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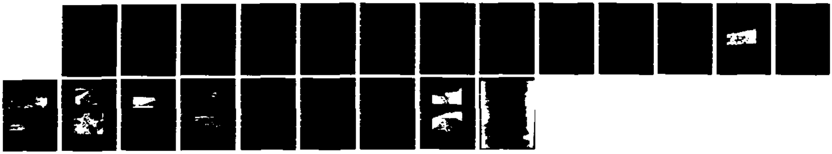

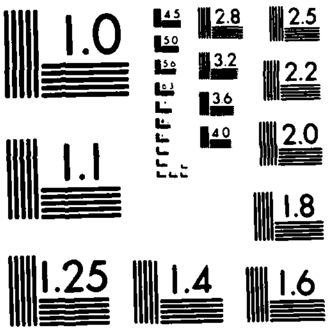
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SECTION 32 PROGRAM
STREAMBANK EROSION CONTROL
EVALUATION AND DEMONSTRATION
WORK UNIT 2-EVALUATION OF EXISTING
BANK PROTECTION

FIELD INSPECTION OF THE MILL CREEK MIDFLOODWAY GABION BARRIER IN THE LOS ANGELES DISTRICT

by

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SECTION 32 PROGRAM

STREAMBANK EROSION CONTROL EVALUATION AND DEMONSTRATION

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1. On 6 August 1979, the U. S. Army Engineer Waterways Experiment Station (WES) Section 32 Program evaluation team inspected the existing site* at mile 2.5** on Mill Creek, near Mentone, Calif. This site is located in the U. S. Army Engineer District, Los Angeles (SPL). WES personnel participating in the effort were Messrs. E. B. Pickett and N. R. Oswalt, Hydraulics Laboratory; Dr. E. B. Perry, Geotechnical Laboratory; and Messrs. M. P. Keown and E. A. Dardeau, Jr., Environmental Laboratory (EL). The WES team was accompanied by Messrs. A. Robles and R. E. Koplin and Dr. M. Mulvihill, SPL, during the inspection. This report was written by Mr. Dardeau. Mr. R. M. Russell, Jr., EL, prepared the figures. Mr. T. J. Albrecht, U. S. Army Engineer Division, South Pacific, and Mr. Koplin reviewed the final draft. Special acknowledgment is made to Mr. Koplin for furnishing the file information needed to prepare this report.

2. Mill Creek is a left-bank tributary of the Santa Ana River, which flows into the Pacific Ocean near Huntington Beach, Orange County, Calif. The Santa Ana River-Mill Creek confluence is near Mentone, approximately 5 miles northeast of Redlands in San Bernardino County, Calif. The rugged mountainous watershed of Mill Creek has an area of 52 square miles, bounded on the north by the San Bernardino Mountains, on the east by the San Gorgonio Mountains, on the south by the Crafton Hills and Yucaipa Ridge, and on the west by the Santa Ana River. Elevations in the watershed range from 1,700 ft at the confluence to nearly 11,500 ft at San Gorgonio peak.† The streambed gradient of Mill Creek in the vicinity of the site is approximately 4 percent (210 ft/mile) (Reference 1).

3. The U. S. Geological Survey (USGS) operated a gaging station at mile 5.3 on Mill Creek from January 1919 to September 1938. In October 1947 this agency resumed operation of this gaging station, which it has continued to operate without interruption to the present time. Prior to October 1954, these data were published as "near Craftonville, Calif.," but since that time they have been published as "near Yucaipa,

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* Existing sites are those locations where the bank protection works were not constructed with Section 32 funds but are being monitored under the Section 32 Program.

** Location of Garnet Street Bridge, near the center of the project (see Figure 1).

† All elevations cited in this report are referenced to mean sea level.

Calif." (Reference 2). Flood flows in Mill Creek transport vast quantities of rock debris (including boulders weighing up to 10 tons) that form temporary dams in the 150-ft-wide canyon upstream from the gage location. When these dams eventually burst, they cause a surge of water to flow through the canyon, resulting in peak discharges that are not characteristic of the broader downstream floodplain.

4. Although there is no discharge regulation upstream from the gaging station, Mill Creek Power Canals Nos. 1, 2, and 3 divert flows from the channel at points 100 ft, 3 miles, and 6 miles upstream, respectively. Discharge records published by the USGS (Reference 2) are in dual form: (a) creek only and (b) combined discharges of the creek and the three canals. Daily discharges of record are: mean 13.0 cfs (creek only) and 33.8 cfs (combined discharges), and minimum no flow (creek only on a number of days during the period of record) and 2.7 cfs (combined discharges on 23 February 1949). The preproject flood of record was 18,100 cfs in March 1938. The postproject flood of record occurred on 25 January 1969; the discharge, which was computed by SPL using PULS Routing modified with reduction in debris load (bulking factor), was equal to the discharge of the March 1938 flood.

5. Prior to the period of record there were probably a number of excessive flows in Mill Creek, as indicated by the huge boulders that have been transported by the stream and deposited in its floodplain. The only relatively large floods prior to 1919 that can definitely be identified are the flood of 1891, which was reported as being of approximately the same discharge as the flood of record, and the flood of 1862, which published local history sources describe as devastating.*

6. The March 1938 flood threatened a large number of homes and citrus groves in the vicinity of Redlands. San Bernardino County, the City of Redlands, and local citizens prevented total devastation of the threatened areas by a sandbagging operation. As a direct result of this flood, local interests obtained funding from the Works Progress Administration (WPA) later the same year to construct two sections of a 200-ft-long and 24- to 26-ft-high masonry wall (Figures 2 and 3). This wall has proved to be adequate protection for all flows since it was constructed, even though the unpredictable pattern of rock debris movement by Mill Creek has been known to cut within 2 or 3 ft of its toe and has left deposits within 2 ft of its top.

7. The Flood Control Act of 1950 authorized levee construction on Mill Creek as a unit of the Santa Ana River Basin Project. SPL completed the 2.36 miles of levee in 1960 in three sections paralleling the left bank of Mill Creek along the foot of the San Bernardino Mountains (Figure 3). This levee is a compacted earth-fill embankment with a top width of 18 ft, channelward side slopes of 1V on 2.25H, landward side slopes of 1V on 2H, and heights ranging from 0 to 16 ft above the natural ground

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* Unpublished file information provided by the SPL.

elevation. Grouted-stone revetment was placed on the channel side of the levee, except in the downstream reach extending from sta 88+70 to 70+00 where the revetment is ungrouted stone (Figure 3). The 1938 WPA masonry wall (paragraph 6) was incorporated into the project. Costs (1960) of the levee construction were $618,000 in Federal funds supplemented by $195,000 provided by local interests.

8. This levee was intended to confine flows to a relatively wide floodway along an alluvial fan (adjacent to right bank) and to prevent overflow into the left-bank floodplain, where residential and agricultural areas had been established. The Mill Creek levee was designed for a standard project flood of 33,000 cfs (with design velocities ranging from 8 to 18 fps); however, the cross-sectional area of the floodway (Figure 3) was constructed many times larger than would be required to accommodate this discharge. SPL intended that this extra channel capacity would provide additional protection for the levee during times of high flow. The significance of the high rock debris loads and the damaging cross-channel flows (i.e., flows not parallel to normal downstream flow that tend to meander through the wide floodway) was not fully considered when the levee was built. Thus, the additional channel capacity has proved to be more harmful than beneficial as a result of cross-channel flow impinging on the levee and eroding below the toe of the levee in some locations and at other nearby locations, piling boulders and cobbles on the levee facing nearly to the top.

9. At the time the levees were constructed, the channel bottom was graded from sta 216+87 to 196+25 on a 4-1/2 percent slope away from the masonry wall for a distance of 150 ft; and from sta 196+25 to 157+25 on a 2-1/2 percent slope away from the levee for a distance of 200 ft. Downstream from sta 157+25, where the flood-flow channel is entrenched along the right bank, the only grading consisted of eliminating islands and ridges that would cause deflection of flow against the levee (Figure 3) (Reference 1).

10. Between 1938 and 1965 the largest discharges measured in Mill Creek were 1,500 cfs in 1946 and 1,060 cfs in 1961. The first test of the levee system was on 22 November 1965 when the USGS recorded a flow of 10,000 cfs (Reference 2). Although SPL found no structural damage, the flood flows carried heavy loads of debris that were deposited as high as the top of the levee in the reach upstream from Garnet Street Bridge. Near the upstream end of the project, debris piled up against the WPA masonry wall to within 2 ft of its top. Several hundred feet downstream from the bridge, huge quantities of rock debris were deposited on the channelward side slopes of the levee to its top. In those reaches where there was heavy deposition on the levee, the floodway was scoured below the elevation of the revetment toe (Reference 1).

11. In early 1966, SPL spent $136,000 of P.L.-875 funds to rechannelize the stream and to remove debris upstream from Garnet Street Bridge. This restoration work included excavating a low-flow channel, 5 ft deep, 20 ft wide, and about 1.3 miles long, to accommodate discharges as high

as 4,000 cfs. Backfill material obtained from the excavation of the low-flow channel was placed over the levee toe to provide a 200-ft-wide graded berm sloping channelward from the levee.

12. On 6 December 1966, another 10,000-cfs flood occurred (Reference 2). This event caused relatively little disturbance in the reach of the creek upstream from Garnet Street Bridge that had been improved after the 1965 flood. The low-flow channel accommodated discharges ranging from an estimated 3,000 to 4,000 cfs without difficulty until the channel became plugged with debris. Some flood flows broke out of the channel and moved to either side of the floodway--partly eroding the graded berm (left side) constructed in early 1966. Most damage from this flood occurred in the reach downstream from Garnet Street Bridge. Flood flows undermined the levee revetment at several locations (Figure 4). A few hundred feet farther downstream from the bridge, flood flows deposited debris on top of the levee, which diverted some flows over the levee and across private property (Figure 5). In the downstream reach, almost half of the ungrouted-stone revetment was damaged (Reference 1) (Figure 6). The 1960 Federal project (paragraph 7), which was severely damaged by this flood, proved to be incapable of controlling a flow approaching the magnitude of the standard project flood; however, this project, including the WPA masonry wall (paragraph 6), and the P.L.-875 restoration, succeeded in keeping the floodwaters out of Mentone and Redlands and in preventing major damage to adjacent property.*

13. The 1965 and 1966 floods clearly demonstrated that the Mill Creek levee was underdesigned to perform its intended purpose and that satisfactory protection of Redlands and the surrounding area could only be achieved by a different concept of protection. As an interim measure in 1967, SPL initiated the necessary work to repair the levee and to make channel improvements. This effort included reworking the graded low-flow channel near the upstream end of the project (essentially a repetition of the 1966 work described in paragraph 11), restoration of the berm, and extension of the low-flow channel for nearly a mile downstream from Garnet Street Bridge. This was accomplished with $355,000 of P.L.-99 funds.*

14. The principal feature of the 1967 project consisted of a two-part midfloodway gabion barrier, about 1,500 ft long, beginning just downstream from Garnet Street Bridge (Figure 3). This structure was designed to prevent development of the cross-channel flow that caused the destruction of the sloping, ungrouted-stone face of the project levee (paragraph 12). Bekaert gabions manufactured and supplied by Terra Aqua Conservation of Reno, Nev. (a division of Bekaert Steel Wire Corp.) were filled with stone from the streambed of Mill Creek. Figure 7 shows a detailed view of the gabion wire mesh and the variation in stone sizes used to fill the gabions. Cost (1967) of the gabion barrier was $34,000. Figure 8 shows a photograph and a cross-sectional view of the

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* Unpublished file information provided by the SPL.

midfloodway gabion barrier under construction in 1967. This type of construction was developed to provide a stable superstructure with stream-face vertical surfaces, resting on a flexible mattress that required a minimum excavation of streambed material but that would deflect downward as a curtain when the streambed eroded, thus preventing undercutting of the superstructure. Some of the material removed in the construction of the low-flow channel (paragraph 13) was disposed downstream from and in line with the gabion barrier to provide limited additional protection of the levee and the downstream end of the barrier; however, most of the excavated material was hauled away from the creek.

15. Excessive rainfall over the Mill Creek watershed on 25 January 1969 resulted in the postproject flood of record (paragraph 4). The restored berm and low-flow channel near the upstream end of the project were not damaged. Neither the WPA masonry wall nor the project levee was topped, and there was no evidence that the streambed was eroded at the toes of these structures. The midfloodway gabion barrier performed as designed, although the streambed adjacent to the toe of this structure was scoured to a depth of 5 ft at several locations. The 1-ft-thick gabion mattress at the toe of the gabion barrier prevented undercutting of the gabion barrier by deflecting into the scoured hole.

16. Several hundred feet upstream from Garnet Street Bridge, where there was no flooding in 1965 or 1966 (and probably not in 1938), some of the flow (estimated by SPL as 1,000 cfs) broke away from the main stream, crossed and destroyed a portion of Garnet Street south of the bridge, and followed a path between the project levee and the midfloodway barrier. The timing of this estimated 1,000-cfs flow with respect to the flood peak is unknown. Even this small discharge that developed by cross-channel flow, gouged out debris along the toe of the levee face, deposited the material farther downstream on and adjacent to the levee face, and eventually overflowed the levee. This action was similar to that which occurred in 1966 (paragraph 12); however, the toe of the levee facing was not undermined but exposed. Although the flow over the levee badly eroded the back slope, it was not sufficient to endanger levee stability* (Figure 9).

17. The San Bernardino County Flood Control District (SBCFCD) carried on an aggressive flood fight during and after the January 1969 flood. Emergency crews removed several thousand cubic yards of streambed material, pushing it up into a 1,000-ft-long barrier to cut off the newly developed channel that had caused destruction of a portion of Garnet Street (paragraph 15). The SBCFCD's work also involved channel rectification downstream from Garnet Street Bridge, including pushing some material against the toe of the midfloodway gabion barrier.

18. An equally serious flood (18,000-cfs peak discharge) occurred on 25 February 1969 (Reference 2). The section of the gabion barrier

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* Unpublished file information provided by the SPL.

downstream from Garnet Street Bridge performed adequately, but the left side of the upstream section of the barrier was badly undermined. During the event, SBCFCD was able to continually reinforce the barrier with boulders by working heavy equipment behind it; this action prevented any flow from bypassing the bridge. Erosion along the toe of the downstream section of the barrier was apparently not deeper than 5 ft; and while the mattress was deflected at additional locations, it again prevented undercutting of the barrier. In contrast, at one downstream levee location (sta 88+70) the flood flows piled streambed boulders and cobbles as high as the top elevation of the levee, with some discharge overtopping the structure (Figure 10). The overflow was small and did no damage. During this flood, the embankment that had been placed downstream from and in line with the gabion barrier (paragraph 14) was attacked and breached. Near the end of the flood, cross-channel flow apparently developed, destroying the low and ungrouted face of the downstream end of the project levee at sta 70+00 (Figure 3).

19. In 1970 the foundation of the gabion barrier downstream from Garnet Street Bridge was modified (as shown in Figure 11). Additionally, two new sections of the gabion barrier were placed immediately upstream from Garnet Street Bridge to divert flows away from the levees and under the bridge. The locations of these upstream gabions and a cross-sectional view are shown in Figures 3 and 12, respectively. The farthest upstream section is 675 ft long, and the section located 300 ft upstream from Garnet Street Bridge is 500 ft long. The cost (1970) of modification to the existing gabions and construction of the new section of the barrier upstream from the bridge was $79,000.

20. The 1976 Water Resources Development Act authorized a number of flood-control improvements on the Santa Ana River. Included in the project plan is the proposed Mentone Dam to be located on the Santa Ana River downstream from its confluence with Mill and Plunge Creeks (right bank tributary). This structure is designed to alleviate flooding in San Bernardino and Orange Counties. An integral part of the Mentone Dam project will be the strengthening and improvement of the Mill Creek levee. Other improvements authorized by this project include channel improvements, construction of debris basins, and improvement and enlargement of existing facilities on the Santa Ana River. The cost was estimated (1978) at $834,000 in Federal and $108,400 in local funds. No work has yet been initiated. The completed project is to be maintained by local interests (Reference 3).

21. High flows resulting from the storms of 8-14 February and 3-6 March 1978* caused some deflection of 200 ft of the farthest upstream section of the gabion barrier. Figure 13 shows the modification designed to maintain the integrity of this portion of the gabion barrier as constructed in September 1978. There was no deflection of the section of the gabion barrier downstream from Garnet Street Bridge.

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* The USGS measured a peak discharge of 5,200 cfs on 10 February 1978.

22. At the time of the 6 August 1979 inspection by the WES Section 32 Program evaluation team, the gabion structure and the levee appeared to be in good condition. Figures 14 and 15 show upstream and downstream views, respectively, of the midfloodway gabion barrier. The WES team found that the upstream section of the barrier (Figure 14) was sound and undamaged but noted that downstream sections of the structure (Figure 15) had been slightly deformed and had rock debris piled adjacent to them. SPL reports that they are satisfied with the performance of the Mill Creek midfloodway gabion barrier.

A-1

REFERENCES

1. U. S. Army Engineer District, Los Angeles, CE, "Report on Engineering Aspects, Floods of January and February 1969 in Southern California," 1974, Los Angeles, Calif.

2. U. S. Geological Survey, Department of the Interior, Water Resources Data for California (Published annually), U. S. Government Printing Office, Washington, D. C.

3. U. S. Army Engineer District, Los Angeles, CE, "Project and Index Maps, Los Angeles District," 1978, Los Angeles, Calif.

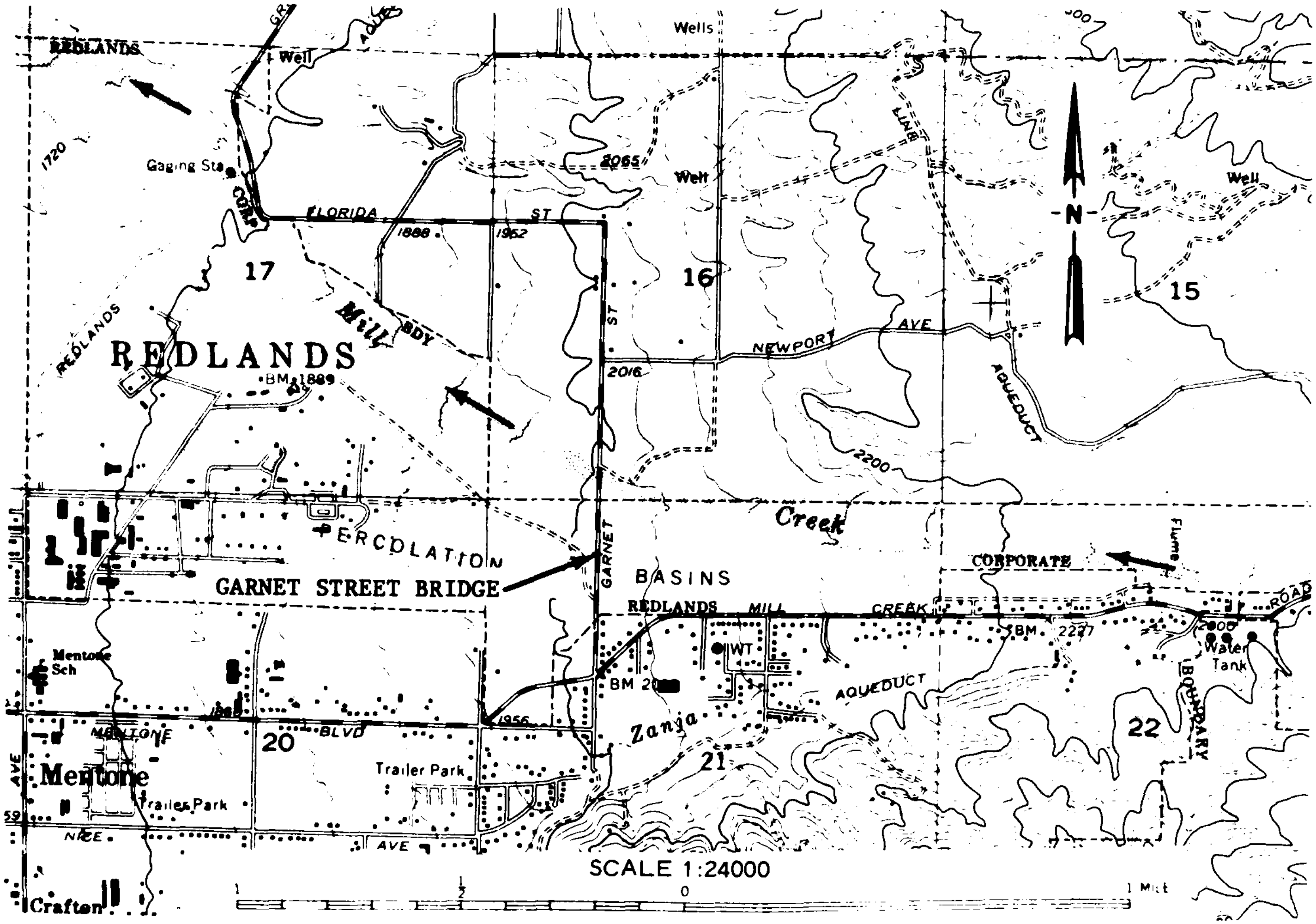


Figure 1. Mill Creek near Mentone, Calif. (Source: USGS 1:24,000 topographic quadrangle map for Yucaipa, Calif., 1967) (photo revised 1973)

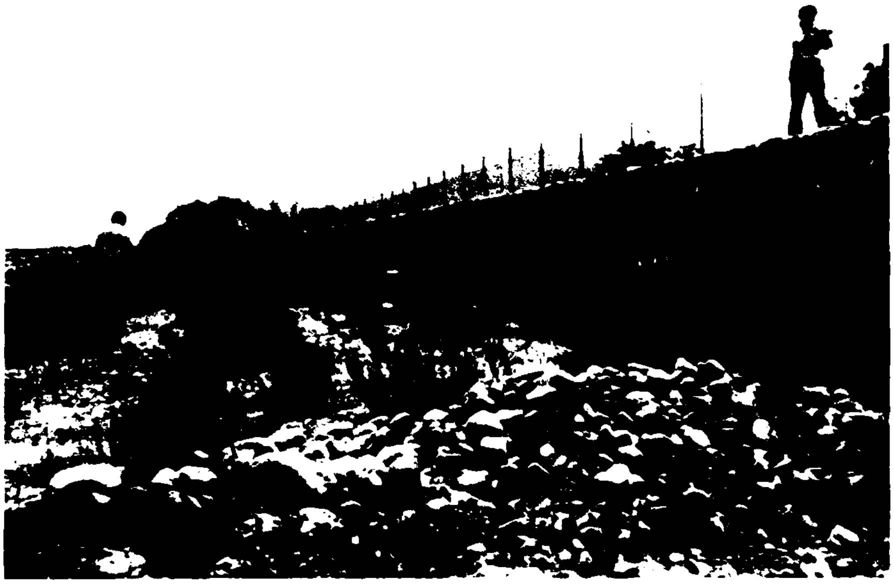


Figure 2. Existing masonry wall constructed in 1938 by local interests with WPA funds (incorporated as part of flood-control levee for Mill Creek in 1960) (photograph taken 6 August 1979)

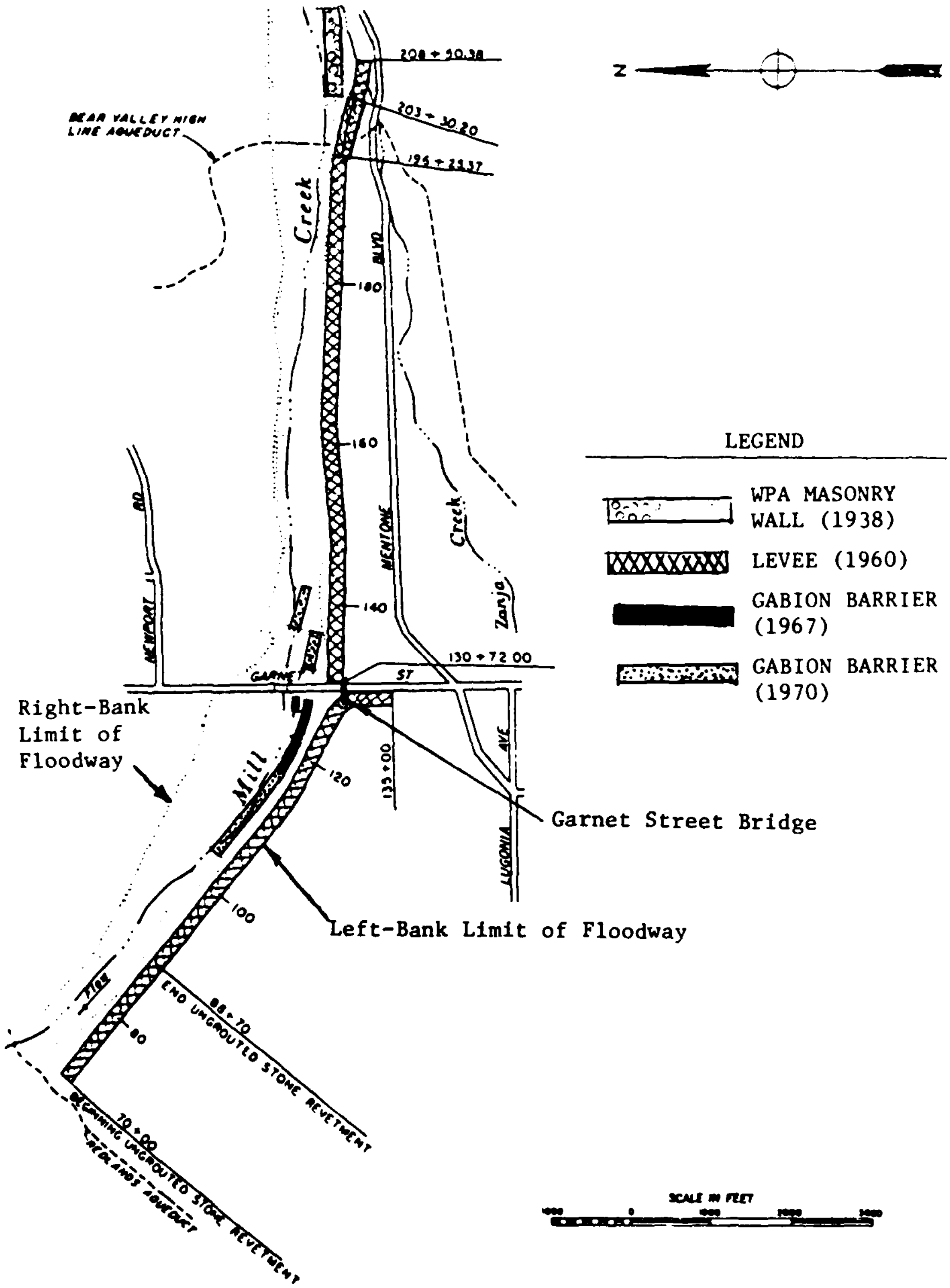


Figure 3. Limits of Mill Creek floodway and locations of WPA masonry wall, levee, and gabion barrier. Station numbers are referenced to 1960 project control line (adapted from Reference 1)

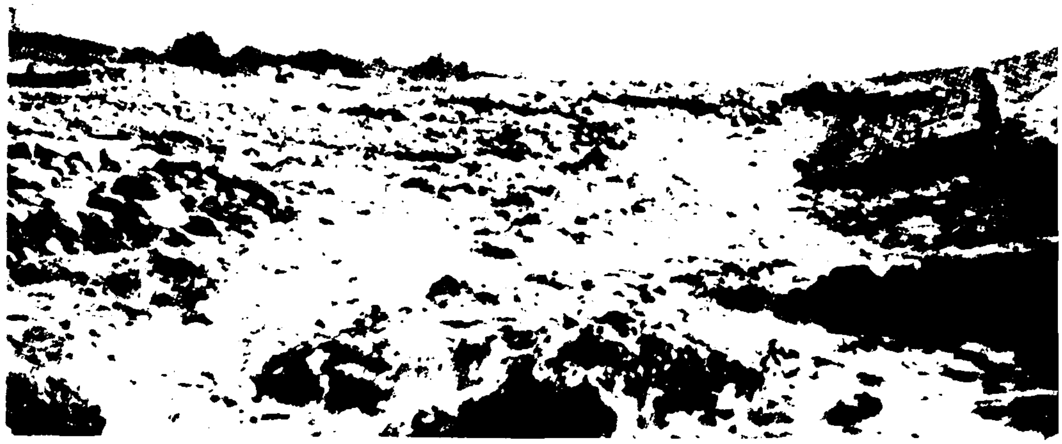


Figure 4. Upstream view from sta 105+00. Flood flow on 6 Decembe
with a peak discharge of 10,000 cfs undermined the Mill Creek leve
revetment (right center of photograph) at several locations downst
from Garnet Street Bridge (Source: Reference 1)

Figure 5. Downstream view from sta 95+00. The 1966 flood flo
on Mill Creek deposited huge loads of boulders and other debri
on the levee, behind the levee, and in the floodway. The man
in the foreground is standing on top of the levee (Source:
Reference 1)

Figure 6. Downstream view from sta 88+00. Almost half the ungrouted-stone revetment (left) in the downstream reach of the Mill Creek levee was severely damaged in the 1966 flood (Source: Reference 1)

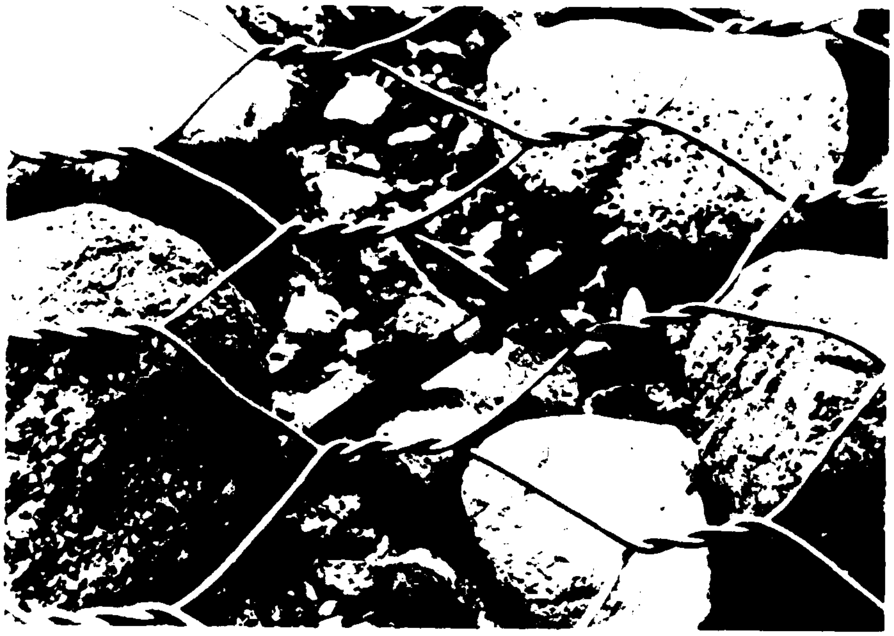
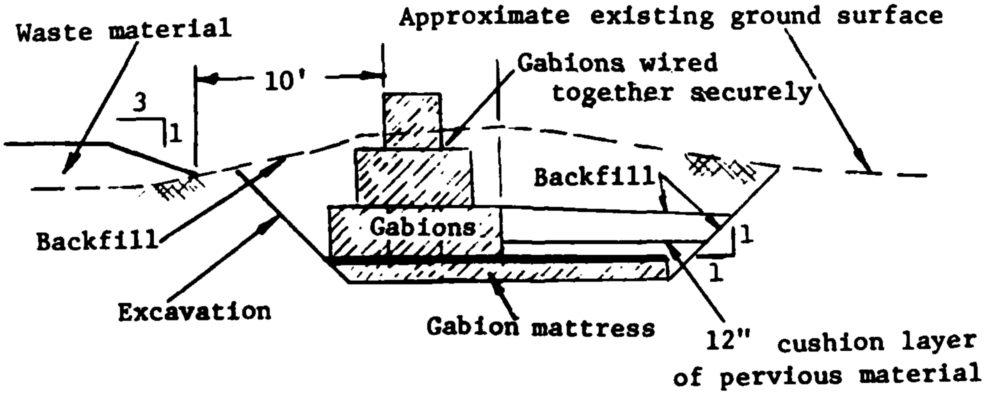


Figure 7. Detailed view showing the wire mesh structure and the variation in streambed stone sizes used to fill the gabions in Mill Creek (photograph taken 6 August 1979)

a. Photograph taken in 1967



b. Cross-sectional view

Figure 8. Photograph and cross-sectional view of midfloodway gabion barrier downstream from Carnet Street Bridge under construction after the 1966 flood

Figure 9. View upstream from sta 88+70. The inadequacy of the Mill Creek levee was clearly demonstrated in the 1969 floods. Flood flows overtopped the levee and eroded the back slope (Source: Reference 1)

Figure 10. Downstream view from sta 165+00. Flood flows in 1969 deposited heavy loads of boulders and other debris in the floodway. The buildup of debris caused flows to overtop the Mill Creek levee (left). The bluff in the background diverted flows back into the floodway (Source: Reference 1)

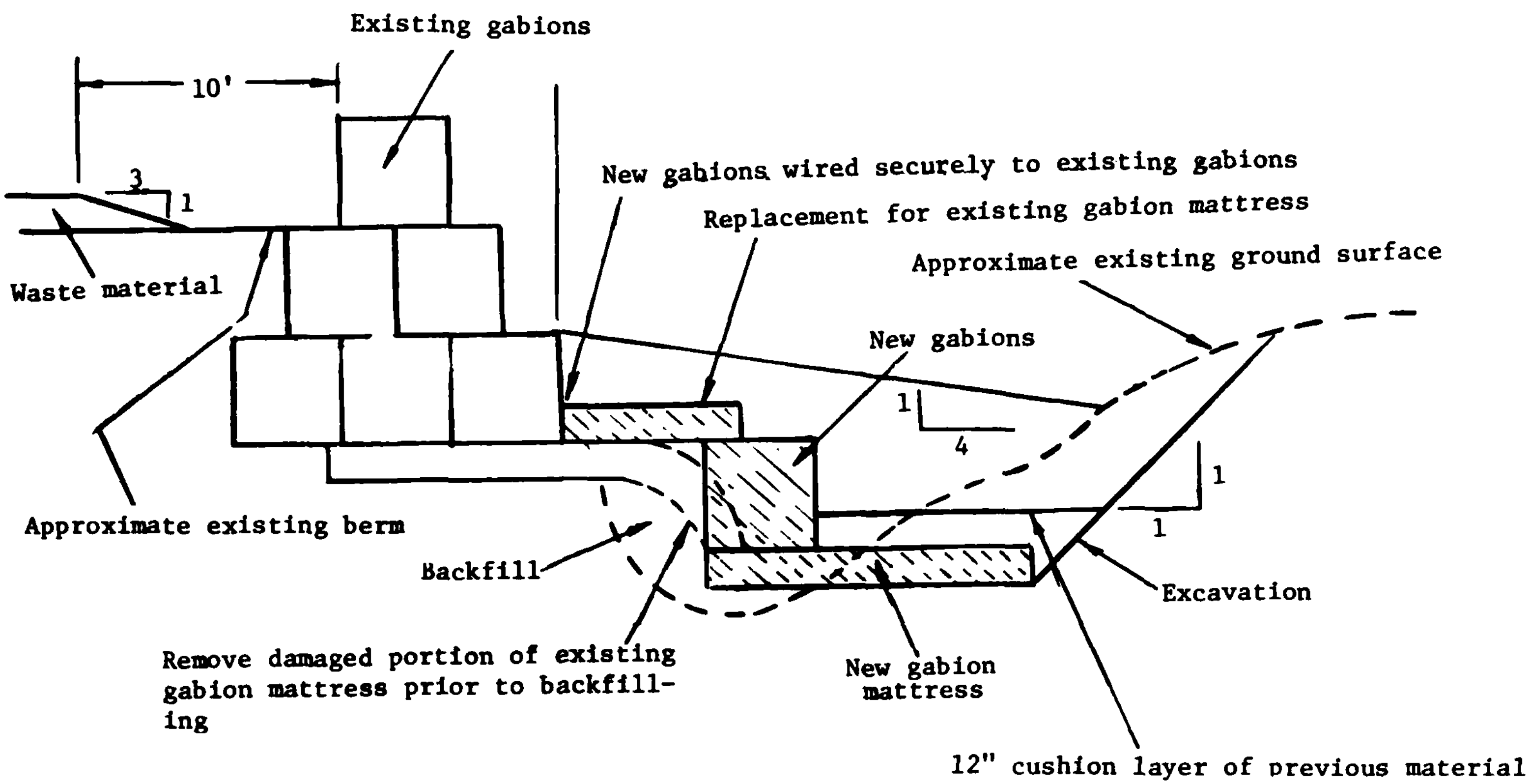


Figure 11. Modification to gabion barrier immediately downstream from Garnet Street Bridge in 1970 after the 1969 Mill Creek floods

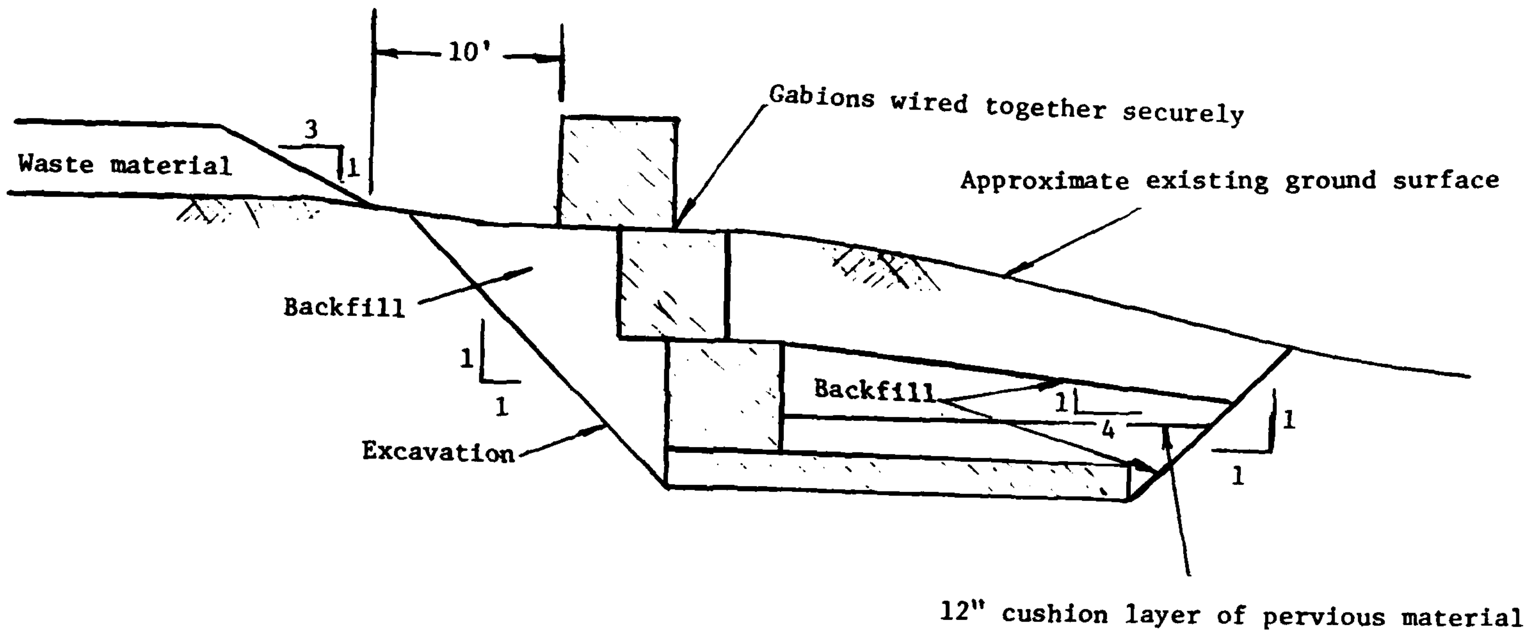


Figure 12. Cross-sectional view of midfloodway gabion barrier placed upstream from Garnet Street Bridge after 1969 floods

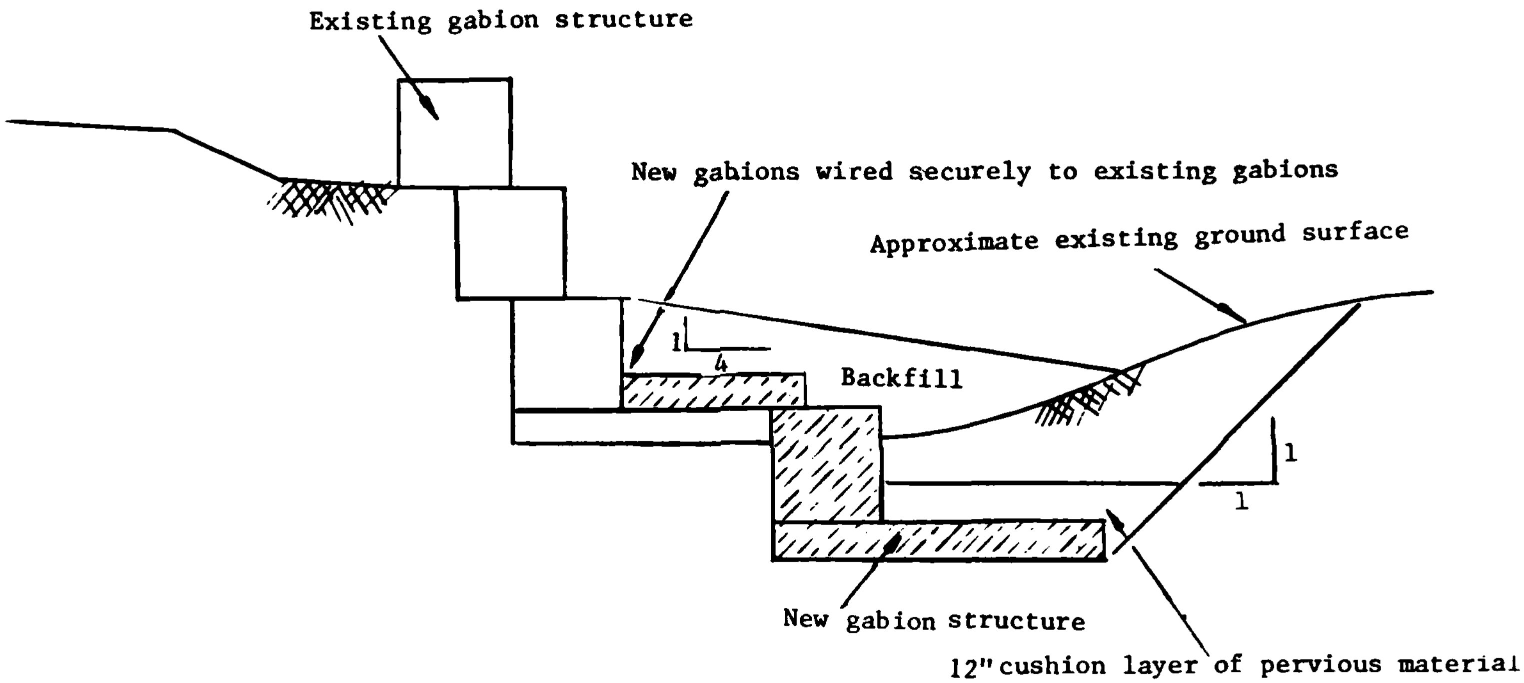


Figure 13. Modification to farthest upstream section of the midfloodway gabion barrier as constructed in September 1978 (paragraph 21)

Figure 14. Typical view of midfloodway gabion barrier in Mill Creek upstream from Garnet Street Bridge as it appeared at the time of the 6 August 1979 inspection

Figure 15. Midfloodway gabion barrier in Mill Creek downstream from Garnet Street Bridge as it appeared at the time of the 6 August 1979 inspection. Note how high flows have deformed this barrier and piled rock debris against its face

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