downstream from a wing dam which is just upstream from the tributary outlet, strong reverse currents were observed. The bank soils are primarily FST and MST. Piping cavities and overland drainage rills were observed at Site 40.

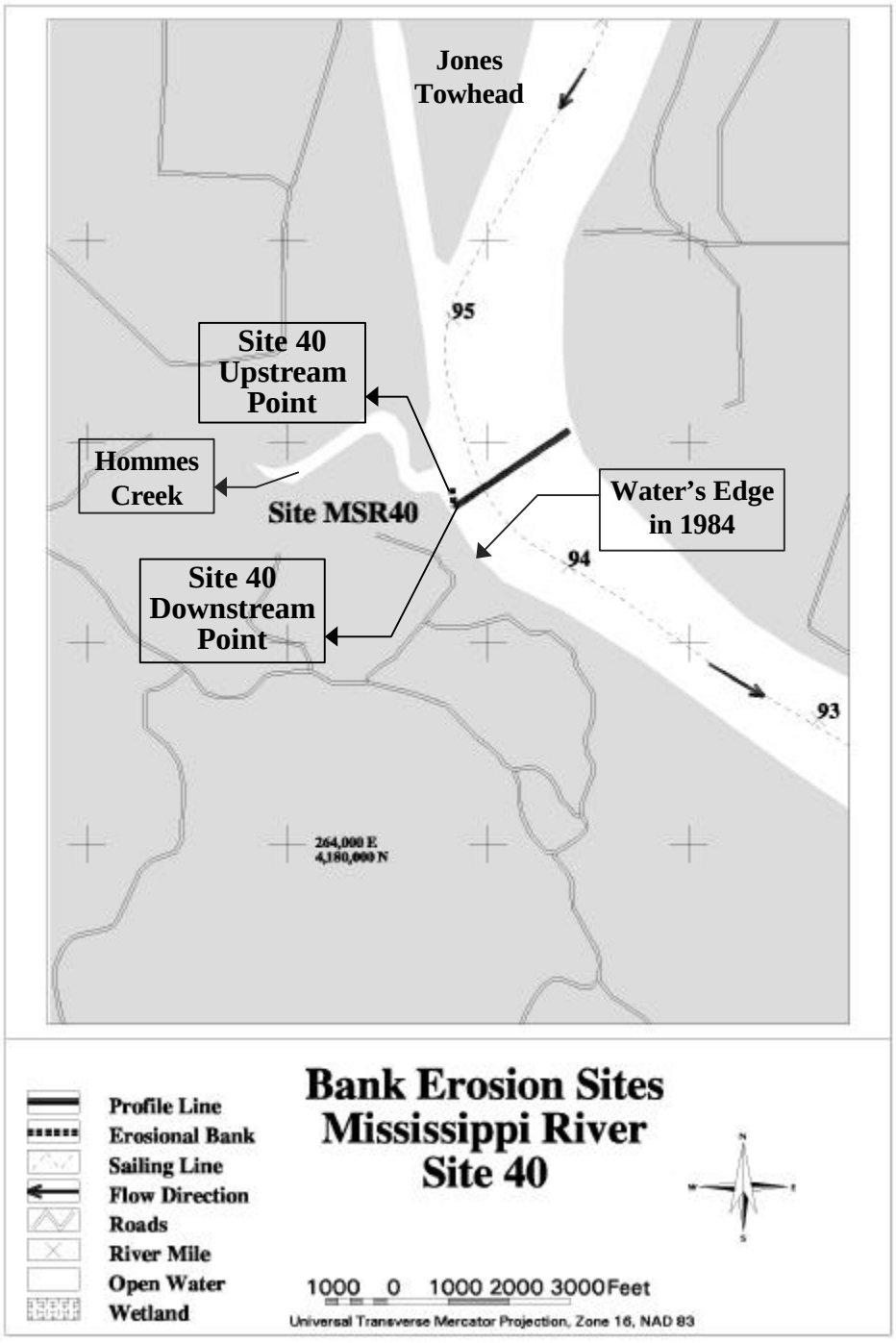

Figure 7-126 A map showing Mississippi River Site 40

Photo 7-111 An upstream view of Site 40 downstream point

Photo 7-112 A downstream view of Site 40 downstream point

Photo 7-113 A close-up view of eroded bench at Site 40 downstream point

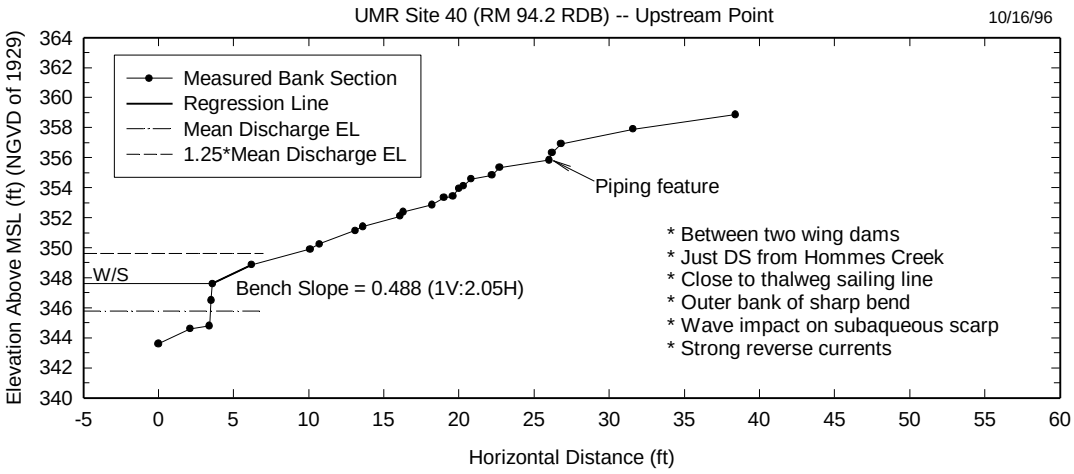

Figure 7-127 Bank section measured at Site 40 upstream point

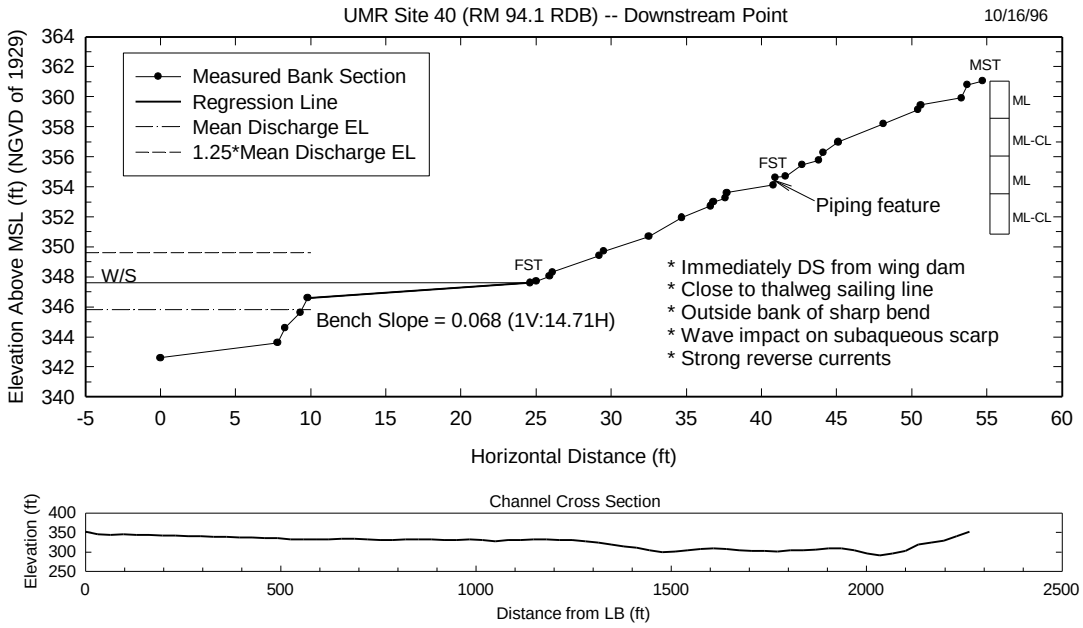

Figure 7-128 Bank section and channel cross section measured at Site 40 downstream point

This erosion site appears to lie on a surface composed entirely of historical alluvium. One sampling tube core showed extremely thick historical deposits. From a bank exposure and from the sampling tube core, it appears that the historical alluvium is in excess of 26 ft thick. The pronounced Mississippi River ridge with swale topography in the nearby areas is protected by a constructed levee. Multiple orientations of the ridges and swales indicate possible older Holocene surfaces in the valley.

Causative factors for bank retreat at this site include flood-flow erosion and recessional failures, piping and collapse, seepage and overland-flow surface erosion, wave and rework-transport of failed soils and recently deposited sediments within berm and bench areas, and impacts due to flow-training structures. Type C describes this site.

41. Site 41 at RM 77.2 RDB (Open Water)

This right bank erosion site, shown in figure 129, is located on the outside of a mild bend across from Grand Tower Island, less than 0.5 mile downstream from a mid-channel island. Upstream and downstream views of the site are shown in Photos 7-114 and 7-115,

respectively. One bank section was obtained, as shown in figure 7-130. The upper bank soil is primarily post-glacial Pleistocene and consists of coarse sand and gravel,

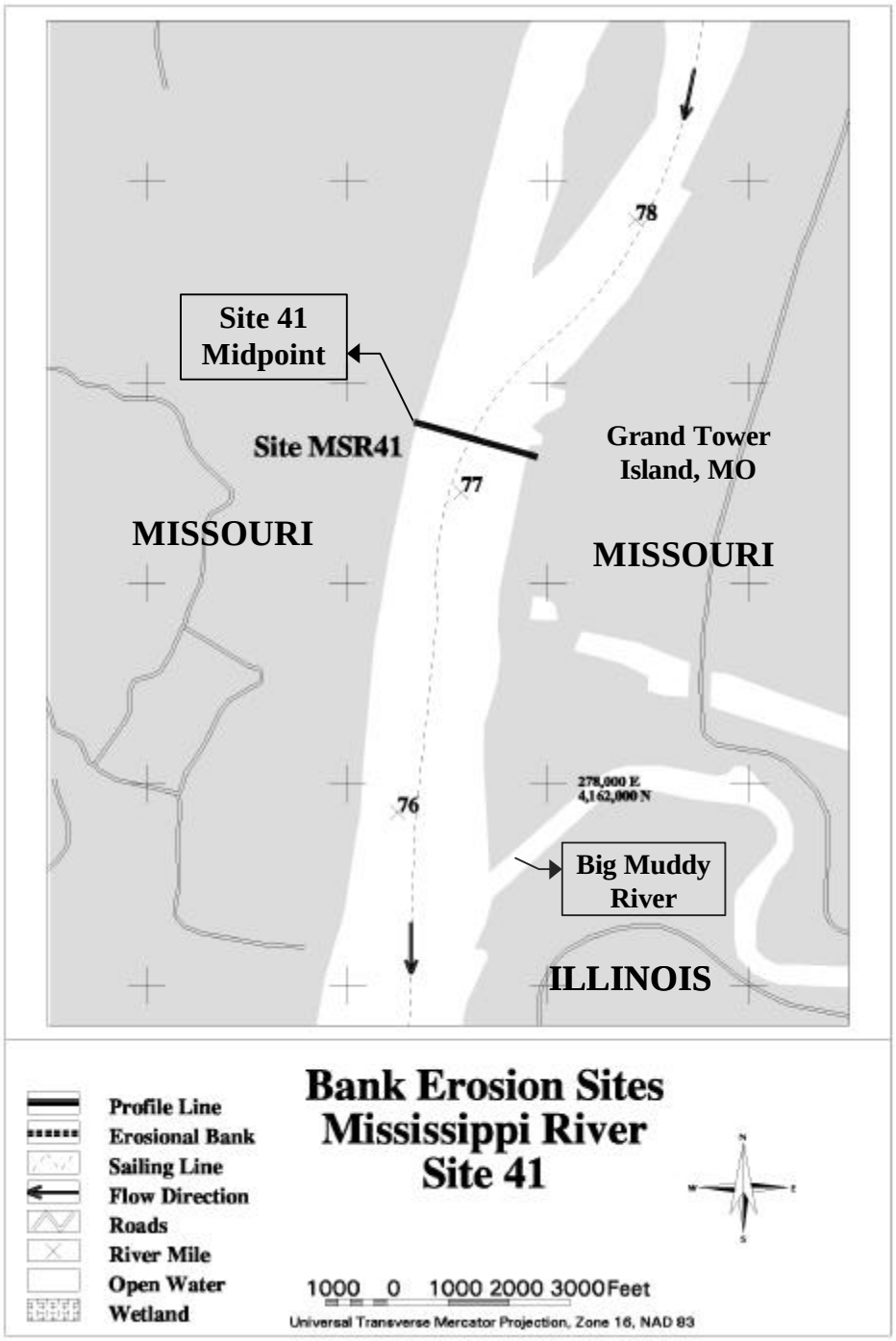

Figure 7-129 A map showing Mississippi River Site 41

Photo 7-114 An upstream view of Site 41 midpoint

Photo 7-115 A downstream view of Site 41 midpoint

Photo 7-116 Piping features of Site 41 midpoint

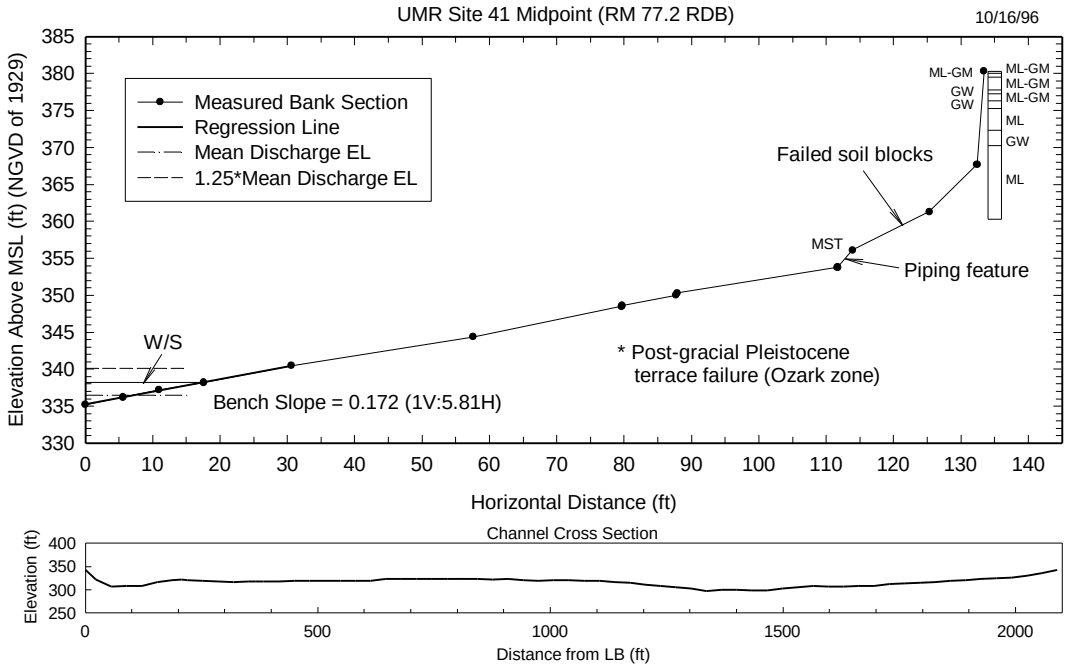

Figure 7-130 Bank section and channel cross section measured at Site 41 midpoint

forming layers and lenses. These deposits are over 25 ft thick. At the base of the scarp, where piping cavities were observed, deposits are silty. Photo 7-117 shows piping cavities.

Site 41 lies along the west valley margin where erosion has formed alluvial fans. Colluvial slopes indicate active failures. A scarp about 25 ft to 30 ft high exposes the fan and toe of slope deposits. A sampling tube core and erosional features examined at the site indicate that a late Wisconsinan to early Holocene colluvial slope is now undergoing active erosion. No paleosols or historical alluvium were observed in the profile. Barge smears at flood stage were observed about 20 ft to 25 ft above the water surface which was at EL 338.2 above MSL (NGVD of 1929).

Causative factors for bank retreat at this site include flood-flow erosion and rapid recessional failures, piping and collapse, overland drainage erosion, and wave actions which erode failed soils and recently deposited sediments within berm and bench areas. A combination of Type E and Type F describes Site 41.

42. Site 42 at RM 53.2 LDB (Open Water)

This left-bank erosion site, shown in figure 7-131, is located along the outside of a bend in the MR at Cape Girardeau. The river channel at this site is about 1,800 ft wide. Photo 7-117 shows an upstream view of the site and Photo 7-118 shows a close-up view of a revetment failure. Photo 7-119 shows a downstream view of the site. Photo 7-120 shows bank failure which was taking place. Undercut blocks fell onto the sandy lower bank. Three bank sections are shown in figures 7-132 through 7-134. The bank soils are primarily MST, FS, and VFS. This site is located within a failure of a hand-placed revetment. Piping features and failed soil blocks were observed at this site. Apparently, bank undercutting occurred and the toe of revetment was truncated, resulting in upslope launching of revetment stone. Once the revetment base, consisting of limestone gravel, is launched, waves or high water flows would erode the slope, resulting in further launching of upper revetment stone.

Site 42 lies on a surface composed entirely of historical alluvium. From a bank exposure and from the sampling tube core, the historical alluvium is considerably greater

than 10 ft, and as much as 30 ft, thick. As at most locations south of St. Louis, considerable storage and removal of historical deposits typically occur channel-ward from the levee.

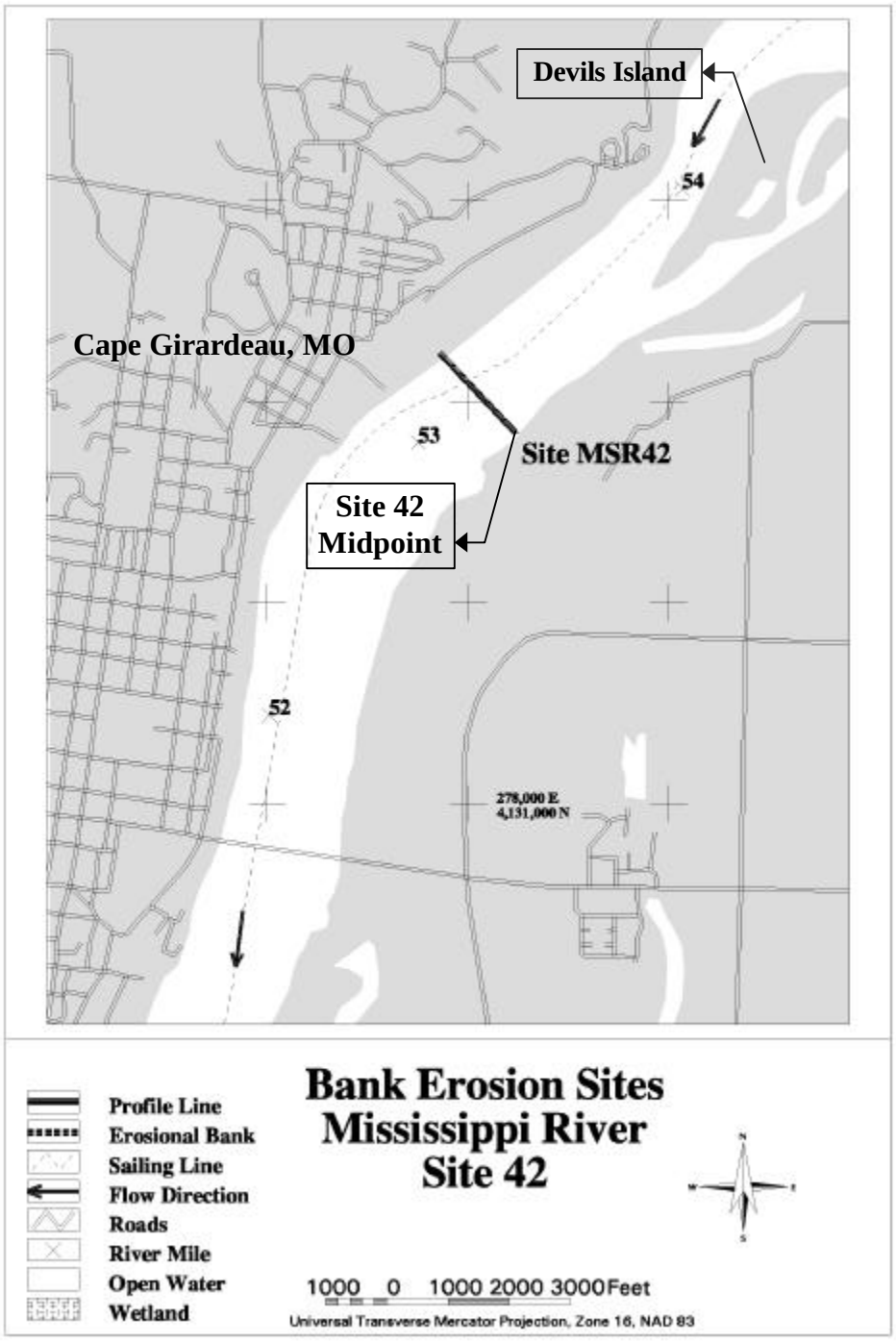

Figure 7-131 A map showing Mississippi River Site 42

Photo 7-117 An upstream view of Site 42 midpoint

Photo 7-118 A close-up view of revetment failure at Site 42 midpoint

Photo 7-119 A downstream view of Site 42 midpoint

Photo 7-120 A close-up view of bank failure of Site 42 midpoint

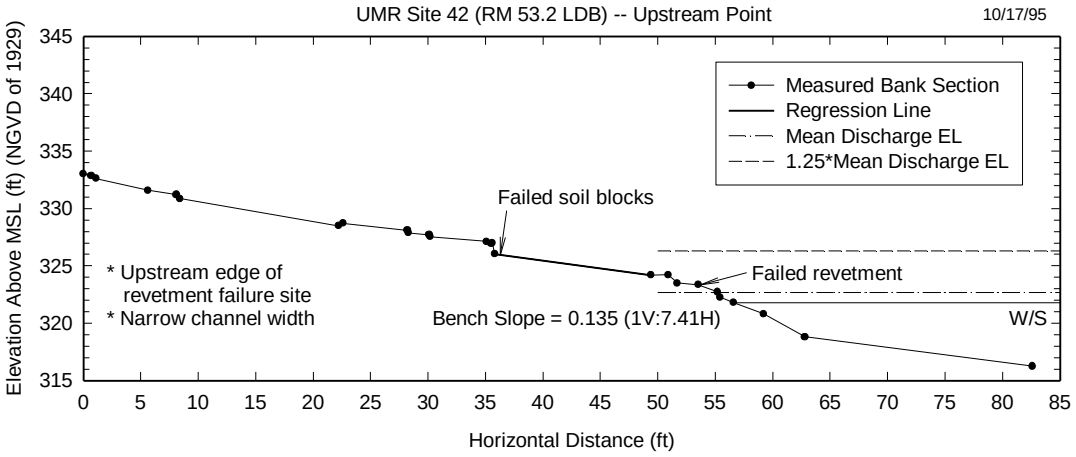

Figure 7-132 Bank section measured at Site 42 upstream point

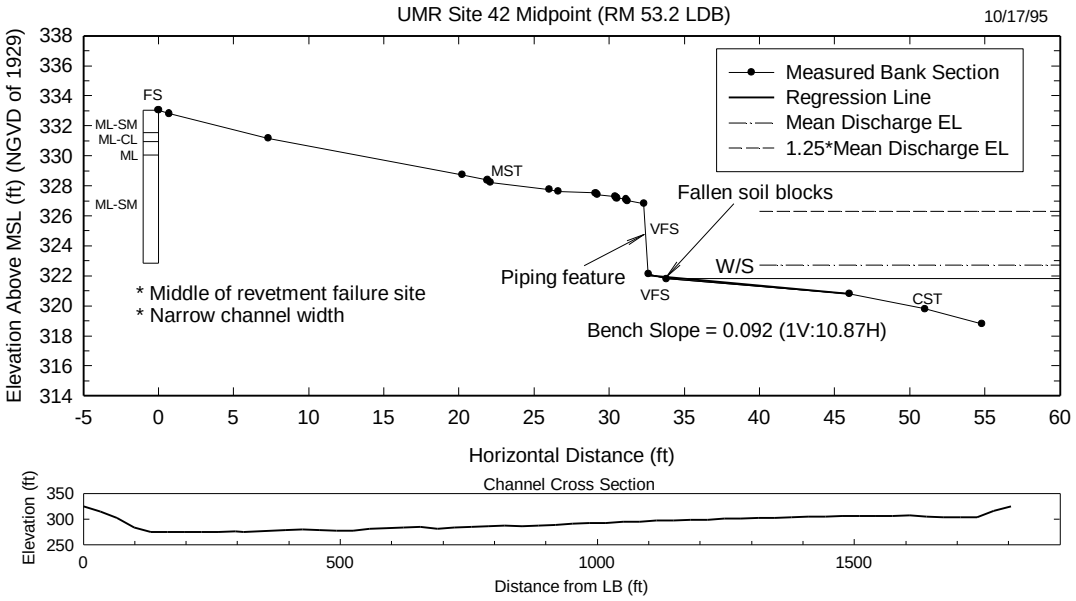

Figure 7-133 Bank section and channel cross section measured at Site 42 midpoint

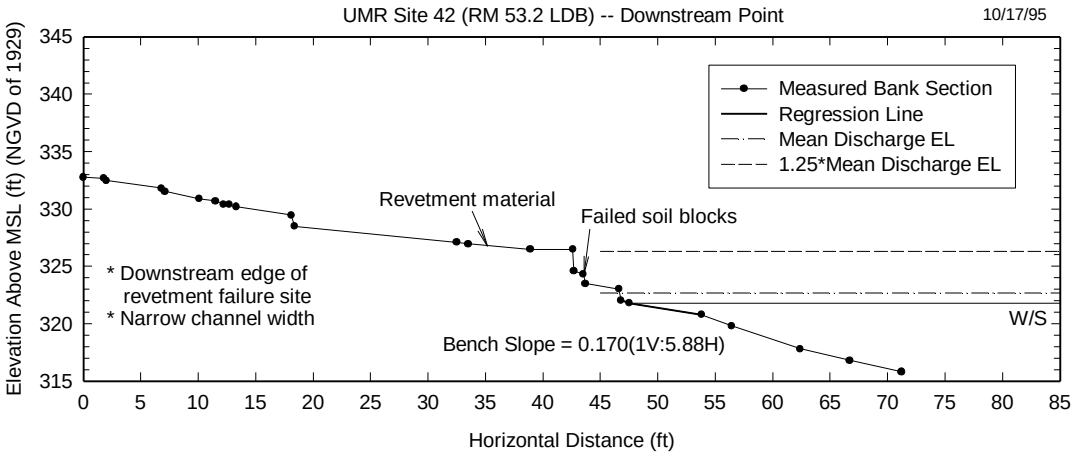

Figure 7-134 Bank section measured at Site 42 downstream point

Causative factors for bank retreat at this site include flood-flow erosion and oversteepening, recession and piping collapse, stone launching, and wave and rework-transport of failed soils and recently deposited sediments within berm and bench areas. Type A conditions best describe Site 42.

43. Site 43 at RM 45.3 LDB (Open Water)

This left-bank site, shown in figure 7-135, is located in a narrow straight reach, immediately downstream from a sharp bend. The bank lies on a shaley siltstone, as depicted in Photo 7-121 and figure 7-136. Photo 7-122 shows a close-up view of the scarp which exposes medium silt (MST) and coarse clay (CC). Photo 7-123 shows the reddish brown bank soil when it was placed in water. The river cross section at Site 43 has a very peculiar shape, practically triangular, indicating a rather steep-slope bedrock-defined channel, with active erosion.

Site 43 is located in a very narrow valley reach, Thebe's Gap. An alluvial fan has entered the MR valley and is being eroded actively. The erosional features and a sampling tube core were used to describe an approximately 26.5 ft profile. The fan appears to be of late Wisconsinan to early Holocene age and lies over other deposits, possibly older than Wisconsinan age. Six paleosols are developed in the fan, and underlying loess and

alluvium. A highly oxidized reddish brown loessal deposit (Loveland Loess-Sangamon) overlies shaley siltstone which outcrops at the toe of slope.

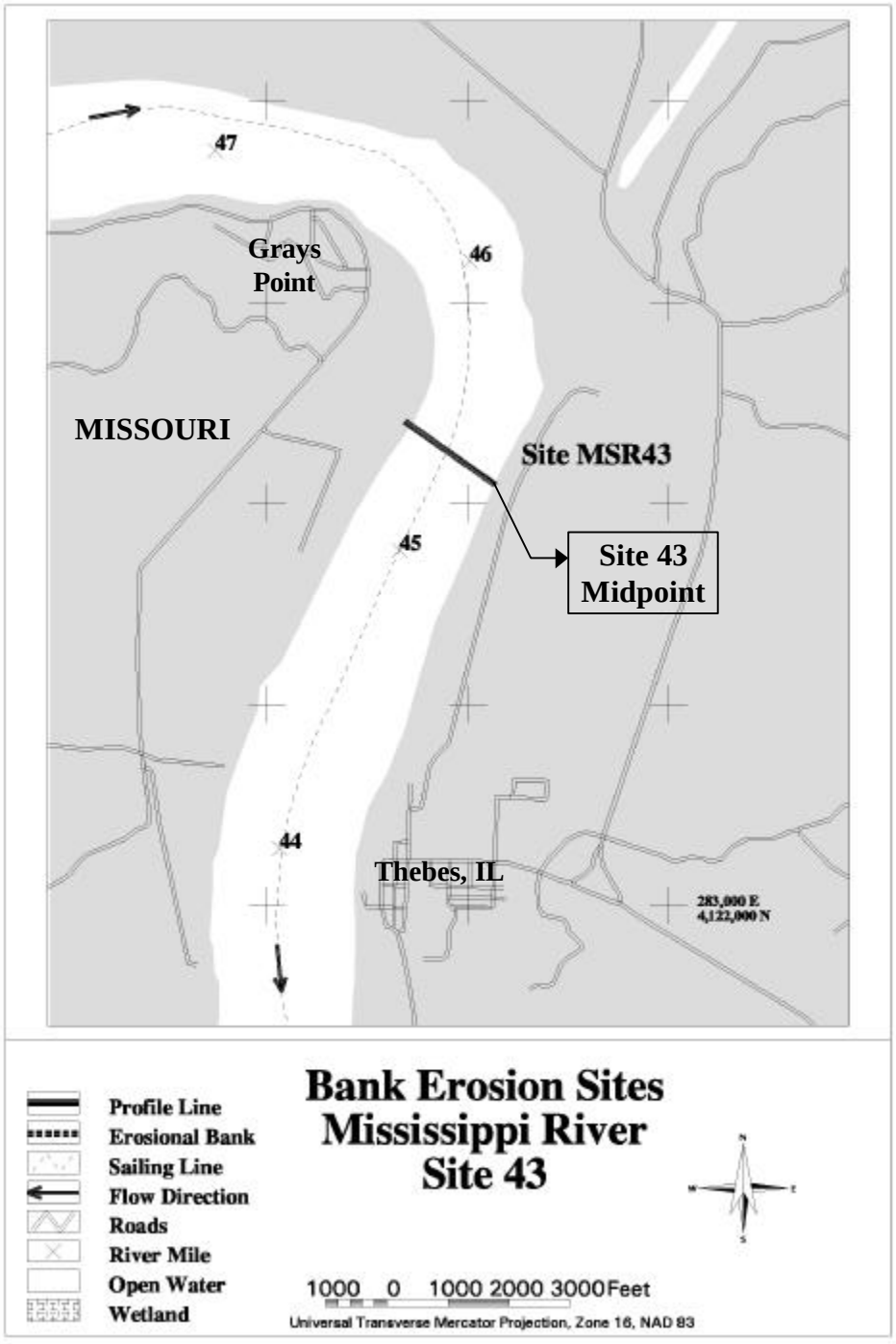

Figure 7-135 A map showing Mississippi River Site 43

Photo 7-121 An upstream side view of Site 43 midpoint

Photo 7-122 A close-up of scarp face of Site 43 midpoint

Photo 7-123 Reddish brown color of soil block in water at Site 43 midpoint

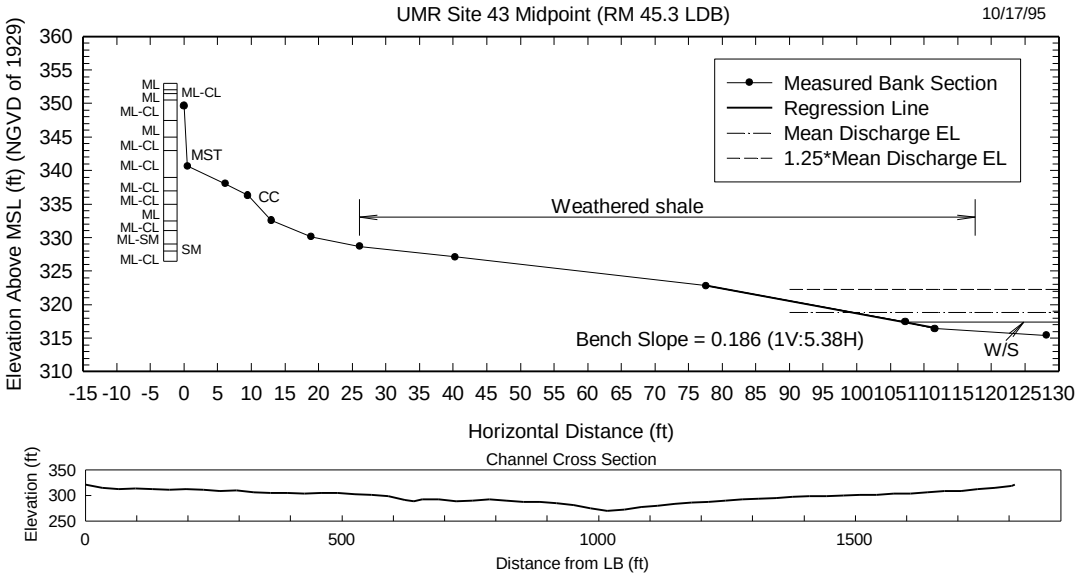

Figure 7-136 Bank section and channel cross section measured at Site 43 midpoint

Causative factors for bank retreat at this site include flood-flow erosion, recession and piping related failures and slaking, overland drainage, and wave and flow rework and transport of failed and slaked soils within bench areas. Type A characterizes Site 43.

44. Site 44 at RM 26.0 RDB (Open Water)

This right-bank site, shown in figure 7-137, is located on an island along the inside bank of a mild bend, which is located about 4 miles upstream from Dogtooth Bend at RM 22.0. Site 44 is located near the entry point into an S bend. As shown in figure 7-137,

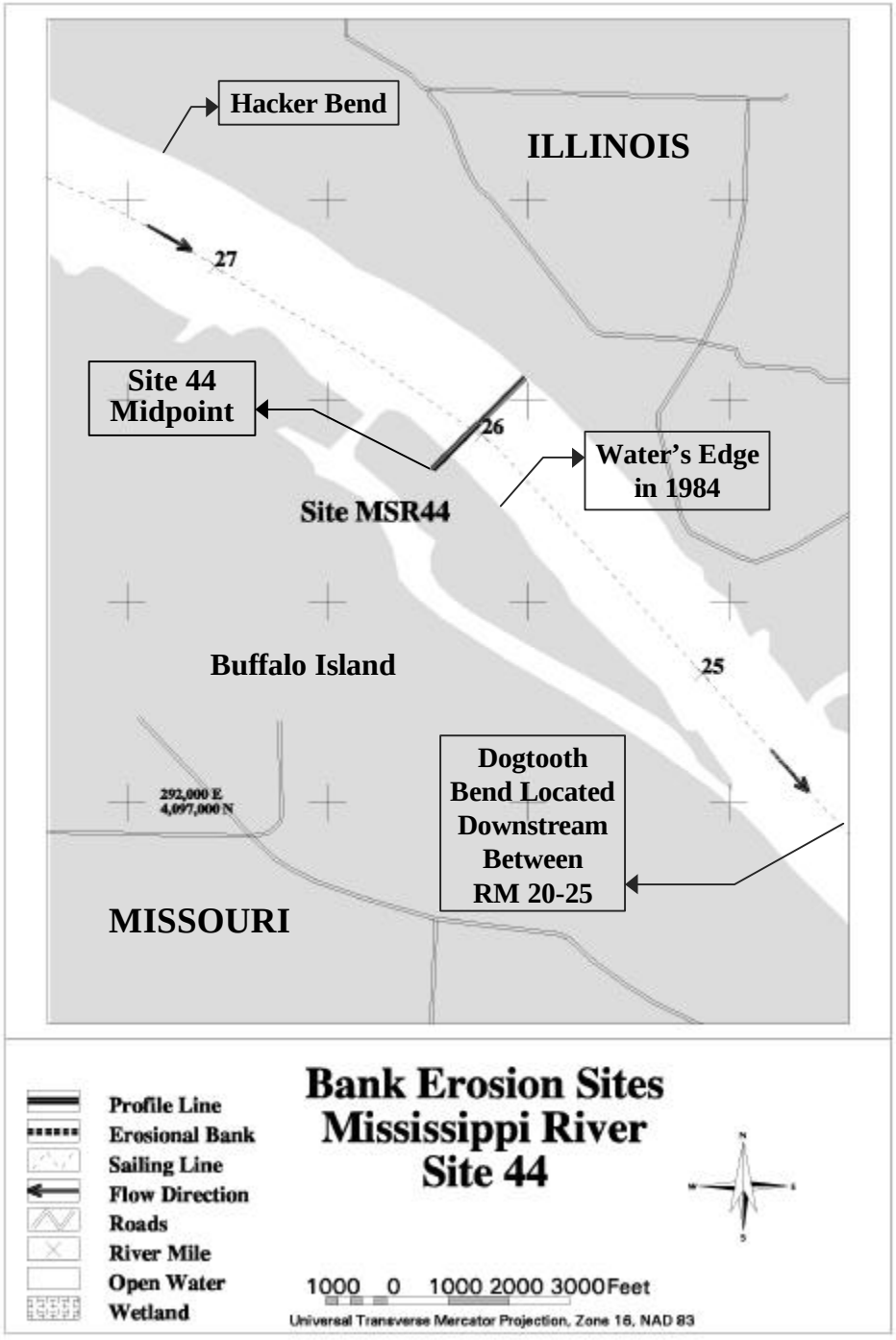

Figure 7-137 A map showing Mississippi River Site 44

Photo 7-124 An upstream view of Site 44 midpoint

Photo 7-125 A downstream view of Site 44 midpoint

Photo 7-126 A close-up view of buried plastic sheet at Site 44 midpoint (see Photo 7-124 for its relative location)

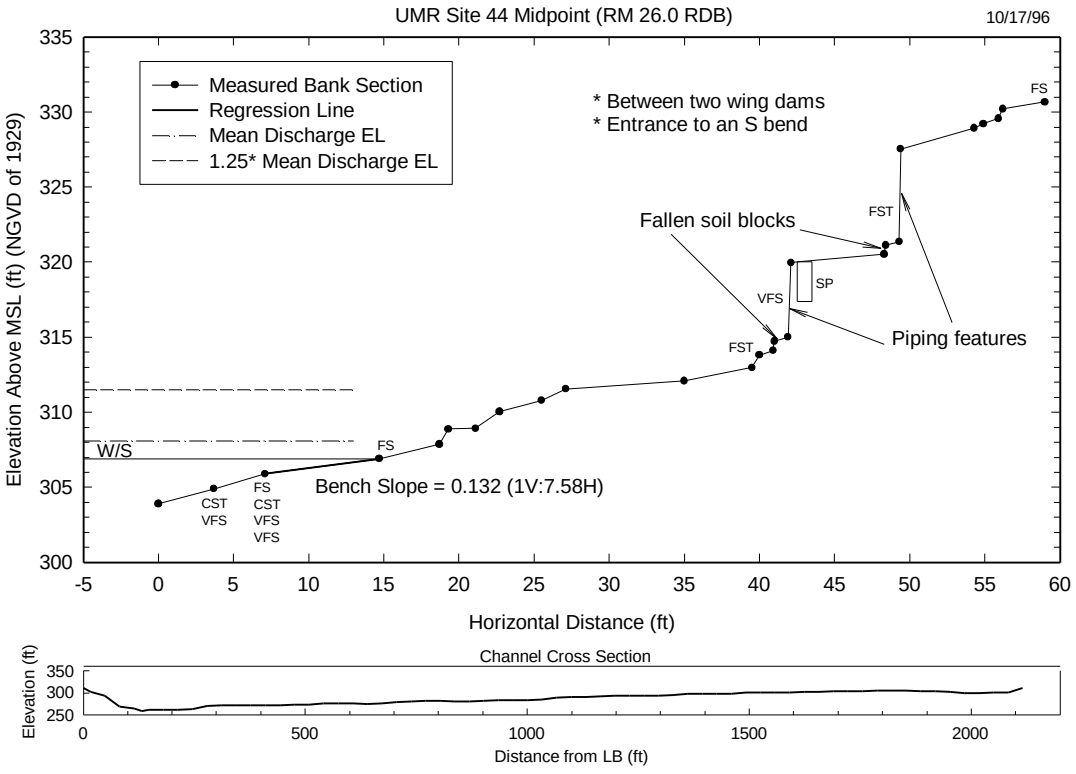

Figure 7-138 Bank section and channel cross section measured at Site 44 midpoint

the Global Positioning System (GPS)-determined river's cross-section end point of Site 44 is located farther into the island, indicating that severe bank retreat took place since 1984. Photos 7-124 and 7-125 show upstream and downstream views of the site, respectively. Photo 7-126 shows a close-up view of a piece of plastic sheet buried in the bank. The bank section taken is shown in figure 7-138. There are several scarps and failed soil blocks at piping cavities. Bank erosion at Site 44 appeared to have been exacerbated by the wing dams surrounding the site. The top of the bank is covered by FS, and soils within scarps consist of FST and FS. Subaqueous sediments consist of silt and sand ranging from CST to VFS.

Site 44 is composed of thick historical alluvium. Two sampling tube cores and a bank retreat showed extremely thickly bedded silt and very fine sand. The core and the bank exposure indicate that the historical deposits are at least 22 ft thick.

Causative factors for bank retreat at this site include flood-flow erosion, recession and piping failures, slaking, and wave and rework-transport of failed soils and recently deposited sediment within berm and bench areas. Type B Characterizes Site 44.

Additional Site Characteristics and Navigation Data

For Sites 1 through 37 (no Site 20) located in Mississippi River pools, relative locations within each pool were identified as being in "upper quarter pool (U1)," "upper middle quarter pool (U2)," "lower middle quarter pool (D3)," and "lower quarter pool (D4)," as shown in table 7-6. The percent of pool length from the downstream Lock and Dam for each site also was calculated, and shown in the table. Table 7-6 also includes fifty-four observation sites (OB-1 through OB-54); thirty-nine observation sites were located in pools and fifteen were in open water. Among the seventy-five sites in pools, thirty-two sites were located in U1(42.7% of the total), twenty in U2 (26.7% of the total), twelve in D3 (16.0% of the total), and eleven in D4 (14.7% of the total). As much as 69.4 percent of the total number of the major and observation sites were located in the upper halves of the pools. Severe bank erosion appears to be occurring more or less in the upper halves of the pools in the Mississippi River, where the main channel width is generally smaller than in the downstream halves, and flow depths are generally smaller,

Table 7-6 Relative location of each site within pool, including the major and observation sites, and locations of other observation sites in open-water reach

Site No.	River Mile (mile) Above Ohio River Mouth	Pool No.	Relative Location Within Pool (see definition sketch below)
1	825.5R	2	D3* (0.32)**
2	791.7R	4	U1 (0.88)
3	763.4L	4	D4 (0.24)
4	751.1L	5	U1 (0.88)
5	746.4L	5	U2 (0.56)
6	727.4R	6	U1 (0.96)
7	727.4L	6	U1 (0.96)
OB-1* **	715.0L	6	D4 (0.06)
8	677.5R	9	U1 (0.95)
9	677.5L	9	U1 (0.95)
OB-2	677.1L	9	U1 (0.94)
10	669.5R	9	U2 (0.69)
OB-3	658.8R	9	D3 (0.35)
OB-4	636.0L	10	U2 (0.64)
11	620.5L	10	D4 (0.16)
OB-5	617.7L	10	D4 (0.08)
12	613.6L	11	U1 (0.95)
13	613.6R	11	U1 (0.95)
14	607.5R	11	U1 (0.76)
OB-6	604.5R	11	U2 (0.67)
15	576.0L	12	U2 (0.73)

* Relative pool locations (U1, U2, D3, and D4) are defined in the sketch shown below.

** Values shown in parentheses indicates percent of pool length from downstream Lock & Dam

*** The prefix "**OB**" denotes "**Ob**servation Site"

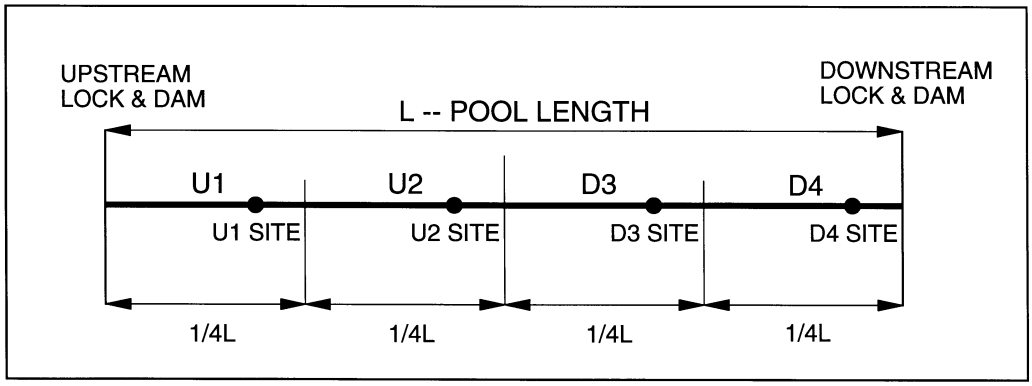

Table 7-6 continued

Site No.	River Mile (mile) Above Ohio River Mouth	Pool No.	Relative Location Within Pool (see definition sketch below)
OB-7	554.2R	13	U1 (0.93)
16	551.9L	13	U1 (0.86)
OB-8	549.5L	13	U1 (0.79)
OB-9	518.0L	14	U1 (0.85)
OB-10	517.2L	14	U1 (0.82)
OB-11	514.0R	14	U2 (0.71)
17	512.7L	14	U2 (0.66)
18	509.2R	14	U2 (0.54)
19	509.2L	14	U2 (0.54)
OB-12	505.4R	14	D3 (0.41)
OB-13	499.0R	14	D4 (0.20)
OB-14	470.9L	16	U2 (0.53)
21	466.7L	16	D3 (0.37)
OB-15	454.0L	17	U1 (0.84)
OB-16	436.9L	18	U1 (0.99)
22	436.4L	18	U1 (0.97)
23	436.4R	18	U1 (0.97)
24	432.3L	18	U1 (0.82)
25	432.3R	18	U1 (0.82)
OB-17	425.0R	18	U2 (0.55)
26	420.0R	18	D3 (0.36)
OB-18	405.0R	19	U1 (0.88)
OB-19	370.2L	19	D4 (0.13)
OB-20	361.5L	20	D3 (0.48)
27	360.0R	20	U1 (0.80)
28	357.6R	20	U2 (0.69)
29	339.3L	21	U1 (0.79)
30	339.3R	21	U1 (0.79)
OB-21	339.2R	21	U1 (0.79)
OB-22	322.8R	22	U1 (0.91)
OB-23	310.8L	22	D3 (0.41)
OB-24	308.6L	22	D3 (0.31)
0B-25	308.3L	22	D3 (0.31)
31	293.0L	24	U2 (0.70)
OB-26	276.2L	24	D4 (0.10)
32	275.3R	24	D4 (0.07)
OB-27	272.8L	25	U1 (0.98)
OB-28	266.8L	25	U2 (0.75)
33	266.5L	25	U2 (0.73)
OB-29	261.0L	25	U2 (0.52)
OB-30	252.7L	25	D4 (0.20)

Table 7-6 continued

Site No.	River Mile (mile) Above Ohio River Mouth	Pool No.	Relative Location Within Pool (see definition sketch below)
OB-31	249.1L	25	D4 (0.06)
OB-32	241.5L	26	U1 (0.87)
OB-33	238.0R	26	U1 (0.79)
OB-34	233.4R	26	U2 (0.69)
34	232.2R	26	U2 (0.66)
35	222.1R	26	D3 (0.41)
OB-35	221.6L	26	D3 (0.42)
36	217.5R	26	D3 (0.33)
OB-36	210.6R	26	D4 (0.17)
OB-37	203.3L	26	D4 (0.01)
OB-38	200.2R	27	U1 (0.85)
37	197.6R	27	U2 (0.71)
OB-39	195.3L	27	U2 (0.59)
OB-40	168.5L	OPEN	N/A*
OB-41	140.7R	OPEN	N/A
OB-42	140.7L	OPEN	N/A
OB-43	134.1R	OPEN	N/A
OB-44	125.6L	OPEN	N/A
OB-45	99.2R	OPEN	N/A
OB-46	87.0L	OPEN	N/A
OB-47	84.6L	OPEN	N/A
OB-48	82.6R	OPEN	N/A
OB-49	53.1L	OPEN	N/A
OB-50	42.6R	OPEN	N/A
OB-51	38.7L	OPEN	N/A
OB-52	22.2L	OPEN	N/A
OB-53	16.0R	OPEN	N/A
OB-54	9.1L	OPEN	N/A

* N/A: Not Applicable

causing much higher flow velocities. Stage recession after floods is greater in the upper ends of pools, and gradients and exposed bank heights for emergent seepage are larger in upper ends of pools, also.

Additional information on the length of eroded bank determined by means of the GPS for each site is tabulated in table 7-7. At sixteen sites, including Sites 1, 7, 13, 21,

Table 7-7 Summary of erosion length identified during the field study

Site No.	1	2	3	4	5	6	7	8	9	10
Erosion Length (ft)	---	984	1,132	1,079	1,138	1,988	---	1,699	945	10,085
Site No.	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**21**
Erosion Length (ft)	1,352	948	---	3,638	4,229	804	1,680	1,181	361	---
Site No.	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**
Erosion Length (ft)	443	---	2,057	---	1,378	---	2,759	1,870	---	---
Site No.	**32**	**33**	**34**	**35**	**36**	**37**	**38**	**39**	**40**	**41**
Erosion Length (ft)	184	1,417	981	899	---	---	761	---	312	---
Site No.	**42**	**43**	**44**							
Erosion Length (ft)	---	---	---							

Note that "---" indicates that the erosion length was not determined.

23, 25, 27, 30, 31, 36, 37, 39, 41, 42, 43, and 44, erosion limits were not established. A total of 46,306 ft of eroded bank was identified from twenty-seven sites, indicating an average length per site of about 1,715 ft. Since forty-three major sites and fifty-four observation sites were identified for the Mississippi River in the present study, a total length of eroded bank could be assumed to be about 31.5 miles [= (43+54)x1,715 = 166,355 ft = 31.5 miles], if it is assumed that the average length of eroded bank were 1,715 ft. This mileage is about 2 percent of the total length of the MR banks upstream from the Ohio River confluence, roughly 1,695 miles (note that Lock & Dam No. 1 is located at RM 847.6). An independent estimate on eroded-bank length conducted by the study team using visual field observations and marking eroded bank on the navigation chart is about 246 miles (about 14 percent of the total river bank). Therefore, the field crew happened to have picked approximately one out of seven potential erosion sites during the study.

Historical records of barge traffic for 1980-1995 along the Upper Mississippi River have been compiled by the three COE Districts. The annual records for upbound and downbound barge traffic are listed in tables 7-8 and 7-9, respectively. On the basis of the records, mean annual barge traffic through each Lock and Dam was computed for both the upbound and downbound barges, as shown in figures 7-139 and 7-140, respectively.

Table 7-8 Historical records of total (both empty and loaded) upbound barge traffic along the Upper Mississippi River

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total	Mean
L&D 1A	1099	617	457	753	740	726	689	513	483	431	788	950	1186	856	995	998	12281	768
L&D 1B	1707	1065	943	1261	1273	1134	1378	997	861	825	1004	957	1207	857	995	994	17458	1091
L&D 1	1762	1112	1021	1273	1271	1127	1299	993	863	847	1015	956	1210	857	1011	995	17612	1101
L&D 2	7827	8257	7736	10476	9151	7439	6010	5567	6414	6299	7708	6182	6879	3644	4577	4555	100894	6306
L&D 3	6792	7415	6948	9595	8536	6401	5714	5562	6377	6274	7703	6210	6865	3628	4573	4547	103140	6446
L&D 4	7194	7887	7321	9982	8792	6612	6042	5901	6638	6543	7990	6552	7275	3803	4803	5012	108347	6772
L&D 5	7095	7936	6968	9966	8733	6510	5888	5862	6543	6489	7929	6523	7135	3823	4954	5032	107386	6712
L&D 5A	7092	7840	7192	9948	8753	6548	5949	5850	6585	6501	7909	6575	7227	3865	4940	5078	107852	6741
L&D 6	7979	8544	7379	10824	9469	6903	6347	6590	7567	7578	9129	7691	8351	4327	5675	6539	120892	7556
L&D 7	7968	8624	7564	10820	9467	6929	6324	6615	7608	7529	9146	7760	7966	4192	5623	6461	120596	7537
L&D 8	8215	8778	6848	11053	9709	7075	6570	6781	7741	7725	9332	7919	8602	4597	5785	6809	123539	7721
L&D 9	8500	9038	7787	11283	9543	6976	6552	6720	7642	7518	9101	7918	8681	5025	6064	7497	125845	7865
L&D 10	9724	10397	8738	12730	10472	7455	7013	7683	9114	8972	10790	9497	10192	5867	7015	9452	145111	9069
L&D 11	9765	10494	9106	12749	10378	7427	6246	7708	9060	8927	10562	9502	10422	6216	7483	9909	145954	9122
L&D 12	10416	11270	9852	14074	11379	8141	7097	9735	10921	11023	12839	11277	12372	6730	7637	10742	165505	10344
L&D 13	10290	11263	9903	14095	11476	8149	7106	9807	11110	11379	13258	11665	12647	6923	7801	11098	167970	10498
L&D 14	12400	13937	12260	17371	13859	10001	9029	13176	14721	14987	17373	15162	16198	9312	10742	14986	215514	13470
L&D 15	12094	13735	12431	17150	13957	9902	9132	13269	14699	14543	16950	14862	15766	9137	10296	14731	212654	13291
L&D 16	12931	15170	13579	18491	15299	10613	10037	14290	15842	15481	17983	15519	16411	9593	10703	15588	227530	14221
L&D 17	14281	15918	14452	19461	15546	11206	10495	15284	16913	16472	19107	16375	17020	9850	10916	15935	239231	14952
L&D 18	13960	16484	15047	19961	15977	11437	10808	15791	17517	16945	19499	16844	17492	10215	11347	16539	245863	15366
L&D 19	15730	17369	15612	20687	17128	12040	11597	16780	18742	17954	20530	17987	18889	11368	12320	17508	262241	16390
L&D 20	16306	17898	15966	21081	17386	12299	11901	17224	19214	18406	20935	18465	19457	11826	12829	18184	269377	16836
L&D 21	17084	18341	16517	21415	18042	12697	12669	17994	19861	18786	21455	19002	20007	12606	13453	18681	278610	17413
L&D 22	17412	18315	16817	21662	18374	12979	13053	18439	20135	19043	21771	19130	20164	12740	13647	18863	282544	17659
L&D 24	18112	19348	17561	22373	19216	13699	13829	19136	20749	19764	21915	19836	20953	13674	14458	19586	294209	18388
L&D 25	18147	19318	17577	22389	19192	13719	13840	19145	20750	19761	21957	19811	20983	13682	14411	19595	294277	18392
L&D 26	36925	38349	34553	41899	36897	29853	31018	36812	37869	36351	38173	37435	38580	31316	32713	38975	577718	36107
L&D 27	41987	42817	42134	46186	39960	33901	34761	41001	42209	40258	40829	40881	41614	34299	35797	42249	640883	40055

Table 7-9 Historical records of total (both empty and loaded) downbound barge traffic along the Upper Mississippi River

	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	Total	Mean
L&D 1A	1093	602	459	759	741	722	674	517	475	446	795	934	1195	859	993	995	12259	766
L&D 1B	1708	1064	962	1256	1256	1125	1371	999	856	832	1009	951	1205	862	999	998	17453	1091
L&D 1	1748	1117	1004	1268	1246	1124	1409	1005	849	806	1010	945	1205	875	998	1011	17620	1101
L&D 2	7871	8315	7769	10502	9072	7360	5997	5800	6461	6254	7733	6193	6790	3665	4562	4521	108865	6804
L&D 3	6909	7527	6959	9586	8390	6342	5762	5740	6425	6257	7712	6175	6904	3656	4540	4539	103423	6464
L&D 4	7326	7985	7352	9994	8733	6571	6056	5982	6741	6513	7984	6609	7163	3834	4866	5038	108747	6797
L&D 5	7238	7993	7029	9890	8653	6433	6113	5924	6580	6495	7887	6452	7132	3881	4972	5100	107772	6736
L&D 5A	7216	7931	7237	9912	8651	6439	6116	5983	6607	6497	7955	6445	7049	3878	4976	5089	107981	6749
L&D 6	8146	8653	7365	10829	9367	6814	6503	6687	7591	7546	9228	7849	8218	4411	5661	6533	121401	7588
L&D 7	8120	8718	7586	10821	9379	6796	6534	6707	7596	7553	9198	7821	7725	4269	5708	6522	121053	7566
L&D 8	8344	8849	6877	11025	9605	6865	6791	6900	7823	7702	9342	7970	8684	4519	5783	6785	123864	7742
L&D 9	8533	9190	7849	11297	9472	6779	6794	6813	7689	7488	9215	7891	8580	5030	6062	7470	126152	7885
L&D 10	9876	10577	8717	12797	10340	7249	7181	7854	9176	9008	10786	9584	10061	5854	6965	9385	145410	9088
L&D 11	9863	10574	9123	12661	10302	7269	6397	7881	9081	8896	10554	9442	10302	6208	7484	9849	145886	9118
L&D 12	10490	11552	9900	13981	11361	7929	7259	9903	10916	10983	12828	11211	12300	6745	7633	10713	165704	10357
L&D 13	10467	11640	9933	14041	11371	7921	7294	9994	11023	11341	13198	11599	12616	6982	7842	10986	168248	10516
L&D 14	12444	14177	12314	17128	13723	9719	9324	13355	14793	14924	17318	15098	16183	9314	10712	14922	215448	13466
L&D 15	12156	13842	12299	16971	13754	9597	9361	13397	14756	14531	16933	14766	15643	9113	10390	14733	212242	13265
L&D 16	13150	15418	13629	18268	15208	10282	10369	14492	15891	15478	17959	15390	16324	9561	10732	15547	227698	14231
L&D 17	14496	16063	14616	19295	15557	10736	10852	15537	17081	16651	19106	16209	16952	9772	10925	15771	239619	14976
L&D 18	14762	16676	15095	19769	16113	11014	11181	15978	17529	16925	19463	16777	17396	10252	11358	16444	246732	15421
L&D 19	16006	17632	15543	19955	17660	11587	11958	16992	18760	17939	20489	17892	18796	11374	12387	17403	262373	16398
L&D 20	16405	17868	15984	20206	18074	11821	12334	17413	19290	18346	20923	18392	19271	11768	12907	18133	269135	16821
L&D 21	17050	18480	16491	20619	18710	12241	13057	18182	20053	18716	21486	18943	19855	12538	13569	18613	278603	17413
L&D 22	17294	18678	16873	20746	19065	12506	13395	18678	20343	18996	21742	19245	20105	12723	13790	18912	283091	17693
L&D 24	18239	19353	17562	21493	19809	13185	14255	19322	20969	19643	21449	19912	20910	13660	14601	19658	294020	18376
L&D 25	18160	19327	17532	21499	19904	13212	14261	19325	20950	19658	21435	19986	20812	13700	14620	19653	294034	18377
L&D 26	36816	37888	34751	41282	37919	44775	31222	37148	38216	35951	38563	37858	38636	30956	32685	38945	593611	37101
L&D 27	41925	42132	41945	45573	41065	33392	34704	41663	42277	39613	41211	41271	41848	33888	35764	41925	640196	40012

As can be seen in these figures, the mean annual traffic, in terms of either upbound or downbound traffics, at Lock & Dam No. 1 is about 1,100 passages, compared to about 6,300 passages at Lock & Dam No. 2. The mean one-way annual traffic increases very slightly downstream, from about 6,300 passages at Lock and Dam No. 2 to 10,300 passages at Lock & Dam No. 12, but it increases rather sharply between Lock & Dam No. 12 and Lock and Dam No. 25 (from about 10,300 passages to 18,400 passages). The mean one-way annual barge traffic doubles to about 36,000 passages suddenly at Lock & Dam No. 26. The mean one-way traffic at Lock & Dam No. 27 is about 40,000 passages

per year. This pool-by-pool information on barge traffic is very important relative to traffic impacts on bank erosion.

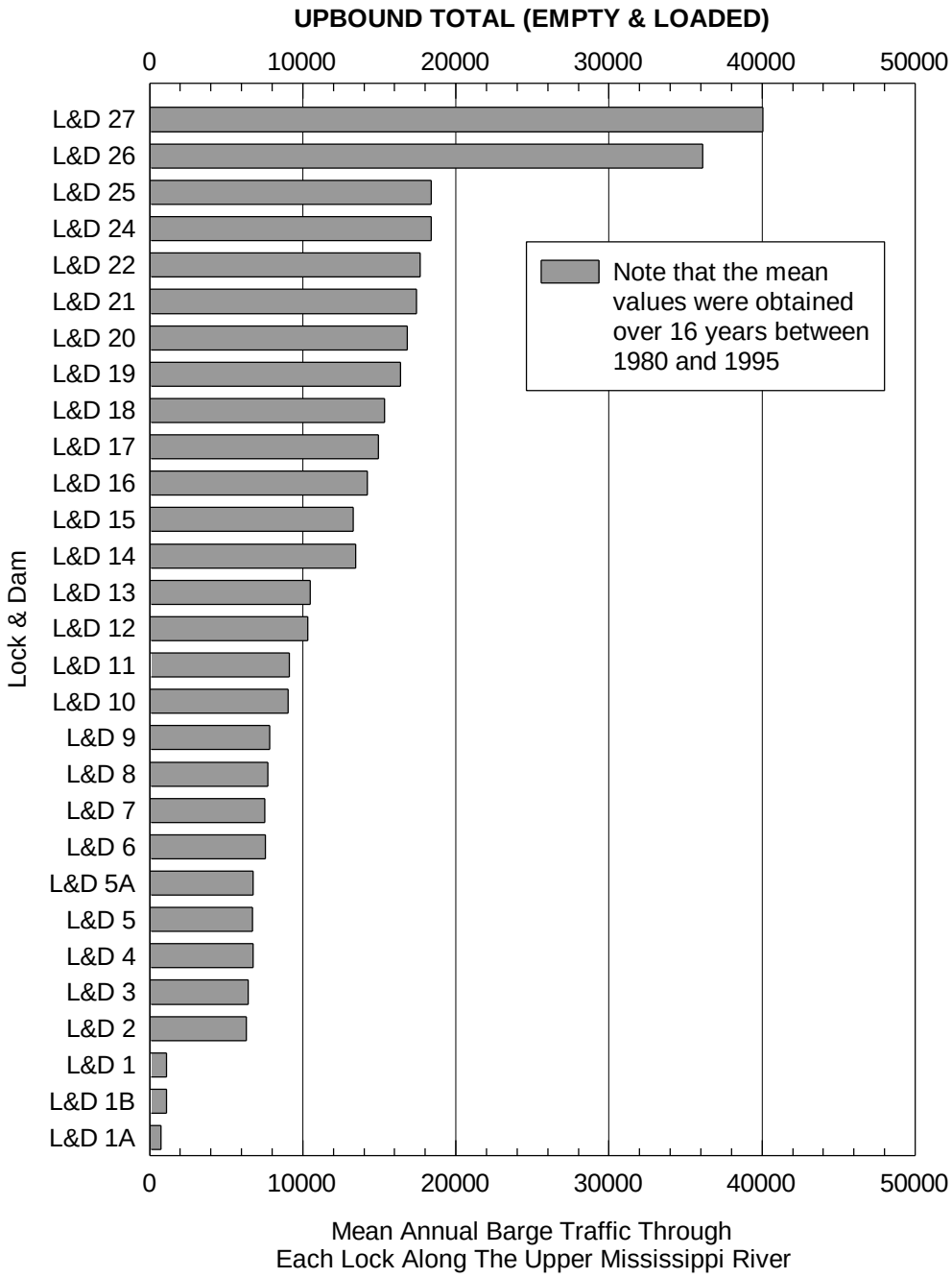

Figure 7-139 Variations in average annual upbound barge traffic Mississippi River locks

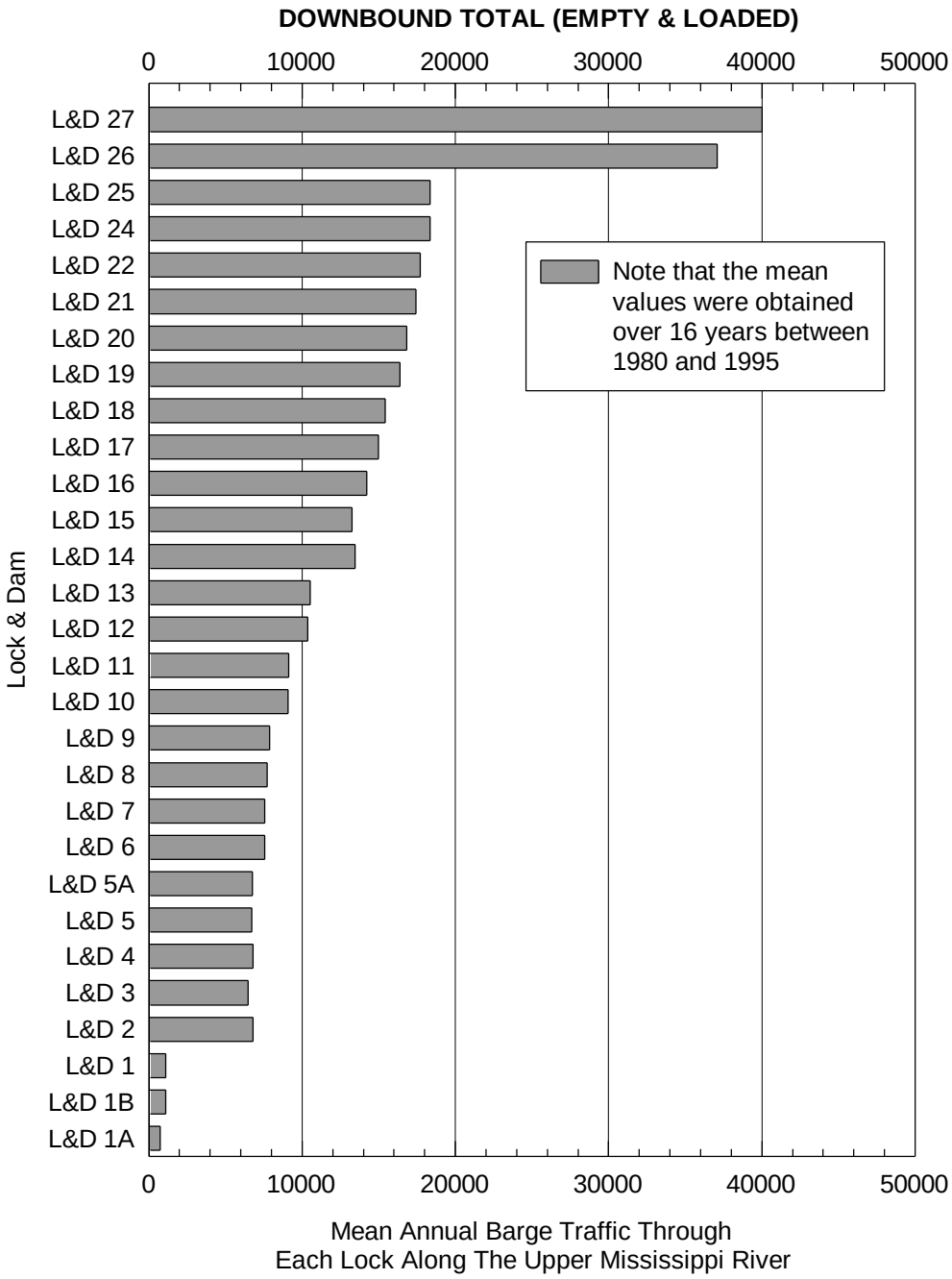

Figure 7-140 Variations in average annual downbound barge traffic through Mississippi River locks

Summary of Conclusions

Conclusions obtained from the present field study can be summarized as follows:

1. Eroded bank sections along the Mississippi River study reach (RM 0.0 at the Ohio River confluence to RM 847.6 at Lock & Dam No. 1) can be classified into six distinct types (Type A through Type F), as defined in table 7-2 and sketched in figure 7-4.
2. The majority of the eroded bank sections investigated in the COE-St. Paul District (Site 1 through Site 11) appear to belong to Type E and Type F, as shown in table 7-5a. Those in the COE-Rock Island District (Site 12 through Site 30) appear to be Type C, Type D, and Type E (see tables 7-5a through 7-5c). Those in the COE-St. Louis District (Site 31 through Site 44) were primarily Type A, Type B, and Type C (see table 7-5c). Surficial bank soils along the upper study reach consist primarily of sand and gravel; silty and sandy deposits were more frequent along the middle study reach; and clayey and silty deposits dominated the lower study reach.
3. Much of the bank erosion in the St. Paul District was found at dredged material placement locations and along Holocene-aged landscapes. Deposits in this portion of the valley are generally coarser compared to those downstream, and historical alluviation is less there compared to downstream reaches.
4. Historical deposits are thicker along the channel margin in the Rock Island District. Erosion of Holocene surfaces is most severe in the upper portion of the pools. The lower pool reaches contain progressively thicker historical deposits which cover most Holocene surfaces. The more or less continuously-constructed protective levee system has greatly focused erosional and depositional events between the levee and channel margins. Generally thickly-bedded historical silt and very fine sand laminae dominate the near-channel alluvial sequences downstream from the Des Moines River.
5. Below St. Louis, the continuous levee and open river systems reveal even more significant historical reworking along the channel margins. Scarps more than 20 ft high, showing historical alluvial sequences, are common. In addition, the relatively small areas where the channel abuts the valley wall, which contains late Wisconsinan and Holocene hillslope and tributary deposits, have been eroded.

6. Because of the Great Flood of ’93, most of the bank-erosion sites investigated, in particular along the middle and lower study reaches, showed such vividly apparent flood impacts that it was extremely difficult to identify any wave-induced rework and transport except at a few fleeting and mooring sites. The lower study reach downstream from the Missouri River confluence also indicated apparent flood impacts of the floods of 1994 and 1995. Major floods had occurred along the study reach at an approximate interval of 5 to 10 years; for example, the flood of 1952, the flood of 1965, the flood of 1969, the flood of 1973, the flood of 1986, and the Great Flood of ’93. Flood effects appear to be much more significant than other erosion mechanisms.
7. Based on the individual geomorphological and hydraulic site characteristics, erosion potential of traffic-induced waves was estimated for each major study site. However, there is no means to estimate bank retreat due to waves from this field reconnaissance study. As stated above, the Great Flood of ’93, the flood of 1994, and the flood of 1995 had left extensive erosion scours and encompassed most of the secondary failure and erosion features due to other causes.
8. Among the seventy-five sites within the MR pools, including the observation sites, approximately 43 percent of them were located in the upper quarter pool; approximately 27 percent in the upper middle quarter pool; approximately 16 percent in the lower middle quarter pool; and approximately 14 percent were located in the lower quarter pool. This means that approximately 70 percent of the study sites (including the observation sites) within the MR pools were located in the upper halves of the pools where the channel is narrower and the river stage varies more frequently than in the lower portion of the pool. Stage recession after floods is also greater in the upper ends of pools, and gradients and exposed bank heights for emergent seepage are larger in upper ends of pools.
9. On the basis of the present field study, approximately 14 percent of the Mississippi River banks are estimated to be actively eroded as of 1995.

REFERENCES

Anderson, J.D. 1968. Postsettlement Alluvium in the Upper Mississippi Valley: Genesis, Character, and Recognition. *Wisconsin Archaeologist*, 72 (1&2): 1-12.

Anderson, R.C. 1968. Drainage Evolution in the Rock Island Area, Western Illinois, and Eastern Iowa. In: *The Quaternary of Illinois*: R.E. Bergstrom, ed., University of Illinois-Urbana College of Agriculture Special Publication, 14: 11-18.

Anderson, J.D., and E.A. Bettis III. 1989. Post Settlement Alluvium in the Upper Mississippi Basin: Recognition, Distribution and Implications Concerning Floodplain Management. *GSA Abstracts with Programs*. Annual Meeting, St. Louis, Missouri.

Anderson, J.D., L. Rogers, and D.S. Stanley. 1989. *Geomorphological Investigations: Mississippi River Pool 22, Illinois and Missouri with Archaeological and Historical Overviews.* U. S. Army Corps of Engineers, Rock Island District, Contract No. DACW-25-87-D-0001, Work Order 17. Donohue & Associates, Inc., Sheboygan, Wisconsin, Vol. 1: 1-68.

Anderson, J.D., W. Green, and R. Vogel. 1988. *Geomorphological Investigation: Mississippi River Pool 21, Illinois and Missouri with Archaeological and Historical Overviews.* U.S. Army Corps of Engineers, Rock Island District, Contract No. DACW-25-87-D-0001, Donohue & Associates, Inc., Sheboygan, Wisconsin: 1-76.

Benn, D.W., J.D. Anderson, and E.A. Bettis III. 1994. *Archaeological and Geomorphological Surveys in Pools 21-22, Upper Mississippi River*. U. S. Army Corps of Engineers, Rock Island District, Contract No. DACW-25-92-D-0008, Work Order No.1. Bear Creek Archeology, Cresco Iowa: 1-147.

Benn, D.W., J.D. Anderson, and D.S. Stanley. 1989. *Archaeology and Geomorphology in Pools 13 and 14, Upper Mississippi River*. U.S. Army Corps of Engineers, Rock Island District, Contract No. DACW-25-88-C-0093, Center for Archaeological Research, Southwest Missouri State University, Springfield, Missouri: 1-250.

Benn, D.W., E.A. Bettis III, and R. Vogel. 1988. *Archaeology and Geomorphology in Pools 17-18, Upper Mississippi River*. U. S. Army Corps of Engineers, Rock Island District, Contract No. DACW-25-87-C-001, Center for Archaeological Research,

Southwest Missouri State University, Springfield, Missouri: 1-389.

Bettis, E.A., III, J.D Anderson, and D.W. Benn. 1996. *Landform Sediment Assemblage Maps for the Mississippi River Valley within the Rock Island District, Illinois, Iowa, Missouri, and Wisconsin*. Bear Creek Archaeology, Inc., Cresco, Iowa: 1-40.

Bettis E.A., III, and J.D. Anderson. 1990. *Geomorphological Overview of Navigation Pools 22-11, Upper Mississippi River*. U.S. Army Corps of Engineers, Rock Island District, Contract No. DACW-25-90-M-1141: 1-27.

Dalrymple, J.B., R.J. Blong, and A.J. Conacher. 1968. A Hypothetical Nine-Unit Land Surfaces Model. *Zeitschrift für Geomorphologie* 12:60-76.

Flock, M.A. 1983. The Late Wisconsin Savanna Terrace in Tributaries to the Upper Mississippi River. *Quaternary Research* 20: 165-176.

Knox, J.C. 1977. Human Impacts on Wisconsin Stream Channels. *Annals of the Association of American Geographers* 67(3): 323-342.

Knox, J.C. 1987. Historical Valley Floor Sedimentation in the Upper Mississippi Valley. *Annals of the Association of American Geographers* 77(2): 224-244. Copyright by Association of American Geographers.

Magilligan, F.J. IV. 1985. Historical Floodplain Sedimentation in the Galena River Basin, Southwest Wisconsin, Northwest Illinois. *Annals of the Association of American Geographers* 75(4): 583-594.

Matsch, C. L. 1983. River Warren, the Southern Outlet of Glacial Lake Agassiz. *Glacial Lake Agassiz*. J.T. Teller and L. Clayton (eds), Geological Association of Canada, Special Paper 26: 231-244.

Maynord, S., and S.K. Martin 1996. *Upper Mississippi River System Navigation/Sedimentation Study – Report 1 Bank Erosion Literature Study*. Technical Report HL-96-10, U.S. Army Corps of Engineers, Waterways Experiment Station, August: 1-89.

Nakato, T., and J.F. Kennedy. 1977. *Field Study of Sediment Transport Characteristics of the Mississippi River Near Fox Island (RM355-6) and Buzzard Island (RM349-50)*. IIHR Report No. 201, Iowa Institute of Hydraulic Research, The University of Iowa, Iowa City, Iowa, July: 1-83.

Nakato, T., R.M. Baker, and J.F. Kennedy. 1979. Mississippi River Shoaling: A Diagnostic Study. *Journal of the Hydraulics Division, Proceedings of the American Society of Civil Engineers*: 105(HY11), November: 1375-1391.

Nakato, T., and J.L. Vadnal. 1981. *Field study and tests of several one-dimensional sediment-transport computer models for Pool 20, Mississippi River*. IIHR Report No. 237, Iowa Institute of Hydraulic Research, The University of Iowa, Iowa City, Iowa, July: 1-125.

Nakato, T. 1983. *Preconstruction Geomorphological Study Near RM 614 Mississippi River: Partial closure of Ackerman's Cut*. IIHR Limited Distribution Report No. 107, Iowa Institute of Hydraulic Research, The University of Iowa, Iowa City, Iowa, December: 1-45.

Overstreet, D.F. 1985. *Archaeological Investigations, Navigation Pool 11, Upper Mississippi River Basin*. Great Lakes Archaeological Research Center, Inc., Report of Investigation No. 151, Wauwatosa, Wisconsin: 1-302.

Titus, S., et al., 1996. *Phase III Data Recovery at the Persimmon Site (11-C-152), Swan Lake Habitat Rehabilitation Enhancement Project (HREP), Environmental Management Program (EMP), Pool 26 Illinois River, Calhoun County, Illinois.* U.S. Army Corps of Engineers, St. Louis District, Contract No. DACW-43-93-D-0514: 1-150.

Toda, K., and T. Nakato. 1987. *Post-Construction Geomorphological Study Near RM614, Mississippi River: Partial Closure of Ackerman's Cut*. IIHR Limited Distribution Report No. 140, Iowa Institute of Hydraulic Research, The University of Iowa, Iowa City, Iowa, February: 1-47.

Willman, H.B., and J.C. Frye. 1970. *Pleistocene Stratigraphy of Illinois*. Illinois State Geological Survey Bulletin No. 94, Urbana, Illinois: 1-162.