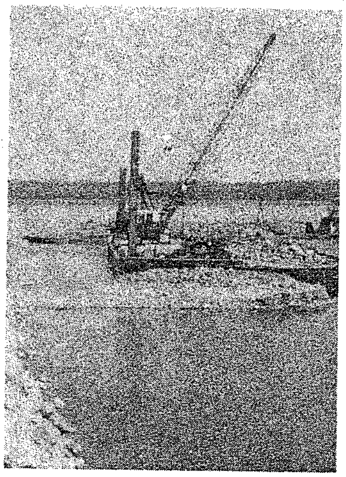
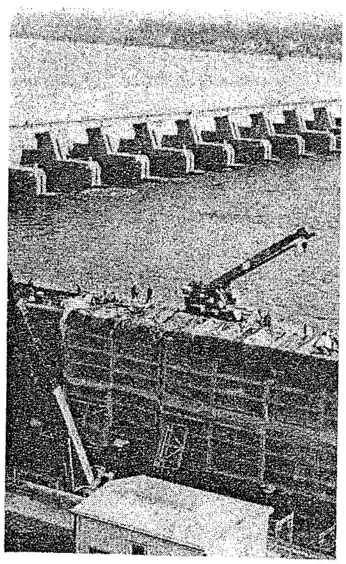
Corps
ers





The REMR *Bulletin*

News from the Repair, Evaluation, Maintenance, and Rehabilitation Research Program

VOL 4, NO. 4 **INFORMATION EXCHANGE BULLETIN** **DEC 1987**

Lock and Dam No. 20 dewatered for rehabilitation

Concrete Rehabilitation at Lock and Dam No. 20, Mississippi River

by
Jerry Wickersham
US Army Engineer District, Rock Island

Lock and Dam No. 20, located near Canton, Missouri, is one of 29 locks and dams on the Mississippi River which operate as a system to provide 9 feet of navigational depth from St. Louis, Missouri, to Minneapolis, Minnesota. The main lock and control house are located on the Missouri shore. The main lock is 110 feet wide and 600 feet long with a normal lift of 10.0 feet. A set of 20-foot-high miter gates is located at the upstream end of the main lock; a 27-foot-high set, at the downstream end. The lock filling and emptying system is the wall-port type. Poiree sills at each end of the lock enable poiree dams to be set and the lock to be dewatered.

Lock and Dam No. 20 was built in the mid 1930's. Construction records give the following concrete mixture proportions: cement, 470 pounds; coarse aggregate (2-inch natural gravel), 2,115 pounds; fine aggregate (natural sand), 1,245 pounds; and water, 250 pounds. The average 28-day compressive strength was 4,535 pounds per square inch (psi).

During the approximately 50 years of the structure's existence, severe climatic conditions plus impact and abrasion from barges and boats deteriorated the surface of the nonair-entrained concrete lock walls. Cores taken during a condition survey in 1985, however, showed the average compressive strength of the underlying sound concrete to be 6,974 psi.

Major rehabilitation of the lock wall surface was begun in 1986. The deteriorated concrete was replaced with conventional air-entrained concrete. Wall armor was embedded in areas susceptible to abrasion and impact (Figure 1). The cost of the concrete rehabilitation was approximately $2 million.

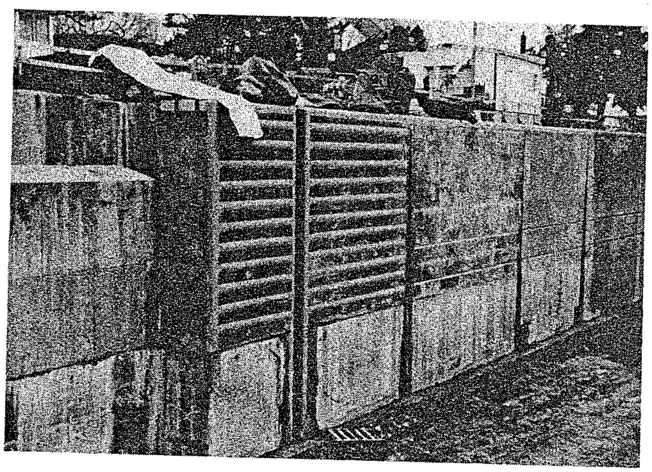


Figure 1. Wall armor embedded in lock wall to minimize the effects of abrasion and impact

Because the work was done during the winter months when the ambient temperature ranged from 20 to 30 degrees Fahrenheit, heated enclosures were provided at each monolith (Figure 2).

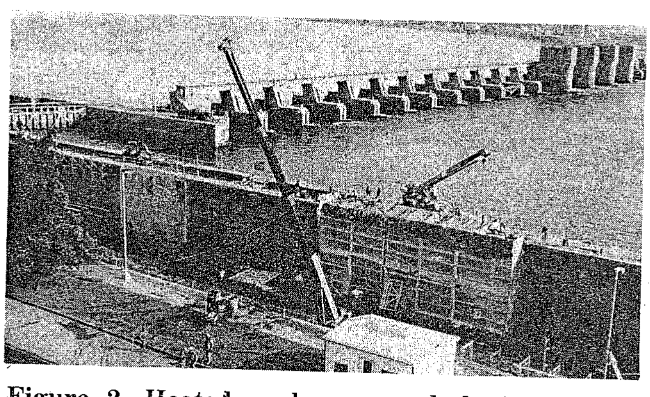


Figure 2. Heated enclosure used during winter repair of Lock and Dam No. 20

The deteriorated concrete was removed by a variety of methods. The areas to be removed were outlined and then saw-cut to a depth of 7 inches, even though specifications called for only 3-inch-deep saw cuts. Line drilling and blasting, machine-mounted demolition hammers, and hand-held chipping hammers were used to remove the concrete. Final cleanup was done with a high-pressure water jet.

Dowels, No. 6 bent reinforcing bars, on 4-foot centers each way, were embedded 1 foot 6 inches into the existing concrete with polyester resin cartridges. In general, the concrete reinforcement was No. 6 bars on 12-inch centers each way. The wooden forms were constructed on site and set inside the heated enclosures.

Concrete was supplied by a ready-mix supplier located about 2 miles from the site. The coarse aggregate was crushed limestone (1-1/2 inch maximum size). The average gradation of the coarse aggregate from quality control tests was:

Sieve Size	Percent Passing
1-1/2 inches	100
1 inch	89
3/4 inch	64
1/2 inch	34
3/8 inch	19
No. 4	5

The fine aggregate was a natural sand. The average gradation of the sand from quality control tests was:

Sieve Size	Percent Passing
3/8 inch	100
No. 4	95
No. 8	88
No. 16	73
No. 30	49
No. 50	9
No. 100	0.4
No. 200	0.2

Saturated surface dry batch weights for 1 cubic yard of the concrete mixture were:

Type I portland cement, pounds	542
Coarse aggregate, pounds	1,805
Fine aggregate, pounds	1,236
Water, pounds	258
Air content, percent	6

The specifications stipulated that the slump be from 1 to 4 inches and that the air content be from 4.5 to 7.5 percent. The slump of the concrete placed varied from 2-1/2 to 4-1/4 inches and the air content varied from 4.2 to 6.2 percent. The concrete placement temperature was approximately 60 degrees Fahrenheit.

Before placing the replacement concrete, the existing surface was kept wet for 2 to 12 hours. A crane located inside the dewatered lock chamber and a bucket were used to place the concrete. The average placement, 12 feet high by 30 feet long by 14 inches thick, was completed in about 2 hours.

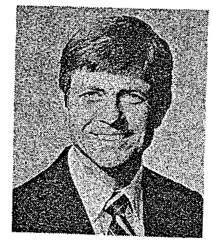
After placement, temperature in the enclosure was maintained at a minimum of 50 degrees Fahrenheit for seven days. A curing compound was used for most of the curing. However, moist curing (wet burlap covered with plastic sheeting) and forms left in place were also used.

The average 28-day compressive strength of test cylinders was 5,941 psi with a standard deviation of 493 psi. The overall coefficient of variation was 8.3 percent; within batch, 1.8 percent. A statistical analysis was performed on 27 sets of data.

Cracking in the replacement concrete on lock walls, a persistent problem, was significantly less in the refaced walls at Lock and Dam No. 20 than at most other rehabilitation projects within the Rock Island District. The reduced cracking may be the result of a combination of factors including lower cement content, larger maximum size coarse aggregate, lower placing and curing temperatures, smaller volumes of placement, and close attention to curing.

For more information contact Jerry Wickersham at (309) 788-6361, extension 247.

Jerry Wickersham, a concrete technologist with the Geotechnical Branch of the Rock Island District, has been with the Corps of Engineers since 1963. He attended St. Ambrose College, the University of Iowa, and Purdue University.



Epoxy Repair of Cracked Wooden Roof Trusses

by
MAJ Sean M. Wachutka
US Army Engineer District, St. Louis

Injected epoxy was used to repair wooden roof trusses in four warehouses at the St. Louis Area Support Center (SLASC), Granite City, Illinois, saving the government nearly 75 percent of the estimated cost for conventional repairs.

In the spring of 1982, following a partial collapse of one roof, the St. Louis District inspected roof truss members and columns in the warehouses. Many of the horizontal, vertical, and diagonal truss members were severely damaged, probably as a result of the heavy snow loads of the previous winter. Some of the 10- by 14-inch timber support columns had failed, and many had severely split. Repair of wooden columns using epoxy was not attempted because a large amount of epoxy would be needed to fill the many cracks and a large amount of sealer would have been needed to completely seal the surfaces of entire columns. Failed columns were replaced, and columns with very large cracks were shored with timber members. All columns were banded to ensure a margin of safety against column failure.

Replacing trusses that contained cracked members would have been time-consuming and would have interfered with normal warehouse activities. Injecting epoxy into cracks was the remedial repair solution to both safety and budget constraints. A two-step procedure was used to repair the wooden trusses. The first step was to prepare the damaged areas for injection by cleaning the surface with wire brushes, installing plastic or copper injection ports, and coating the surface with crack-sealing (CS) epoxy. This epoxy (which has a grease-like consistency before curing) sealed the surface and prevented any of the injected epoxy from venting out through small cracks. CS epoxy must be of the proper consistency, since a sealer with too high a viscosity will require extra labor for application, and a sealer with too low a viscosity will drain into the joint and interfere with the injection operation. Sicadur High Mod Jel was used in this repair.

The next step was to inject low-viscosity (LV) epoxy into the cracks. Using an injection pump about the size of a large briefcase, the two-part LV epoxy, Sicadur Hi Mod LV, was mixed and pumped through the lowest central injection port. As it penetrated the crack, it was forced out of secondary or breather ports which were promptly closed when the epoxy appeared. These breather ports verified that the epoxy was penetrating the cracks as desired. The injection continued until the epoxy emerged from the last breather port, which was then crimped closed, along with the injection port. Within an hour the LV epoxy began to set, and after 24 to 48 hours, it exceeded the strength of the wood it bonded.

Equipment necessary for this type of repair, which can fit on a four-man scissors lift, consists of the injection pump, two 5-gallon reservoirs for the LV epoxy, and plastic tubes to connect the pump to the injection ports (Figure 1).

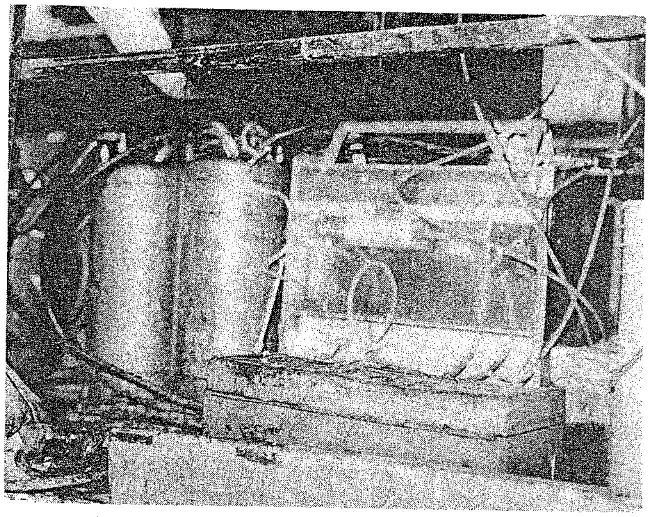


Figure 1. Injection pump, two 5-gallon reservoirs, and plastic tubes to connect the pump to the injection ports

Quality assurance was a prime consideration because any error during injection would have made completing the repair by other methods difficult and expensive. Before the LV epoxy injection began, the contractor was required to prepare three test specimens, each consisting of two 2-inch by 4-inch by 2-foot boards which had been sealed together with CS epoxy and which contained four injection ports. After the CS epoxy cured, the LV epoxy was pumped in and the breaker ports were sealed as the LV epoxy appeared. The procedure is shown in Figure 2. After curing at least 24 hours, each specimen was cut into 6-inch lengths and tested for failure in shear. Required minimum shear strength was 600 pounds per square inch (psi). The contractor was required to have a representative of the epoxy manufacturer on site for the first two days of the repair to observe the injection methods. Specimens were prepared before the start of each workday, after every fifth repair, and repeated if there was more than a 30-minute break in injection. Another regular check to verify epoxy component proportioning was the taking of hourly samples, consisting of two or three ounces of LV epoxy, directly from the injection pump into a cup. To meet requirements the samples had to set within an hour.

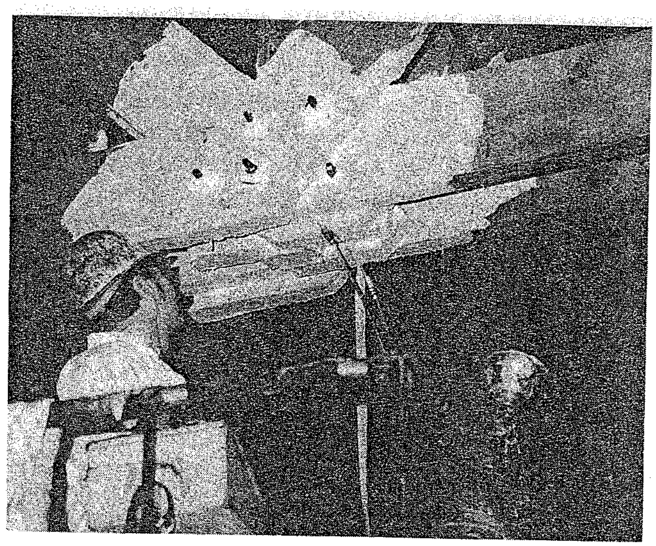


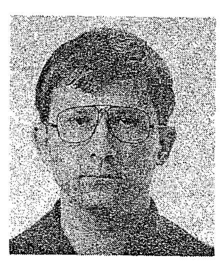
Figure 2. Injecting low-viscosity epoxy into a cracked roof truss

Injection pressure was limited to a maximum of 40 psi, thus providing time for the epoxy to penetrate wood fibers before being forced from the breather ports. By controlling injection pressure, blowouts of the LV epoxy through the CS epoxy were kept to a minimum.

The use of a contractor experienced in epoxy injection of wood was important since there are many techniques for applying the crack sealant, and injecting the epoxy as the contractor did could only be learned from experience. An inspector for the contracting officer also must be present at all times during the injection process.

The cost for the epoxy work on two warehouses, including repairs at nearly 300 separate locations, was about $115,000 per building. The original cost estimate based on more traditional techniques exceeded $400,000.

The use of epoxies is not limited to the repair of wooden structures. Products are commercially available for repairing concrete, steel, masonry, and fiberglass.



MAJ Sean Wachutka has just completed a tour as the Area Engineer, El Salvador. He is presently serving as a civil engineer with the US Army Engineer District, St. Louis, while awaiting assignment to the Command and General Staff College. He received a B.S. degree in civil engineering from the University of Washington and an M.S. degree in civil engineering from the University of Florida.

Stabilized Channel Maintenance and Aquatic Habitat

by
F. Douglas Shields, Jr.
US Army Engineer Waterways Experiment Station

During the last century, river training structures—dikes and revetments—have been used to stabilize over 3,500 miles of major waterways in the United States. Although the Corps of Engineers (CE) was involved in building river training works as early as 1839, most existing structures were built between 1920 and 1940. Dikes have been constructed with stone, timber pilings, and metal jacks; revetments have been made of timber mattresses, stone riprap, and articulated concrete mattresses. Quarried stone riprap is presently the most commonly used material for both dikes and revetments. Articulated concrete mattress revetment is used mainly on the lower Mississippi River, and large-scale use of pile dikes is confined to the lower Columbia River.

Annual CE expenditures for river training structures range between $25-30 million. Damage to the structures is caused by ice, impacts from floating debris and vessels, and turbulence associated with high flows and vessel wakes. Maintenance work on stone dikes and revetments typically consists of replacing stone to restore design dimensions or making minor changes in structure configuration. Pile dikes require replacement of piles and rock blanket foundations.

Channel Stabilization and Habitat

River channel stabilization, paradoxically, tends to have both negative and positive environmental impacts. Stabilization of the lower Missouri and lower Mississippi Rivers has been associated with major shifts in aquatic habitat (Reference 1). For example, water surface area of the Iowa portion of the lower Missouri River decreased 34 percent between 1947 and 1976. Changes in lower Mississippi water surface area between 1964 and 1976 were insignificant, but the number and area of bars and islands decreased by 36 percent while the area of dike-held pools increased from 0.21 square mile to 5.37 square miles.

CE biological studies on the lower Mississippi, Arkansas, Missouri, and Willamette Rivers (Reference 2) indicate that areas of low water velocity near training works are valuable aquatic habitats. River training structures are usually inhabited by a dense and diverse assemblage of benthic invertebrates, and the spaces between the stones provide a refugia for juvenile and larval fish. As long as they remain aquatic, regions between transverse spur dikes (dike-field habitat) often support the most diverse fish communities of any habitat within the river. Burch and others (Reference 3) suggested techniques for improving fish habitats that could be incorporated into maintenance activities. These techniques include:

- Dredging accumulated sediments from dike fields and maintaining connecting channels between backwater pools and the main channel.
- Raising and lowering dike crests and using brush, boulders, stone, or automobile tires to provide artificial fish shelters.
- Allowing crests of training structures to degrade below design elevations if not detrimental to the stabilized channel.
- Constructing gaps or notches in dikes to hinder sediment accretion (Figure 1).
- Constructing dikes with a gap between the dike structure and the river bank.

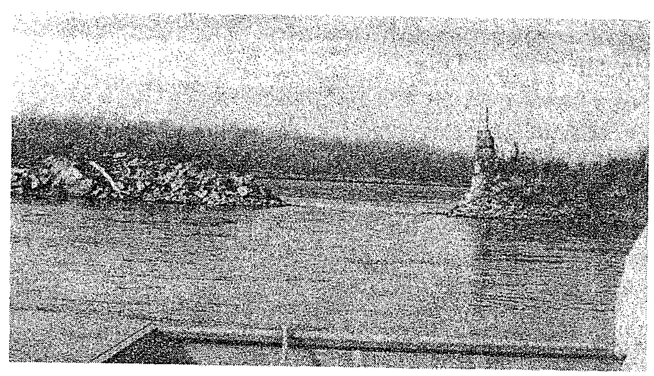


Figure 1. Gaps or notches in dikes which hinder sediment accretion

- In addition, Lower Mississippi Valley Division personnel have considered leaving short segments of unprotected bank line in otherwise continuous revetment. Unprotected bank line segments tend to erode into scalloped areas which produce eddies. During subsequent maintenance operations, these areas may be stabilized with riprap (Reference 1).

Missouri River Study

Although the value of dikes and dike fields as aquatic habitats has been established, relative values associated with specific maintenance techniques have not been documented. The study described herein is intended to partially fill this information gap. The most widely employed dike maintenance technique for environmental management purposes to date is the excavation of notches in spur dikes. Over 1,600 notches have been created in dikes and revetments along the lower Missouri River in the Omaha and Kansas City Districts. Accordingly, this study seeks to describe physical and attendant biological effects of spur dike notching at Missouri River study sites.

The physical portion of the study is based on intensive before-and-after notching hydrographic surveys in the vicinities of twenty spur dikes. The same notch dimensions were used for each structure, and the stone removed to create the notch was deposited about 50 feet downstream to create a reef. Preliminary results indicate that notching resulted in increased water depth and surface area at most of the dikes during the first two to three years after notching. Study dikes were located in two reaches, one above and one below the Platte River confluence. Increases in aquatic habitat were much greater for the downstream reach, which experienced higher stages relative to notch invert elevations than for the upstream reach. The response of the river channel habitat immediately adjacent to notched dikes was related to the hydrograph and to the initial elevation of the bed relative to notch elevation.

The biological component of the study involved collections of data at nine dikes in the reach upstream of the Platte confluence on two sampling dates (June and August 1986). Areas around three unmodified dikes, three notched dikes, and three notched dikes with downstream reefs were sampled. Fish populations were sampled using hoop nets, seines, and electroshockers. Water quality, velocity, and substrate (bed material) were also measured. Preliminary results indicate no significant differences in fish populations, velocity levels, or substrate sizes among the three types of dikes.

Spur dike notching appears to be an effective method for increasing the quantity of valuable aquatic habitat along the lower Missouri River. Fish populations at high and moderate flow in the summer are similar at notched and unmodified dikes. The increases in aquatic habitat associated with notching are minor relative to system-wide changes associated with channel stabilization and closure of upstream dams. Additional work is needed to extend these results to other river reaches.

Some funding for the analysis of collected data referred to in this article was provided by the Omaha District.

For further information, contact F. Douglas Shields, Jr. at (601) 634-3707.

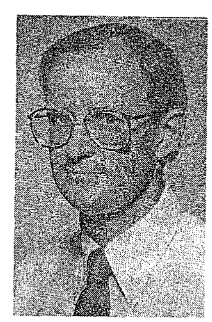
References

1. Nunnally, N. R., and Beverly, L. B. 1986. "Morphologic Effects of Lower Mississippi River Dike Fields," Miscellaneous Paper E-86-2, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

2. Sandheinrich, M. B., and Atchinson, G. J. 1986. "Environmental Effects of Dikes and Revetments on Large Riverine Systems," Technical Report E-86-5, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

3. Burch, C. W., and others. 1984. "Environmental Guidelines for Dike Fields," Technical Report E-84-4, US Army Engineer Waterways Experiment Station, Vicksburg, Miss.

F. Douglas Shields, Jr., is a research civil engineer in the Environmental Laboratory, WES. He received a B.S. degree in mathematics from Harding University in 1975, an M.S. degree in environmental and water resources engineering from Vanderbilt University in 1977, and a Ph.D. degree in civil engineering from Colorado State University in 1987. He is a registered professional engineer in the State of Mississippi.



Request for Articles

If you have experience in any of the areas being addressed by the REMR Research Program, *The REMR Bulletin* is actively soliciting articles. Articles by individuals outside the Corps will be considered if relevant to REMR activities of the Corps.

To submit an article, write to: Commander and Director, US Army Engineer Waterways Experiment Station, ATTN: CEWES-SC-A, PO Box 631, Vicksburg, MS 39180-0631.

When submitting photographs with articles, please provide glossy prints or film rather than prescreened negatives.

Workshop Scheduled on Geotechnical Aspects of Rock Erosion in Emergency Spillway Channels

A REMR workshop, "Geotechnical Aspects of Rock Erosion in Emergency Spillway Channels," will be held May 3-5, 1988 in Des Moines, Iowa. Sponsors are the US Army Engineer Waterways Experiment Station (WES) and the US Army Engineer District, Rock Island. Technical sessions will acquaint geotechnical personnel from the Corps of Engineers, Soil Conservation Service, Bureau of Reclamation, and other agencies with the causes, consequences, and remediation of rock erosion in unlined emergency spillway channels, as well as with prediction techniques.

Topics to be discussed include emergency spillway design, case histories of significant flow events, laboratory research, remediation, and outlook and recommendations. Also, on May 5, personnel from the Rock Island District and the Iowa Geological Survey will conduct a field trip to examine damage from erosion in the spillway at Saylorville Reservoir.

For further information, contact James H. May at (601) 634-3395 or David M. Patrick at (601) 634-3157.

Field Review Group Meetings

The 10th meeting of the Field Review Group (FRG) for the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program was held in Champaign, Illinois, August 25-27, 1987. The meeting was sponsored by the US Army Construction Engineering Research Laboratory. Progress in the work units of the seven problem areas of the REMR program were discussed, as well as technology transfer needs and plans.

The 11th meeting of the FRG is scheduled for April 12-14, 1988 in San Francisco, California, and will be sponsored by the South Pacific Division.

COVER PHOTOS

Maintenance work on a stone dike.

Heated enclosure around a monolith used during winter repair of Lock and Dam No. 20.

The REMR *Bulletin*

The REMR Bulletin is published in accordance with AR 310-2 as one of the information exchange functions of the Corps of Engineers. It is primarily intended to be a forum whereby information on repair, evaluation, maintenance, and rehabilitation work done or managed by Corps field offices can be rapidly and widely disseminated to other Corps offices, other US Government agencies, and the engineering community in general. Contributions of articles, news, reviews, notices, and other pertinent types of information are solicited from all sources and will be considered for publication so long as they are relevant to REMR activities. Special consideration will be given to reports of Corps field experience in repair and maintenance of civil works projects. In considering the application of technology described herein, the reader should note that the purpose of *The REMR Bulletin* is information exchange and not the promulgation of Corps policy; thus, guidance on recommended practice in any given area should be sought through appropriate channels or in other documents. The contents of this bulletin are not to be used for advertising, publication, or promotional purposes. Citation of trade names does not constitute an official endorsement or approval of the use of such commercial products. *The REMR Bulletin* will be issued on an irregular basis as dictated by the quantity and importance of information available for dissemination. Communications are welcomed and should be made by writing the Commander and Director, US Army Engineer Waterways Experiment Station, ATTN: Bill McCleese (CEWES-SC-A), PO Box 631, Vicksburg, MS 39180-0631, or calling 601-634-2587.

DWAYNE G. LEE
Colonel, Corps of Engineers
Commander and Director

DEPARTMENT OF THE ARMY
WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
PO BOX 631
VICKSBURG, MISSISSIPPI 39180-0631

OFFICIAL BUSINESS
PENALTY FOR PRIVATE USE, $300

CEWES-SC-A