimes limy shale with interbedded sandstone in places. The top 10 feet of the formation is silty to sandy shale which is poorly consolidated and contains limy nodules. This bed grades into an underlying 10-foot section of subfirm, thinly bedded, waxy shale. The 25-foot thick Codell Member is next in sequence, consisting of brown, friable, medium grained, cross-bedded sandstone. This is underlain by a 25-foot section of interbedded sandy shale and sandstone. The remaining formation is firm, waxy, silty shale which becomes increasingly calcareous toward the base. It is the firm, waxy, silty shale section that forms the bedrock floor in the river's flood plain.

The Niobrara chalk, which forms the majority of the trench walls along this reach, is the most prominent Cretaceous formation, varying in thickness from 105 to 185 feet. It commonly forms prominent cliffs along the river. The Niobrara Formation is a dark gray, argillaceous, soft but firm chalk and chalky shale which contains many microscopic shells of Foraminifera and Ostracoda. When closely examined the chalk has a salt-and-pepper appearance due to light colored shell and clastic fragments in a darker groundmass. The color changes to a buff or light gray when the formation is weathered. Thin layers of bentonitic clay with thicknesses up to 2 inches occur throughout the formation, but they are more concentrated in the upper 20 feet.

Pierre shale overlies the Niobrara chalk, rising above the chalk cliffs as grass covered slopes. The Pierre shale contact with the underlying Niobrara Formation occurs sharply at about elevation 1320. The formation is susceptible to landsliding, and it may be generally described as a non-calcareous to highly calcareous, gray, green, brown or black, tough, gummy, marine shale with zones of bentonite seams and iron-manganese concretions.

Overburden along this reach of the river consists of glacial till, valley fill (alluvium), river terrace and loess deposits. The glacial till is a heterogeneous mixture of clay, silt, sand, gravel and boulders with numerous fragments of shale and chalk. The till has a maximum thickness of 90 feet in the vicinity of Ft. Randall Dam, but is generally less than 50 feet. Unsorted glacial deposits blanket the uplands along much of the east side of the trench and are exposed in many places along the east wall of the trench. Till occurs chiefly in small isolated patches on the west side of the trench primarily at lower elevations. Valley fill consists of alluvial sand which ranges from fine to medium in grain size. The fine-to-medium sizes predominate throughout this fill, but with increasing depth the sand becomes more coarse and in part, gravelly. The thickness of alluvium varies across the river bottom from a relatively shallow depth to a maximum thickness of 175 feet. Some thin layers of gravel occur in this material, but they appear to be restricted lenses with no great lateral extent. There are also occasional small seams of clay, silty sand, lime and lignite float. The lower deposits are probably of glacial origin. River terraces consist of poorly compacted alluvial clays, silts and sands. The material is generally lean to fat clay which contains an appreciable amount of silt. The loess consists of uniform silt sized grains for the most part, with some fine sand sizes. The loess forms a patchy blanket along the Missouri River trench walls and on the bordering uplands. In most of the Fort Randall area, it is a few inches to a few feet in thickness, although thicknesses of 30 feet or more are present in some areas.

2. **VALLEY LAND USE.** The use of the valley lands landward of the high bank is predominantly agricultural. Much of the remaining flood plain forest is as yet uncleared land adjacent to the river banks. There is a developing trend, throughout the reach, to construct private homes and private recreational facilities along the riverbanks.

3. **HYDROLOGIC AND METEORLOGIC CHARACTERISTICS.** The Ft. Randall Dam to Niobrara River reach of the Missouri River has a climate typical of the interior of large continents in middle latitude. It has moderate rainfall, low humidity, hot summers, cold winters, great variations in temperature and rainfall from year to year, and frequent changes in weather from day to day or week to week.

In an average year, the annual precipitation totals 24 inches. Most of the precipitation comes during the warmer months from April to September, almost wholly in the form of showers and thunderstorms. Practically all precipitation in the colder months is in the form of snow. June is normally the wettest month and averages 4.4 inches. January is normally the driest month and averages 0.5 inch.

The daily maximum and minimum temperatures for July, the warmest month, average 89°F. and 62°F., respectively. The daily maximum and minimum temperatures for January, the coldest month, average 31°F. and 8°F. The average length of the frost-free period is 150 days, with the last freezing temperatures in the spring near May 6 and the first freezing temperatures in autumn near October 3.

The projected 100-year release from Ft. Randall Dam is 75,000 c.f.s. With no major tributaries in the reach between Ft. Randall Dam and the Niobrara River, local flooding has generally been an infrequent occurance.

4. **EXISTING CHANNEL CONDITIONS.** The Ft. Randall Dam to Niobrara Reach of the Missouri River is essentially a meandering stream regulated by Ft. Randall Dam. This reach consists of 36.3 river miles, and 16 bankline miles of the reach are in bluff contact (control points). Power peaking at the dam results in fluctuations of the water level from 2.5 to 11.0 feet, decreasing in amplitude in the downstream direction. Essentially all river stages in the open river reach downstream of the dam have been confined within the channel below the high river banks, with the exception of the 10-mile reach upstream of the Niobrara river confluence; here, backwaters caused by Niobrara River delta deposits in the Missouri River channel have resulted in flooding during higher than normal releases from the dam.

5. **ENVIRONMENTAL CONDITIONS.** The relatively unaltered reaches of the Missouri River support a fish community of a minimum of 50 species. Schmulbach et. al. (1975) listed 113 species that could occur in the Missouri River. Most recent fish fauna surveys have reported 40 to 50 species. Sauger, carp, channel catfish, freshwater drum, and white bass are the most abundant fish in the fisherman's creel. Sport fish harvest rates from the Missouri River were comparable with those from smaller warmwater rivers in the upper Midwest (Groen and Schmulbach 1978).

The continued existence of the fish community and the fishery of this Missouri River reach is dependent on the maintenance of the variety of habitats that exist in the unaltered reaches. Kallemeyn and Novotny (1977) concluded that even though some fish species exhibited preferences for particular habitats, most required several habitats to successfully complete their life span. Thus, disruption of the system of habitats in a river reach will result in widespread changes in the fish community. Such changes are evident in the channelized Missouri River where the total aquatic surface area per linear mile has been reduced to one-third of that on an equal distance in the unchannelized river (Morris et. al. 1968). Researchers have found that fish are more abundant in the unchannelized rather than the channelized river and that the diversity of the fish population declines as the habitat becomes less variable (Funk and Robison 1974, Schmulbach et. al. 1975).

Species that evolved under riverine conditions, such as sturgeon, paddlefish, and certain chubs and minnows, are particularly susceptible to habitat alteration. Where the Missouri River has been impounded or channelized, these species have either disappeared or been reduced to extremely low numbers. The reductions have caused the South Dakota Department of Game, Fish and Parks to place the pallid sturgeon, sturgeon chub (Hybopsis Gelida), and sicklefin chub (Hybopsis meeki) on its list of threatened fish, while the Nebraska Game and Parks Commission has designated the pallid sturgeon and lake sturgeon (Acipenser fluvescens) as threatened.

The various habitats that exist in and along the unaltered reaches of the Missouri River support a large and diverse wildlife community. In his study of the wildlife habitats along the unchannelized Missouri River in South Dakota, Clapp (1976) presented lists of the mammals, birds, reptiles, and amphibians that may be expected to occur in the area.

Mammals include 51 species, with small mammals such as mice, voles, bats, moles, rats, and ground squirrels comprising over 50 percent of the species. Furbearers in the area are beaver, muskrat, mink, red fox, raccoon, coyote, skunk, and oppossum. The area also supports populations of Eastern cottontail and fox squirrel, both of which are classified by South Dakota and Nebraska as small game animals. White-tailed deer, a big game animal, are present in significant numbers; and occasionally mule deer are seen. The extensive breaks along the Nebraska side of the river, coupled with the interspersed brush, timber, and cultivated land on the floodplain, comprise good deer habitat.

Birds in the region include 269 species, of which 29 are classified as being permanent residents of southeastern South Dakota. An additional 96 species are summer residents. Another 25 species commonly winter in the area. Over 115 species use the corridor regularly on their spring migration and 110 use it during the fall migration.

The bald eagle, an endangered species, winters on the open (unimpounded) reaches of the Missouri River downstream of both Gavins Point and Fort Randall Dams. The eagles usually arrive in November and remain until March or early April. They use the large cottonwoods along the river for roosting and as perches from which they spot prey. In early winter, they feed primarily on fish. Later in the season, they eat waterfowl, upland game animals, and carrion.

The first National Wildlife Refuge created specifically for bald eagles is located 2 miles downstream from Fort Randall Dam, primarily on the timbered flood plain of the Missouri River. The eagles winter in stands of mature cottonwoods adjacent to an open water. The river, which is ice-free throughout the winter, provides an abundance of fish, such as goldeye, shad, and white bass, plus wintering ducks and geese (mostly mallard and Canada geese). In 1967, a peak of 283 eagles was observed, establishing the Fort Randall population of wintering eagles as the largest in the contiguous 48 states.

Although nongame birds comprise the largest percentage of the bird fauna in the river corridor, game birds receive most of the public attention. Pheasant, bobwhite quail, and mourning dove use the mosaic of forest, brush, and agricultural lands on the flood plain. The flood plain offers fair to good hunting for these species. Although turkeys live on both sides of the river, the largest numbers live in the wooded breaks on the Nebraska side of the river. In this area, the State of Nebraska has a spring hunting season for male turkeys.

The open (unimpounded) reaches of the Missouri River are particularly important to many species of migratory waterfowl and shorebirds because of the project's location within the Central Flyway. Thousands of ducks and geese use the river as a staging area as they migrate to their northern nesting grounds. In addition, mallard, gadwall, blue-winged teal, shoveler, and wood duck nest along the river. The open river reaches provide quality waterfowl hunting. The principal ducks harvested are mallard, pintail, green-winged and blue-winged teal, scaup, gadwall, and baldpate, while hunters also take blue, snow and Canada geese. Sites for hunting blinds are in great demand along both river reaches, with the number of blinds averaging five per mile.

The amphibians and reptiles that may occur in the project area include one salamander species, nine species of frogs and toads, five turtle species, two lizard species, and twelve species of snakes. The South Dakota Department of Game, Fish and Parks has placed several species that live in the area on its list of threatened species; they are the false map turtle, Eastern hognose snake, and lined snake.

B. DEMONSTRATION PROJECT REACH

1. HYDRAULIC CHARACTERISTICS

a. Channel Widths and Depths. The floodway width (distance between high banks) at the Sunshine Bottom Area ranges from 3,600 feet to 2,000 feet and at the White Swan Area ranges from 3,500 feet down to 2,000 feet. The distance between high banks over the entire reach averages over 3,000 feet and varies from 1,000 feet to 7,500 feet. The main channel width at the Sunshine Bottom Area ranges from 3,500 feet down to 1,300 feet with main channel thalwag depths of approximately averaging 16 feet. The main channel widths at the White Swan Area range from 3,400 feet to 1,000 feet with main channel depths of approximately 13 feet. The primary channel thalwag over the entire reach usually ranges between 6 and 20 feet; however, deeper scour holes are occasionally recorded.

b. Normal Water Surface. The Normal Water Surface (NWS) represents the estimated water surface profile for a steady state discharge of 34,200 cfs from Fort Randall Dam. This flow represents the flow equalled or exceeded 50 percent of the time, since closure of the dam, during the open-water season from April through October, as shown on Plate 0-5. The NWS thus represents a key elevation for structure design. Further, the NWS provides a practical datum plane in the field to effectively monitor construction operations and to periodically evaluate completed structures. Plate 0-4 shows the Normal Water Surface for Fort Randall Dam to Niobrara.

c. **Sustained High Stages.** Daily average discharges of 45,000 cfs or greater are expected to occur 20 percent of the time during the open-water season.

d. **Sediment Characteristics.** The sediment characteristics of the Ft. Randall Dam to Lewis and Clark Lake reach are typical of a reach in a state of degradation in which the upstream reservoir traps virtually all incoming sediment load. Sediment load in the downstream reach consists of bed material load derived from the river bed, and bed material and wash load derived from eroded river banks and tributary inflows. The estimated average annual sediment load through the reach ranges from 0 at the dam to 1,927,000 tons per year at the Niobrara River where an additional 2,328,000 tons per year is being contributed to the reach from the Niobrara River. Since a sediment measurement station is not available for this part of the Missouri River, the variation in annual sediment load is not known, nor is the percent of sand, silt, and clay contribution; however, the contribution is believed to be about 30% silt and clay and 70% sand. Over the first 3 miles below the dam the channel bed is armored with a layer of relatively nonmovable coarse sands, gravels and cobbles. From there, downstream, the bed surface is composed of coarse to fine grained sediments with the D50 grain sizes averaging about 1.3 mm at the upstream end of the reach and decreasing exponentially to a value of 0.25 mm forty miles downstream.

e. **Degradation.** Degradation in the reach, since the closure of Ft. Randall Dam, ranges from about 5 feet in the tailwater area immediately below the dam to less than 1 foot at the Greenwood Gage 15 miles downstream. The average annual rate of degradation immediately below the dam is about 0.27 ft per year.

f. **Slope.** The slope of the energy grade line averages approximately 0.5 feet per mile over the reach from Ft. Randall Dam to Niobrara and varies from 0.35 feet per mile to 0.6 feet per mile as shown on Plate O-4. Since the velocity head is usually small and the discharges fairly uniform over a given time, the slopes of the water surface and the energy grade line are nearly equal. The slope at the Sunshine Bottom Area is 0.46 feet per mile and the slope at the White Swan Area is 0.45 feet per mile.

g. **Streambank Erosion Rates.** Aerial photographic surveys for different years have been analyzed to obtain estimates of valley lands lost due to bank erosion. Table 2-1 shows the erosion losses at the Sunshine Bottom and White Swan Areas. Table 2-1 shows the average erosion rate losses along the entire reach and Table 2-3 shows the high bank erosion loss for the 1953 to 1975 period correlated to distances downstream from Ft. Randall Dam. The erosion along this reach is not limited to the highbank areas. Islands and vegetated bar areas are also lost rapidly. Like the high banks, the higher island areas cannot be recreated naturally. Although new vegetated bars are developing, it appears that the rate of higher vegetated bar/island destruction exceeds the rate of formation. Bank erosion in the 36.3 mile reach below the dam varies substantially from location to location, but tends to average about 0.83 acres per river mile per year.

Table 2-1

High Bank Erosion Rates by Project Area

Area	Bank	Period	Total Erosion Loss (acres)	Erosion Rate (acres/mile/year)
Sunshine Bottom	Right	1976-1978	4.5	1.9
White Swan	Left	1974-1978	4.13	0.29

FIGURE 2-1

AVERAGE LOSSES

FORT RANDALL DAM
to
NIOBRARA, NEBRASKA

(1953-1975)

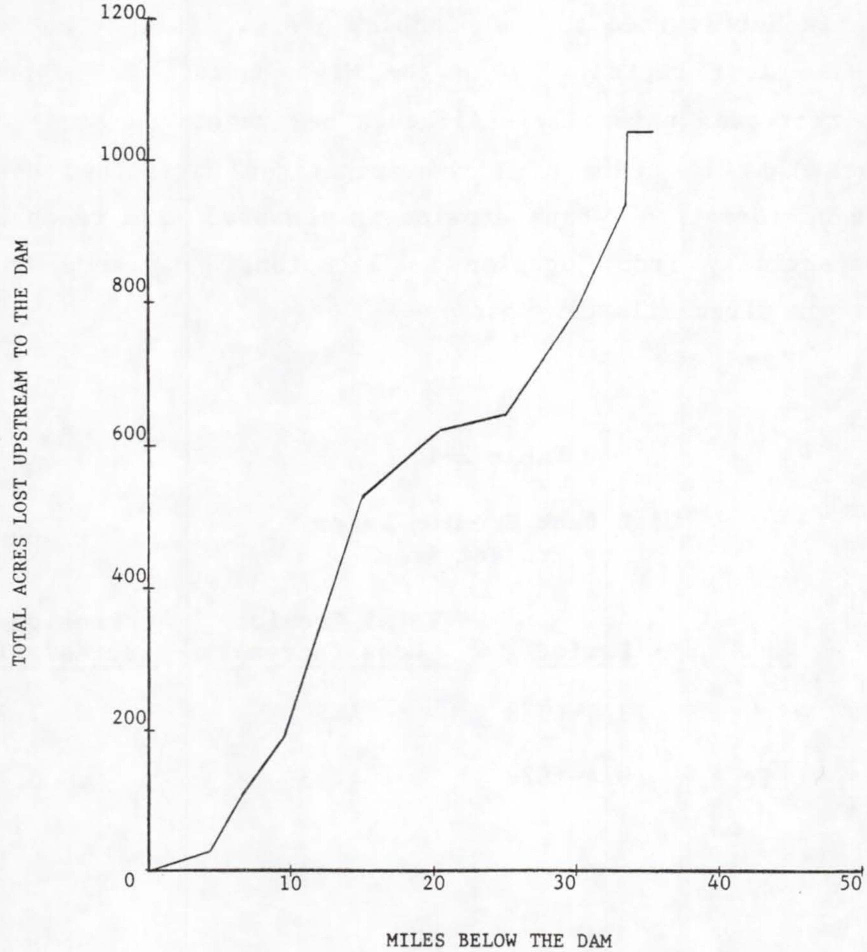


Table 2-2
FORT RANDALL DAM TO NIOBRARA BANK EROSION

SUMMATION OF EROSION LOSSES

		Left Bank			Right Bank		
Period	**Time (Yr)**	**Erodible Bankline (Mi)**	**Total Loss (Ac)**	**Average Erosion Losses (Ac/yr)**	**Erodible Bankline (Mi)**	**Total Loss (Ac)**	**Average Erosion Losses (Ac/yr)**
Apr 1953 - May 1956	3.1	31.8	79.0	25.5	24.4	167.1	53.9
Jun 1956 - May 1961	5.0	31.8	123.0	24.6	24.4	167.1	33.4
Jun 1961 - May 1966	5.0	31.8	148.7	29.7	24.4	81.7	16.4
Jun 1966 - Aug 1969	3.3	31.8	75.2	22.8	24.4	52.3	15.8
Sep 1969 - Jun 1974	4.8	31.8	64.3	13.4	24.4	45.8	9.7
Jul 1974 - Aug 1975	1.1	31.8	35.8	32.6	24.4	16.5	15.0
Aug 1975 - Oct 1976	1.2	31.8	21.1	17.6	24.4	26.7	22.3
Apr 1953 - Oct 1976	23.5	31.8	546.4	23.3	24.4	557.2	23.7

Total Reach Length = 36.3 miles. Left bank bluff contact = 4.5 miles. Right bank bluff contact = 11.9 miles.

Table 2-3

Variation in Erosion Loss with Distance Downstream from Dam
Fort Randall Dam to Niobrara (1953-1975)

Miles Below Dam	Existing Power Peaking Fluctuations (ft)	Erosion Loss 1953-1975 (acres/mile)
0 - 10	11.0 - 6.7	17.4
10 - 20	6.7 - 5.4	41.9
20 - 30	5.4 - 3.2	19.4
30 - 36	3.2 - 2.5	24.7

III - DESIGN AND CONSTRUCTION

A. GENERAL.

In keeping with the Streambank Erosion Control Evaluation and Demonstration Act of 1974, the salient feature of each demonstration project was the control of streambank erosion by employing river management techniques using a variety of structural bank protection measures in combinations appropriate for local river conditions. Typical structural elements considered for each test reach were revetments, earth core dikes, and artificial hardpoints, each discussed in detail in paragraph B of this section. The general design considerations investigated for each demonstration site are delineated below. Critical technical factors affecting structural design and stability were bed-scour at the toe of the bank, weathering in the zone of stage variation, and ice action. Because of the control imposed by the Ft. Randall Dam in this reach, it was unlikely that the protection works would be damaged by frequent flooding. The river stages remained below the top of existing high banks and varied between well defined limits.

1. **FIELD CONDITIONS.** Field conditions are physical conditions which must be delineated and evaluated to permit development of structural designs that are equally functional, constructible, and environmentally acceptable. The following is a list of field conditions evaluated at each site.

- Channel location and alignment (main and secondary)
- Channel geometry (cross-section)
- Bar/island formation (location, orientation, elevation, material)
- Near-bank flow conditions (depth, velocity)
- Bank heights, configuration and materials
- High bank land use
- Riverbed and bank material types and conditions
- Stage-duration relationships (average daily and long-term probability)

- Tributary streams and surface runoff locations
- Ground water seepage
- Potential wave erosion
- Existing erosion controls (natural, manmade)
- Degradation projections

2. **CONSTRUCTIBILITY FACTORS.** Constructibility factors are those practical factors relative to actual construction materials, operations, and techniques which must be considered to assure optimum project economics and to minimize potential environmental impacts.

a. Material sources (stone, earth, cobbles, gravel)

- Quality
- Quantity available
- Location from project (haul distance)
- Cost, at source (royalties, quarrying, gathering)

b. Land access to structural locations

- Haul road location and conditions
- Near bank-conditions (height, soils, vegetation)
- Mobilization and materials handling sites

c. River Access (floating plant construction)

- River depths along project bankline
- Near-bank conditions
- Mobilization and material handling sites
- River depths, distance, and alignment from project site to potential mobilization and material handling sites

3. **ENGINEERING OBJECTIVES.** Engineering objectives are those goals established to provide perspective and scope to individual project formulation and design.

- Least-cost, multipurpose problem solutions
- Materials
- Construction techniques
- Structure type, location, and orientation
- Minimize potential future maintenance costs

4. **ENVIRONMENTAL OBJECTIVES.** These are environmental considerations taken into account in the formulation and general design of individual projects.

- Minimize woodland clearing or the disturbance of any other sensitive or unique habitat
- Protect important or critical habitat
- Avoid disturbance of endangered fish and wildlife species during construction
- Create desirable aquatic habitat with structure configuration or various types of structure materials
- Consider structure designs that improve pedestrian and wildlife access to the water's edge
- Preserve the natural appearance and aesthetics of the waterway; conceal structures with topsoil and native vegetation; low profile structures are generally less noticeable
- Avoid destruction of or protect cultural resources as appropriate.

B. BASIS OF DESIGN FOR EACH TYPE OF PROTECTION.

Typical bank protection schemes considered for demonstration sites in the Ft. Randall to Niobrara reach of the Missouri River are shown on Plates 0-6, 0-7 and 0-8 and discussed in the following paragraphs.

The range of stone application rates along with the average tons per linear foot by structure type for the Fort Randall to Niobrara reach are shown in Table 2-4.

Table 2-4

Structure Type	Application Range (Tons/Linear Foot)	Avg. Application Rate (Tons/Linear Foot)
Reinforced Revetment	5.1 - 5.3	5.2
Composite Revetment	4.4 - 4.5	4.43
Windrow Revetment	3.5 - 4.5	4.0
Windrow Refusal	4.8 - 7.1	5.9
Hardpoints	6.0 - 6.8	6.4

1. **REVETMENT.** Revetments consist of a facing of stone or other material placed adjacent and parallel to the bankline to protect against erosion. These structures are generally utilized where river flows are concentrated along the bank and where depths, bankline configuration or bankline conditions preclude the use of other methods. Typical demonstration structure layouts intentionally leave 200 feet to 1,000 feet of unprotected bank between structure segments. The extent of interstructure erosion is limited by the prevailing water depth and velocity riverward of the structure alignment (the theoretical line connecting the riverward extremity of all the structures in the system); the bank height and composition; and the structure spacing. As the river erodes into the bank, the flow path becomes longer since the water entering the erosion "bight" must return to the original bank location at the next downstream structure. Accordingly, the energy gradient becomes proportionally less as the size of the bight grows. Thus, at a given river stage (discharge) the bight ceases to grow when the energy gradient is no longer sufficient to remove material from the bank. The resulting configuration and cross section of the "stable" bank will remain stable as long as extended duration flows do not exceed the flow level which created that configuration.

Revetments in this river reach have three distinct zones in which stresses differ and accordingly, the material requirements can be varied. The toe zone is that portion of the structure below normal low-water, subject only to river current erosion. Material in this zone must be of sufficient size and quality to resist the erosive force of the river velocities continually flowing over it; and it must be of sufficient gradation and quantity to form a reasonably dense blanket over the slope, down to the depth of anticipated maximum scour. This material is seldom exposed to freeze-thaw or wet-dry action, or ice and debris movement. Accordingly, material of relatively inferior mechanical properties (weak, brittle, soft, etc.) should function adequately in this zone, if of sufficient size to resist movement by the flow.

The splash zone is that portion between the normal high-water and normal low-water. This is the zone of highest stress. The material is frequently exposed to wet-dry and freeze-thaw cycles, to ice and debris movement, wave-wash, and erosive river currents. These stresses will generally require high quality stone; however, some combination of gravel, clay, filter cloth, etc., may be functional here.

The bank zone is that portion above normal high-water. Material in this zone is continually exposed to weathering, and periodically exposed to high stage erosion, wave-wash, ice and debris, and traffic by animals or man. It appears that a tough vegetation cover on a graded bank would be an optimum solution. However, types of vegetation and the minimum degree of grading to provide a durable, low-maintenance solution need development. In some cases, a stronger treatment may be necessary, such as gravel, clay, soil cement, etc. General revetment applications include variations of three basic designs, as field conditions, environmental, and cultural consideration dictate.

a. **Windrow Revetment.** The Windrow Revetment structure, shown on Plate 0-8, consists of a mound of stone placed either on the overbank, or partially or totally buried, immediately adjacent and parallel to the general alignment of the eroding bankline. In theory, a minimum windrow is placed first and then as the bank erodes, the stone sloughs and blankets the new bank at a naturally established slope. Then stone material is added on an as-needed basis until equilibrium (i.e., a stable bank) is established. This provides a structure containing the least possible amount of stone, and accordingly, the least cost for a revetment-type structure. Variable factors that require evaluation include stone gradation, mound size and shape, minimum initial application rate, size and shape of the excavated trench, and structural segment lengths and spacing. The Windrow Revetment is an excellent technique in areas where river flows are unusually deep and swift along the toe of the bankline. This technique avoids the excessive quantity of material needed to construct a fill within the water area in such situations. However, the presence of improvements or heavy timber usually necessitates substitution of alternate techniques in areas otherwise suited to windrow revetment.

b. **Composite Revetment.** The Composite Revetment structure, shown on Plate 0-6, is used where flows are concentrated along the bankline, but where depths or curvature preclude hardpoint systems and bankline or environmental conditions preclude windrow revetment. Composite revetment consists of a toe of erosion-resistant material, a splash zone treatment covering the area of normal seasonal fluctuations, and a freeboard zone that is generally vegetated. Toe crown elevations are normally placed at the estimated low water elevations to reduce exposure to freeze-thaw and wet-dry cycles and thus permit the use of relatively low quality erosion-resistant material in the toe. Toe material is generally placed on the natural riverbed; however, minor excavation is accomplished whenever necessary to provide an adequate structural section. The upper bank treatment generally includes erosion resistant material placed in the configuration to best satisfy aesthetic, environmental, and economic criteria.

c. **Reinforced Revetment.** The Reinforced Revetment structure, shown on Plate 0-7, consists of a toe of erosion-resistant material placed somewhat riverward of the bankline. The toe is then reinforced by intermittent stone-filled tiebacks, which are placed on the riverbank or in an excavated trench and extend landward from the toe to or into the riverbank. The toe fill material may either be high quality stone, low grade material, or both. The fill material used in the tieback is generally stone. The toe material is placed on the riverbed generally parallel to the natural bankline. The toe fill crown is generally constructed to the normal water surface elevation but may be lower. The stone tiebacks slope upward from the crown of the toe to several feet above the normal water surface elevation at the existing bankline. Between tiebacks, the upper bank may be graded to fill in the voids between tiebacks, the bank, and the toe. The upper bank surfaces of the reinforced revetment may be generally covered with either gravel or topsoil and seeded to satisfy aesthetic and environmental considerations.

2. **HARDPOINTS.** The Hardpoint structure, shown on Plate 0-8, are used when possible in lieu of revetment systems as a more economical measure and also to develop diversity in the aquatic and near-bank environment. They are best utilized along relatively long, convex-shaped or straight bankline increments having water depths of 5 to 10 feet. A hardpoint consists of two components: a short spur 30 to 50 feet long of erosion resistant material extending from the bank into the river; and a root of erosion-resistant material 30 to 50 feet long placed in a trench excavated landward from the bankline. The upstreammost hardpoint in multi-hardpoint systems may be of heavier section than the "shaded" downstream hardpoints. The crown width of the spur varies up to 10 feet maximum and is generally inversely proportional to water depth. This width may also reflect maintenance and access considerations. The crown elevation is generally at the normal water surface at the riverward end, and slopes up to varying elevations at the bankline, depending on bank height and root type. There are two basic root types; a deep "V" trench excavation for high banks and a wide, shallow trench for low banks. Spurs are angled 10°-20° downstream of the normal to the bankline and are designed to provide an adequate amount of material to withstand anticipated scour conditions.

3. **WINDROW REFUSAL.** A windrow refusal, shown on Plate 1-3, is usually constructed at the upstream end of each revetment segment to prevent flanking of the revetment as the interstructure bight develops and flow concentrations return to the original bank location. Each refusal generally consists of erosion-resistant material placed in a trench varying from 30 to 100 feet which is excavated landward from the bankline. Refusals are usually angled 10°-20° downstream of the normal to the bankline, depending upon local bankline conditions.

4. **SPECIAL CONTRACT PROVISIONS.** Bidding schedules, plans, and specifications advertised for each demonstration project contained options for allowing the bidder to utilize low grade material in all structures specified on the construction schedule as "Stone or Low Grade Material" or to utilize all high quality stone in these structures. The low bid for utilization of stone and low grade material was accepted unless the low bid for utilization of all stone did not exceed the stone and low grade material low bid by a predetermined percentage. This percentage was based on District bid experience for similar contracts and an engineering determination of the premium worth of construction utilizing high quality materials exclusively, and varied from contract to contract.

Stone, as specified for the contracts in this reach, was defined as durable material meeting specified acceptability levels based on service records and laboratory tests, such as petrographic analysis, specific gravity, absorption, wetting and drying, soundness in magnesium sulfate, and freezing and thawing. Gradations were determined by field conditions or experimental considerations. Neither the breadth nor the thickness of any piece of stone shall be less than one-third of its length. Stone shall be reasonably well-graded from coarse to fine. Dirt and fines of less than 1/2-inch maximum cross-section, accumulated from interledge layers or from blasting or handling operations shall not exceed 5 percent by weight. Acceptance testing of field boulders for compliance with quality requirements was not required.

Low grade materials, such as softer sandstones, limestone or chalk, were suitable for utilization to provide the bulk necessary in the toe of revetments and the core of hardpoints, provided laboratory testing, field tests, and service records demonstrated minimum acceptability within the specifications. Low grade material was specified only by minimum specific gravity, a maximum allowable absorption and loss after a reasonable period of immersion, a liberal gradation range, and a requirement that it be obtained from the source and placed in the structure without excessive deterioration or mechanical breakdown.

Gravels, cobbles and spalls used to provide an upper bank treatment are specified as tough, durable particles reasonably free from flat, thin and elongated pieces, and containing no objectionable quantities of soft, friable materials or organic matter. Gradation limits may be liberal to promote trial of locally available material and possibly material from the channel bed in the vicinity of the structures utilizing gravel. Gradations specified at each demonstration site in this reach are discussed in Section III-C.

C. CONSTRUCTION DETAILS AT EACH DEMONSTRATION PROJECT.

1. **WHITE SWAN PROJECT AREA**. The general plan for this project is shown on Plate 1-1. The project area consists of approximately 1.3 miles of bankline protected by three segments of windrow revetment totalling 1,600 linear feet, one segment of composite revetment totalling 500 linear feet, three segments of reinforced revetment totalling 1,000 linear feet, one system of 11 hardpoints at various spacings, and seven windrow refusals totalling 400 feet. Typical sections of the structure types used in this project are shown on Plates 1-2 and 1-3. Mandatory floating plant was not required for this project; therefore, the successful low bidder accomplished all work with land-based equipment. Low grade material did not display sufficient economic advantage as a bid item for this contract; all structures in this project were constructed of durable stone.

The project area can be divided into three distinct zones. Zone A, bounded by Refusal 870.01 and Revetment 870.0, Station 6+00, is characterized by moderately high banks contiguous to a back chute area of emergent sandbars dissected by small, shallow channels. Zone B, extending from Revetment 870.0, Station 6+00, to Hardpoint 869.1, is delineated by high, steep banks adjacent to the primary river channel. Zone C, the remaining downstream portion of the project area, includes lower banks adjoining a shallow secondary channel with a few nearly emergent reefs. All of Zone A and the upstream half of Zone B landward of the riverbank are pasture lands with well-spaced, mature trees and minimal understory. The downstream half of Zone B and the upstream half of Zone C are heavily timbered, with trees ranging in diameter from 4 to 10 inches. The downstream half of Zone C is lower, recent accretion land considered good wildlife habitat. The project area is displayed in Photos 1 through 8.

Erosion losses along the left bank at the White Swan project area were analyzed using two independent methods. Planimetric measurement of bankline changes as depicted on comparative aerial photographs for 1974 and 1978 indicated an average erosion loss of 0.29 acres/mile/year. Analysis of Corps of Engineers sediment range data for the years 1952 through 1976 yielded an erosion rate of 3.34 acres per mile per year. These analyses indicated that the entire project area bankline had, at one time or another, experienced severe erosion, and that erosion had been chronic since at least 1952 and is unlikely to cease in the foreseeable future. Erosion in Zone A is not presently a problem, since the flows along the bankline are shallow. However, the long-term integrity of the entire project is dependent upon the stability of this zone.

The primary channel now impinges against the project bankline at the downstream end of Zone A (see Plate 1-1), but flow patterns indicate that this point of critical attack may move upstream in the future. This will cause severe pressure on the point of land formed by the main channel and the back chute. Further, the back chute could quite possibly become a large, secondary channel in the future, particularly in view of the potential for avulsions caused by ice jams upstream from the project area. If either of the above-discussed channel changes occur, the present bankline alignment in Zone A would be highly undesirable. Consequently, the project design includes a buried windrow revetment placed along an alignment designed to stablize future entrance conditions into the project area as the windrow becomes functional.

Zone B encompasses that portion of the project bankline which experienced severe erosion. Bank protection methods considered for this zone were limited to revetments because of the deep primary channel flows immediately adjacent to steep high banks. Interstructure gap lengths throughout this zone were optimized to decrease the probability of rehabilitative construction. Two segments of windrow revetment were designed for the upstream portion of Zone B and since the banks are nearly vertical, the channel is immediately against the bank toe, and the near-bank area contains only scattered timber. A section of composite revetment was constructed downstream of the windrow, where field conditions are similar, except that considerable timber would have to be cleared for either a windrow or reinforced revetment. Downstream of the composite revetment, the heavier timber continues; but the banks are less steep and a moderate bench exists between the bank toe and the deep channel. Two reinforced revetment segments were constructed in this area. The construction was conducted largely along the bench, thus avoiding intensive clearing on the high banks. Near the downstream extremity of Zone B, the main channel leaves the left bank. Two closely spaced hardpoints were designed to protect the bankline and irrigation intake site. Both structures are located near an existing trail, thus little clearing was required. These two structures are the initial increment in a series of 10 hardpoints which extend approximately 1,900 feet into Zone C.

Zone C is the lowest priority area along the project bankline. Relative to the other zones, the banks adjacent to the river are generally lower, the soil sandier, and the vegetation less mature. The shallow, secondary channel flows caused intermittent moderate erosion in this zone, except at the very downstream end, where erosion was severe. These conditions were all favorable for hardpoint structures. The erosion between hardpoints does not cause any significant damage to the higher quality bottomlands lying somewhat landward of the present bankline. The series of eight hardpoints economically protects most of this zone and affords an excellent opportunity to quantify erosion between structures. A segment of reinforced revetment was designed at the downstream end of Zone C because of the bankline curvature and deeper river flow conditions. This structure helps assure long-term project integrity by permanently stabilizing the present overall alignment.

Table 2-5 displays the small and large stone and gravel gradations. The smaller stone gradations were used for upper composite revetment toes, reinforced revetment tiebacks, windrow revetment and refusals, and hardpoint upper paving fill and roots. The larger stone gradations were used for the lower composite revetment toes, reinforced revetment toes, and hardpoint cores.

Stone application rates in average tons per linear foot by structure type for this project site are as follows:

Reinforced Revetment	5.3
Composite Revetment	4.5
Windrow Revetment	4.0
Windrow Refusal	6.0
Hardpoints	6.0

Table 2-5
WHITE SWAN PROJECT AREA

STONE AND GRAVEL GRADATIONS

Small Stone Gradation

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
	Gradation A (3.5 T/LF Application Rate)
130 pounds	100
35 pounds	35-60
2-inch screen	0-15
	Gradation B (4.5 T/LF Application Rate)
200 pounds	100
50 pounds	35-60
2-inch screen	0-15

Large Stone Gradation

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 pounds	100
165 pounds	35-60
3-inch screen	0-15

Gravel Gradation

Seive Size	Percent Passing
3"	30-100
1-1/2"	55-80
3/4"	30-55
3/8"	15-35
#4	0-10

Gradation A was utilized on an experimental basis in Revetment 870.0, windrow revetment, stations 3+00 to 6+00 and stations 15+50 to 20+50. This was the first use of windrow revetment in the Fort Randall Dam to Niobrara reach. Reinforced revetment was constructed using several tieback spacing and elevation combinations. Some of the interstructural, landward cells were backfilled and others were left open. In addition, the upstream-most reinforced revetment segment was terminated in a Type II hardpoint, which is of greater section than a typical tieback and extends riverward of the revetment toe. Hardpoints (Type I) were arranged in a pattern designed to provide a good basis for developing a quantitative prototype relationship between hardpoint spacing and the erosion occurring between hardpoints. Composite revetment was constructed using two different configurations which vary the toe crown elevation with respect to NWS (See Typical Sections). A complete construction schedule is shown on Table 2-6 and the bid schedule is shown on Table 2-7.

Quality requirements specified in the contract include bulk specific gravity, soundness in magnesium sulfate, and soundness in freezing and thawing. Method CRD-C 107-69 for bulk specific gravity, saturated surface-dry basis, required not less than 2.35. Soundness in magnesium sulfate, ASTM Standard C88-76, required not more than 12 percent loss at 12 cycles. Modified AASHTO Designation T103-78, soundness in freezing and thawing method for riprap rock, required not more than 10 percent loss in 12 cycles.

Revetment 868.62 was extended downstream with 100 feet of composite revetment by the Contracting Officer's Representative in the field to provide additional protection to the project bankline located farthest downstream. Concentrated flows increased the erosion activity in this area since the contract award.

No significant long-term detrimental environmental impacts are anticipated as a direct result of construction of this demonstration project.

Table 2-6
CONSTRUCTION SCHEDULE

WHITE SWAN AREA

STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	NWS ELEV.	ESTIMATED QUANTITIES STONE (TONS)	GRAVEL (TONS)	EXCAVATION (C.Y.)
Ref. 870.01	L	75'	0+95 to 1+70	Windrow Refusal	1231.2	450	---	350
Rev. 870.0	L	300'	0+00 to 3+00	Windrow Revetment Type B, Gradation B	1231.2	1,350	---	1,200
	L	300'	3+00 to 6+00	Windrow Revetment Type C, Gradation A	----	1,050	---	950
	L	500'	8+00 to 13+00	Windrow Revetment Type A, Gradation B	1231.15	2,250	---	3,000
	L	500'	15+50 to 20+50	Windrow Revetment Type A, Gradation A	1231.07	1,750	---	3,000
Ref. 869.87	L	50'	2+40 to 2+90	Windrow Refusal	1231.15	300	---	225
Ref. 869.73	L	50'	1+70 to 2+20	Windrow Refusal	1231.07	300	---	225
Ref. 869.58	L	50'	1+90 to 2+40	Windrow Refusal	1231.07	300	---	225
Rev. 869.57	L	250'	0+00 to 2+50	Composite Revetment Type F	1231.01	1,125	150	---
	L	250'	2+50 to 5+00	Composite Revetment Type E	----	1,125	150	---
Ref. 869.31	L	50'	2+80 to 3+30	Windrow Refusal	1230.9	300	---	225
Rev. 869.3	L	250'	0+00 to 2+50	Reinforced Revetment Type IV (Tieback internal at 100') 4/ Open Cells	1230.9	2,325	150	750
	L	250'	4+50 to 7+00	Reinforced Revetment Type IV (Tieback internal at 100') 3/ Open Cells	1230.88	2,325	150	750

Table 2-6 (cont.)
CONSTRUCTION SCHEDULE

WHITE SWAN AREA

STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	NWS ELEV.	STONE (TONS)	GRAVEL (TONS)	EXCAVATION (C.Y.)
						ESTIMATED QUANTITIES		
HP 869.24	L	52'	3+90 to 4+42	Hardpoint, Type II	1230.86	375	30	---
Ref. 869.2	L	50'	3+50 to 4+00	Windrow Refusal	1230.86	300	---	225
HP 869.12	L	50'	2+60 to 3+10	Stone Root, Type A 1/	1230.81	225	---	300
	L	50'	3+10 to 3+60	Hardpoint, Type I 2/	----	375	30	---
HP 869.1	L	50'	2+10 to 2+60	Stone Root, Type A 1/	1230.8	375	---	300
	L	50'	2+60 to 3+10	Hardpoint, Type I 2/	----	125	30	---
HP 869.0	L	50'	1+90 to 2+40	Stone Root, Type A 1/	1230.76	225	---	300
	L	50'	2+40 to 2+90	Hardpoint, Type A 2/	----	375	30	---
HP 868.96	L	50'	1+70 to 2+20	Stone Root, Type A 1/	1230.74	225	---	300
	L	50'	2+20 to 2+70	Hardpoint, Type I 2/	----	375	30	---
HP 868.92	L	50'	1+70 to 2+20	Stone Root, Type A 1/	1230.72	225	---	300
	L	50'	2+20 to 2+70	Hardpoint, Type I 2/	----	375	30	---
HP 868.88	L	50'	1+50 to 2+00	Stone Root, Type A 1/	1230.7	225	---	300
	L	50'	2+00 to 2+50	Hardpoint, Type I 2/	----	375	30	---

Table 2-6 (cont.)
CONSTRUCTION SCHEDULE

WHITE SWAN AREA

STRUCTURE	BANK	LENGTH (FEET)	STATION TO STATION	DESCRIPTION	NWS ELEV.	ESTIMATED QUANTITIES STONE (TONS)	GRAVEL (TONS)	EXCAVATION (C.Y.)
HP 868.81	L	50'	1+65 to 2+15	Stone Root, Type A 1/	1230.68	225	---	300
	L	50'	2+15 to 2+65	Hardpoint, Type I 2/	----	375	30	---
HP 868.76	L	50'	2+00 to 2+50	Stone Root, Type A 1/	1230.65	225	---	300
	L	50'	2+50 to 3+00	Hardpoint, Type I 2/	----	375	30	---
HP 868.71	L	50'	1+90 to 2+40	Stone Root, Type A 1/	1230.63	375	---	300
	L	50'	2+40 to 2+90	Hardpoint, Type A 2/	----	125	30	---
HP 868.66	L	50'	1+65 to 2+15	Stone Root, Type A 1/	1230.6	225	---	300
	L	50'	2+15 to 2+65	Hardpoint, Type I 2/	----	375	30	---
Ref. 868.63	L	75'	1+15 to 1+90	Windrow Refusal	1230.58	450	---	350
Rev. 868.62	L	400'	0+00 to 4+00	Reinforced Revetment Type VI (Tieback internal at 100' 5/	1230.58	2,125	240	1,200
				TOTALS		20,200	1,170	15,675

1/ Root Elevation - 2 feet below existing ground elecation at landward end of root.
2/ Hard Point Elevation - NWS+3.0, Hardpoint Crown Width 5.0'.
3/ On this reference revetment segment no tieback is constructed at the downstream end of the structure, and the middle cell will be left open.
4/ On this reinforced revetment segment a Hardpoint Type II is constructed in lieu of a tieback at the downstream end of the structure, and the two most downstream cells will be left open.
5/ On this revetment segment, the two middle cells are left open.

Table 2-7

BID SCHEDULE
WHITE SWAN AREA

	QUANTITY	UNIT	UNIT PRICE	ESTIMATED AMOUNT
STONE	22,200	TON	$12.90	286,380
GRAVEL	1,170	TON	14.50	16,965
EXCAVATION	15,675	CUBIC YARD	2.00	31,350
CLEARING AND GRUBBING		LUMP SUM		18,000
SEEDING		LUMP SUM		4,000
MONITORING AND DOCUMENTATION				
a. Photography		LUMP SUM		1,000
b. Cross Sections		LUMP SUM		8,000
		TOTAL COST		$365,695

PHOTO 1. 200 LB. GRADATION STONE
(Photo Taken September 1980)

PHOTO 2. 500 LB. GRADATION STONE
(Photo Taken September 1980)

White Swan Area
Photos 1 and 2

PHOTO 3. TYPICAL SEVERE EROSION CONDITIONS ALONG UPSTREAM PORTION OF THE PROJECT AREA. (Photo Taken 15 April 1980)

PHOTO 4. TYPICAL SEVERE EROSION CONDITIONS ALONG THE DOWNSTREAM PORTION OF THE PROJECT AREA. THIS BANKLINE WILL CONTAIN HARDPOINTS. (Photo Taken 15 April 1980)

White Swan Area
Photos 3 and 4

PHOTO 5. **HARDPOINT 869.24, LOOKING UPSTREAM ALONG THE MIDDLE AND DOWNSTREAM PORTION OF THE PROJECT AREA.** (Photo Taken 6 April 1981)

PHOTO 6. **COMPOSITE REVETMENT 869.57, IMMEDIATELY AFTER COMPLETION.** (Photo Taken December 1980)

White Swan Area
Photos 5 and 6

PHOTO 7. SITE OF WINDROW REVETMENT 870.0, STATION 15+50 PRIOR TO CONSTRUCTION. (Photo Taken 19 September 1980)

PHOTO 8. WINDROW REVETMENT 870.0, STATION 15+50, IMMEDIATELY AFTER COMPLETION. (Photo Taken December 1980)

White Swan Area
Photos 7 and 8

2. **SUNSHINE BOTTOM PROJECT AREA.** The general plan for this project is shown on Plate 2-1. The demonstration area consists of approximately 2 miles of bankline protected by six segments of reinforced revetment totalling 3,000 linear feet; three segments of composite revetment totalling 1,860 linear feet; eight hardpoints in four systems of two each; and nine windrow refusals for a total of 550 linear feet. Typical sections of the structure types used in this project are shown on Plates 2-2 and 2-3.

All composite revetments constructed are Case II, which require excavation. The three reinforced revetment segments farthest upstream are Type I, while the remaining three revetment segments are Type II. All hardpoint roots are Type A sections. Reinforced revetment tiebacks are spaced at 100-foot intervals except Revetment 867.0, Stations 26+00 to 31+00, which has tieback intervals of 80 feet. In addition, a tieback was constructed at the terminus of each reinforced revetment segment. Mandatory floating plant was not required in this contract; therefore, the successful low bidder accomplished all construction by land plant. Low grade material did not display sufficient economic advantage as a bid item for this contract; therefore, all structures in this project were constructed of durable stone.

Stone application rates in average tons per linear foot by structure type for this project site are as follows:

Reinforced Revetment	5.2
Composite Revetment	4.4
Windrow Refusal	5.8
Hardpoints	6.8

Table 2-8 displays the specified small and large stone and gravel gradations.

The stone material used in the construction of this project was required to meet the following standards. Bulk specific gravity, saturated surface-dry basis Method CRD-C 107-69, required not less than 2.40. Soundness in magnesium sulfate, ASTM Standard C88-76, required a loss at 5 cycles of not more than 12%. Soundness in freezing and thawing, AASHTO designation T103-62, required a loss at 12 cycles not to exceed 10%.

Table 2-8

SUNSHINE BOTTOM PROPECT AREA

STONE AND GRAVEL GRADATIONS

Small Stone Gradation

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
200 lbs	100
50 lbs	35-60
2-in screen	0-15

Large Stone Gradation

Weight or Size Per Stone	Percent of Total Weight Lighter Than or Passing
500 lbs	100
165 lbs	35-60
3-in screen	0-15

Gravel Gradation

Sieve Size	Percent Passing
3"	90-100
1-1/2"	55-80
3/4"	30-55
3/8"	15-35
#4	0-10

Table 2-9 provides construction material unit prices for this project site while Table 2-10 provides a construction program which includes material quantities and costs by structure.

Photographs of representative erosion areas and structures during and after construction are shown in Photos 11 through 16.

The area bounded by the bluffs and project bankline contains approximately 582 acres, of which about 375 acres are in agricultural use and 207 acres are wooded natural habitat. About 75 percent of the linear length of the project bankline was wooded prior to construction. About 20 acres of habitat was lost as a result of project construction. Most of the loss was in revetment areas in order to provide haul roads and near-bank access for dragline equipment. Habitat was also cleared to establish terrestrial survey data hubs. Aquatic impacts during construction include a temporary increase in suspended solids load and sedimentation during construction. Long-term erosion protection results in a decrease in suspended solids and sedimentation problems. Fish habitat not previously available was created by hardpoint structures which produced a permanent scour hole at the tip of the structure two to six feet deeper than the riverbed. There is a slight potential for reducing the creation of new shallow water aquatic habitat, by preventing or reducing the erosion process; however, the destruction of terrestrial and riparian habitat is significantly prevented or reduced by structures.

Table 2-9
SUNSHINE BOTTOM CONSTRUCTION
MATERIAL UNIT PRICES

Description	Unit	Unit Price
Stone	Ton	$ 17.50
Gravel, Cobbles, and/or Spalls	Ton	8.80
Excavation	Cubic Yards	1.65
Clearing and Grubbing	Lump Sum	12,320.00
Seeding	Lump Sum	4,435.00

SUNSHINE BOTTOM CONSTRUCTION PROGRAM

TABLE 2-10

STRUCTURE NO.	TYPE*	TOTAL LENGTH	DATE STARTED	DATE ENDED	TOTAL STONE (TONS)	TOTAL GRAVEL (TONS)	TOTAL (CY) EXCAVATION	TOTAL COST	COST/FT OF STRUCTURE
867.75	WRF	50'	09/16/78	09/22/78	329	-----	552	$ 6,674	$133.48
867.9	WRF	75'	09/13/78	09/21/78	458	-----	352	8,599	114.65
868.01	WRF	115'	09/12/78	09/15/78	556	-----	462	10,496	91.27
868.0									
0+00 to 6+50	CR	650'	09/14/78	05/02/79	2,869	338	1,516	55,695	86.00
7+50 to 14+60	CR	720'	10/05/78	05/01/79	3,126	356	1,878	60,942	85.00
15+00 to 20+00	CR	500'	10/11/78	10/20/78	2,200	301	1,265	43,227	86.00
867.6	HP	75'	10/21/78	05/05/79	640	16	173	11,626	155.02
867.55	HP	80'	10/24/78	04/29/79	606	17	155	11,003	137.53
867.46	WRF	50'	10/26/78	10/26/78	356	-----	216	6,587	131.73
867.45	RR	500'	10/19/78	11/08/78	2,600	145	899	48,530	96.52
867.3	HP	100'	10/27/78	11/08/78	597	16	101	10,755	107.55
867.25	HP	100'	11/02/78	11/08/78	646	17	84	11,586	115.86
867.21	WRF	50'	11/04/78	11/04/78	308	-----	132	5,608	112.16
867.2	RR	500'	11/07/78	11/24/78	2,631	152	905	48,879	97.76
867.15	HP	100'	11/04/78	11/24/78	608	16	90	10,938	109.38
867.1	HP	90'	11/06/78	11/24/78	601	16	96	10,815	120.17
867.0									
0+00 to 5+00	RR	500'	11/16/78	04/22/79	2,578	151	935	47,986	96.00
16+00 to 22+00	RR	600'	11/16/78	04/23/79	3,075	256	3,613	62,021	103.00
26+00 to 31+00	RR	500'	11/19/78	04/24/79	2,560	1,857	2,578	50,919	102.00
33+00 to 37+00	RR	400'	12/07/78	04/25/79	2,075	180	2,472	41,966	105.00
867.0	RR	2,000'	11/16/78	04/25/79	10,287	798	9,598	202,894	101.45
866.9	HP	110'	04/24/79	04/30/79	740	33	72	13,359	121.45
866.8	HP	110'	04/19/79	04/25/79	790	31	72	14,217	129.25
866.7	WRF	60'	03/07/79	03/08/79	290	-----	372	5,525	92.08
866.55	WRF	50'	03/10/79	03/10/79	295	-----	370	5,773	115.45
866.45	WRF	50'	03/14/79	03/14/79	301	-----	176	5,557	111.15

Subtotal	$615,000
Clearing and Grubbing	12,000
Seeding	4,000
Monitoring	31,000
Supervision and Administration	37,000
Engineering and Design	27,000
TOTAL COST	$726,000

* WRF = Windrow Refusal; CR = Composite Revetment; HP = Hardpoint; RR = Reinforced Revetment

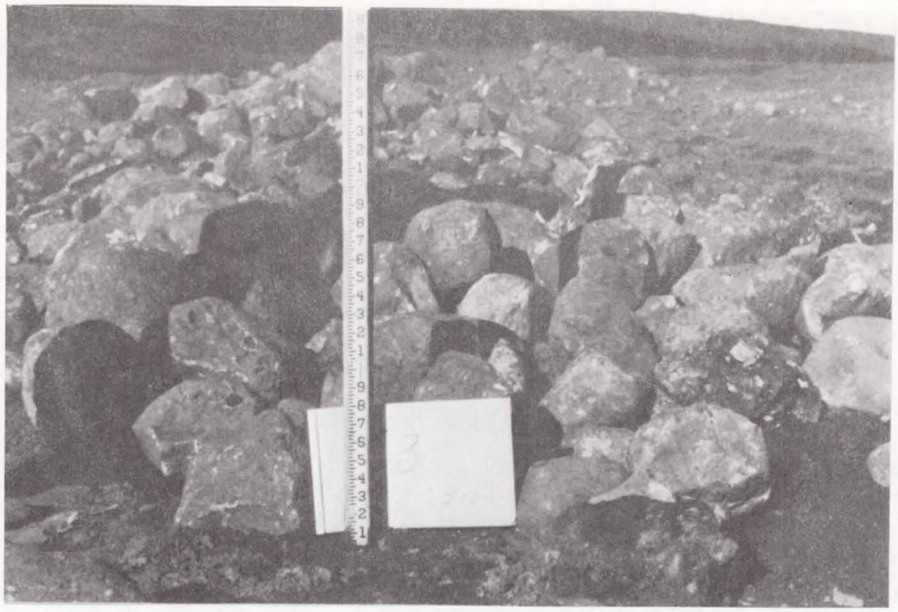


PHOTO 9. 200 LB. GRADATION TEST
(Photo Taken 19 April 1979)

PHOTO 10. 500 LB. GRADATION TEST
(Photo Taken 10 March 1979)

SUNSHINE BOTTOM PROJECT AREA
Photos 9 and 10

PHOTO 11. HARDPOINTS 866.9 AND 866.8, APPROXIMATELY 1 YEAR AFTER COMPLETION. (Photo Taken 15 April 1980)

PHOTO 12. REINFORCED REVETMENT 867.0, STA. 10+00, AFTER STONE TOE PLACEMENT AND PRIOR TO TIEBACK CONSTRUCTION. (Photo Taken 23 April 1979)

SUNSHINE BOTTOM PROJECT AREA
Photos 11 and 12

PHOTO 13. REINFORCED REVETMENT 867.0, STATION 10+00, IMMEDIATELY AFTER COMPLETION. (Photo Taken 12 April 1979)

PHOTO 14. REINFORCED REVETMENT 867.0, STA. 10+00, APPROXIMATELY 15 MONTHS AFTER COMPLETION. (Photo Taken August 1980)

PHOTO 15. REINFORCED REVETMENT 867.0, STATION 0+00, APPROXIMATELY 15 MONTHS AFTER COMPLETION. (Photo Taken August 1980)

PHOTO 16. COMPOSITE REVETMENT 868.0, STA. 17+00, APPROXIMATELY 11 MONTHS AFTER COMPLETION. (Photo Taken 15 April 1980)

SUNSHINE BOTTOM PROJECT AREA
Photos 15 and 16

D. CONTRACT AND MODIFICATION COSTS.

1. **White Swan Project Area.** This project was completed in the spring of 1981. Table 2-6 displays the project construction schedule and Table 2-7 displays the bid schedule which includes estimated material quantities and total initial contract bid costs.

2. **Sunshine Bottom Project Area.** Only one modification was made to the construction contract. This modification substituted HP 866.9 and HP 866.8 for a windrow refusal and reinforced revetment segment called for in the original plan. The modification resulted in a decrease of $12,043 in the contract cost. Total project construction costs were $631,000, and are shown by structure on table 2-9.

IV. PERFORMANCE OF PROTECTION

A. MONITORING PROGRAM.

The monitoring program for the Sunshine Bottom demonstration project was developed in November 1978, and the monitoring schedule for the White Swan project was developed in September 1980. The monitoring programs for both projects in this reach are composed of several common items, as follows: bankline location surveys; overbank/streambank cross sections; velocity measurements; controlled aerial photography; ground level photographs; and qualitative structural changes.

A lump sum bid item, "Monitoring and Documentation," was included in the construction contracts. This bid item consisted of two parts, cross sections and photography.

1. CROSS SECTIONS. Cross sections were obtained at the intervals described below for each structure type.

a. Hardpoints: Root sections, 25 feet or less (2 minimum) oriented perpendicular to the root alignment; and one following the structure alignment or centerline from the landward end of the root and extending riverward past the terminus of the hardpoint spur.

b. Reinforced Revetment: Two hundred feet or less oriented perpendicular to the structure alignment; and a minimum of one section at the upstream and downstream ends and the midpoint of any segment ordered on the construction schedule.

c. **Windrow Refusals:** One oriented along the refusal alignment.

d. **Composite Revetment:** Two hundred feet or less oriented perpendicular to the riverbank; and a minimum of one section at the upstream and downstream ends and the midpoint of any segment ordered on the construction schedule.

e. **Windrow Revetments:** Two hundred feet or less and a minimum of one section at the upstream and downstream ends and the midpoint of any segment ordered on the construction schedule. Each section shall be oriented perpendicular to the structure alignment.

f. **Interstructure Gaps:** Two hundred feet or less and a minimum of one section located at the midpoint of the gap.

Each cross section was monumented by the contractor to allow simple reestablishment of the cross section location to within 2 feet of its original position at any time within 5 years after construction has been completed. A recording sonic sounder which produced a continuous strip chart recording was required by the contract specifications to complete cross sections across water areas. A set of complete cross sections was taken prior to any construction activity. Partial or complete sections were obtained to accurately document the following construction activities.

- The lines and grades of all excavations immediately prior to placement of stone or other protective materials.

• The lines and grades immediately after placement of protective materials, including underwater portions of reinforced revetment and composite revetment toes, and hardpoint spurs.

• Lines and grades following backfilling and grading.

Additional cross sections were required at locations on either side of obvious topographic changes and on each end of transition zones between structure types.

2. **PHOTOGRAPHY.** Photography consisted of two different items: construction progress photographs and structure photographs. Black and white structure photographs of selected, representative structures consist of three photographs for each selected structure: one taken prior to construction work; one taken during construction; and one taken after construction is complete. Construction progress photographs, in color, conform to the following location and frequency criteria:

a. Material Acquisition Sites: Photographs were obtained of the rock and gravel when stockpiled for each gradation test at the quarry site and the job site. The field of view includes a 1-foot (minimum) interval of a rod, graduated to tenths-of-feet or smaller, for dimensional reference.

b. Reinforced Revetment: Photographs were obtained of the upstream end and at 500-foot intervals for each revetment segment longer than 1,000 feet. For revetment segments between 1,000 and 500 feet in length, photographs were obtained for the upstream end and at the midpoint of the segment. For revetment segments 500 feet or less in length, photographs were obtained at the upstream end. All photographs were oriented in the downstream direction.

The photographs were taken prior to any construction; prior to application of the bank zone treatments; and after structure completion. The same vantage point was used for each series of photos.

c. Composite Revetment: Photographs were obtained of the upstream end and at 500-foot intervals for each revetment segment longer than 1,000 feet. For revetment segments less than 1,000 feet in length, photographs were obtained for the upstream end and at the midpoint of the segment. All photographs were oriented in the downstream direction. The photographs shall be taken prior to any clearing, excavation, stone placement, and backfilling; then after backfilling and grading. The same vantage point was used for each series of photos.

d. Hardpoints: Photographs were obtained at each hardpoint location. The photographs include the bankline prior to construction; the completed structure, taken along the structure azimuth line; and the structure and downstream bankline, taken parallel to the bankline.

3. SITE SPECIFIC MONITORING.

a. The Sunshine Bottom Project has been monitored for 18 months since its completion in August 1979. A bankline location survey and overbank/streambank cross section measurements were taken in July 1978. Velocity measurements were taken in 1978 and 1980. Comparative velocity trends are shown on Plate 2-8. Cross sections were also taken by the contractor upon completion of each structure. The preconstruction bankline location for 1978 and the bankline location for 1980 are shown on Plate 2-1. Controlled aerial photography was taken in 1978 and 1980. Ground level photographs were taken and qualitative structural changes were noted during each field reconnaissance in the project vicinity.

b. The White Swan project area was completed in the spring, 1981, and cross sections are being taken by the contractor, as described above.

B. EVALUATION OF PROTECTION PERFORMANCE

1. **SUNSHINE BOTTOM AREA.** This project area was constructed of three basic types of structures, including composite revetment, reinforced revetment and hardpoints. The upstream 1/3 of the project bankline is stabilized with 3 segments of composite revetment. The remaining 2/3 of the project is composed of reinforced revetment segments and intermittent hardpoints along an relatively straight bankline.

a. Specific Observations. The composite revetment segments and reinforced revetment segments were incorrectly constructed with very irregular sloped stone toes which do not exactly follow the typical section. The rear bank channel conditions along the three segments of composite revetment located along the upstream 1/3 of the project have significantly changed since structure completion. Channel depths were reduced by more than 50% within 50 feet of the bankline and average velocities within 50 feet have been significantly reduced. This is caused by the most upstream structure system redirecting the main flows away from the previously eroding bankline. Each of the six reinforced revetment structures have functioned very well in eliminating the previous erosion conditions. Channel depths along the remaining 2/3 of the project length have not changed much since structure completion and remain approximately 5 to 10 feet. The underwater slope along the composite revetment and reinforced revetment in the project area became more uniform and much flatter. The hardpoints along the entire project have been very effective in redirecting the main flows away from the highly erodible bankline. Hardpoints 866.9 and 866.8 were constructed as L-heads due to channel depths of approximately 10 feet within 50 feet of the bankline. The bankline is generally protected by 600-foot revetment segments with gaps ranging from 40 feet to 400 feet. The percentage of actual protected bankline at this project site is approximately 70 percent, however, the entire project area is effectively stabilized, with no damage areas encountered.

b. Recommendations. In this area, the hardpoints, reinforced revetment and composite revetment structures demonstrated have all been very effective in eliminating erosion along this area. Construction of the reinforced revetment segments and hardpoints resulted in significant amounts of clearing which can be partially explained by the contractor undertaking more clearing than necessary. Even though the composite revetment and reinforced revetment segments did not follow the general bankline configuration very well, they have been effective. Recommendations on tieback spacing intervals cannot be made because the tieback spacings have not been adequately tested. The composite revetment structures were the simplest to construct and most effective in eliminating erosion. Also, since these structures are constructed entirely riverward of the highbank, they require the least amount of upper bank disturbance (clearing) to construct.

2. WHITE SWAN AREA. The contract for this project was not completed until Spring 1981. Therefore, the various structures constructed at this project site have not been functional for a sufficient time to evaluate their design and effectiveness. This project does contain a new, previously untested, hardpoint design (HARDPOINT - TYPE II), which is composed of only an approximate 50 foot hardpoint extending riverward from the bankline without a stone root constructed into the bank to protect the structure from landward erosion flanking. This structure is exemplified by Hardpoint 869.24. In addition, a series of 10 hardpoints were constructed at varying interval spacings (150 feet to 350 feet) which will provide an excellent demonstration of spacing effects on the structure erosion control capability. The reinforced revetments were constructed significantly different from previous reinforced revetment designs demonstrated. Several of the reinforced revetment segments were constructed using a stone toe placed slightly riverward of the bankline, without placing earth fill landward of the stone toe, thereby resulting in an open cell area between the tiebacks. In addition, the crown of the stone toe was variable from a horizontal elevation, two feet below normal water surface, to a sloping crown which began at the normal water surface elevation at the tieback and sloped to two feet below normal water surface at the next downstream tieback. The windrow revetment structures were constructed using an application range of 3.5 to 4.5 tons per linear foot of stone. To date, these segments of windrow revetment have not started the stone displacement process to form the lower bank erosion resistent layer.

C. GENERAL CONCLUSIONS FOR THE ENTIRE FT. RANDALL TO NIOBRARA REACH OF THE MISSOURI RIVER.

a. The only windrow revetment segments constructed in this reach are at the White Swan Area, and were completed in Spring 1981. The stone is just beginning to displace and has not yet reached a stable condition, therefore, conclusions cannot be made.

b. Reinforced revetment maximum toe crown elevations should be at two feet below normal water surface to allow effective utilization of stone tiebacks.

c. Conclusions on tieback spacing cannot be made at this time because the tiebacks, spaced at 100 feet, have not been adequately tested.

d. The composite revetment segments have been very effective in providing immediate erosion protection with the least amount of upper bank disturbance. Stone material application rate of 4.4 tons of stone per linear foot of bankline is an optimum rate for composite revetment structure stability for the normal conditions encountered in this reach.

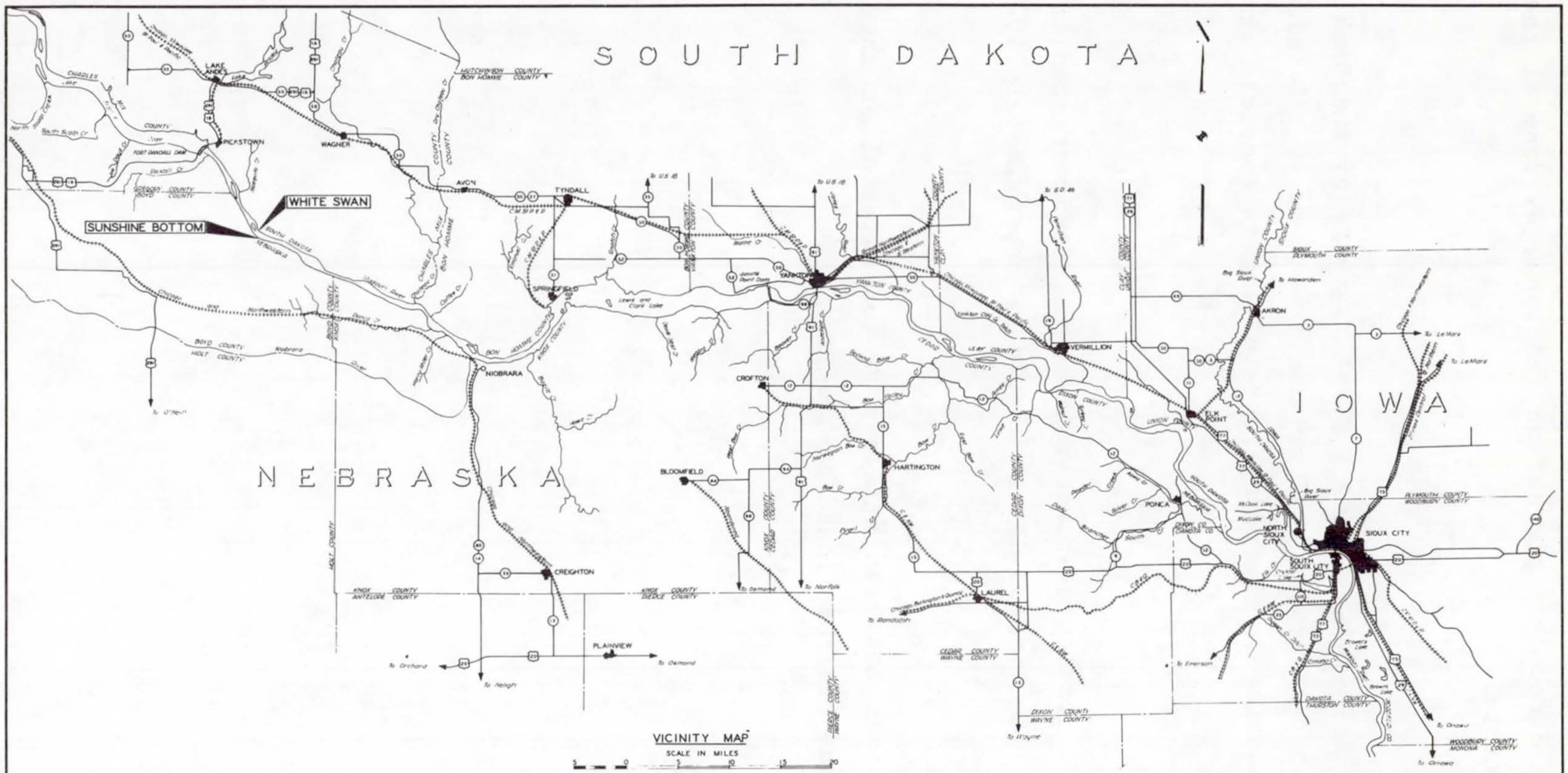
e. Hardpoints should be constructed along concave shaped banklines where the flows are not directly impingent on the bank, as done at the White Swan Area, shown on Plate 1-1.

f. Windrow refusals extending 50 to 75 feet landward of the bank should be constructed at the upstream end of each revetment segment to eliminate the possibility of flows flanking the structure, resulting in complete structure failure.

g. The length of a single revetment segment is dependent upon the specific site conditions. The minimum length should be approximately 400 feet.

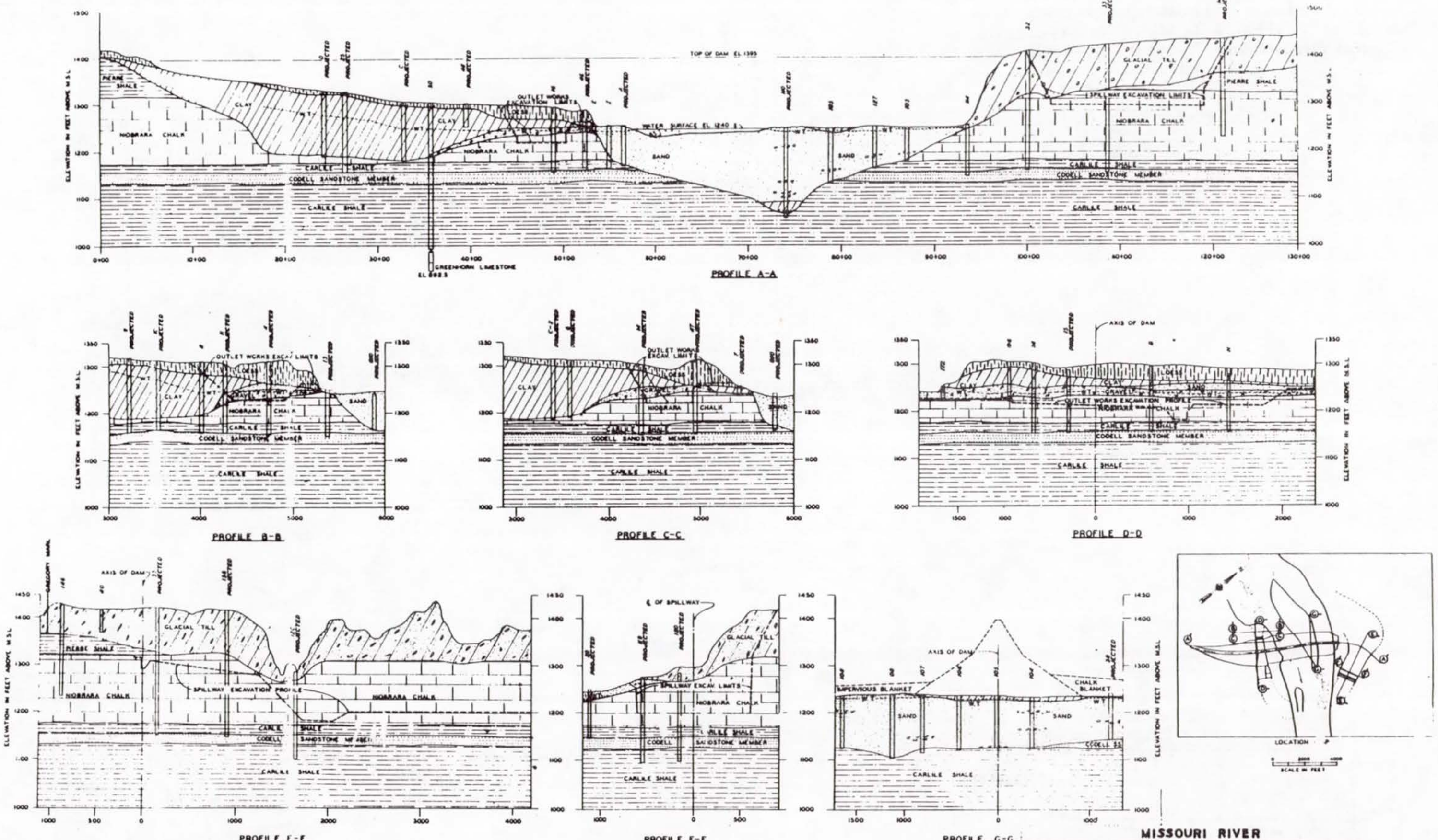
h. Only quality stone has been utilized as toe material on this reach of the Missouri River, and has functioned very well.

PLATE 0-1



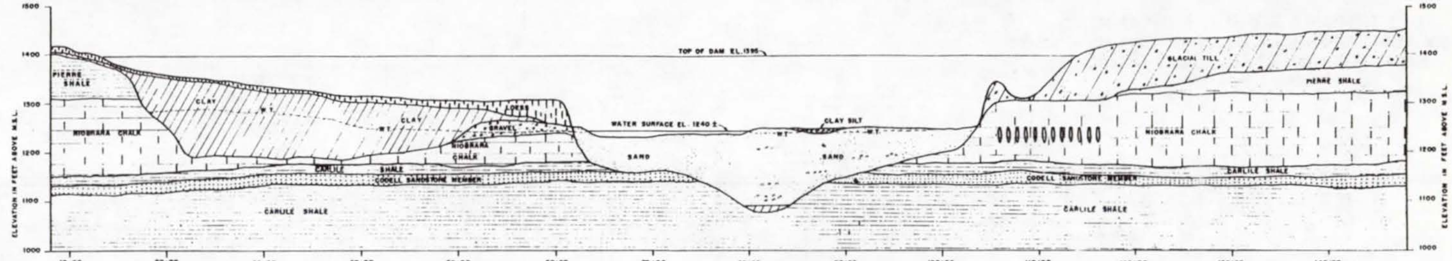
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
LOCATION AND VICINITY MAP

E-2-56



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FORT RANDALL DAM TO NIOBRARA, NEBRASKA
GEOLOGIC PROFILES - SHEET 1

PLATE 0-3

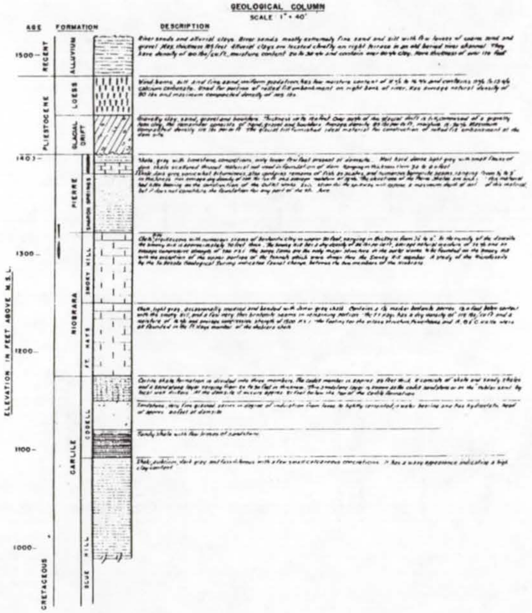


GEOLOGICAL PROFILE ON AXIS OF DAM

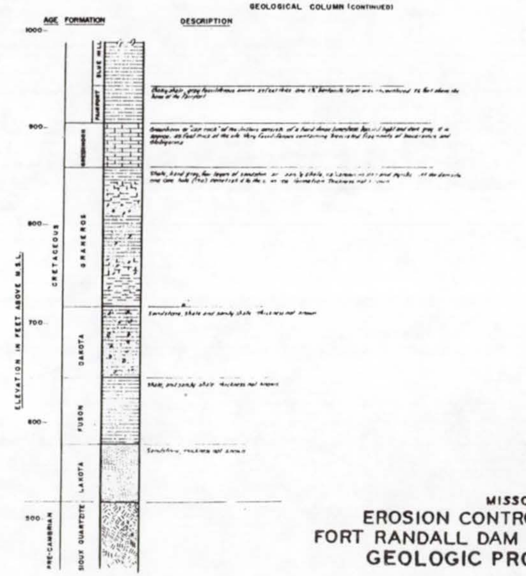
SCALE
HORIZ 1" = 400'
VERT 1" = 80'

GEOLOGICAL COLUMN

SCALE 1" = 40'

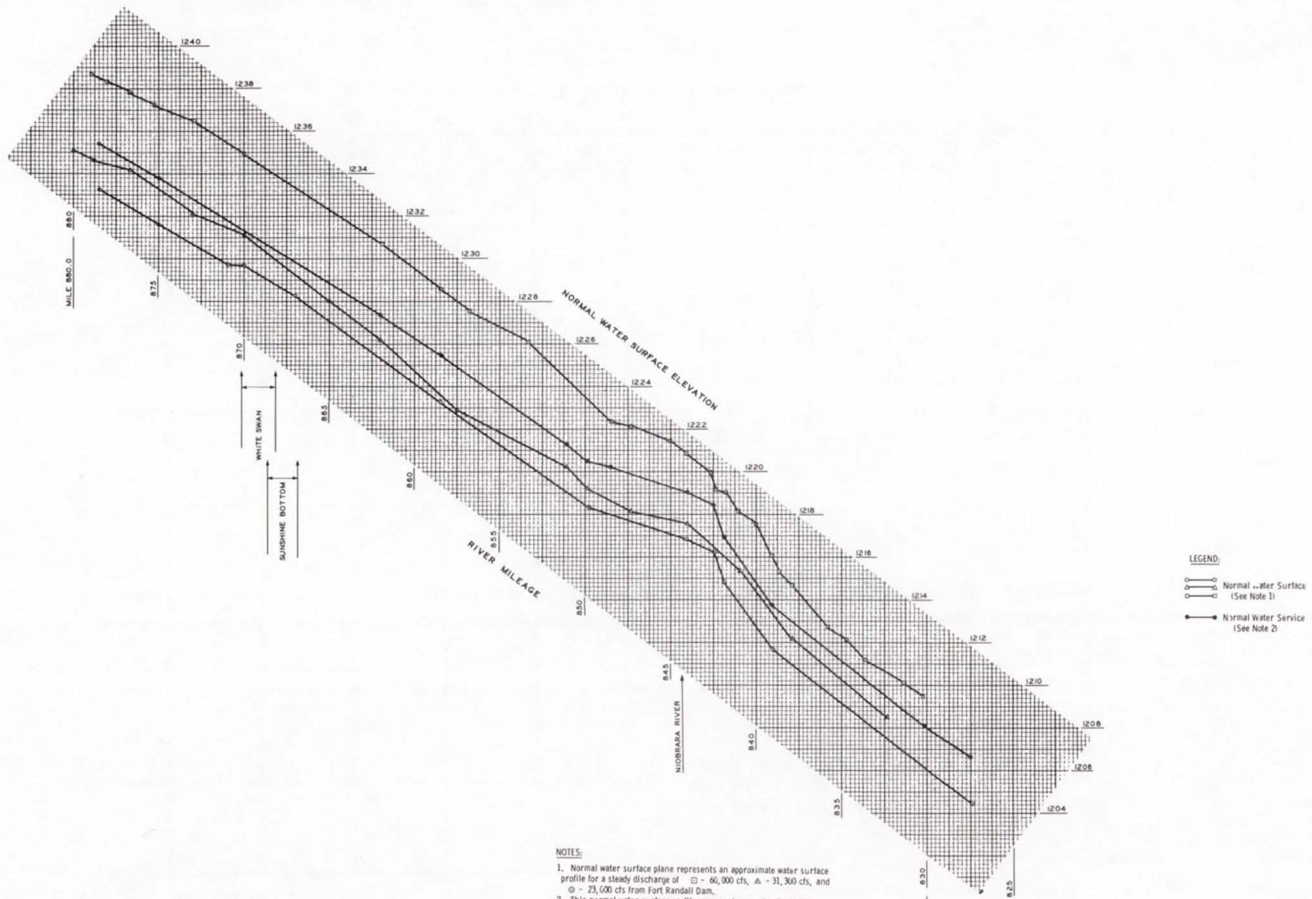


GEOLOGICAL COLUMN (CONTINUED)



THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FORT RANDALL DAM TO NIOBRARA, NEBRASKA
GEOLOGIC PROFILE - SHEET 2



NOTES:

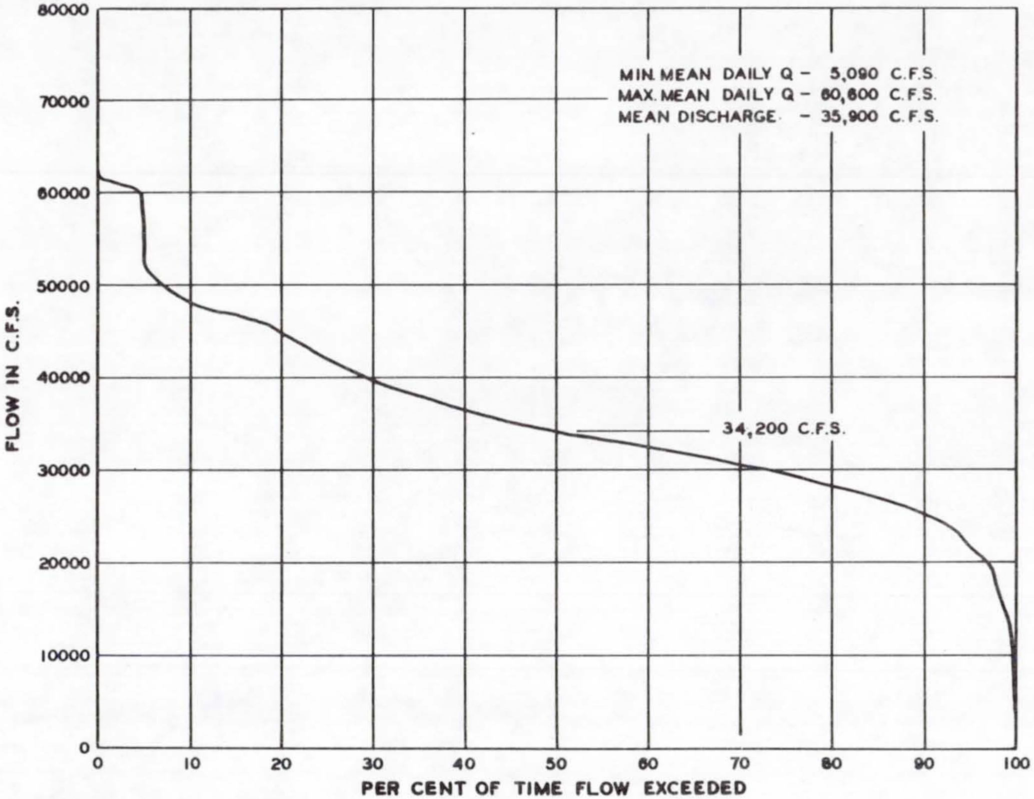
1. Normal water surface plane represents an approximate water surface profile for a steady discharge of ⊡ - 60,000 cfs, △ - 31,300 cfs, and ⊙ - 23,000 cfs from Fort Randall Dam.
2. This normal water surface profile represents a synthesized water surface profile for a steady discharge of 34,200 cfs from Fort Randall Dam, based on June 1980 survey data.

MISSOURI RIVER

EROSION CONTROL DEMONSTRATION

FT. RANDALL DAM TO NIOBRARA, NEBRASKA

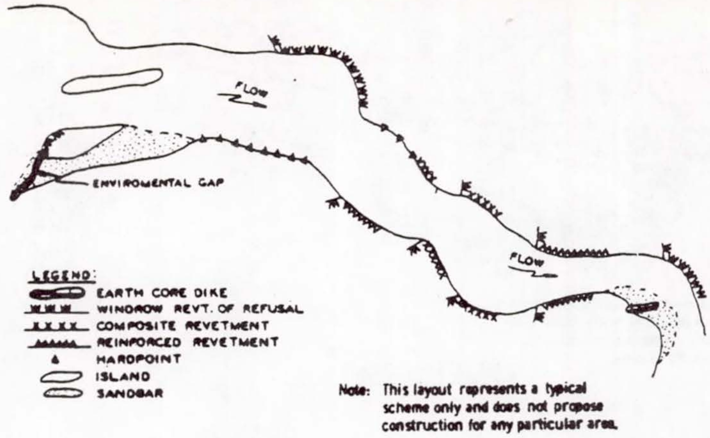
WATER SURFACE PROFILES



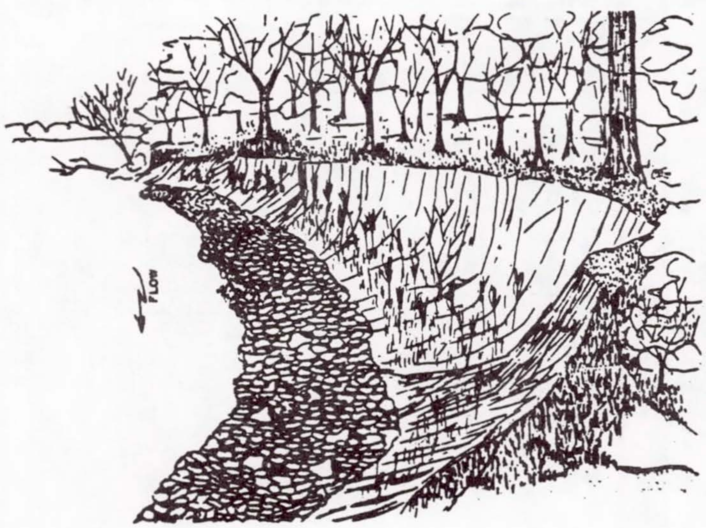
NOTE:

PERIOD APR 01 THRU OCT 31, YEARS 1967 THRU OCT 1976

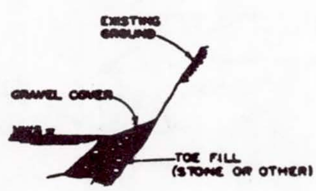
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FORT RANDALL DAM TO NIOBRARA, NEBRASKA
FLOW DURATION CURVE



TYPICAL BANK PROTECTION SCHEMES
FOR EROSION CONTROL



COMPOSITE REVETMENT



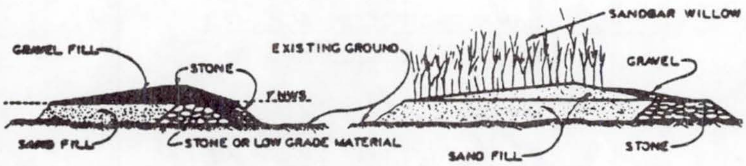
TYPICAL SECTION

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
TYPICAL BANK PROTECTION SCHEMES

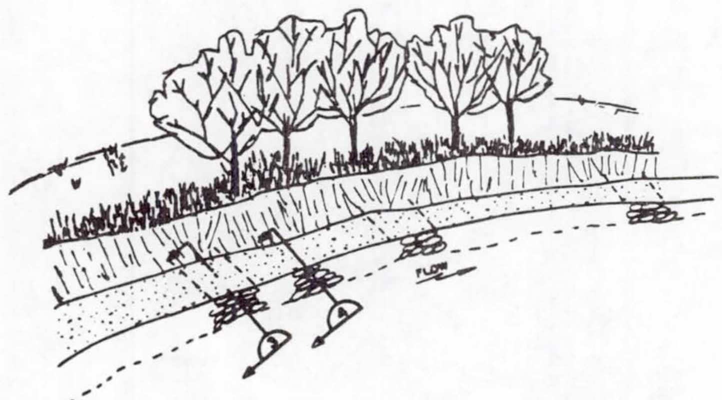
PLATE 0-6

NOTE: Low elevation gaps are incorporated into structure for high level river flows to enhance environmental area downstream.

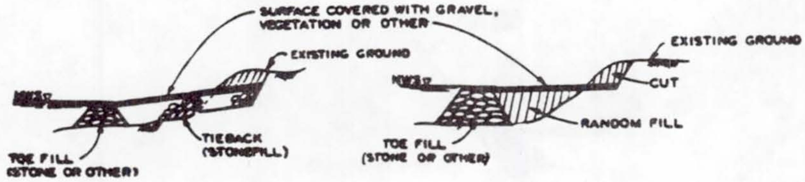
EARTH CORE DIKE



TYPICAL SECTIONS



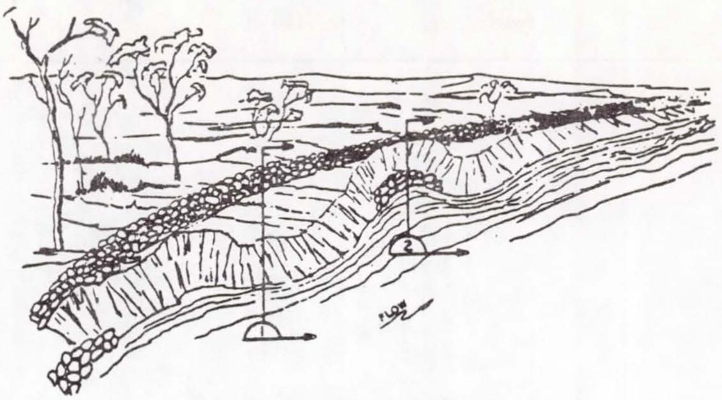
REINFORCED REVETMENT



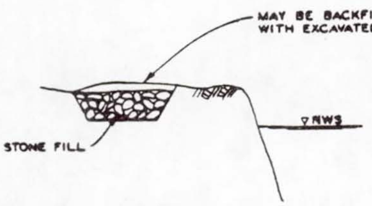
SECTION 3 SECTION 4

MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
TYPICAL BANK PROTECTION SCHEMES

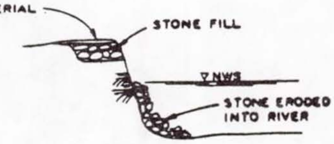
PLATE 0-7



WINDROW REVETMENT

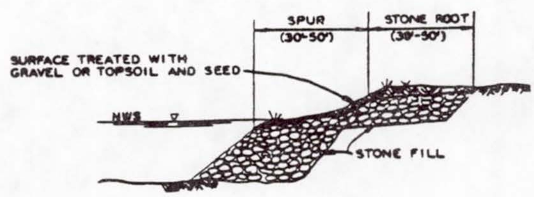


SECTION ①



SECTION ②

HARD POINT SYSTEM



TYPICAL SECTION

MISSOURI RIVER

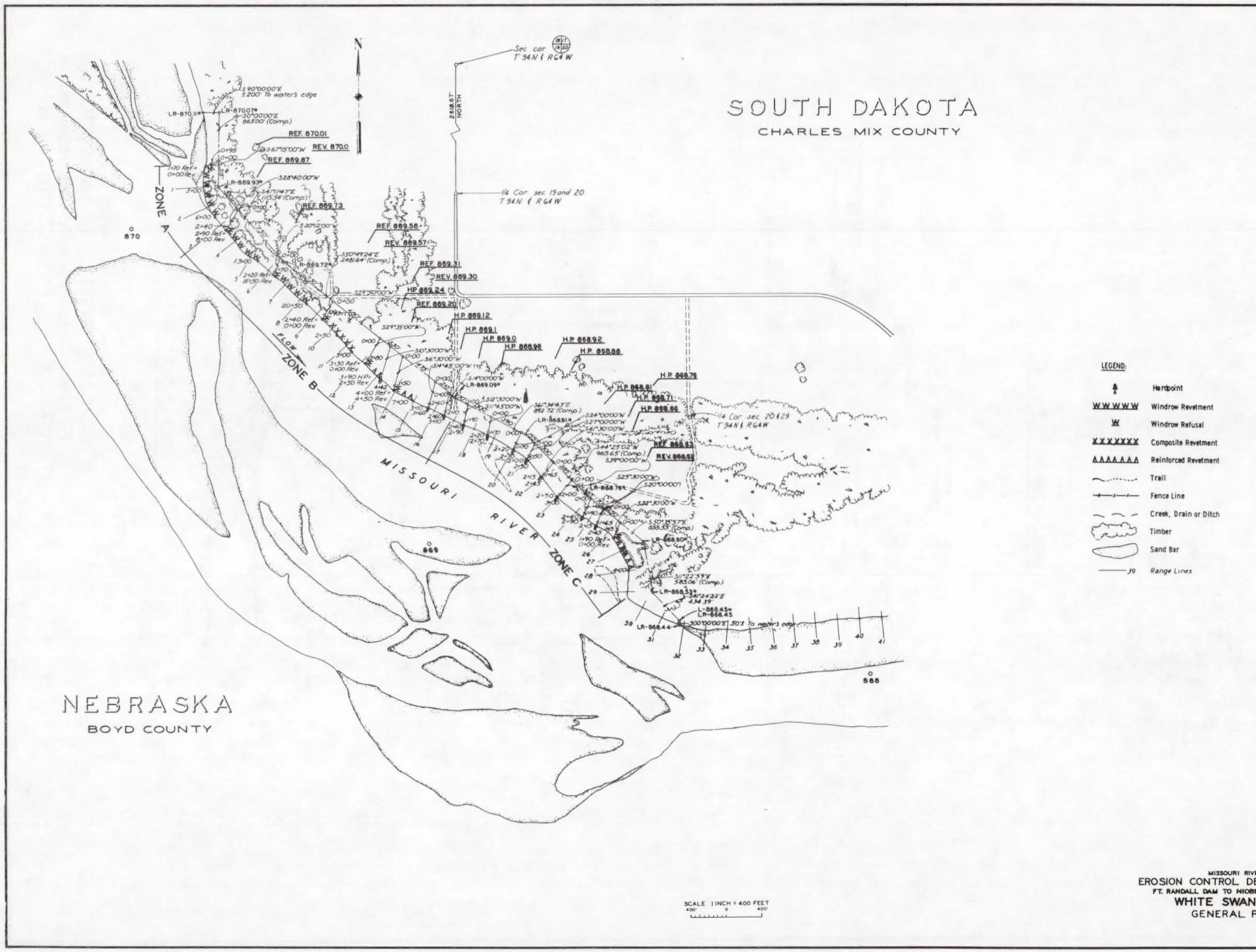
EROSION CONTROL DEMONSTRATION

FT. RANDALL DAM TO NIOBRARA, NEBRASKA

TYPICAL BANK PROTECTION SCHEMES

PLATE 0-8

PLATE 1-1



E-2-64

E-2-65

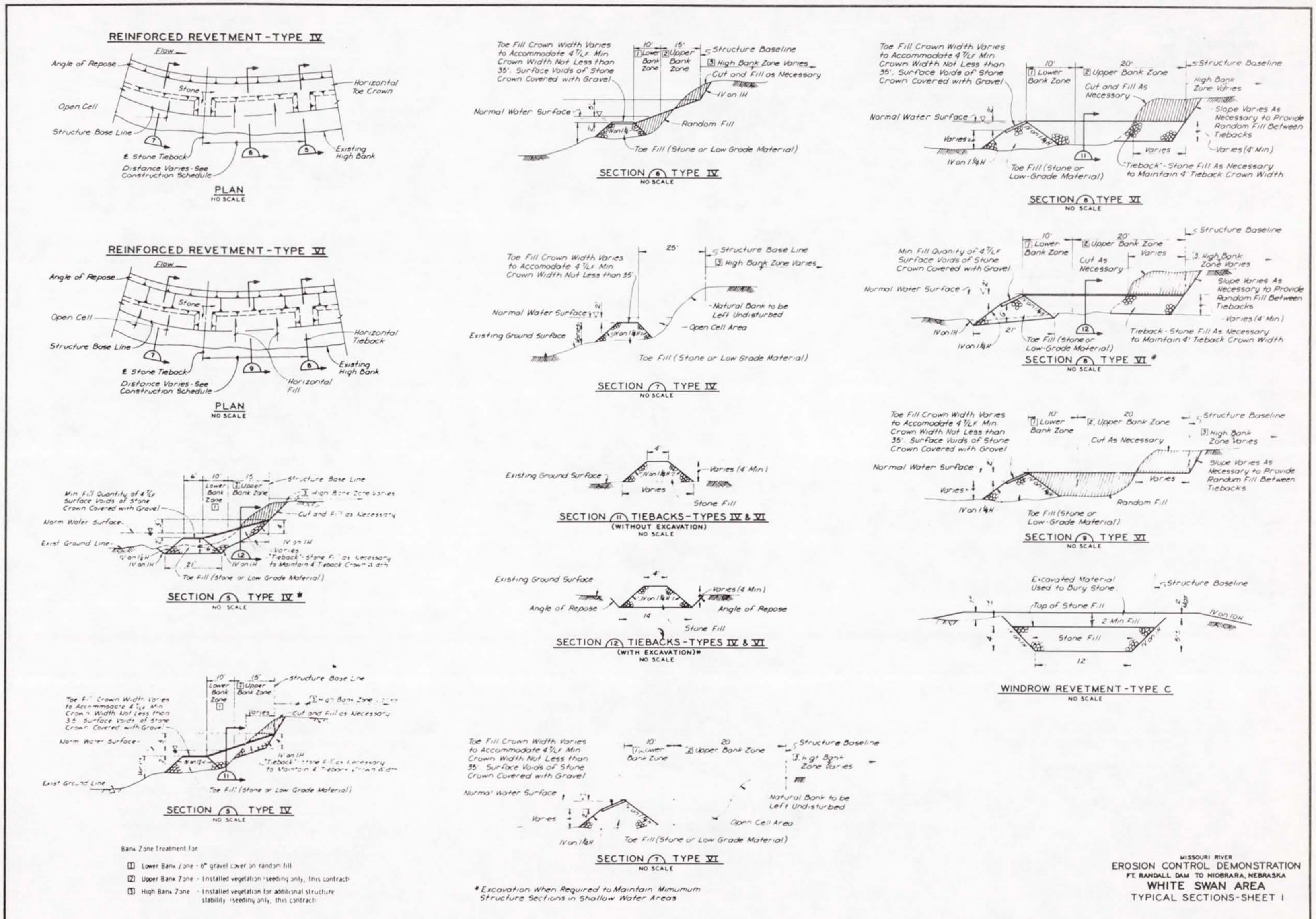
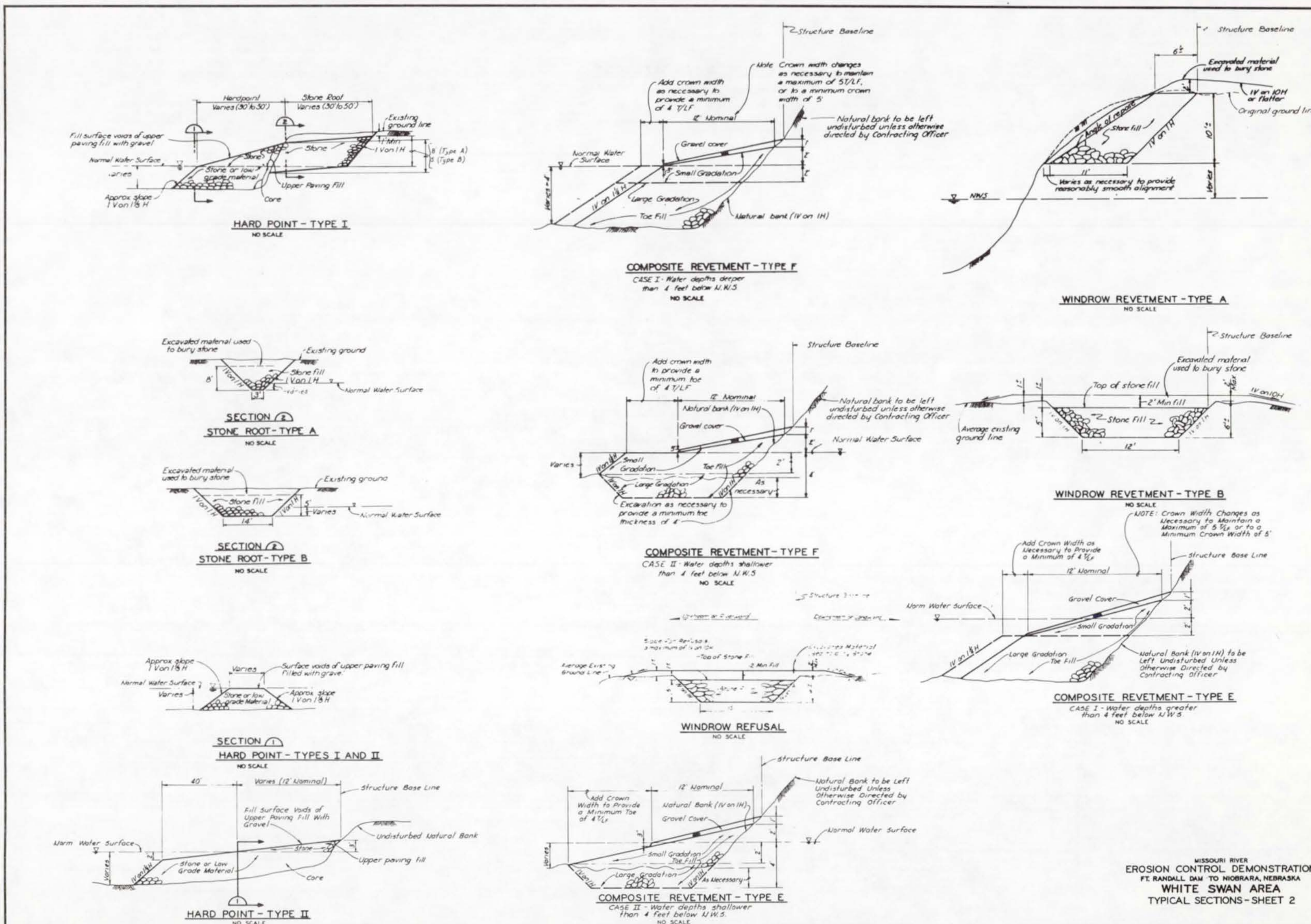
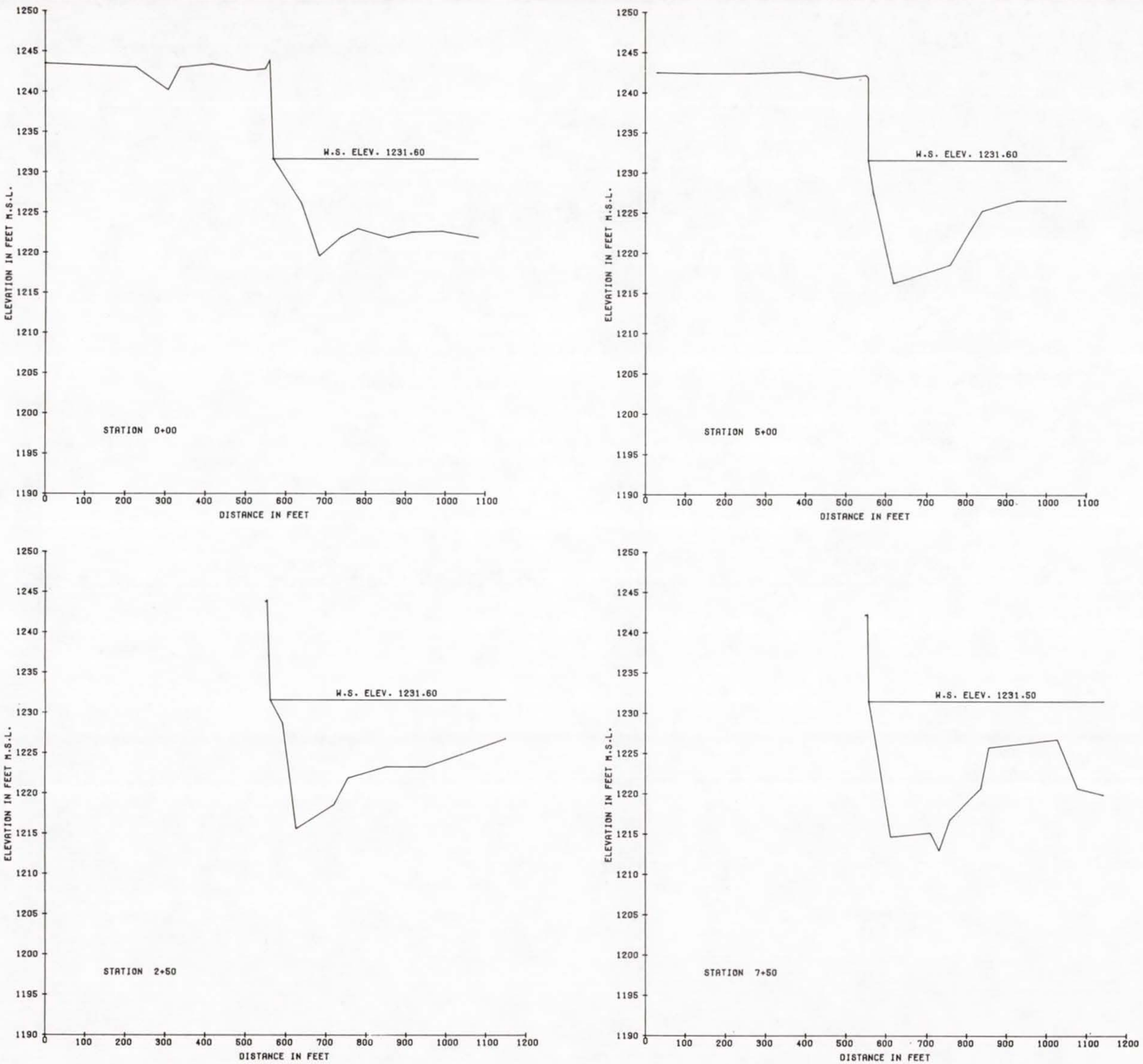


PLATE 1-2

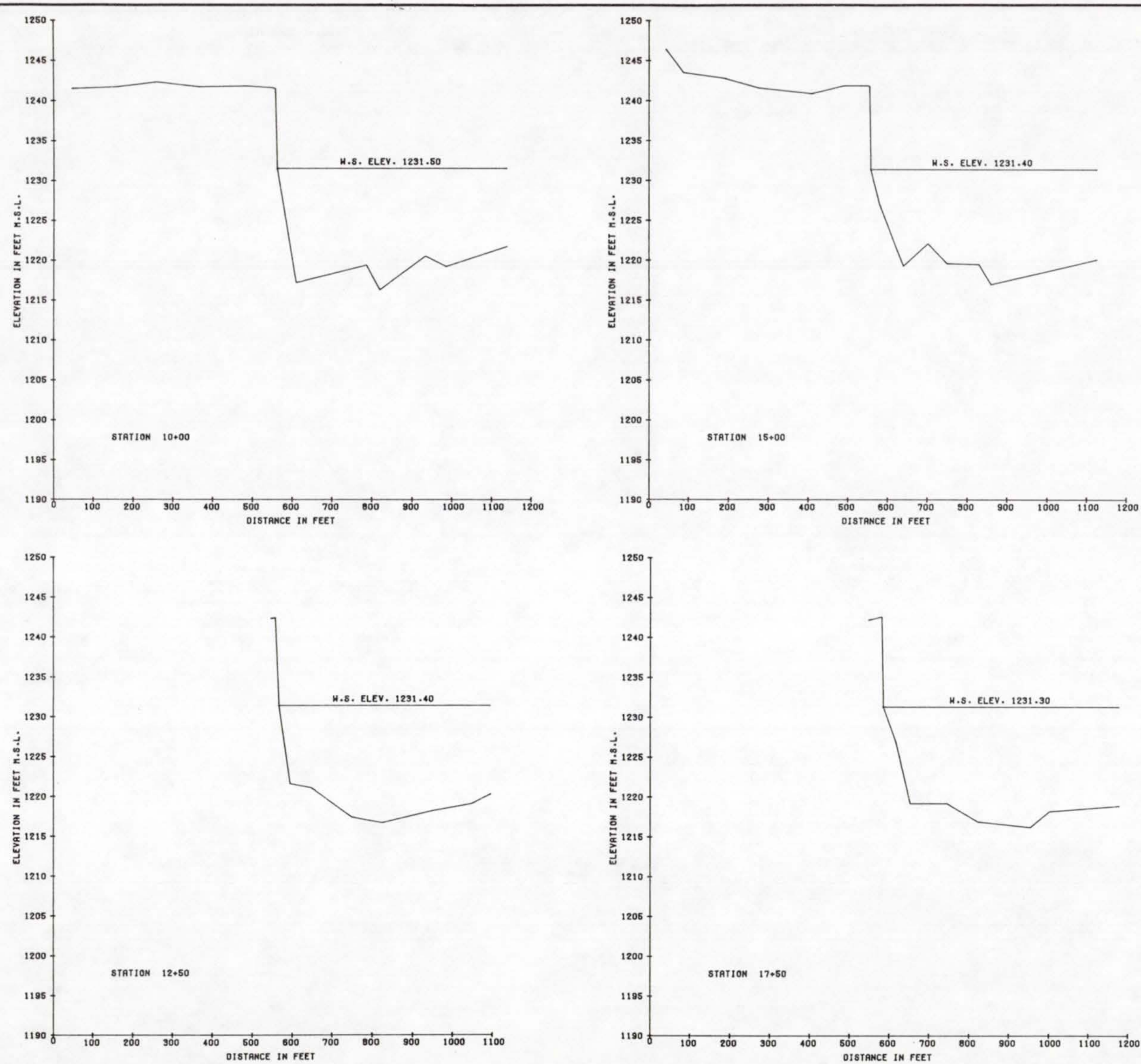


MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
WHITE SWAN AREA
TYPICAL SECTIONS - SHEET 2

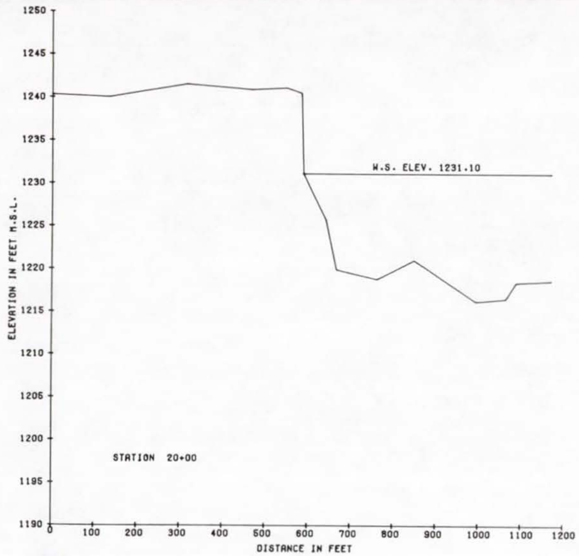


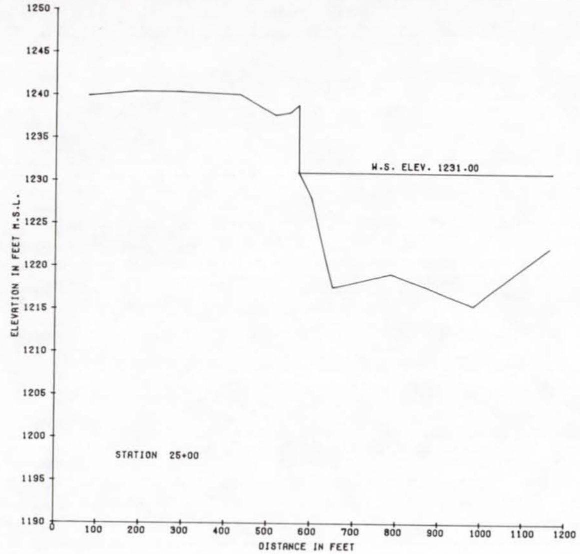
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
WHITE SWAN AREA
CROSS SECTIONS-SHEET 1

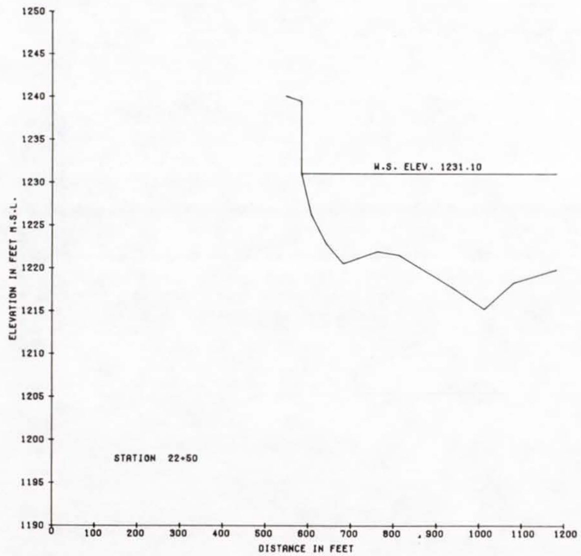
PLATE 1-5

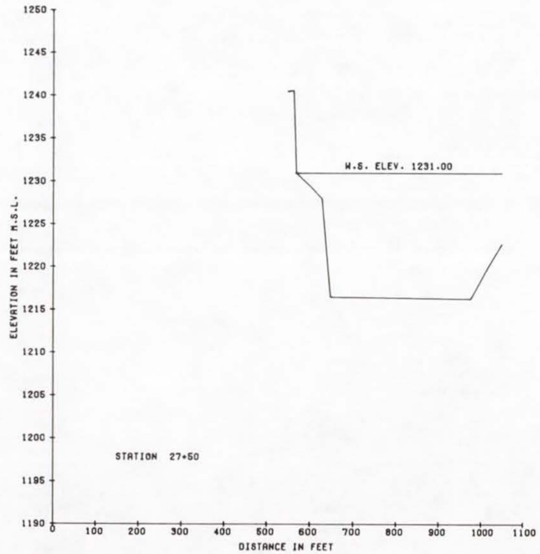


MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
WHITE SWAN AREA
CROSS SECTIONS - SHEET 2





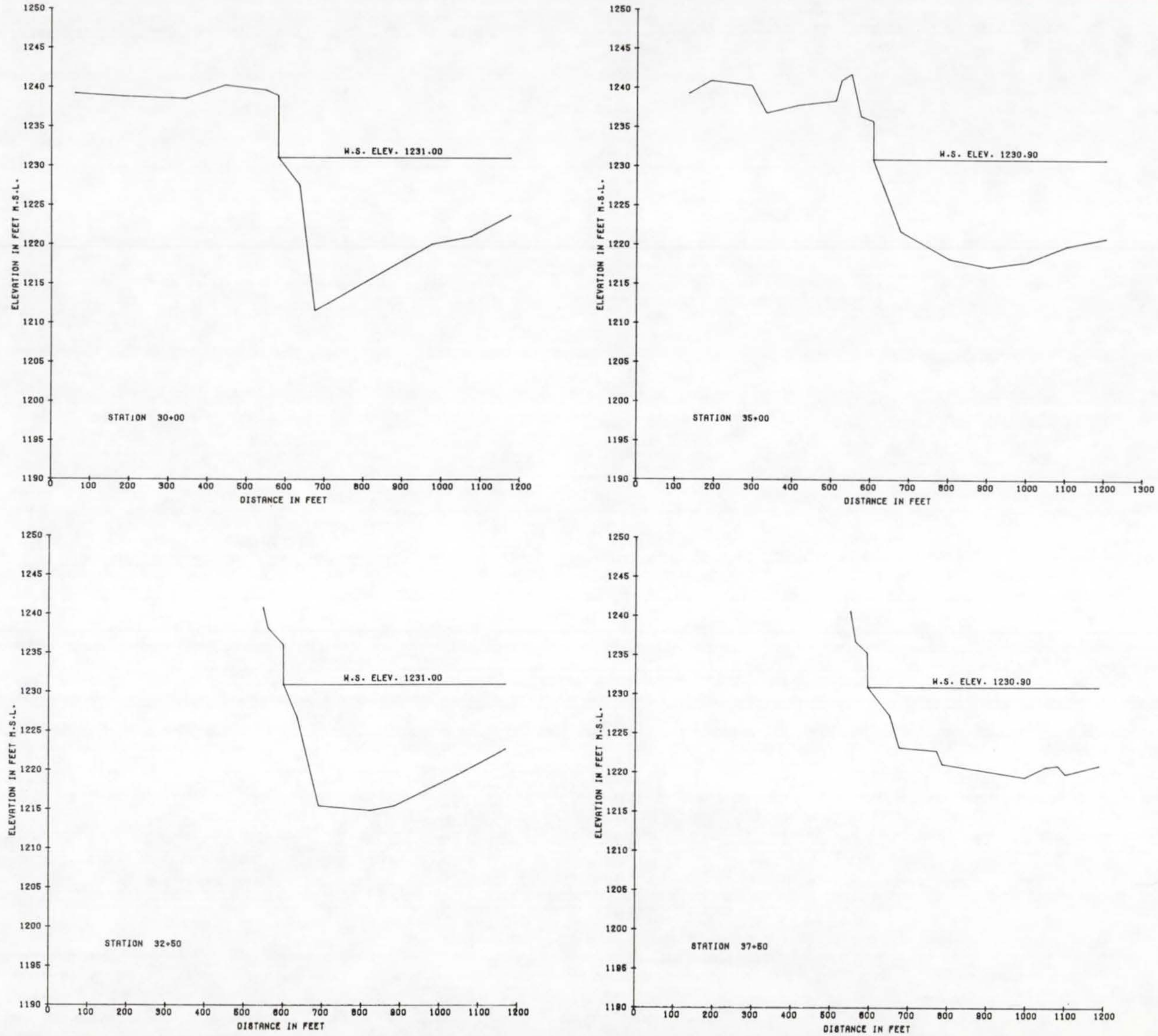




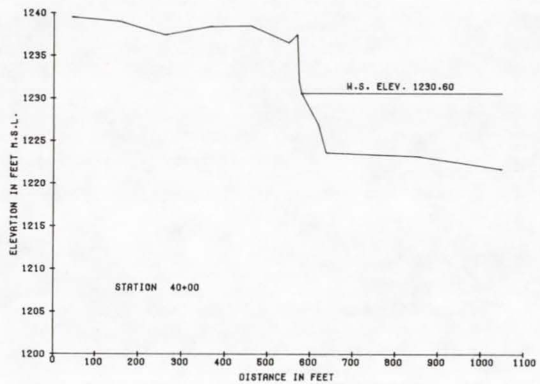
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
WHITE SWAN AREA
CROSS SECTIONS - SHEET 3

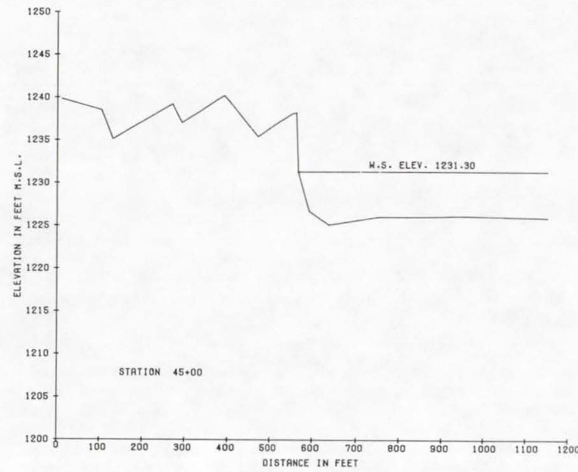
PLATE 1-6

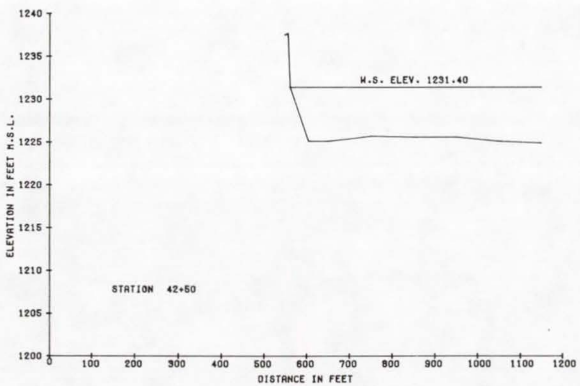
PLATE 1-7

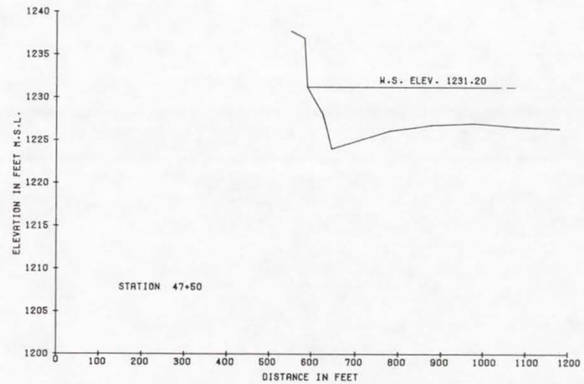


MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
WHITE SWAN AREA
CROSS SECTIONS - SHEET 4







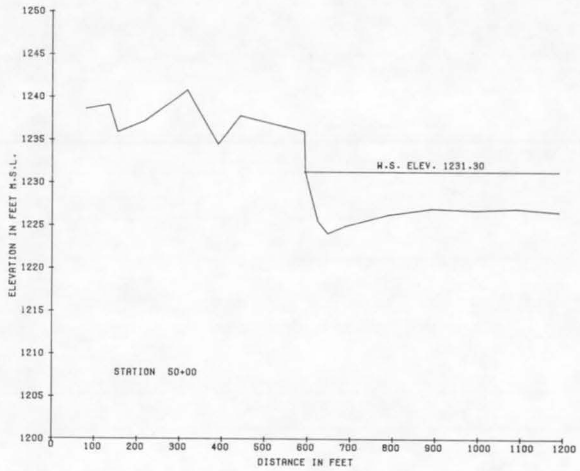


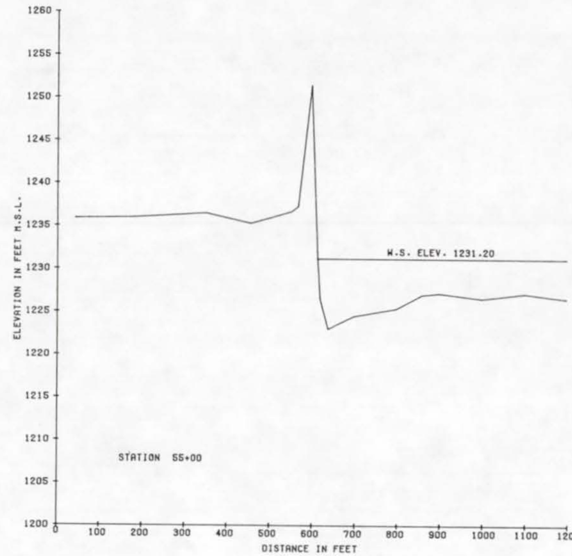
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
WHITE SWAN AREA
CROSS SECTIONS - SHEET 5

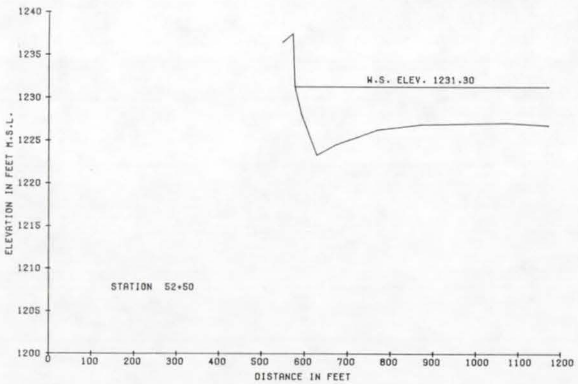
E-2-71

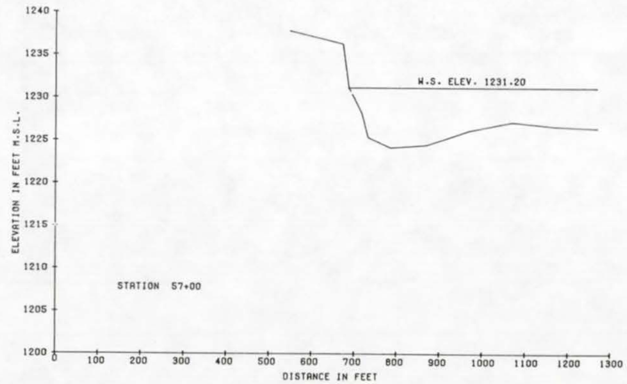
PLATE 1-8

PLATE 1-9

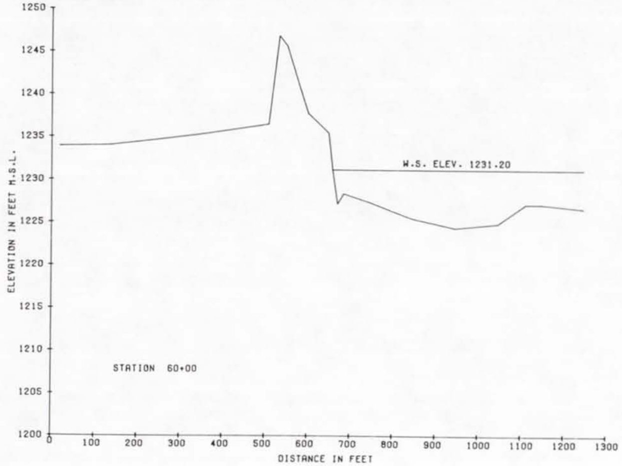


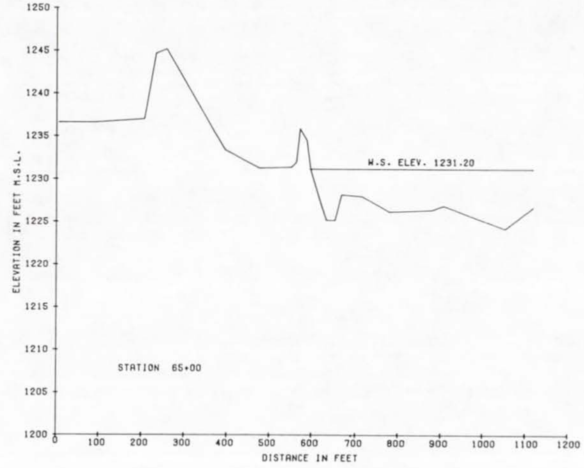


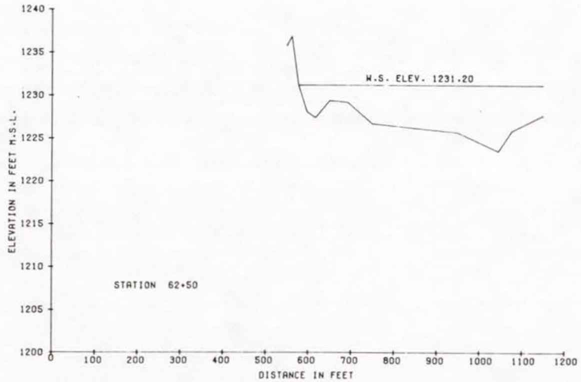


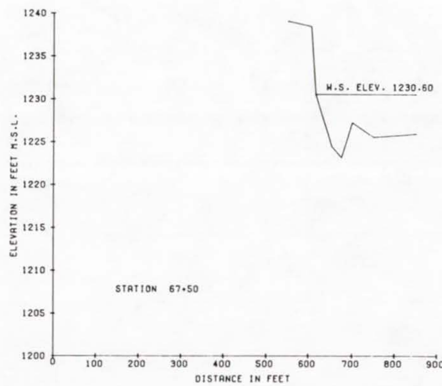


MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
WHITE SWAN AREA
CROSS SECTIONS-SHEET 6





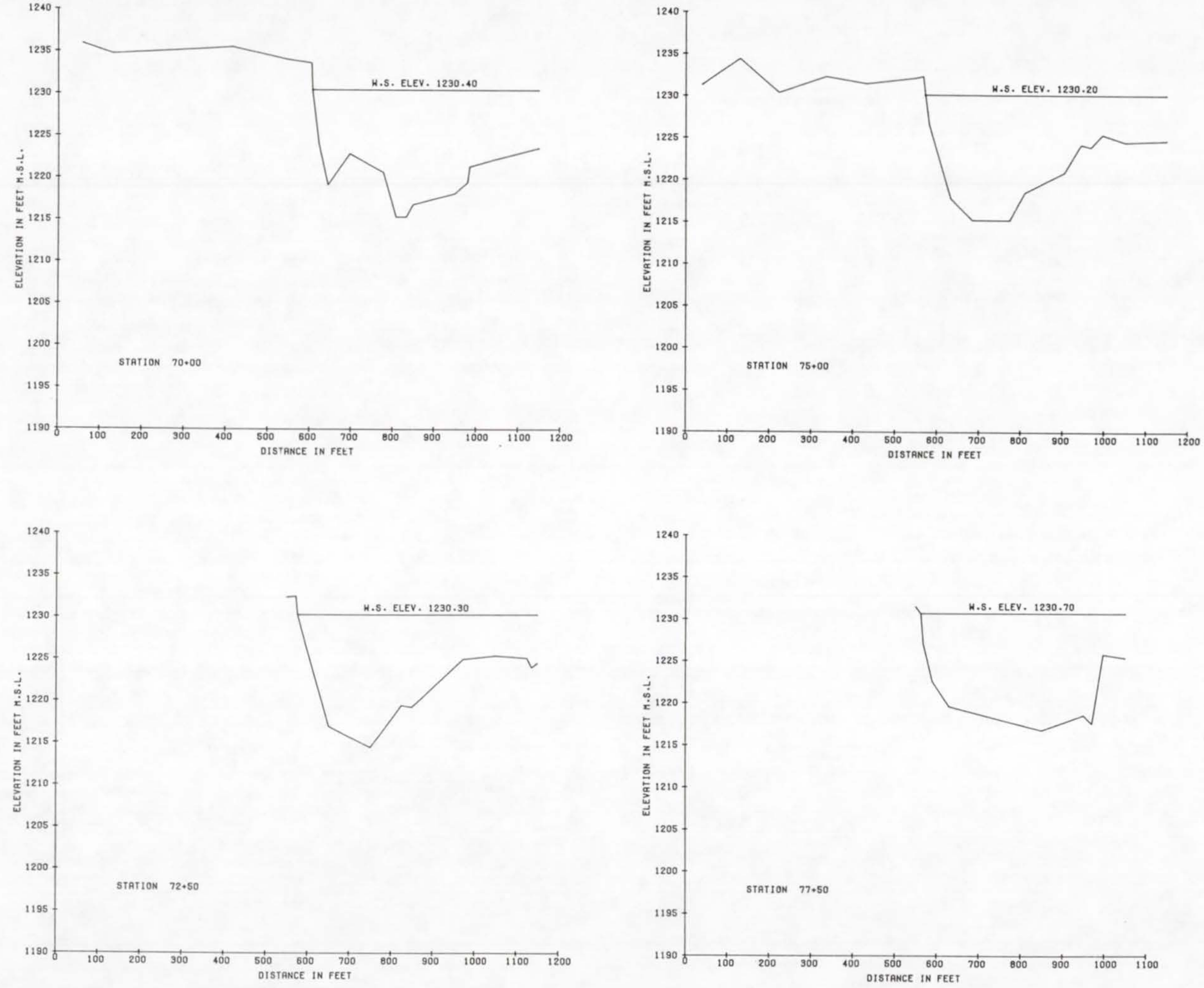




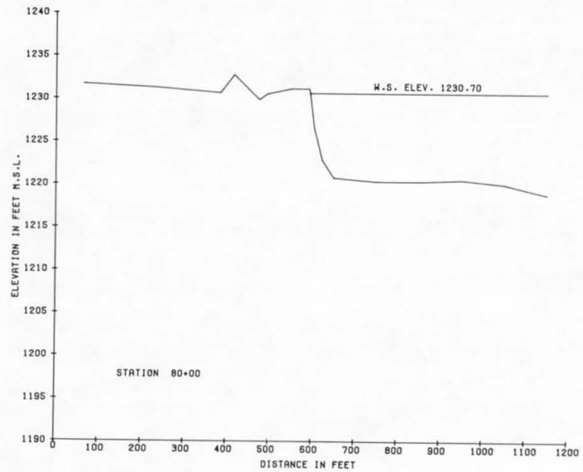
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
WHITE SWAN AREA
CROSS SECTIONS-SHEET 7

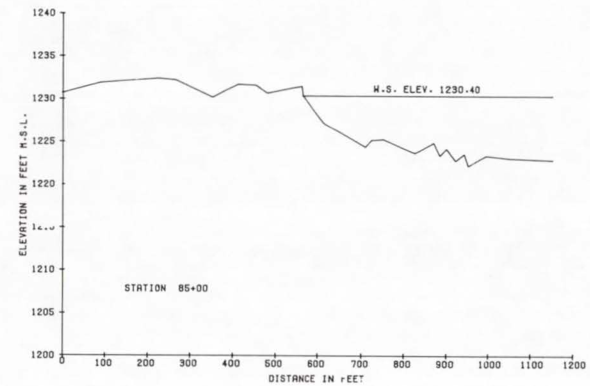
PLATE 1-11

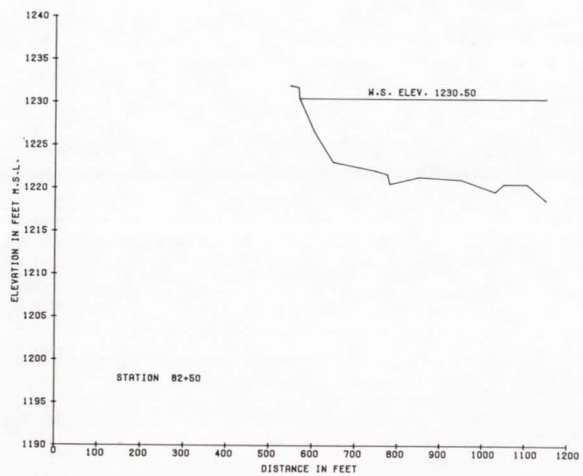
E-2-74

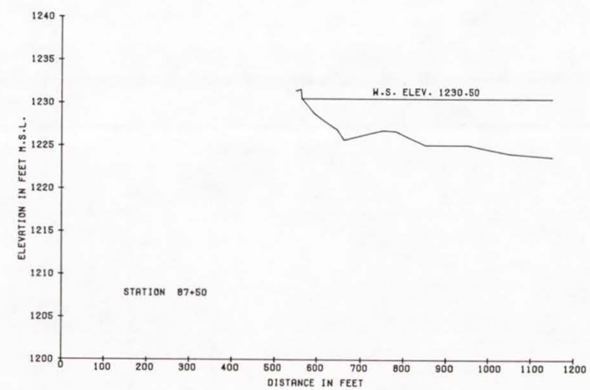


MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
WHITE SWAN AREA
CROSS SECTIONS-SHEET 8







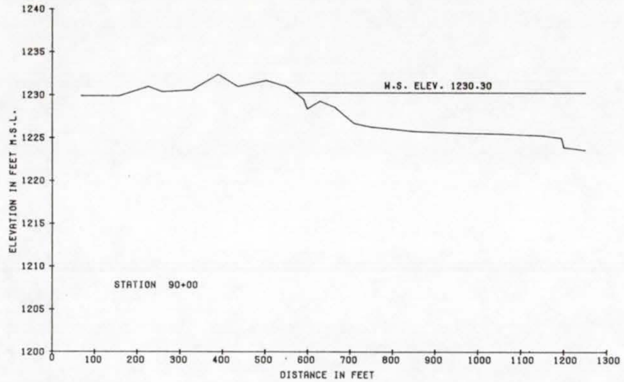


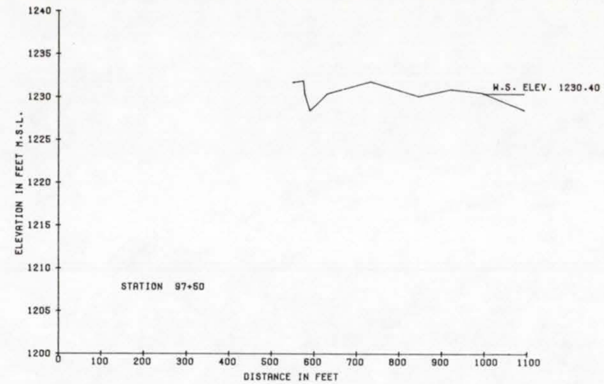
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
WHITE SWAN AREA
CROSS SECTIONS-SHEET 9

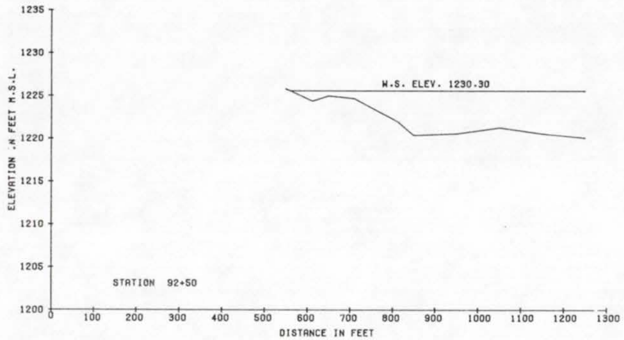
E-2-75

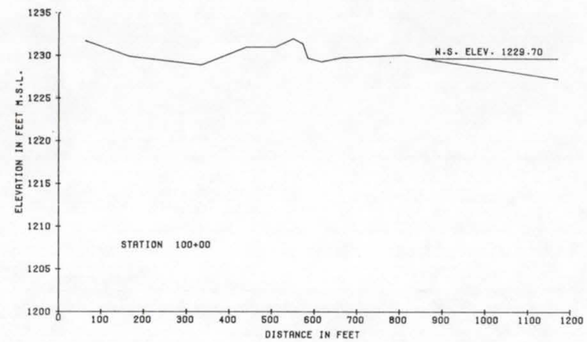
PLATE 1-12

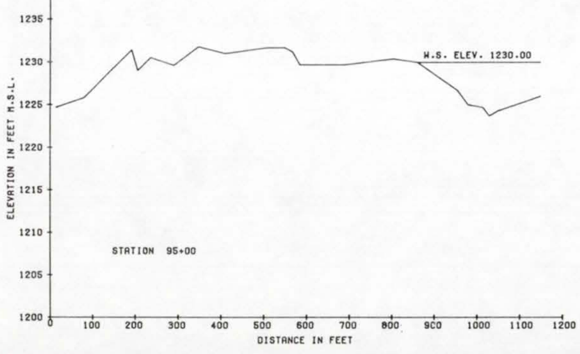
PLATE 1-13



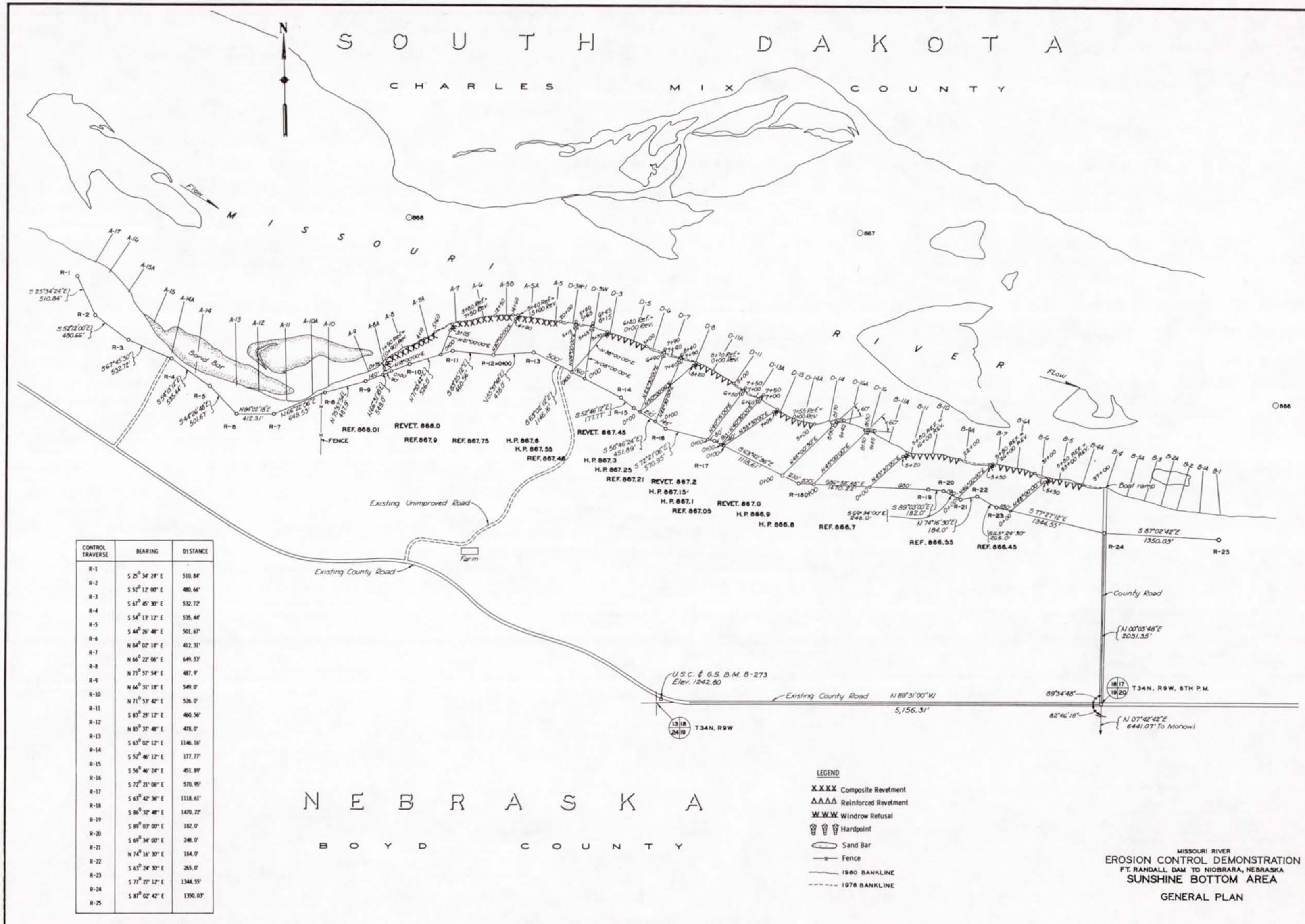








MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
WHITE SWAN AREA
CROSS SECTIONS–SHEET 10

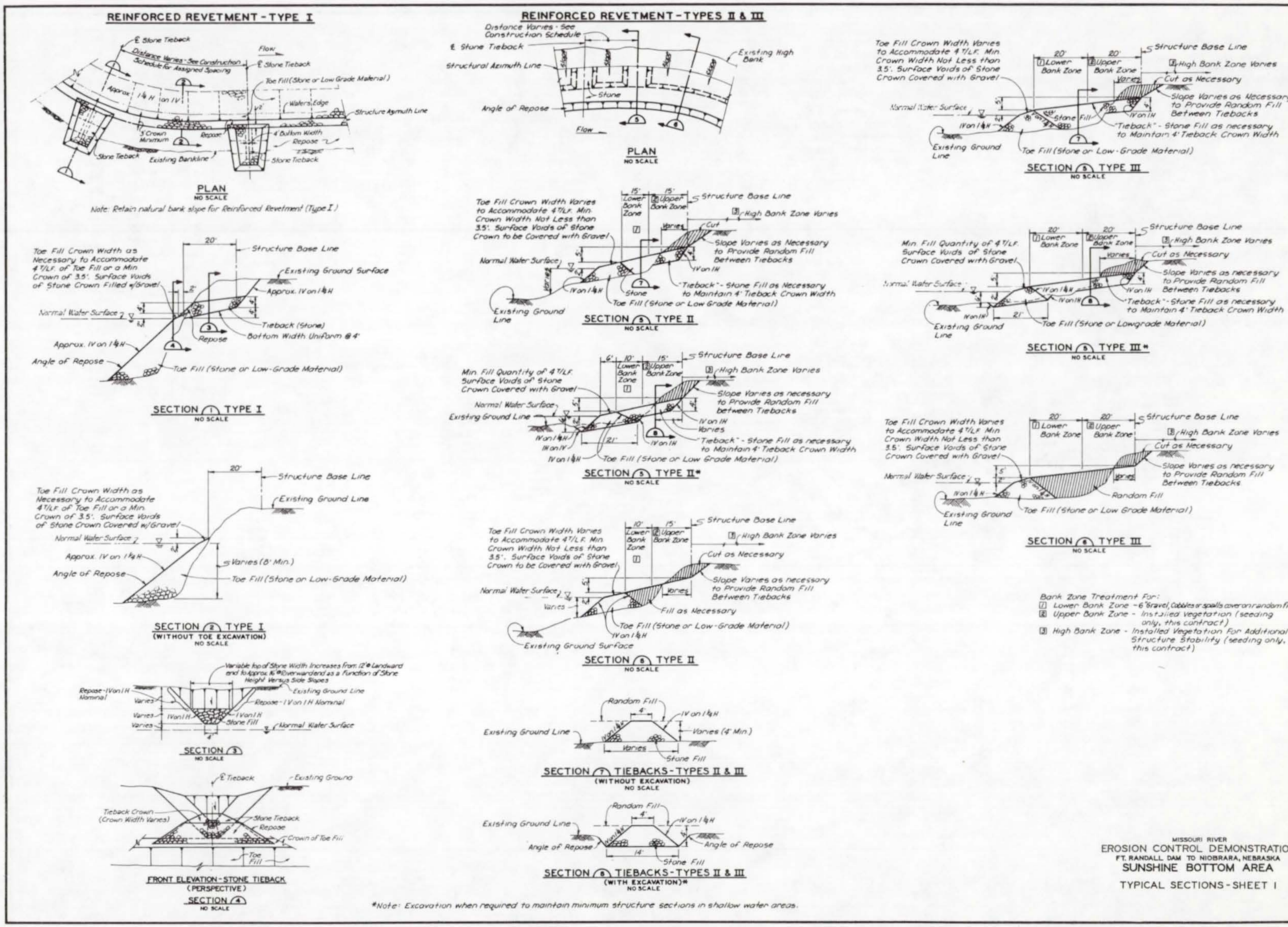


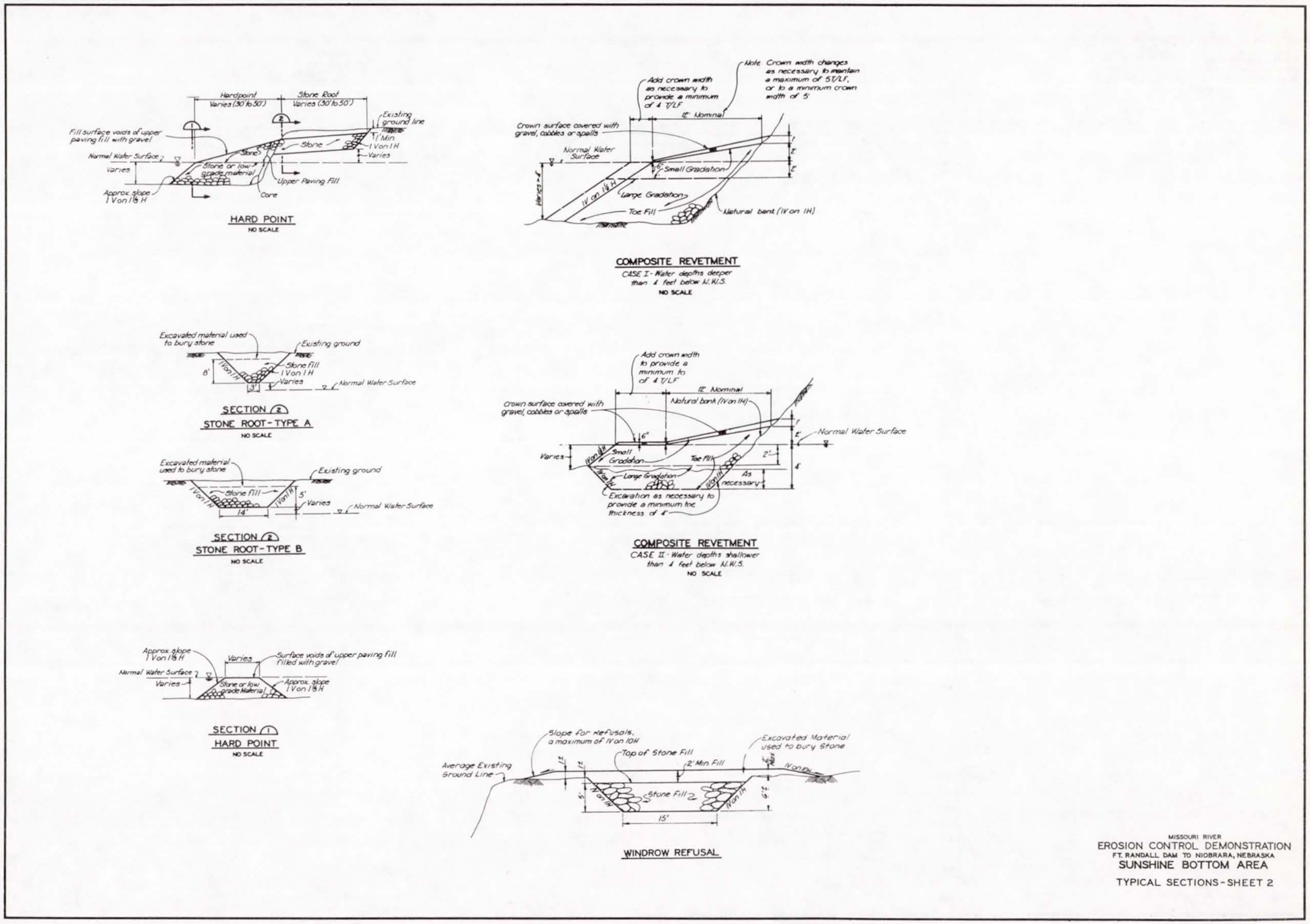
CONTROL TRAVERSE	BEARING	DISTANCE
R-1	S 25° 34' 24" E	510.84'
R-2	S 52° 12' 00" E	480.66'
R-3	S 67° 45' 30" E	532.72'
R-4	S 54° 13' 12" E	535.44'
R-5	S 44° 26' 48" E	501.67'
R-6	N 84° 02' 18" E	412.31'
R-7	N 66° 22' 06" E	649.53'
R-8	N 75° 57' 54" E	487.9'
R-9	N 66° 31' 18" E	549.0'
R-10	N 71° 53' 42" E	526.0'
R-11	S 83° 25' 12" E	460.56'
R-12	N 85° 37' 48" E	478.0'
R-13	S 63° 02' 12" E	1146.16'
R-14	S 52° 46' 12" E	177.77'
R-15	S 56° 46' 24" E	451.89'
R-16	S 72° 21' 06" E	570.95'
R-17	S 63° 42' 36" E	1118.61'
R-18	S 86° 32' 48" E	1470.22'
R-19	S 89° 03' 00" E	182.0'
R-20	S 69° 34' 00" E	248.0'
R-21	N 74° 16' 30" E	184.0'
R-22	S 63° 24' 30" E	265.0'
R-23	S 77° 27' 12" E	1344.55'
R-24	S 87° 02' 42" E	1350.03'
R-25		

E-2-77

PLATE 2-1

PLATE 2-2


REINFORCED REVETMENT - TYPE I
℄ Stone Tieback
Distance Varies - See Construction Schedule for Assigned Spacing
℄ Stone Tieback
Flow
Toe Fill (Stone or Low Grade Material)
Water's Edge
Structure Azimuth Line
Approx. 1¼H on 1V
5' Crown Minimum
Repose
4' Bottom Width
Stone Tieback
Existing Bankline
PLAN
NO SCALE
Note: Retain natural bank slope for Reinforced Revetment (Type I)
Toe Fill Crown Width as Necessary to Accommodate 4 T/LF. of Toe Fill or a Min. Crown of 3.5'. Surface Voids of Stone Crown Filled w/Gravel
Structure Base Line
Existing Ground Surface
Approx. 1V on 1¼H
Normal Water Surface
Tieback (Stone)
Bottom Width Uniform @ 4'
Repose
Approx. 1V on 1¼H
Angle of Repose
Toe Fill (Stone or Low-Grade Material)
SECTION 1 TYPE I
NO SCALE
Toe Fill Crown Width as Necessary to Accommodate 4 T/LF. of Toe Fill or a Min. Crown of 3.5'. Surface Voids of Stone Crown Covered w/Gravel
Structure Base Line
Existing Ground Line
Normal Water Surface
Approx. 1V on 1¼H
Varies (8' Min.)
Angle of Repose
Toe Fill (Stone or Low-Grade Material)
SECTION 2 TYPE I
(WITHOUT TOE EXCAVATION)
NO SCALE
Variable Top of Stone Width Increases from 12'± Landward end to Approx. 16'± Riverward end as a Function of Stone Height Versus Side Slopes
Existing Ground Line
Repose - 1V on 1H Nominal
Repose - 1V on 1H Nominal
Stone Fill
Normal Water Surface
SECTION 3
NO SCALE
℄ Tieback
Existing Ground
Tieback Crown (Crown Width Varies)
Stone Tieback
Repose
Crown of Toe Fill
Toe Fill
FRONT ELEVATION - STONE TIEBACK
(PERSPECTIVE)
SECTION 4
NO SCALE
REINFORCED REVETMENT - TYPES II & III
Distance Varies - See Construction Schedule
℄ Stone Tieback
Existing High Bank
Structural Azimuth Line
Stone
Angle of Repose
Flow
PLAN
NO SCALE
Toe Fill Crown Width Varies to Accommodate 4 T/LF. Min. Crown Width Not Less than 3.5'. Surface Voids of Stone Crown to be Covered with Gravel
Lower Bank Zone
Upper Bank Zone
Structure Base Line
High Bank Zone Varies
Cut
Slope Varies as Necessary to Provide Random Fill Between Tiebacks
Normal Water Surface
"Tieback" - Stone Fill as Necessary to Maintain 4' Tieback Crown Width
Existing Ground Line
Toe Fill (Stone or Low Grade Material)
SECTION 5 TYPE II
NO SCALE
Min. Fill Quantity of 4 T/LF. Surface Voids of Stone Crown Covered with Gravel
Normal Water Surface
Existing Ground Line
Slope Varies as necessary to Provide Random Fill between Tiebacks
"Tieback" - Stone Fill as necessary to Maintain 4' Tieback Crown Width
Toe Fill (Stone or Low Grade Material)
SECTION 5 TYPE II*
NO SCALE
Toe Fill Crown Width Varies to Accommodate 4 T/LF. Min. Crown Width Not Less than 3.5'. Surface Voids of Stone Crown to be Covered with Gravel
Cut as Necessary
Slope Varies as necessary to Provide Random Fill Between Tiebacks
Fill as Necessary
Toe Fill (Stone or Low-Grade Material)
Existing Ground Surface
SECTION 6 TYPE II
NO SCALE
Random Fill
Existing Ground Line
Varies (4' Min.)
Stone Fill
SECTION 7 TIEBACKS - TYPES II & III
(WITHOUT EXCAVATION)
NO SCALE
Random Fill
Existing Ground Line
Angle of Repose
Angle of Repose
Stone Fill
SECTION 8 TIEBACKS - TYPES II & III
(WITH EXCAVATION)*
NO SCALE
*Note: Excavation when required to maintain minimum structure sections in shallow water areas.
Toe Fill Crown Width Varies to Accommodate 4 T/LF. Min. Crown Width Not Less than 3.5'. Surface Voids of Stone Crown Covered with Gravel
Lower Bank Zone
Upper Bank Zone
Structure Base Line
High Bank Zone Varies
Cut as Necessary
Slope Varies as Necessary to Provide Random Fill Between Tiebacks
"Tieback" - Stone Fill as necessary to Maintain 4' Tieback Crown Width
Existing Ground Line
Toe Fill (Stone or Low-Grade Material)
SECTION 5 TYPE III
NO SCALE
Min. Fill Quantity of 4 T/LF. Surface Voids of Stone Crown Covered with Gravel
Slope Varies as necessary to Provide Random Fill Between Tiebacks
"Tieback" - Stone Fill as necessary to Maintain 4' Tieback Crown Width
Toe Fill (Stone or Lowgrade Material)
SECTION 5 TYPE III*
NO SCALE
Toe Fill Crown Width Varies to Accommodate 4 T/LF. Min. Crown Width Not Less than 3.5'. Surface Voids of Stone Crown Covered with Gravel
Cut as Necessary
Slope Varies as necessary to Provide Random Fill Between Tiebacks
Random Fill
Toe Fill (Stone or Low Grade Material)
SECTION 6 TYPE III
NO SCALE
Bank Zone Treatment For:
1 Lower Bank Zone - 6" Gravel, Cobbles or spalls cover on random fill
2 Upper Bank Zone - Installed Vegetation (seeding only, this contract)
3 High Bank Zone - Installed Vegetation For Additional Structure Stability (seeding only, this contract)
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
SUNSHINE BOTTOM AREA
TYPICAL SECTIONS - SHEET 1

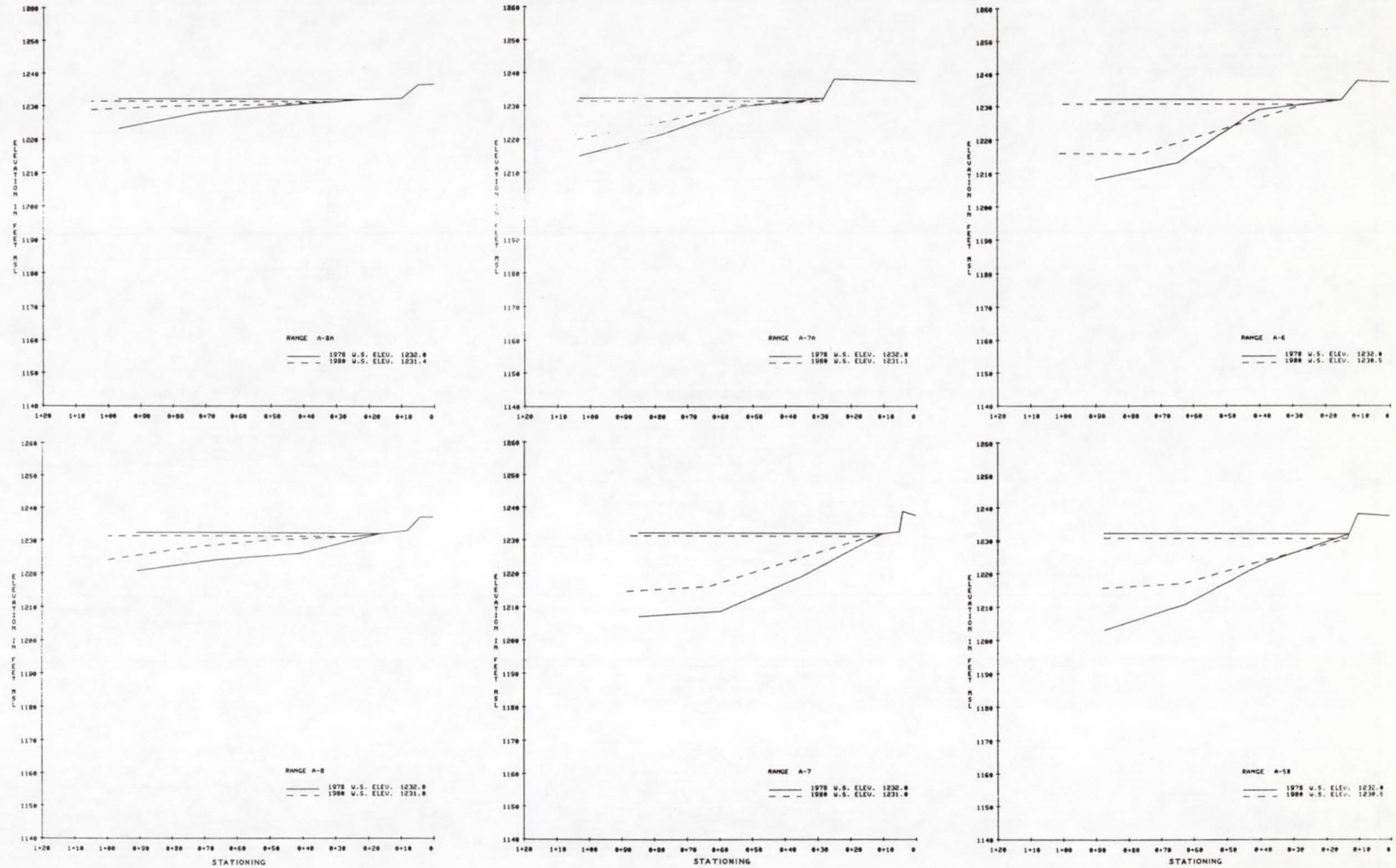


MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
SUNSHINE BOTTOM AREA
TYPICAL SECTIONS - SHEET 2

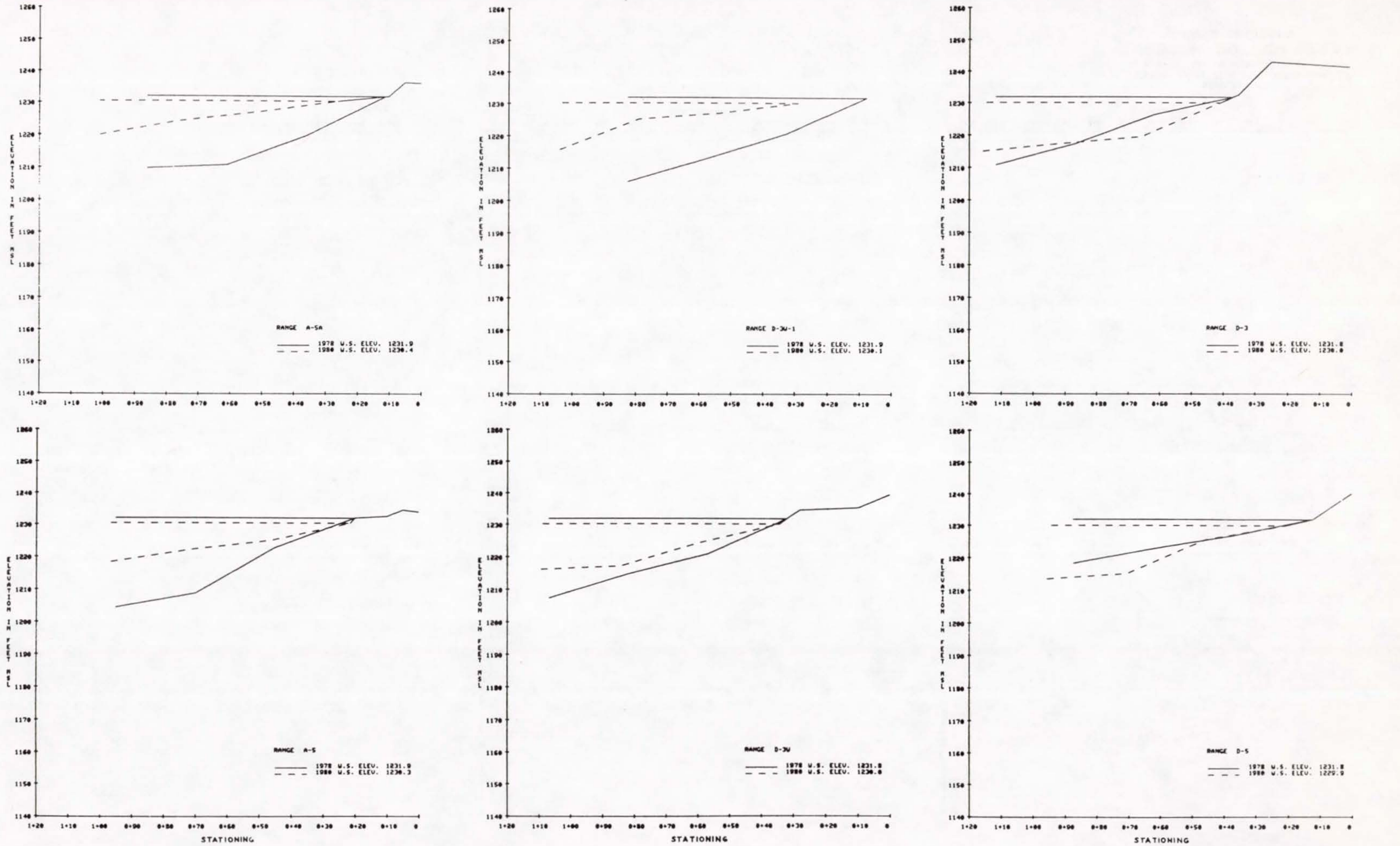
E-2-79

PLATE 2-3

PLATE 2-4



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
SUNSHINE BOTTOM AREA
CROSS SECTIONS
SHEET 1



MISSOURI RIVER

EROSION CONTROL DEMONSTRATION

FT. RANDALL DAM TO NIOBRARA, NEBRASKA

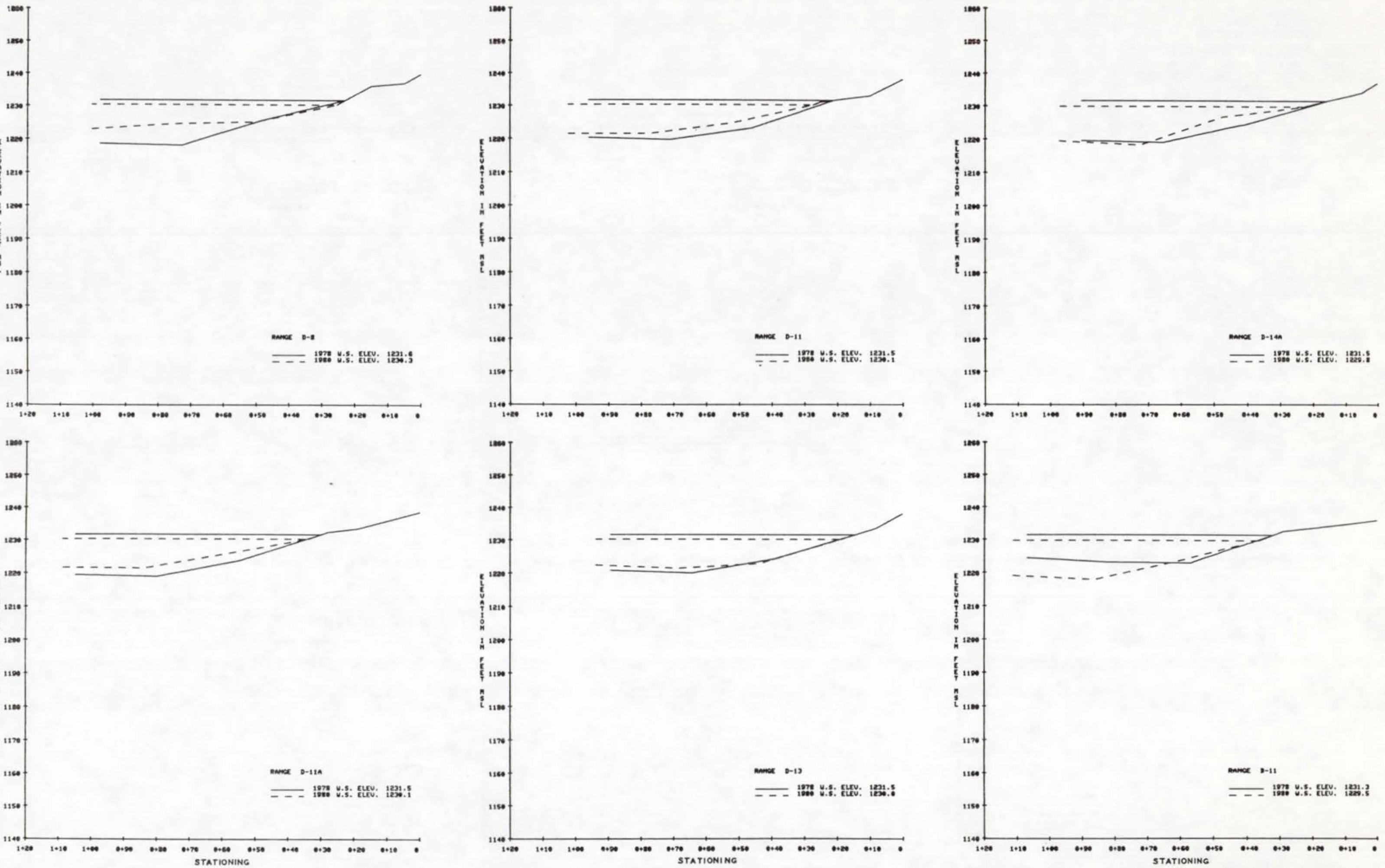
SUNSHINE BOTTOM AREA

CROSS SECTIONS

SHEET 2

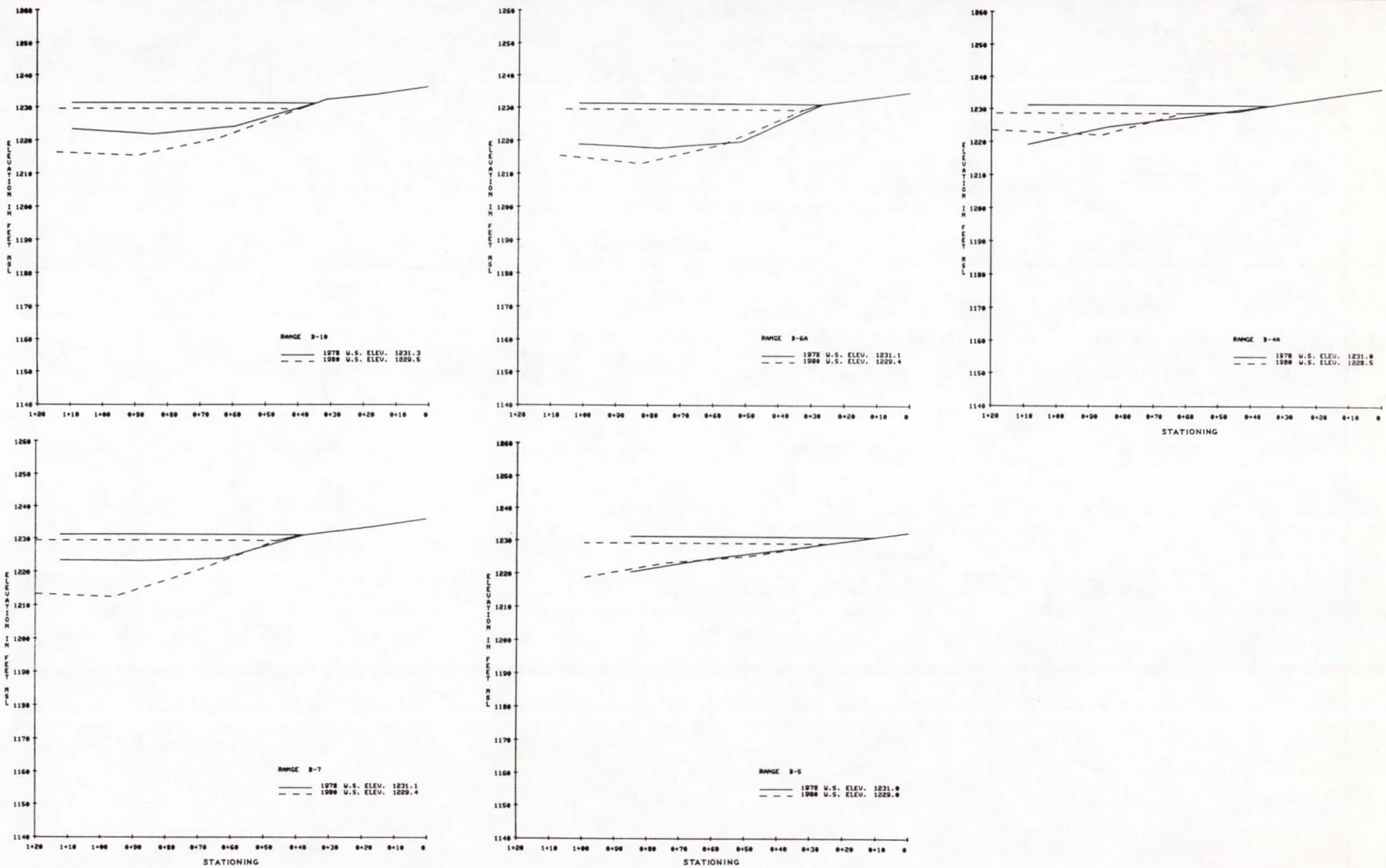
PLATE 2-5

PLATE 2-6



MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA

SUNSHINE BOTTOM AREA
CROSS SECTIONS
SHEET 3



MISSOURI RIVER

EROSION CONTROL DEMONSTRATION

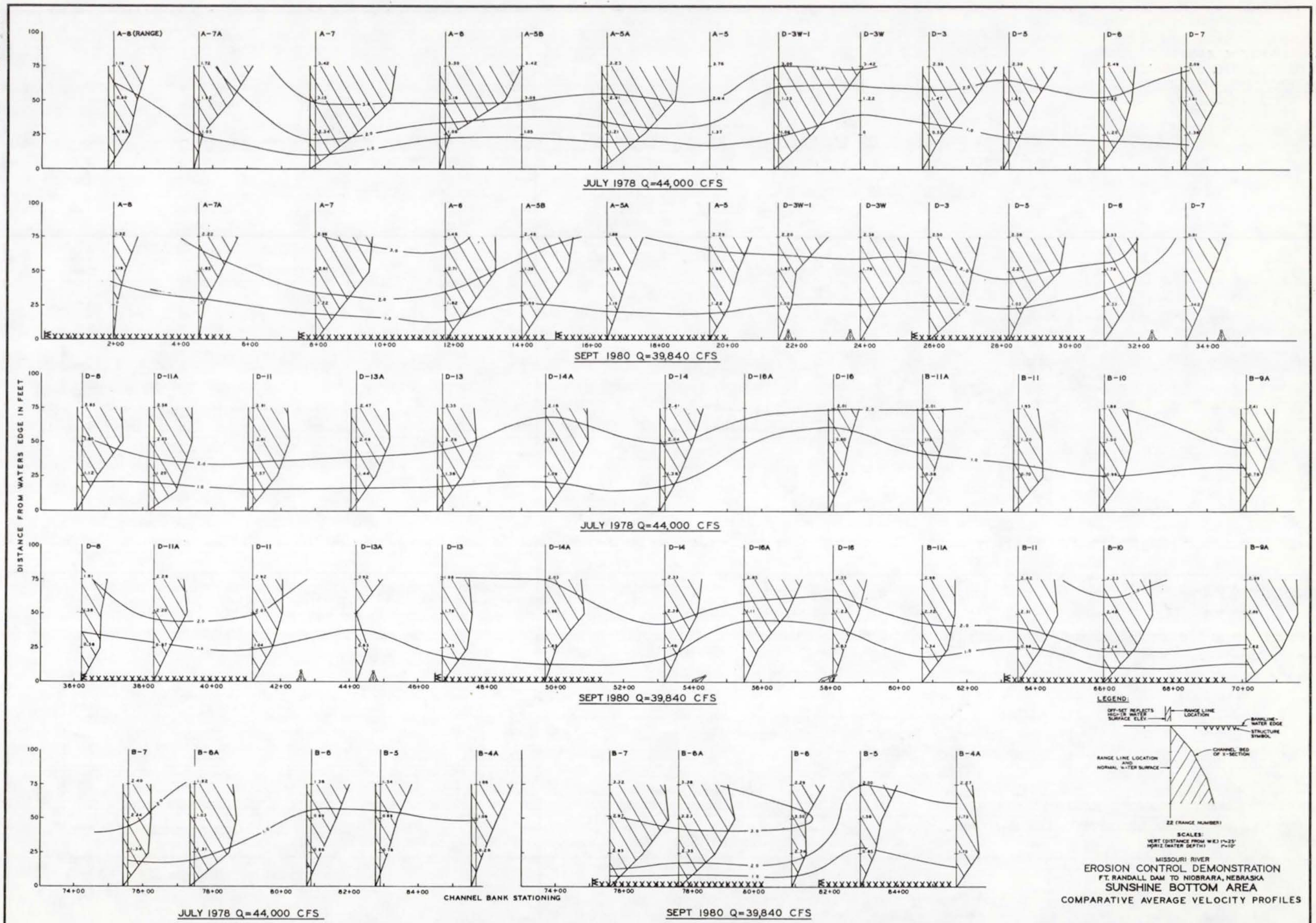
FT. RANDALL DAM TO NIOBRARA, NEBRASKA

SUNSHINE BOTTOM AREA

CROSS SECTIONS

SHEET 4

PLATE 2-8



DISTANCE FROM WATERS EDGE IN FEET
A-8 (RANGE)
A-7A
A-7
A-6
A-5B
A-5A
A-5
D-3W-1
D-3W
D-3
D-5
D-6
D-7
JULY 1978 Q=44,000 CFS
SEPT 1980 Q=39,840 CFS
D-8
D-11A
D-11
D-13A
D-13
D-14A
D-14
D-16A
D-16
B-11A
B-11
B-10
B-9A
JULY 1978 Q=44,000 CFS
SEPT 1980 Q=39,840 CFS
B-7
B-6A
B-6
B-5
B-4A
CHANNEL BANK STATIONING
JULY 1978 Q=44,000 CFS
SEPT 1980 Q=39,840 CFS
LEGEND:
OFF-SET REFLECTS HIGHER WATER SURFACE ELEV.
RANGE LINE LOCATION
BANKLINE-WATER EDGE
STRUCTURE SYMBOL
CHANNEL BED OF X-SECTION
RANGE LINE LOCATION AND NORMAL WATER SURFACE
22 (RANGE NUMBER)
SCALES:
VERT (DISTANCE FROM W.E.) 1"=25'
HORIZ (WATER DEPTH) 1"=10'
MISSOURI RIVER
EROSION CONTROL DEMONSTRATION
FT. RANDALL DAM TO NIOBRARA, NEBRASKA
SUNSHINE BOTTOM AREA
COMPARATIVE AVERAGE VELOCITY PROFILES