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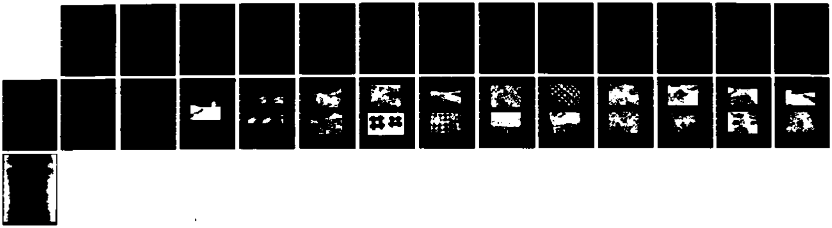

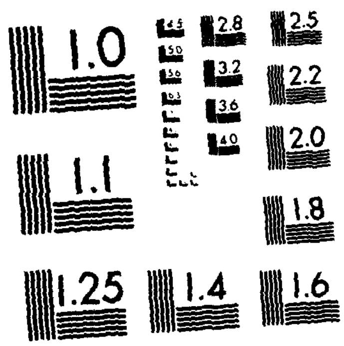

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SECTION 32 PROGRAM
STREAMBANK EROSION CONTROL
EVALUATION AND DEMONSTRATION
WORK UNIT 2-EVALUATION OF EXISTING
BANK PROTECTION

FIELD INSPECTION OF MORAMEAL REVETMENT ON THE RED RIVER

by

Malcolm P. Keown, E. A. Dardeau, Jr.

Hydraulics Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

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Inspection Report 7

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SECTION 32 PROGRAM

STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION

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FIELD INSPECTION OF MORAMEAL REVETMENT ON THE RED RIVER

1. The Morameal Revetment is located on the left bank of the Red River near Elm Grove, Louisiana (Figure 1), with the downstream end of the bank protection works beginning at mile 256.6 (mileage established in 1967 by the Corps of Engineers). The revetment was inspected by the U. S. Army Engineer Waterways Experiment Station (WES) evaluation team on 9 May 78. WES personnel participating in the effort were Messrs. E. B. Pickett (WES project manager for the Section 32 Program), N. R. Oswalt (project manager for Work Unit 02 of the Section 32 Program), and S. T. Maynord, all of the Hydraulics Laboratory, Dr. E. B. Perry, Geotechnical Laboratory, and Messrs. M. P. Keown and E. A. Dardeau, Jr., both of the Environmental Laboratory. In addition, Messrs. G. B. Berndsen and B. Dyba, both of New Orleans District (LMN) accompanied the team. Messrs. Keown and Dardeau prepared this inspection report.

2. The Morameal Revetment was placed as part of the Red River Waterway Project[1] as authorized by the River and Harbor Act of 13 Aug 1968 in accordance with House Document 304, 90th Congress, 2nd Session. The project provides in part for a 9-ft-deep stabilized navigation channel extending from the Mississippi River through Old River and Red River to the vicinity of Shreveport, Louisiana, and then through Twelvemile and Cypress Bayous to a turning basin in the Lake O' The Pines (Ferrells Bridge Reservoir) near Daingerfield, Texas.[2] Eight locks and dams will provide the required depths for navigation. The project also makes provisions for comprehensive bank stabilization in the reach from Shreveport to Index, Arkansas, of which the Morameal Revetment is a part.

3. No discharge or sediment data are available at the Morameal site; however, discharge and suspended sediment data are available for the gaging station at Shreveport (miles 277.6 and 277.8, respectively). The discharge passing Shreveport is somewhat regulated by Denison Dam (closed 1943), Texarkana Dam (closed 1956), and Millwood Dam (closed 16 August 1966). The discharges of record (from 1928) prior to 16 August 1966 are: maximum 303,000 cfs and minimum 690 cfs. (No mean discharge value is available for the period prior to 16 August 1966.) After 16 August 1966, the discharges of record (to the present) are: maximum 165,000 cfs, mean 26,100 cfs, and minimum 1,600 cfs. Suspended sediment samples have been taken by LMN at mile 277.8 since 1966. The data have not been published[3]; however, LMN anticipates that they will reduced and published during 1979.

A-1

4. The bank material in the vicinity of the Morameal Revetment is a lean clay with a trace of sand; the bed material consists of medium and fine sands. The most recent hydrographic survey[4] indicates that the thalweg in the reach which includes Morameal Revetment varies from an elevation* of 98 to 110 ft.

Experimental Revetment Design and Placement

5. The Morameal Revetment was constructed as an experimental stabilization structure using the conventional trenchfill design section but utilizing alternate materials in addition to the standard stone. The revetment was placed in seven test sections, each having a 1V-on-3H upper bank slope with the bank being paved from the toe of the upper bank slope to the 140-ft elevation contour.[5] The downstream end of the revetment begins at mile 256.6, left bank, and extends upstream 7100 ft (Figure 2). Table 1 summarizes the work at the Morameal site by test section, and Table 2 provides final 1974 costs for all of the construction items.

6. Significant bank recession occurred throughout Morameal bend from the inception of the construction effort (June 1974) until the contract was completed (April 1976).** The initial design required 6,360 ft of revetment to stabilize the bend. After initiation of construction under contract, unusually high stages were experienced over an eight-month period, and construction work had to be discontinued. When stages were again favorable for work, the alignment of the revetment was modified to conform to the new geometry of the bendway. Some of the original work at the upstream end of the bend had to be abandoned, and the final design required 7,100 ft of revetment to stabilize the bend. The revetment was constructed by initially excavating a trenchfill section, followed by placement of the experimental revetment and trench material. Material removed from the trench was disposed of riverward of and parallel to the streambank. This disposed material (Figure 3) provided some degree of protection from river action during construction. The seven test sections comprising the revetment are hereafter referred to as Sections A-G (Table 1 and Figure 4). Each of these sections is discussed below.

Section A - Type A limestone

7. The revetment in section A (sta 0+00 to 10+00) consists of 1,000 lin ft of dumped quarry-run limestone (from Arkansas) meeting standard stone quality requirements (classified as Type A). Type A

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* All elevations given in this report are referenced to mean sea level.

** Unpublished file information provided by the U. S. Army Engineer District, New Orleans.

specifications limit the maximum acceptable stone weight to 350 lb, with at least 50 percent by weight of the stone in each shipment weighing 25 lb or more, and being "reasonably well graded" to the maximum allowable stone weight. Stone diameters may range from 4 in. to 24 in., and length-width ratios from 1:1 to 4:1. The contract specified that the average thickness of the upper bank paving be about 18 in. (12 in. near the top of the paving to 21 in. near the toe trench). Thicknesses at the time of the inspection visit were varied and ranged from sparse on the lower bank (Figure 5) to 12 in. or more on the upper bank (Figure 6). The shift of the individual stones can be attributable to overbank drainage and soil leaching as well as to current and wave action. Figure 7, a view of the in-place stone on the upper bank, illustrates the variation in size and shape of the individual stones and shows that some areas may not be fully protected. Both woody and herbaceous vegetation have begun to grow in the spaces between the stones.

8. The toe trench of Section A was filled with 21 in. of anhydrite (Type B quarry-run stone; 135 lb/cu ft) obtained from the cap rock of a Winnfield, Louisiana, salt dome quarry. The Winnfield quarrystone falls below specifications because the surface of the stone chemically reacts with water forming soft, friable, lightweight gypsum material. The stone is also susceptible to rapid deterioration under freeze-thaw conditions, however, the Morameal Revetment is not in a climatic zone subject to severe freeze-thaw cycles that tend to reduce the dimensions and weight of the rock. The Winnfield stone was placed as part of the experimental revetment in order that the performance of substandard riprap could be evaluated. The elevation of the water surface at the time of the inspection prevented examination of the rock in the toe trench.

Section B - Gobi Blocks

9. Gobi Blocks, manufactured by Erco Systems, Inc., New Orleans, Louisiana, were used as upper bank paving for Section B (sta 10+00 to 25+00). The Gobi Blocks are cellular concrete blocks cast using sand, gravel, 20 percent cement, and water. The mix is pressed into molds to form blocks (Figure 8). The blocks used under this contract were 8-in. square and 4 in. thick, weighing approximately 12.5 lb, with 232 blocks being required to cover a square (i.e. 100 sq ft). Four unskilled laborers placed an average of 6,000 to 7,000 blocks in a 10-hr day. Placement of the blocks was often difficult because of the variation in surface topography and the heavy rains that persisted during the installation. During the placement effort, there was some sliding of the blocks on the saturated bank. Figure 9 is a downstream view of Section B. A detailed view of the Gobi Block installation is provided in Figure 10; note that vegetation has begun to grow in the open areas within and between the blocks. This revetment section has never been subject to attack by high-velocity flow or wave action. Several small depressions were noted during the inspection visit (Figure 11), where the blocks have settled as a result of leaching of underlying bank

material probably due to the effects of overbank drainage which was also noted landward of Section B (Figure 12). The toe trench of this section was constructed with Type A stone.

10. A 4-ft section of Gobimat (Gobi Blocks glued to filter cloth) was specified along toe of upper bank for alignment and stability. The mats were prepared by cementing four rows of Gobi Blocks to a Nicolon carrier fabric sheet (5 × 16 ft) with a polyester adhesive. The Nicolon carrier fabric sheet was strengthened during manufacture with white polyethylene and polyester monofilament line. The Gobimats were placed end to end along the toe of the upper bank with a mobile crane.

Section C - Gobimats (Gobi Blocks placed on filter fabric)

11. Gobi Blocks were placed on Poly-Filter X filter fabric as upper bank paving for Section C (sta 25+00 to 40+00). A 4-ft wide section of Gobimat (Gobi Blocks glued to filter cloth) was initially placed along the toe of the upper bank as in Section B.

12. The Gobi Blocks were hand-placed on the Poly-Filter X fabric and butted together for continuous coverage. During the installation, heavy rains and rising river stages hampered work. In some portions of this section, overbank drainage and/or groundwater entered between the fabric and bank resulting in a buildup of deposition between the fabric and bank causing bulging of the overlying fabric and blocks. This action necessitated replacement of fabric and repositioning of the blocks in several areas. The upper edge of the filter fabric was then buried to prevent infiltration of overbank drainage.

13. At the time of the inspection, the filter fabric was not visible through most of this section because of deposition and the growth of vegetation. The general appearance of the revetment section was not unlike that of Section B (Figure 9). At the few locations where the filter fabric was visible, it seemed to be in good condition (Figure 13). Overbank drainage has removed some of the protective soil covering the fabric at the landward edge of the section (Figure 14); piping beneath the fabric was also noted at several locations (Figure 15). The trench-filled toe of this section was constructed with Type A stone.

Section D - rock and wire mattresses

14. No locally available stone meeting durability requirements exists in Louisiana; therefore stone must be imported at high cost. A means to alleviate that condition would be to substitute an alternate material for stone or to minimize the quantity of stone needed. The use of stone-filled wire mattresses can reduce the amount of stone needed for upper bank paving under the normal thickness for equivalent protection. A specially designed 6-in.-thin rock-filled wire mattress composed of individual wire baskets (loosely termed gabions) was used as revetment in Section D (sta 40+00 to 50+00). The baskets were fabricated

with dimensions of 7 ft. 6 in. long by 6 ft 6-in. wide by 6 in. thick (with three equally divided compartment sections) and with 2-in. by 2-3/8-in. mesh openings. At the time of revetment construction, there was no domestic supplier from which gabions less than 1 ft thick could be obtained, so it was necessary to consider foreign sources in order to avoid prohibitive rock-fill costs. A total of 770 galvanized wire gabions meeting project requirements were obtained in flat bundles from Maccaferri Gabions of Italy. These gabions were hand-placed on the bank and wired together by laborers (Figure 16). Four contiguous gabions were placed above the toe along the entire 1000-ft length of Section D to form the rock-filled wire mattress upper bank paving (Figure 17).

15. The graded stone (sandstone) used to fill the gabions met the following criteria:

- a. Not more than 5 percent by weight could pass a 2-in. mesh screen. The material passing the 2-in. mesh screen could include soil, rock fragments, and foreign material accumulated from blasting or loading operations.
- b. Not more than 40 percent could pass a 3-in. mesh screen.
- c. One hundred percent must pass a 4-in. mesh screen.

Each gabion was filled with 1.4 to 1.8 tons of stone. Attempts to fill the gabions using a clamshell bucket and a template proved more cumbersome than the clamshell bucket alone; thus the majority of the units were filled using only the clamshell bucket. Laborers dressed the stone with rakes and then wired the tops to each gabion. Additional bank paving (using the same type of stone that was used to fill the gabions) was placed between the landward edge of the rock and wire mattress and 143.9 ft elevation (approximately 3 ft width). This test section was the only part of the Morameal Revetment not disrupted during construction by prolonged rains, rising stages, and bank sloughing. The trench-filled toe of this section was constructed with Type A stone.

16. After completion of the installation, settling of the mattress occurred at several locations (Figure 18). These depressions in the mattress have been generally attributed to overbank drainage, piping, and leaching of soil from beneath the mattress. The WES evaluation team noted that most of the settling occurred along the joints where two gabions had been wired together. These depressions may have resulted in part from placing the gabions such that there were long, continuous joints that allowed overbank drainage to concentrate and to erode unchecked. If the gabions had been placed in a staggered manner, i.e., such as bricks are commonly laid, then the long, continuous joints would have been lessened.

<u>Section E - sand-filled acyrilic bags</u>

17. The experimental revetment placed in Section E (sta 50+100 to 53+61) consisted of sand-filled acrylic bags (also called acrilan

sand pillows) manufactured by Monsanto Textiles Company, St. Louis, Missouri. The bags were made from 1 sq yd of fabric woven of unused nondelustered 8.0 to 18.0 denier acrylic staple fiber and stiched with acrylic fiber thread. It was intended by the specifications that the bags would be filled with jobsite material excavated in constructing the revetment. The contractor, however, chose to subcontract the filling of the bags to Cobb Industry of Coushatta, Louisiana. Each bag was filled with 100 lb of twice-washed sand (air-dried by a blower) and then stitched. The entire procedure was accomplished in an assembly line operation. The original plans called for construction of a revetment test section with 150,000 sandbags, but delays in fabric production and the high unit cost per bag ($5.00) made it necessary to reject all initial bids and redesign a 361-ft-long test section using 47,500 bags.

18. The filled bags were stockpiled on pallets at Coushatta and later delivered to the jobsite. At the jobsite the filled bags were exposed to heavy rains and some of the bags split or became mildewed (even though the acrilan fabric was supposed to be mildew-resistant). A few bags were also damaged by the teeth of a forklift that was used to move the pallets and by the boards of the pallets splitting and gouging the fabric. Lost sand fill was replaced with material removed during bank grading and preparation, and bag rips were repaired by hand-stitching. None of the bags split at the seams despite the rough handling and exposure to the elements.

19. The excavated toe trench was filled with bags dumped from a dragline bucket. During the excavation and dumping operation, it was necessary to place a clay plug at the upstream end of the trench and to continuously run two pumps in order to keep seepage water below the elevation of the ongoing work. On the graded bank, the bags were hand-placed and lapped in much the same manner as roofing shingles (Figure 19).

20. At the time of the inspection, the bags seemed to have fared very well in resisting deterioration due to seepage, overbank drainage, and ultraviolet radiation. A healthy stand of grass has become established on the upper bank and between the bags. Of all the revetment test at the Morameal site, Section E provides the best access to river water for cattle. Some damage was noted as a result of the cattle traffic (Figure 20).

<u>Section F - soil-cement blocks</u>

21. Soil-cement blocks were placed in Section F (sta 53+61 to 63+61) as a substitute for quarry-run stone. These blocks were fabricated at the construction site and placed on the bank. Prior to placement, borings were taken to depths of 50 ft to obtain samples of the soil types present. The boring samples were taken to WES to determine the suitability of the material to produce soil-cement.

22. To provide additional information, a test area was established near the construction site. Prior to working in the test area, the

turf and topsoil were removed. Soil-cement mixes of 6, 8, 10, and 12 percent by weight of cement were prepared in four contiguous test strips, each being 23 × 200 ft. The test strip soils were thoroughly mixed with cement using a pH soil stabilizer with four rows of cutting and mixing vanes, after which, the strips were compacted with successive passes of a sheepsfoot roller. A motor patrol then pulled a disc cutter over each section to cut the soil-cement into blocks with 2- by 2-ft surface areas. The cut soi'-cement was covered with emulsified asphalt (grade 55-1) for curing.

23. After a seven-day ing period, sections of the soil-cement strips were removed with a front-end loader, beginning with the 10 and 12 percent mix strips. Approximately one-third of the blocks produced had at least one dimension of 8 to 18 in., but the remainder of these two strips yielded minimum dimensions in the 2- to 3-in. range. The 6 and 8 percent mix strips contained very few usable pieces of soil-cement with the majority of the material being soil-size particles. Sample blocks from each strip plus some 200 to 500 lb of untreated soil were sent to WES for analyses to aid in the determination of the correct cement percentage to be used with the existing soil at the Morameal site. Tests at WES showed that a 10 percent cement content should have produced satisfactory results.

24. A new work area (510 ft by 210 ft) landward of Section F was used to fabricate the soil-cement blocks to be placed as fill for the toe trench and as upper bank paving. LMN personnel elected to excavate the entire work area to a depth of 2.5 ft to facilitate drying of the subbase. After drying, the subbase was leveled and then compacted with a 35-ton pneumatic roller and six passes of a sheepsfoot roller. Since there was insufficient material stockpiled to fabricate a 1-ft lift of soil-cement, a 2-in. soil cushion, and a final 6-in. layer of soil-cement, it was necessary to find additional fill material. Borrow material (not analyzed by WES) was located landward of sta 32+00. Later analyses of the soil secured from the borrow area indicated that it was a fine silty sand. Material for the 1-ft lift was spread to a 15-in. depth over the work area. Tanker trucks then spread sufficient cement for a 10 percent content, followed by the pH soil stabilizer which made three passes to achieve a good soil-cement mix. The material was compacted by three passes of a sheepsfoot roller and the entire 1-ft lift was disc-cut to a 1-ft depth. The cut material was then additionally compacted by four passes of a sheepsfoot roller, finish-rolled with a 35-ton pneumatic roller, and sealed with asphalt emulsion.

25. After the first lift was allowed to cure for 14 days, it was covered with 2 in. of soil to cushion fabrication for a second 6-in.-thick lift. Suitable material was again secured from the borrow pit at sta 32+00. The same procedures as noted above were generally followed in fabricating the 6-in. lift except that more passes of the sheepsfoot roller were made which resulted in a decrease in the density of the material and water content. Water was added to the soil-cement

to offset the drying effect resulting from the passes of the sheepsfoot roller. The lift was then allowed to cure 10 days.

26. Excavation of the toe trench to receive the soil-cement blocks was hampered by severe caving on both sides of the trench. After excavation of the trench was completed, the fresh soil-cement was removed from the work area with a front-end loader, placed in a dump truck held by a safety cable attached to a D-15 dozer, and let down the graded bank to be tail dumped into the toe trench. The soil-cement broke into fine fragments with only few sizable blocks present. The fine fragments were probably attributable to differences in the curing of the lifts as compared with the curing of the material in the test sections plus the fact that the borrow material was not the same as the material used in the test sections, and thus a 10 percent cement content may not have been adequate. Heavy rains fell during the hauling and placement of the soil-cement causing some of the cement to leach out of the mixture.

27. The remaining soil-cement in the work area was bulldozed into a layer on the upper bank of this section. This material was mostly fines that resembled the in situ soil. The paved bank was then graded and dressed which resulted in further pulverizing of the soil-cement. Figure 21 shows a downstream view of the completed revetment section as it appeared at the time of inspection; the bare area is exposed soil-cement. A detailed view of a larger soil-cement block is shown in Figure 22.

Section G - Type A limestone

28. Section G (sta 63+61 to 71+00) was constructed as a downstream extension to the original revetment to prevent loss of the stabilized navigation alignment. A trench was excavated from the downstream end of the soil-cement test section to sta 71+00 and then filled with Type A stone. The bank was dressed and then covered with Type A stone in a 12-in. layer tapering to 21 in. thick at the toe or about 12 tons/lin ft.

Performance of the Revetment

29. At the time of the inspection visit, the revetment had not been tested by high stream velocities or wave action. The only failures appeared to be attributable to overbank drainage and piping.

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1. U. S. Army Engineer District, New Orleans, CE, "Project Maps; Vol 1, Rivers and Harbors," 1 Nov 1977, New Orleans, La.

2. __________, "Red River Waterways, Louisiana, Texas, Arkansas, Oklahoma; Stabilization and Cutoffs," Design Memorandum No. 1, May 1972, New Orleans, La.

3. Keown, M. P., Dardeau, E. A., Jr., and Kennedy, J. G., "Inventory of Sediment Sample Collection Stations in the Mississippi River Basin," Technical Report M-77-1, Mar 1977, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

4. U. S. Army Engineer District, New Orleans, CE, "Red River Hydrographic Survey," Vol 1, Mar 1970, New Orleans, La.

5. __________, "Specifications for Red River, Morameal, Bossier Parish, La., Experimental Revetment, Item R-257.0-L (1967 Mileage)," Solicitation No. DACW29-74-B0300, 3 May 1974, New Orleans, La.

6. Oswalt, N. R., George, J. F., and Pickering, G. A., "Fourmile Run Local Flood-Control Project, Alexandria and Arlington County, Virginia; Hydraulic Model Investigation," Technical Report H-75-19, Dec 1975, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

Table 1

Test Sections - Morameal Revetment

Section	Length of Section, ft, (Station Designation)*	Type of Material		Date Completed
		Bank	Toe	
A	1000 (sta 0+00 to 10+00)	Type A limestone**	Type B, anhydrite**	Nov 1975
B	1500 (sta 10+00 to 25+00)	Gobi Blocks; Gobimats	Type A limestone	Oct 1975
C	1500 (sta 25+00 to 40+00)	Gobi Blocks placed on filter fabric; Gobimats	Type A limestone	Aug 1975
D	1000 (sta 40+00 to 50+00)	Rock and wire mattresses	Type A limestone	Aug 1975
E	361 (sta 50+00 to 53+61)	Sand-filled acrylic bags	Sand-filled acrylic bags	Aug 1975
F	1000 (sta 53+61 to 63+61)	Soil-cement blocks	Soil-cement blocks	Nov 1975
G	739 (sta 63+61 to 71+00)	Type A limestone	Type A limestone	Apr 1976

* Sta 0+00 at mile 257.95; sta 71+00 at mile 256.60.

** Type A and Type B stone are described in paragraphs 7 and 8.

Table 2

Quantities and Costs Incurred (1974 dollars) for Placement of the Moramеal Revetment

Item	Quantity	Unit Price (1974 dollars)	Total Cost (1974 dollars)	Remarks
Mobilization and demobilization			$ 85,000.00	Includes cost of transporting equipment to and from jobsite
Clearing	11.97 acres	$1500/acre	17,955.00	
Excavation and grading	495,765 cu yd	0.54/cu yd	267,713.10	
Type A limestone	49,969 tons	13.15/ton	657,092.35	Sections A and G
Graded stone	1031.85 tons	20/ton	20,637.00	Used in Section D
Gabions	770 gabions	29.50/ea	22,715.00	Used in Section D, includes cost of shipping plus duty
Type B anhydrite	13,188 tons	10.94/ton	144,276.72	Toe trench, Section A
Gobi Blocks	454.35 squares	200/square	90,870.00	Section B
Gobi Blocks placed on filter fabric	444.44 squares	250/square	111,110.00	Section C
Gobimats	120.48 squares	340/square	40,963.20	Section C
Soil-cement fabrication	6507.19 yd	25/yd	162,679.75	Section F (cost of labor and equipment)

(Continued)

Table 2 (Concluded)

Item	Quantity	Unit Price (1974 dollars)	Total Cost (1974 dollars)	Remarks
Cement	15,533 cwt	$2.80/cwt	$ 43,492.40	Cement used in fabrication of soil-cement, Section F
Sand-filled acrylic bags	47,537 bags	5/ea	237,685.00	Section E
Environment protection			12,000.00	All labor, materials and equipment used in prevention of environmental pollution during and as a result of construction operations, also cleanup operations, and recording and preserving historical and archeological finds.
Fertilizing	12.52 acres	400/acre	5,008.00	
Seeding	12.52 acres	400/acre	5,008.00	
			$1,924,205.52	

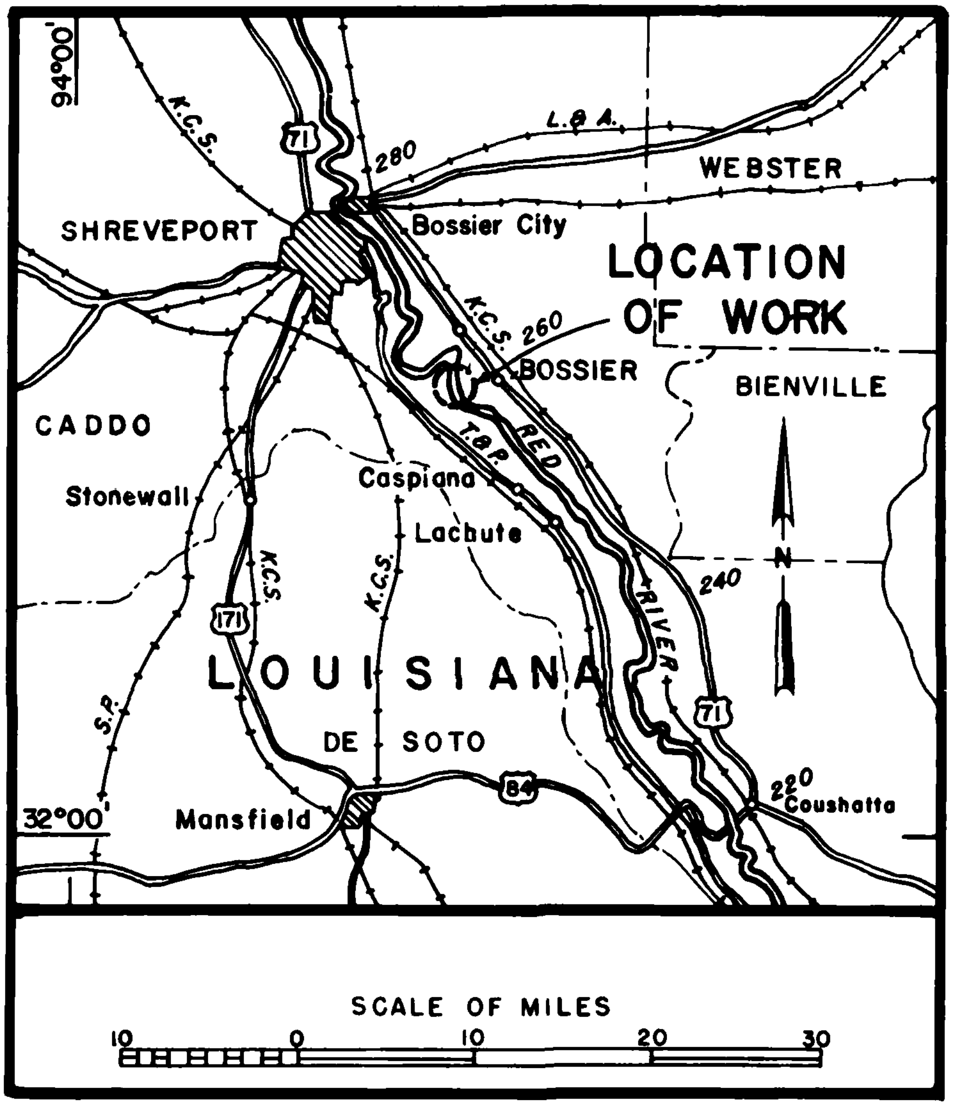


Figure 1. Morameal Revetment vicinity map

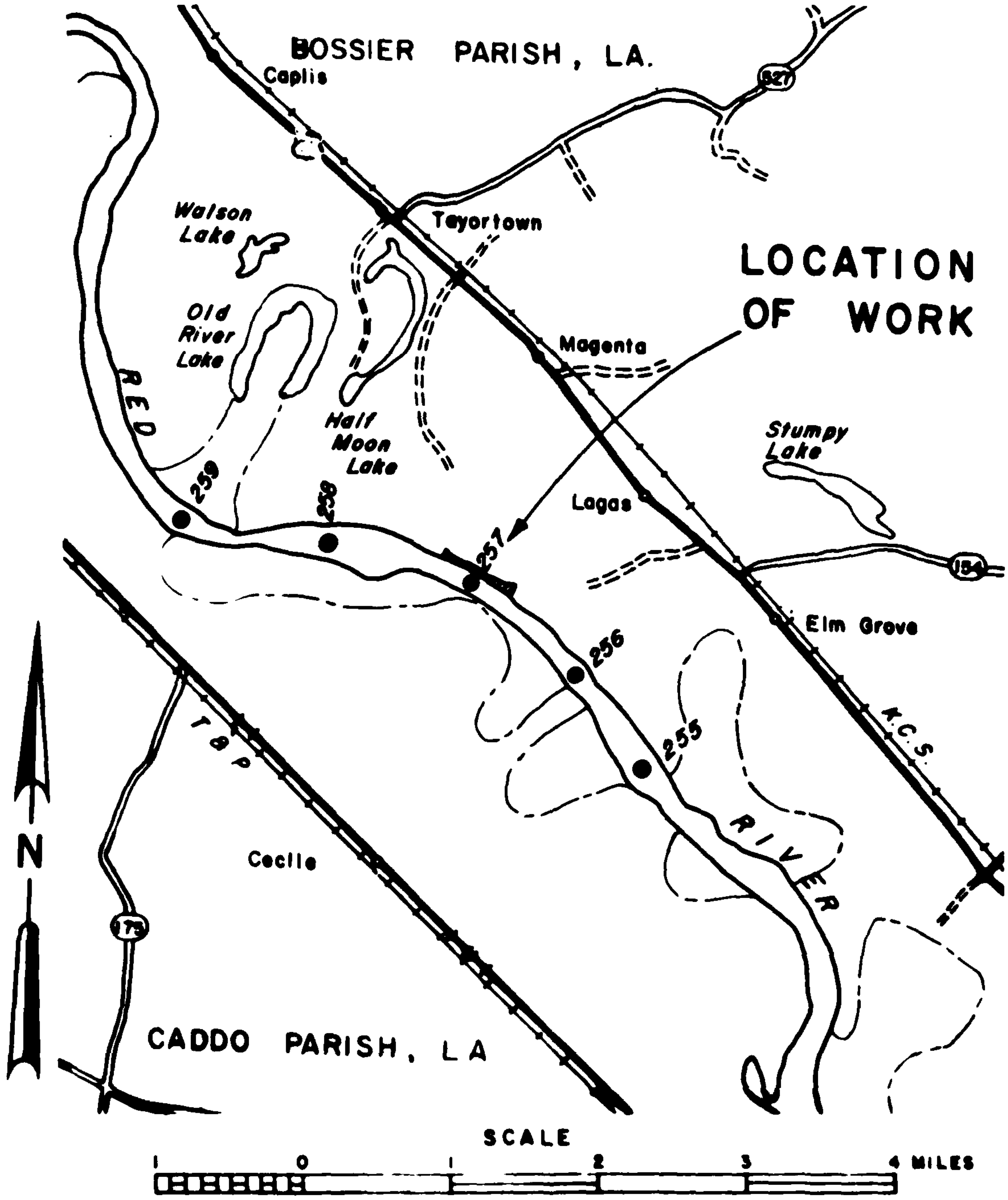
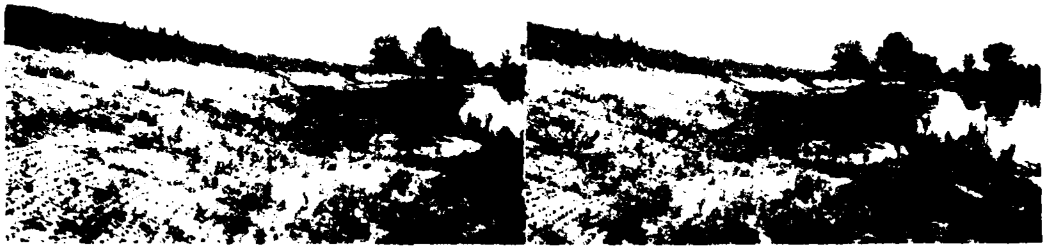


Figure 2. Morameal Revetment site map

Figure 3. Upstream view of revetment showing spoil bank (left side) constructed with material removed from toe trench and deposited riverward and parallel to the streambank



a. Downstream view taken from sta 38+00. Note disposed material at right resulting from toe trench excavation. Gobimats and rock and wire mattresses are in the foreground (paragraphs 9 and 12)

b. Upstream view taken at sta 42+00. Rock and wire mattress and Gobimats are in the foreground

Figure 4. Stereoscopic views of Morameal Revetment

Figure 5. Upstream view of lower bank riprap (Section A)

Figure 6. Upstream view of upper bank riprap (Section A)

Figure 7. Type A limestone used on the upper bank (Section A); note variation of size, shape, and thickness of riprap cover

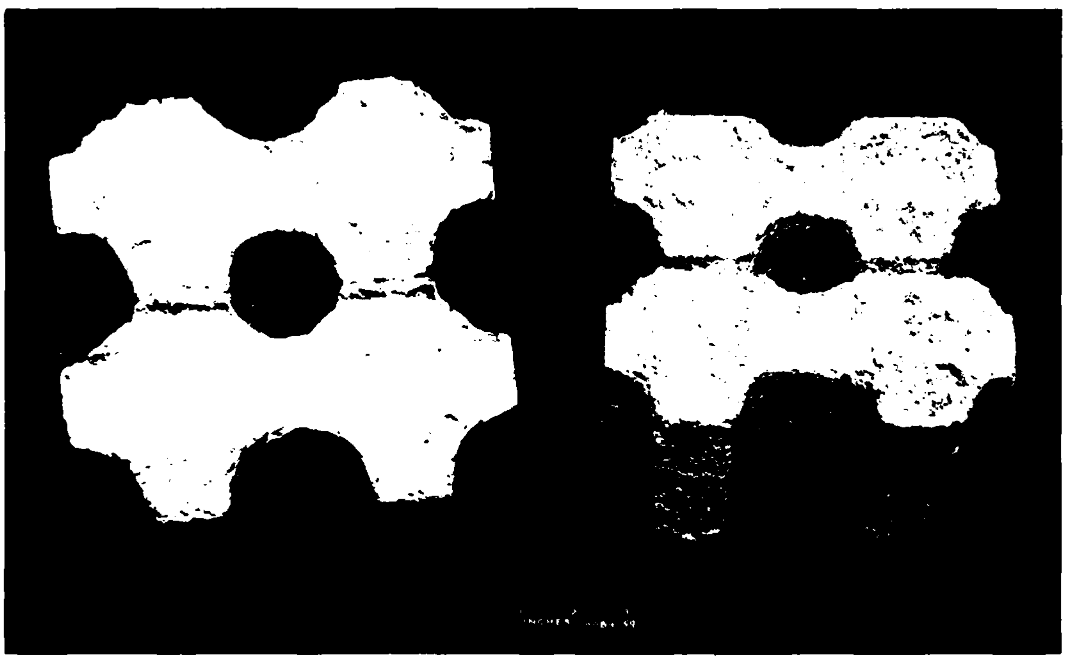


Figure 8. Gobi Blocks

Figure 9. Downstream view of Gobi-Block revetment (Section B). Spoil bank is located in the extreme right portion of photograph

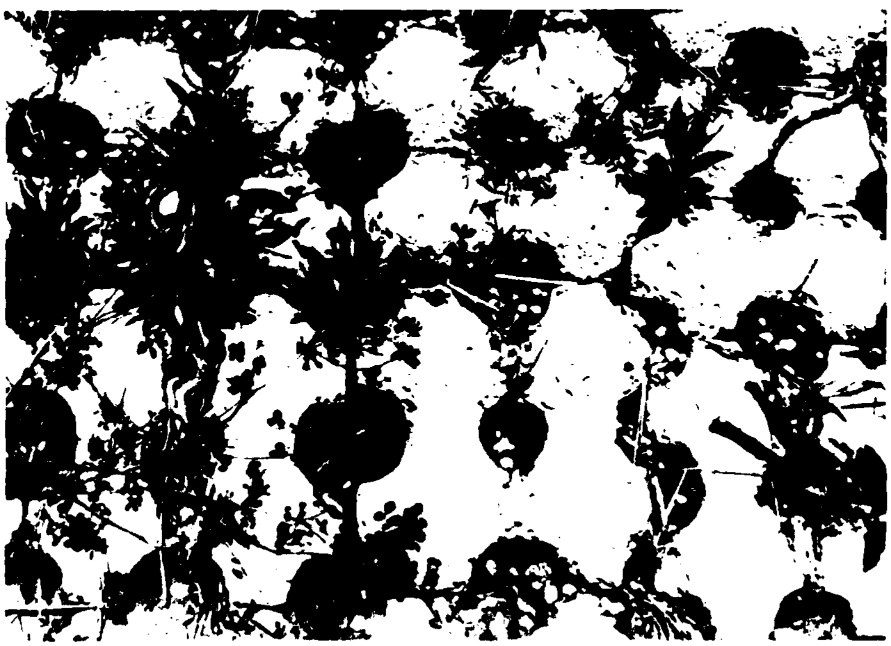


Figure 10. Detailed view of Gobi-Block revetment (Section B)

Figure 11. Subsidence of Gobi-Block revetment (Section B)

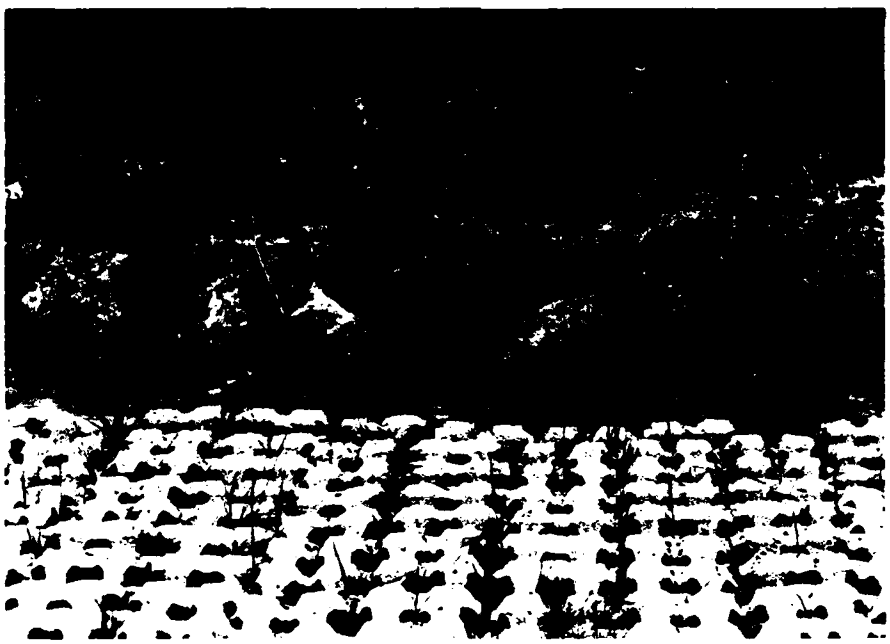


Figure 12. Upper bank erosion resulting from overbank drainage (Section B)

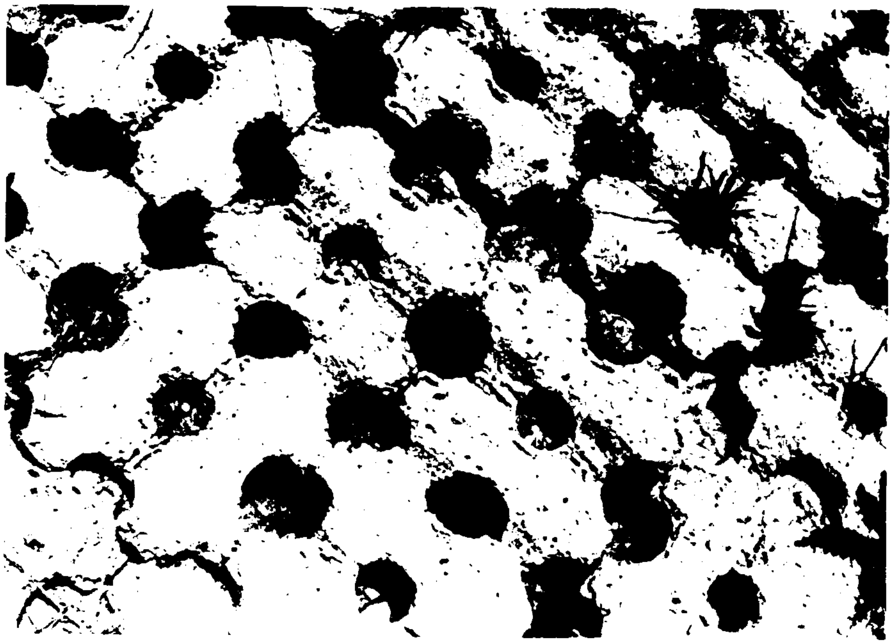


Figure 13. Poly-Filter X filter fabric visible through Gobi Blocks (Section C)

Figure 14. Filter fabric (Poly-Filter X) exposed at the landward edge of revetment (Section C)

Figure 15. Piping detected beneath the Poly-Filter X filter fabric (Section C)

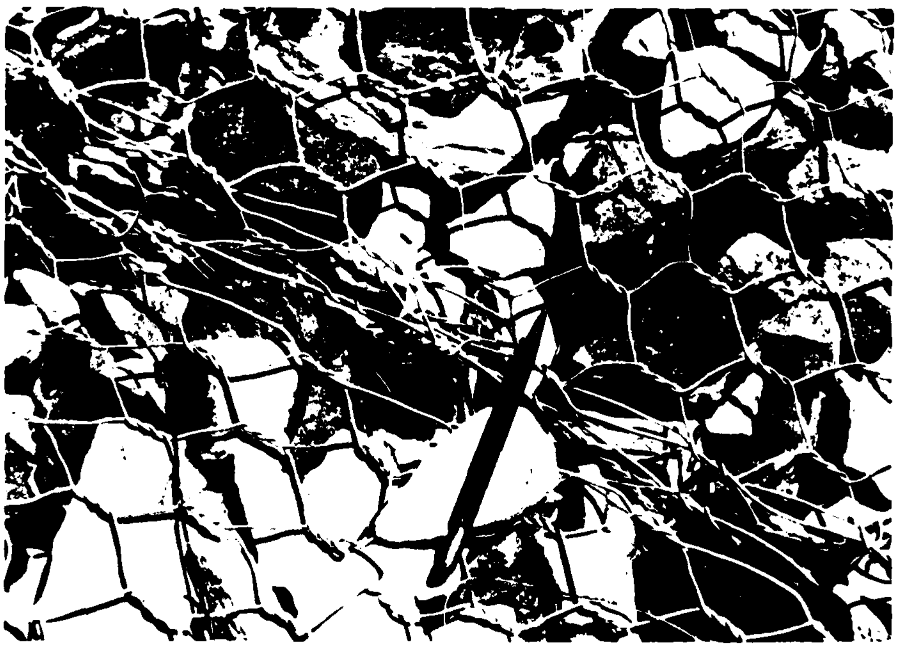


Figure 16. Detail view of rock and wire mattress where two gabions have been wired together (Section D)

Figure 17. Upstream view of rock and wire mattress (Section D)

Figure 18. Subsidence of upper bank paving and mattress (Section D)

Figure 19. Upstream view of sand-filled acrylic bag test section (Section E). Disposed material removed from the toe trench is located in the extreme left portion of photograph

Figure 20. Damage to sand-filled bag by cattle hoof (Section E)

Figure 21. Downstream view of soil-cement section (Section F). Disposed material removed from the toe trench is located in the extreme right portion of the photograph

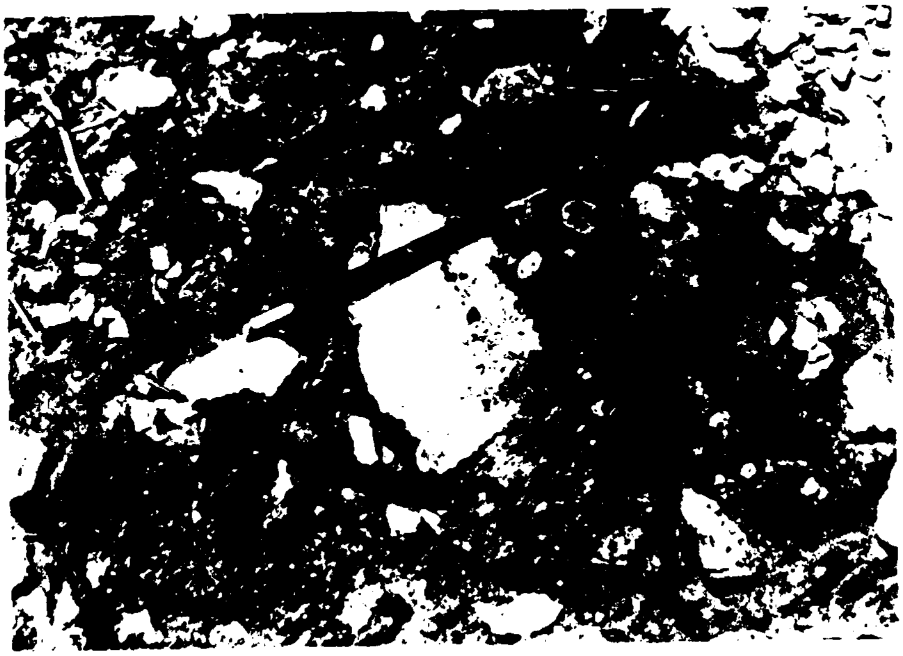


Figure 22. Detailed view of a larger soil-cement block (Section F)

END

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