US Army Corps of Engineers

(Albuquerque District)

Floodwater Lessons Learned:

Best of Lessons Learned

PDH: 3 Hours

Don Soards, P.E.

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Floodwater: Best of Lessons Learned

1. Course Overview

This course satisfies 3-hours of engineering continuing education requirement for Professional Engineer license renewal.

One thing common to all engineering disciplines is protection against flooding. Our systems need to work when it rains.

This course in Best of Lessons Learned is intended to encourage the engineer to consider the big-picture result of field performance of many projects over many decades.

The engineer’s duty is to make things work. Following instructions, complying with the law, and using current best practices are usually good enough for the present. But the engineer’s task to make things work in the future. This requires making projections about future conditions and use. While engineers prefer hard facts, we are sometimes forced to work with “soft data” that require evaluating many possible options. During this evaluation, we use legal requirements and best technology as tools.

When I headed the Albuquerque District's Inspection of Completed Works (one of three major programs I had as Chief of Emergency Management for a dozen years), I noticed the same design/construction errors being repeated. The US Army's version of Total Quality Management (TQM) was Total Army Quality (TAQ). Under TAQ, the process of continuous improvement was building, feedback, and improved building.

The problem was a lack of feedback because flood control structures may sit for decades without being tested by significant flooding. I strove to compensate for this lack of immediate feedback by having studies made of the histories of over one hundred projects constructed by the Albuquerque District Corps of Engineers since 1948. I selected Professor Richard J. Heggen, a hydrology/hydraulics teacher at UNM, to write many of these, including Best of Lessons Learned. His interesting and entertaining lecture style is reflected in his writing.

2. Learning Objectives

Upon successful completion of this course, the participants will be able to:

- Recognize many defects in existing flood control structures.
- Review plans to avoid those defects.
- Consider how the life of flood control structures may impact current engineering systems.
- Inspect flood control projects.

3. Summary

In this course, we examined key features of flood control and bank protection projects that worked over time and a number of those that faced challenges during their long life. Suggestions for improvement were made for many of the problems encountered.

Reference Best of Lessons Learned by Professor Richard J. Heggen

US ARMY CORPS OF ENGINEERS
(ALBUQUERQUE DISTRICT)
BEST OF LEASONS LEARNED

Best of Lessons Learned

September 1998

Richard J. Heggen
Department of Civil Engineering
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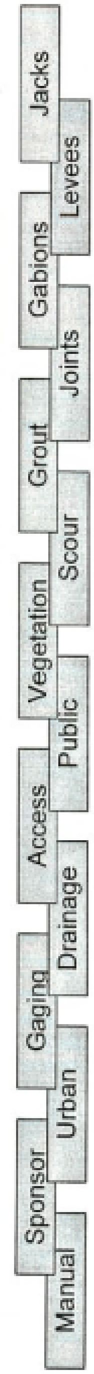
Lessons Learned

1. Jetty Jacks:
   American champion
2. Levees
   A case for obesity and tough skin
3. Gabions and Wire Wrapped Riprap:
   Undercut and sidestepped
4. Joints:
   The vulnerable connection
5. Grout:
   Bright lipstick and thick rouge
6. Scour, Deposition and Meanders:
   Sleeping in a mobile bed
7. Vegetation:
   Triumph of the green
8. The Public:
   The bell curve
9. Access:
   The demon
10. Local Drainage:
    The train doesn't stop here anymore
11. Gaging:
    Lost history
12. Urban Development:
    The Corps as a player
13. Sponsor:
    The best of intentions and the reality of resources
14. Operation and Maintenance Manual:
    Death by Xerox



Best of Lessons Learned

September 1998

Photo 1. A $598,528 lesson

Introduction

Photo 1 has lessons to tell. US Army Corps of Engineers project DACW47-79-C-0055, 18,850 feet of levees and 1,375 feet of single-line jetty jacks, repaired 1978 flood damage on the Gila River, NM. The caption indicates the cost.

A 1980 flood damaged the levee toe. The sponsor, a private party, did not address progressive failure noted in Corps inspections. Flooding in 1983, the time of the photograph, further eroded the earthwork, flanked the levee, and pulled out the jackline, all visible in the picture. Flooding in 1984 destroyed the project.

What can be learned from failure? What can be learned from success?

Lessons Learned Reports

In an initiative of Total Quality Management, the Albuquerque District, US Army Corps of Engineers, reviewed the performance of approximately two hundred Emergency Flood Control Works constructed since 1949. Project review generally includes:

(1) Tabulation and condensation of project inspection records,
(2) Discussion with the personnel familiar with the project,
(3) A site visit, and
(4) General observations.

Forty-six *Lessons Learned* reports cover the projects. *Lessons Learned* are not technical reanalyzes or forensic determinations. *Lessons Learned* emphasize field experience, the weak side of a novice design engineer armed with just Engineering Manual theory.

Lessons Learned reports are not judiciously impartial. Emergency Works include an array of technologies in a spectrum of environments monitored by a series of observers. *Lessons Learned* reflect opinions of field inspectors over the project life and the impressions of the reviewer. The frontier of Engineering is in the subjective issues.

Lessons Learned reports are illustrational. Seeing is believing. If something could happen to an engineered work, District files probably have a photograph.

A *Lessons Learned* report may group projects by treatment, *e.g.*, the common history of jetty jacks. Most *Lessons Learned* simply reflect an inspection itinerary, *e.g.*, site histories in one corner of the state, not themes.

Designer's Index

Any one *Lessons Learned* report, having the breadth of at most a few projects, may miss the larger patterns. The *Designer's Index* is a database of *Lessons Learned*, sorting project histories for similarities of technical challenge and performance. The *Designer's Index* is not in itself new data; it is a vantage point from which to pursue that information. If a particular treatment functions well in some projects and poorly in others, the *Designer's Index* identifies the pertinent works. The discriminating eye can seek the differential factor.

Best of Lessons Learned

Best of Lessons Learned are fundamental observations derived from both the sagas of individual *Lessons Learned* and the tally of the *Designer's Index*. Lessons are deemed "best" not because they are the most sophisticated or spectacular, but rather for reasons of the opposite.

Best of Lesson Learned relate to the realities of the field. Design manuals (and worse so, software) can't reconnoiter the site.

Best of Lessons Learned are not topics of analytic complexity. A wrong treatment elegantly sized is still a wrong treatment.

Best of Lessons Learned promote design caution, not engineering revolution. Tested technologies merit improvement.

Best of Lessons Learned provide stand-alone guidance for the novice designer, Corps' employee or otherwise.

Lesson 1

Jacks

Jetty Jacks:
American champion

Henry Ford, Alexander Graham Bell and Henry Kellner were three American inventor capitalists. Two heralded a future of indecipherable technology, built-in obsolesce, landscape crisscrossed with wires and concrete, cellular calls from traffic jams. And from the patents, unbounded corporate profit. The other produced an item of a half dozen parts that costs little, achieves its objective, self-repairs, and works with nature. The patent, given to the public. In terms of fundamental cost/benefit, the Ford motor car and the Bell telephone pall before the Kellner jetty jack.

The Kellner jetty jack is the pinnacle of Albuquerque District's engineering successes. Approximately 150,000 units have been installed. Only a few have failed. Photo 1.1 shows jacks newly placed on the overbank.

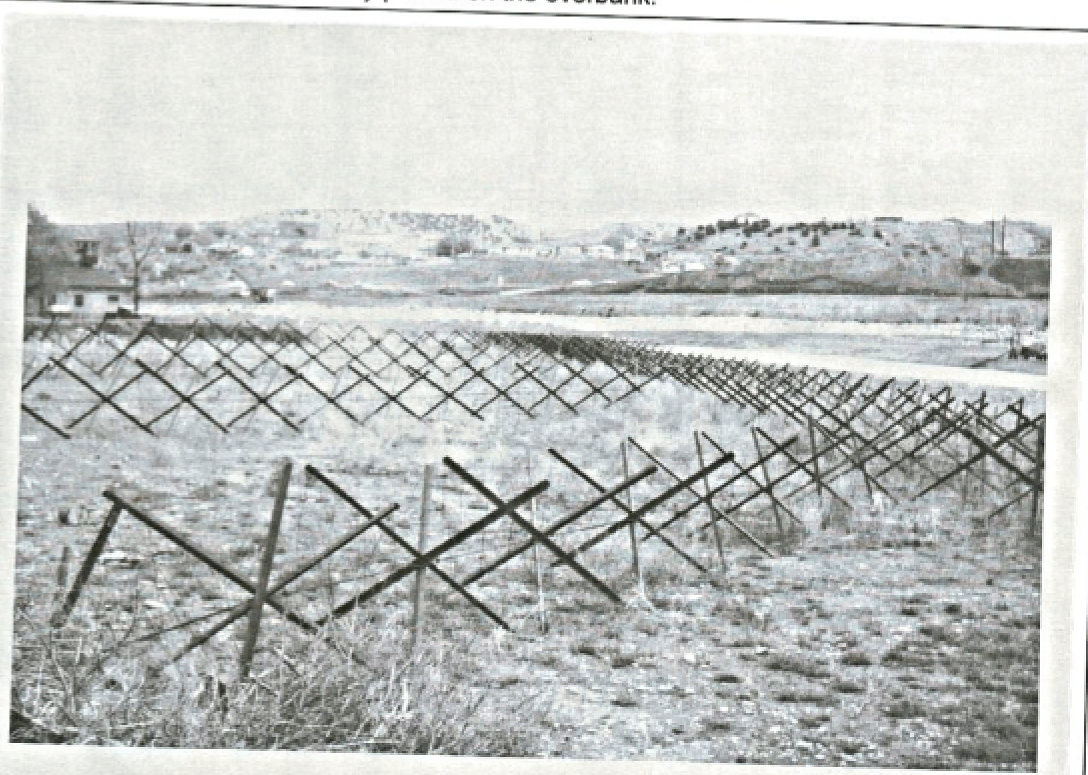


Photo 1.1. New jacks

Jacks

When first installed, jack design life was presumed to be 50 years. That duration is now achieved and the units show few signs of age. Photo 1.2 reveals new-looking steel in a sawed section.

Photo 1.2 also illustrates the work of thieves. Jacks in accessible areas are occasionally stolen for their angle iron. The jacklines are sufficiently robust to compensate for several missing members.

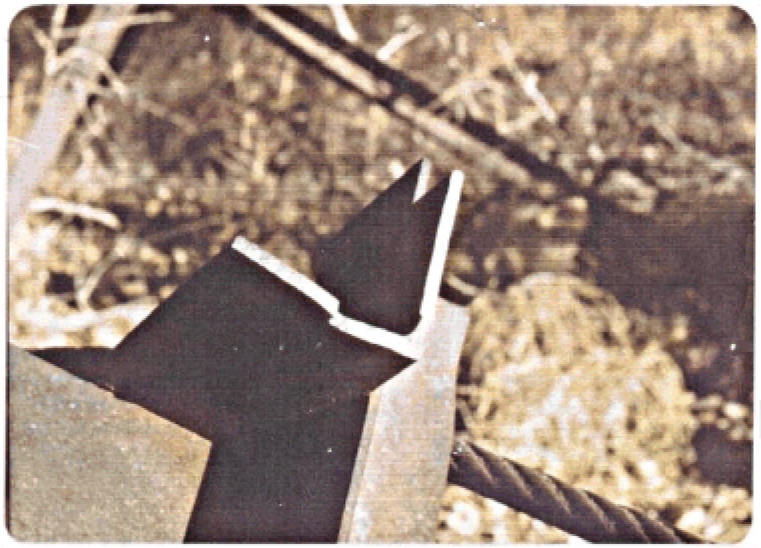


Photo 1.2. Jack steel

Photo 1.3 shows jacks smaller than the standard Kellner design. Several jack fields appear deficient by standard specifications. Significantly, these units appear to function well. The Kellner design appears to be conservative.

Photo 1.3. Eight-foot jacks

Jacks

Jacks are not problem free. Photo 1.4 shows erosion under a jack line, most likely due to clean water.

The more the debris and the higher the turbidity, the better the jack performance.

Photo 1.4. Eroded line

The jackline in Photo 1 pulled out from its end anchoring. Photo 1.5 illustrates tieback to a tree. Secure jacklines with deadman anchors, not vegetation.

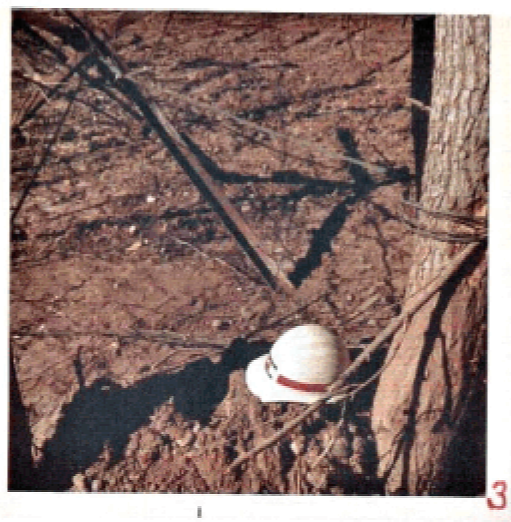


Photo 1.5. Inadequate tieback

The Kellner jack is the District's great success.

Lesson 2

Levees:

A case for obesity and tough skin

Levees

As the Corps stands tall, so do its levees. HEC-1 and HEC-2 are mature models. Engineers can reasonably anticipate hydrographs and size conveyance accordingly. User friendliness, not truer results, drives HEC-HMS and HEC-RAS. Practical proof of analytic maturity is the rarity of overtopped levees. Their height is sufficient.

The Corps is a lean agency, a physiology also manifested in its levees. To contain cost, levee width, not height, is minimized. Were there a HEC-X for geotechnical determinations, an optimal cross-section might be achieved. As it is, levee height is by the computer. Base width is the sum of a driveway crown and height times sideslope near the angle of repose. That width is often insufficient.

Common sense suggests that levees built from channel material are rarely stable. Flow that can move particles down a channel can also move those particles off a levee face. Compare channel velocity to allowable velocity for the levee material. Table 2-5, EM 110-2-1601, 1991, provides quick appraisal.

Levee erosion is the closest the District has come to having a systemic structural problem. Photos 2.1 and 2.2 show levee erosion, in all cases by flows that did not exceed levee height

If erosive forces exceed the stability of the levee material, protect the levee. If space permits and earth is available, add sacrificial width and reliable access for the repairs ultimately needed.

Alternatively (or even better, conjunctively) protect the levee with riprap, vegetation or erosion-resistant soil.

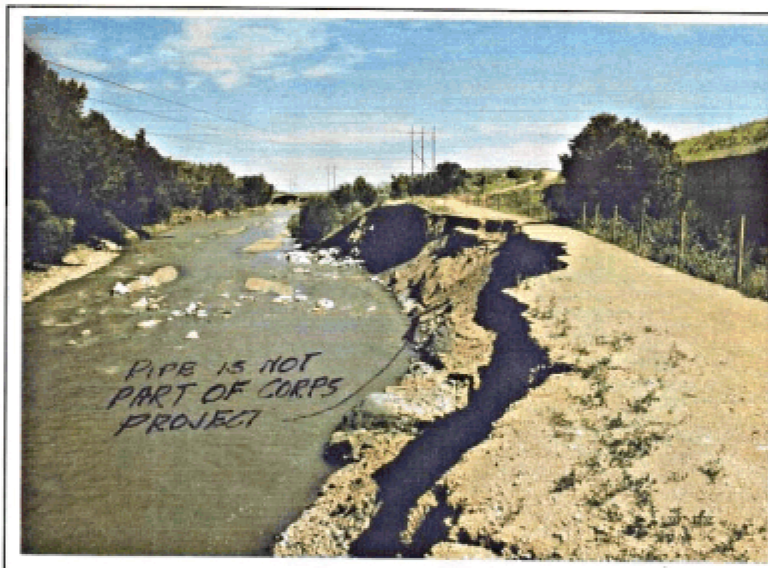


Photo 2.1. Levee erosion

Levees

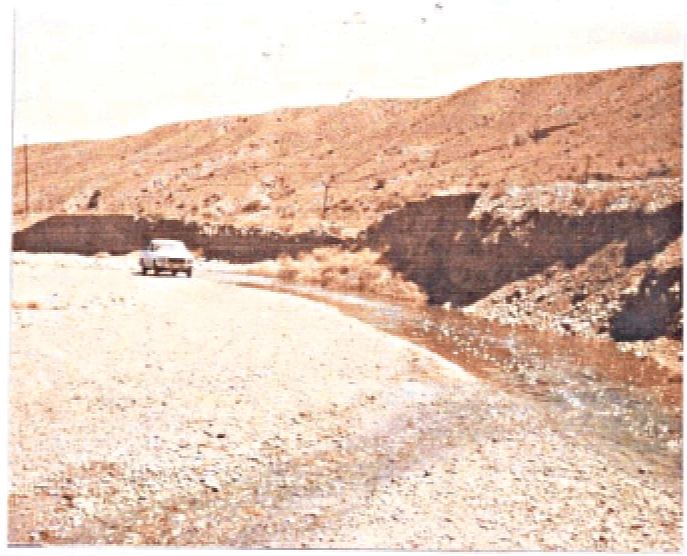


Photo 2.2. Levee erosion

Photo 2.3 shows the remnants of an eroded levee. The project is no longer functional.

Photo 2.3. Remnants

Resistance to toe erosion is a levee's most important design parameter. A fat levee is a good levee. A thick-skinned levee is even a better levee.

Lesson 3

Gabions and Wire Wrapped Riprap:
Undercut and sidestepped

Gabions

Engineers prefer to view gabions as freebody rectangles, a sum-of-force and sum-of-moment application. Novice designers have the tools. So engineered, gabion walls thus rarely tip. Rock blankets rarely slide.

Maccaferri specifications reflect 120 years of material development. Baskets rarely disintegrate. Gabions are moderately aesthetic, rarely vandalized and most certainly never stolen. Yet gabions are a treatment prone to failure.

Water finds the easiest path downstream. Given the opportunity, water improves upon that path. That path is too often around or under the gabion or wire wrapped rocks. In Photo 3.1, the path is under the toe (or, as suspected by the inspector, through the sand where the toe wasn't built).

Photo 3.1. No footing

The wire wrapped riprap in Photo 3.2 is undercut, leaving the weight of the rock bearing on the mesh.

Bank treatment should be keyed beneath the channel bed a minimum of 2 feet, greater if additional degradation is possible.

Photo 3.2. Undercutting

Gabions

Flow has moved around the end of the drop structure in Photo 3.3. The drop needs substantial endwalls.

Photo 3.3. End erosion

Large riprap protects the end of the wire wrapped riprap in Photo 3.4. While the cost of this protection is significant, the expense of loosing the protection is probably greater.

Photo 3.4. Rocks at end

The attack is at the edges. Defend accordingly.

Lesson 4

Joints:

The vulnerable connections

One hundred and fourteen persons died when the walkway of the Kansas City Hyatt Regency collapsed in 1981. Most building disasters initiate at faulty connections, the flange bolts in this case.

Hydraulic structures are no different. Precursing gross failure are concrete spalls at construction joints, as seen in Photo 4.1. Spalls may have multiple causes: inadequate attention to thermal or curing stresses; lack of construction control; substandard materials; water infusion, etc. Joint problems are not easily remedied retroactively.

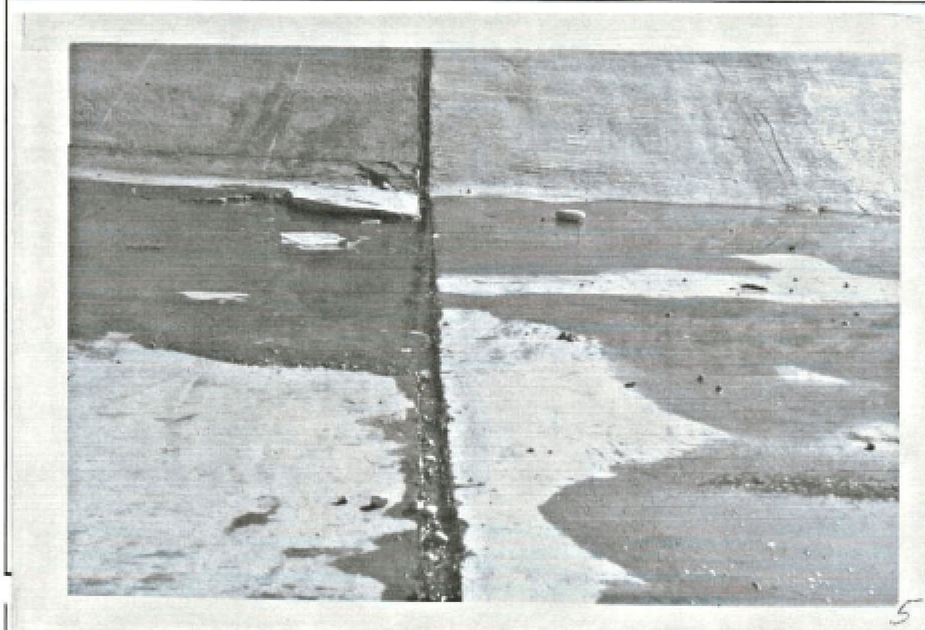


Photo 4.1. Spalling at construction joint

Joints

An open joint leads to subsequent problems. Photo 4.2 shows a 6-inch uplift, mechanism unknown

Photo 4.2. Uplift

Problems manifest at side channel junctions where here is no mass resistance to concrete working transversely to the wall. Photo 4.3 shows the result.

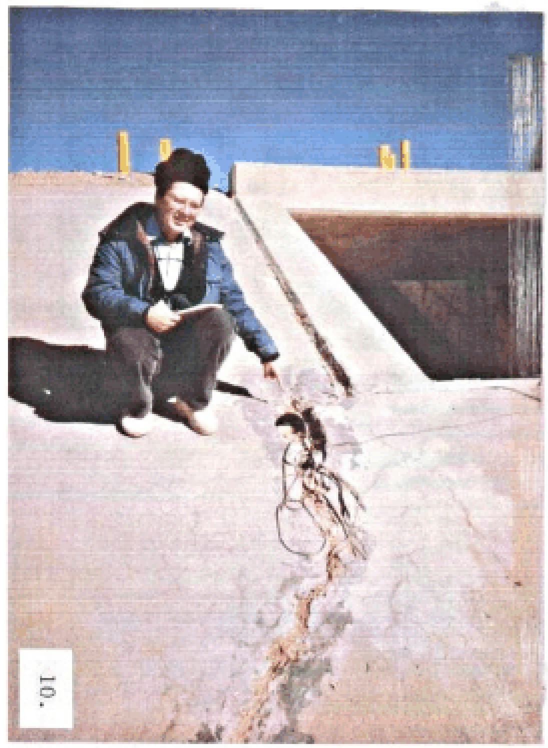


Photo 4.3. Thrust failure

Where concrete faces are perpendicular, Photo 4.4 shows the spall.

Photo 4.4. Spall at joint

Joints

For a lasting joint, invest in design detail, material specification and construction inspection.

Lesson 5

Grout:

Bright lipstick and thick rouge

What lipstick and rouge do for the aging woman (or careful combing for the balding man), regrouting can do for hydraulic structures. Cosmetics work best over a short term and from a distant perspective. Scrutiny unmasks the reality beneath.

The material first to fail in mortared construction is typically the grout, demonstrated in Photo 5.1.

Photo 5.1. Masonry

Grout

Repair by injection is costly and rarely achieves a bond better than that which failed.

Mortar and grout are rarely long-term successes in harsh environments. Grout has a life of only a few years when frozen and thawed frequently. Photo 5.2 shows the inevitable deterioration.

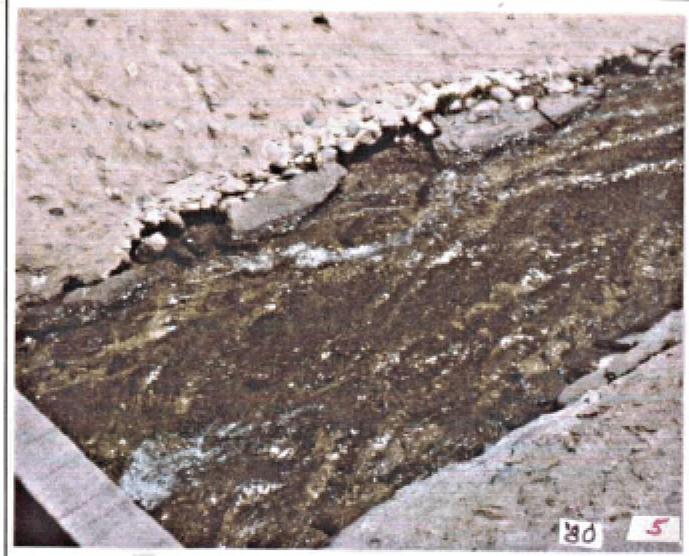


Photo 5.2. Grout failure at waterline

Grout

Grout can fill a void or smooth a surface, but contributes little to the long-term stability of rock lining. The grout cover of Photo 5.3 is breaking up as the rocks wash into the channel.

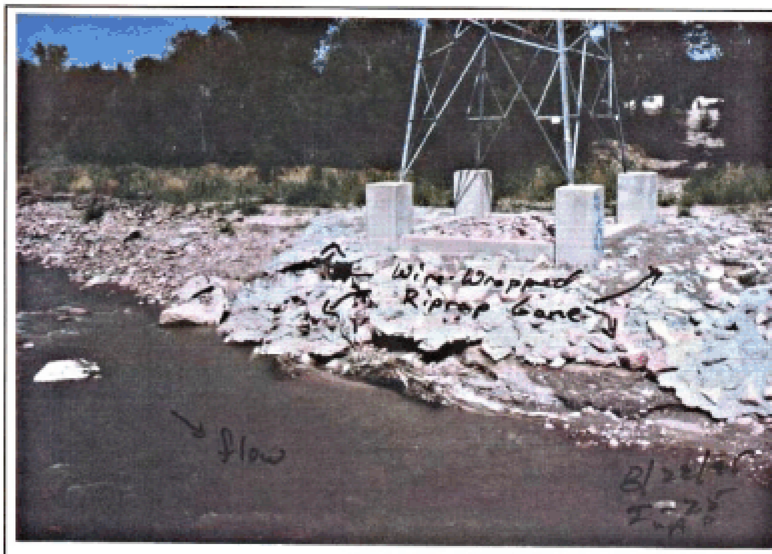


Photo 5.3. Grout over rock

Grout tends to be ugly. Engineering rational for protecting the crossing with grout in Photo 5.4 is illusive. The cavities beneath are dangerous.

Photo 5.4. Grout canopy

Grout

Grout is out.

Lesson 6

Scour, Deposition and Meanders:
Sleeping in a mobile bed

Avoid sleeping on a mobile bed. One might awaken in a different room.

To hydraulic engineers, a mobile bed means a sandy river. The danger associated with repose is the same. One might wake up in a different channel.

Photo 6.1 is of bridge pier scour. The sponsor desired scour to increase channel conveyance, a goal that should have been incorporated into the bridge design.

Photo 6.2 shows that same "desirable" scour, this time headcutting to a culvert crossing. Again, channel management is at cross-purposes.

Photo 6.1. Pier scour

Photo 6.2. Headcut

Scour

The bridge abutment of Photo 6.3 is completely severed by channel migration. The crossing probably initiated the currents that circumvented the crossing.

Photo 6.3. Lost abutment

Scour

Mobile channels also aggrade. The floodplain of Photo 6.5 accumulates sand deposits with each overbank event, raising flow depths against the outside levee which eventually ruptured.

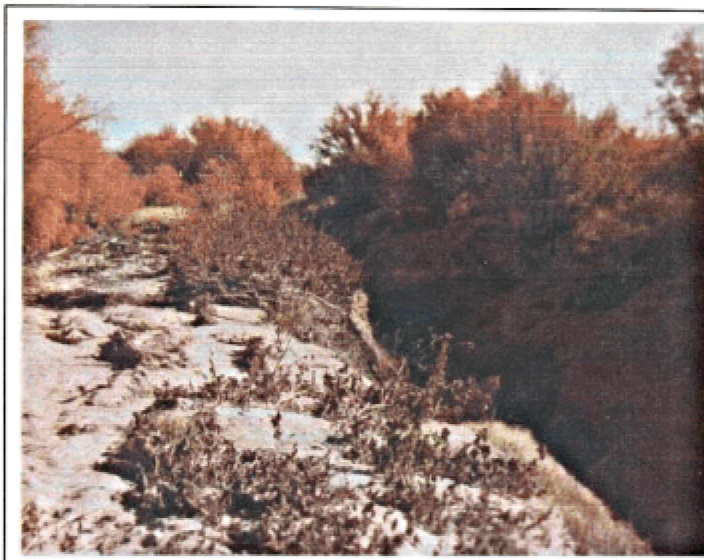


Photo 6.5. Sand on overbank

Design for the channel of today and the channel yet to come.

Lesson 7

Vegetation:
Triumph of the green

Vegetation conquers most waterways in arid New Mexico. No Corps project escapes the photosynthetic onslaught. Seedlings sprout in the thermal joints of sterile concrete slabs. Piñons root through gabions and riprap. Some vegetation enhances project performance; other vegetation destroys. No project should be designed without greening in mind.

Photos 7.1-7.3 trace the history of a gabion drop structure. Assuming the roots don't damage the gabions (a risky assumption), the energy dissipation is enhanced. The conveyance is diminished.

Photo 7.1. 1985

Vegetation

Photo 7.2. 1990

Photo 7.3. 1993

Vegetation

The trees in Photo 7.4 relieve the gabions of bank preservation duty. When the trees die, the channel walls may collapse.

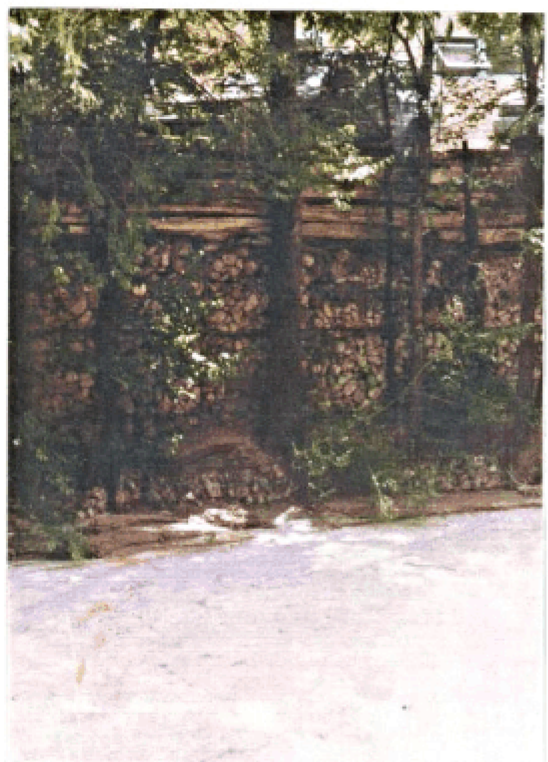


Photo 7.4. Trees holding gabions

Vegetation is not only an issue of site conditions. Watershed flotsam accumulates in the reservoir of Photo 7.5, clogging the trashrack. No designer looked upstream.

Photo 7.5. Wood at Cuchillo

Vegetation

Effectively used, vegetation can enhance project functionality. The post trees, Photo 7.6, have sufficient space to grow into overbank stabilization without jeopardizing the levee behind.

Photo 7.6. Post trees

Plan for a green project.

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Lesson 8

The Public:

The bell curve

Designers are familiar with the bell curve, the graphical picture statistical variance. Most concrete will have compressive strength near 2,000 psi. A few batches will be rich; another few, lean. Structural design employs a factor of safety with the latter in mind.

A bell curve more spread than that of concrete strength is the bell curve of the public. Most citizens abide by the rules, staying on the trail, allegorically or physically. A few enhance a public work, perhaps placing stepping stones where the trail descends a streambank. Another few ignore the trail, or even worse, destroy the signs.

Photo 8.1 shows the lower tail of the bell curve, wanton vandalism. Significantly, the bullet-ridden sign yet stands. The project behind it still serves.

Public works must withstand the lower tail of the public bell curve, actions that willingly or unthinkingly jeopardize the project.

Photo 8.1. Target

Public

Design must be predicated on the following unfortunate realities.

Some of the public steals. Jetty jacks look like free angle iron.

Some of the public vandalizes. Bolts look like a good test for a wrench.

Some of the public lacks experience and/or common sense. A floodplain looks like free land. A wall looks like a walkway.

Some of the public does not understand a project's functionality. A roadcut punched through a levee looks to be of little consequence.

Photos 8.2-8.4 illustrate floodway encroachment. Photo 8.2 is of a concrete product plant needing space for its wears.

Photo 8.2. Concrete products

Photo 8.3 illustrates loss of floodway conveyance when neighbors dump earth in the easement.

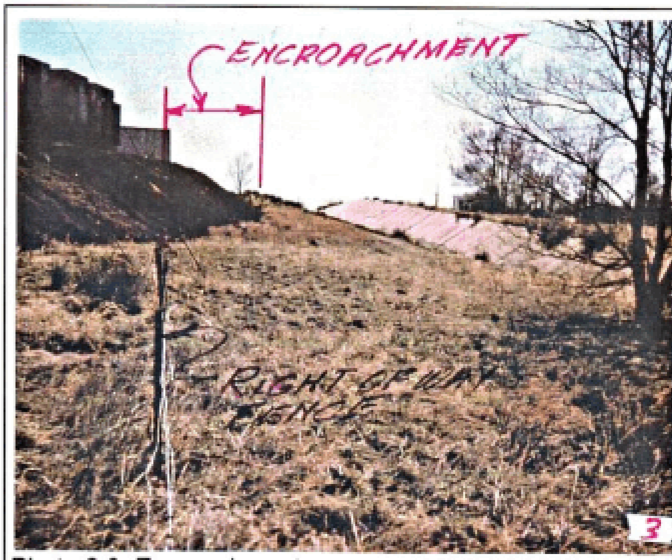

Photo 8.3. Encroachment

Public

Encroachment not only diminishes flood conveyance capacity, but it also hinders flood fight actions to protect the levee.

Photo 8.4 shows a mobile home prudently sited high above the floodplain, unfortunately on the levee top. The mobile home was replaced by a permanent dwelling, compounding the problem.

Photo 8.4. House

On some occasions, the public acts inexcusably. The channel in Photo 8.5 is a handy site for trash dumping.

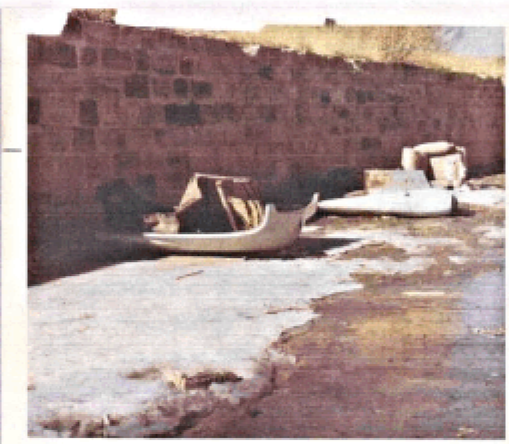

Photo 8.5. Junk in channel

Public

The same channel is also a handy site for large storage tanks, Photo 8.6. This illegal action is the work of an institution of higher education.

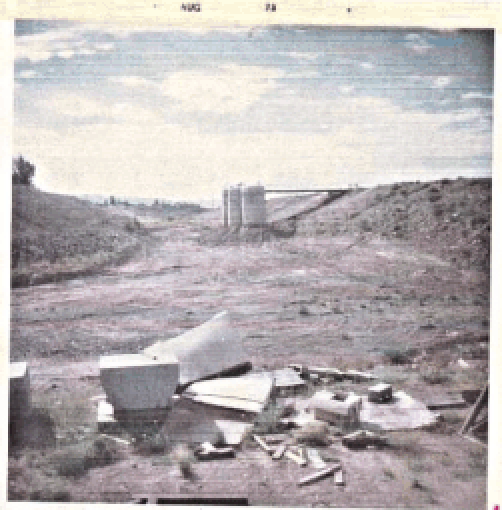

Photo 8.6. Tanks in channel

Children converted the levee gully into a fort, Photo 8.7. Their endeavor jeopardizes the embankment.

The trespass is potentially more tragic than the flooding which might break through the weakened dike. The children are endangered if the unstable walls slough.

Photo 8.7. Playhouse

Anticipate the lower tail of the public bell curve.

Public

Lesson 9

Access:
The demon

In 1871 James Maxwell proposed that a being small enough to observe individual molecules might be able to violate the second law of thermodynamics, ending the scarcity of harnessable energy, realizing perpetual motion, and fundamentally changing the nature of human existence. Maxwell's microscopic, intelligent demon operates a sliding door between two rooms. The creature allows higher energy molecules to pass one way, lower energy molecules, the other way. One room heats; the other cools without the input of work.

Flood control works need such demons at project boundaries. Open the door for inspectors, rescue personnel and mannered citizens. Close the door to vandals, off-road vehicles and those bearing garbage.

Maxwell's demon is currently engaged in cold fusion research and is unavailable to the Corps. Access control to flood projects is by door size alone. Works should be accessible for the desirable entrants, but inhospitable to the others, a fundamental dilemma. The design challenge is neither that of inclusion or exclusion, but rather anticipating the nature of the callers.

Doors to close

Photo 9.1 is pastoral, but not pretty. Goats grazing on the embankment destroy the groundcover and enhance erosion. Fence it.

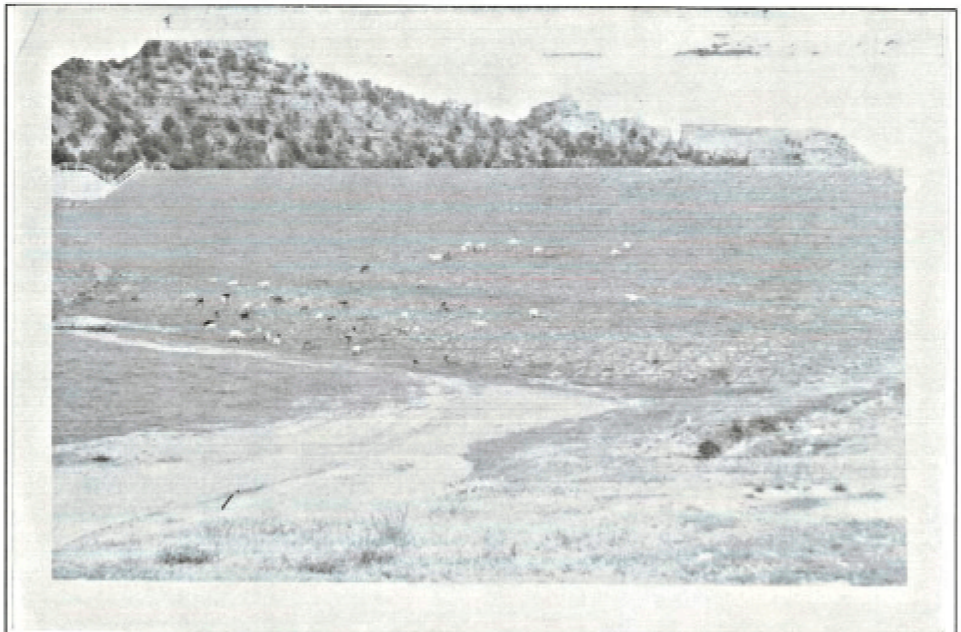

Photo 9.1. Goats eating a dam

Access

Photo 9.2 shows a jackline cut for a road crossing. The cut is convenient for drivers, but jeopardizes the channel.

Photo 9.3 shows a jackline cut by another government agency. The pipeline path becomes a floodwater crossing.

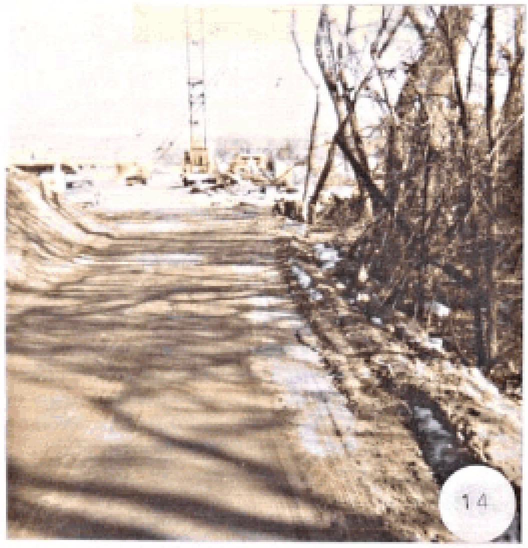

Photo 9.2. Road crossing


Photo 9.3. Pipeline crossing

Access

Photos 9.4 and 9.5 show riprap displaced for vehicle access into the channel. Unless trespass can be precluded, it may be wiser to work such access into the engineering.

Photo 9.4. Riprap removed

Photo 9.5. Off-road vehicle trail

Access

Photos 9.6 and 9.7 show the obvious countermeasure to undesirable access. Lock the gate. Many times, trespassers find another entrance. In some cases, locks bar Corps' inspectors.

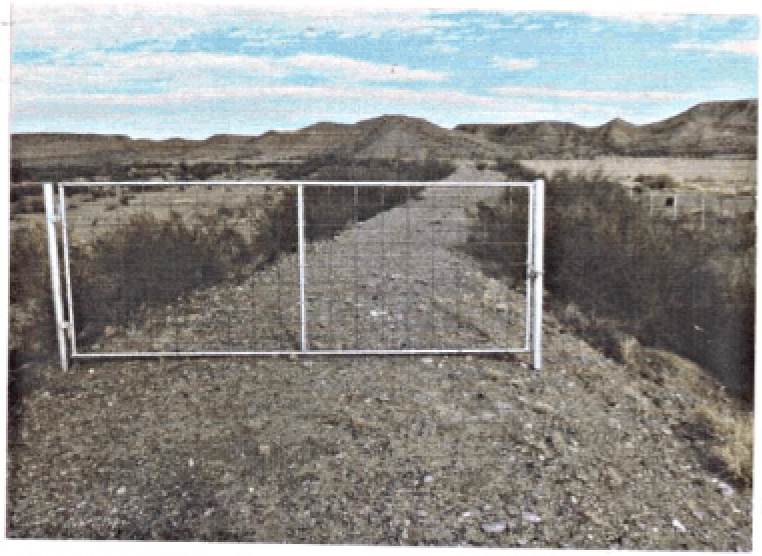

Photo 9.6. Levee gate

Photo 9.7. Locked gate

Access

Doors to open

Photos 9.8 and 9.9 show project design hindering maintenance access. The ribs were eventually removed. Cleaning the box culvert remains a challenge.

Photo 9.8. Ribs

Photo 9.9. Hard to clean

Access

Access cannot be an afterthought.

Lesson 10

Local Drainage:

The train doesn't stop here anymore

Natural floodways are like the passenger trains of 1916, delivering the mail on 254,000 miles of track. Engineered floodways are like today's railroads, safer and efficient, but half the mileage and a fraction of the stations. Getting on board is more difficult.

Flood conveyance channels are optimized to move water quickly. Intermediate flow addition complicates the hydraulics, disrupts the right-of-way and drives up the cost. Small, local flooding problems are left parked on the siding.

Photos 10.1 and 10.2 illustrate the consequence of inattention to local inflows. Water prefers the path around the wire wrapped rock. Lacking outfall protection, the pipe inlet disassembles itself over time.

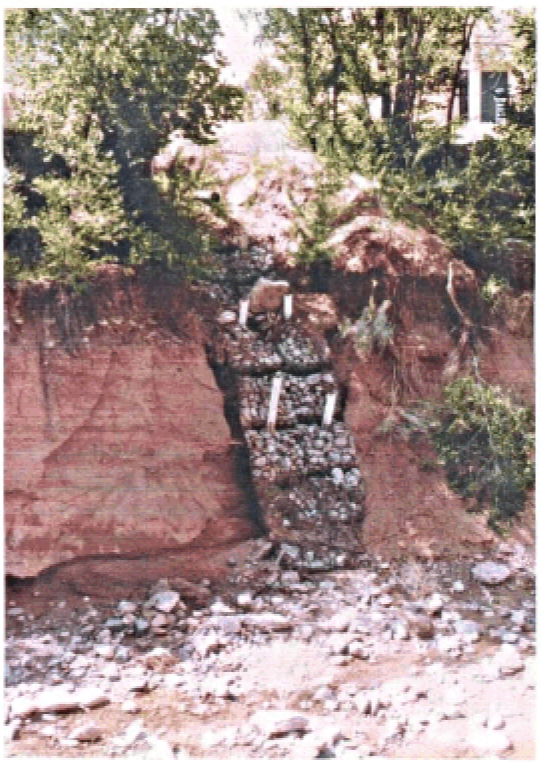

Photo 10.1. Rundown

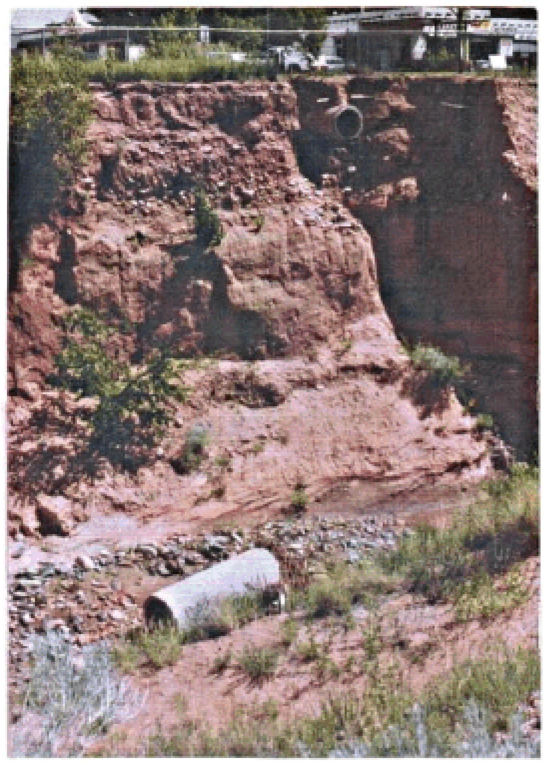

Photo 10.2. Pipe inlet

The headcut in Photo 10.3 began with piping from the high bluff above the project. While the jacks below stand guard, the bank collapses behind.

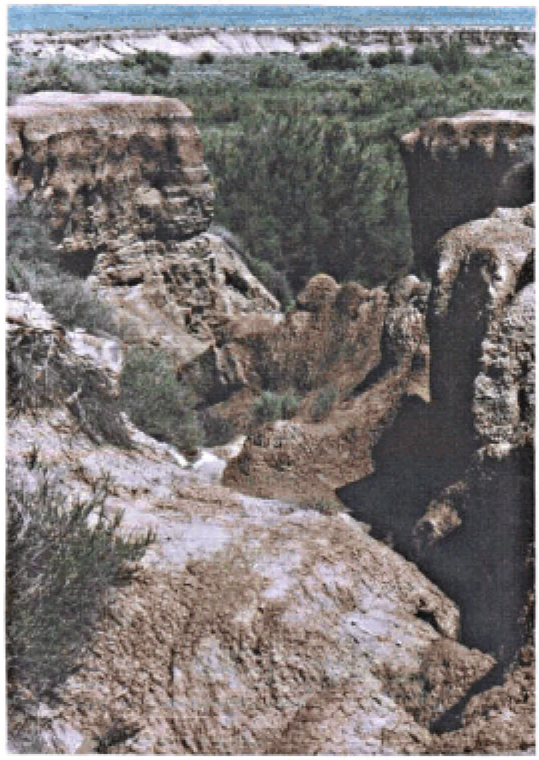

Photo 10.3. Headcut

Photo 10.4 shows a tributary inlet dammed to retain water. At Corps' insistence, the dam was breached.

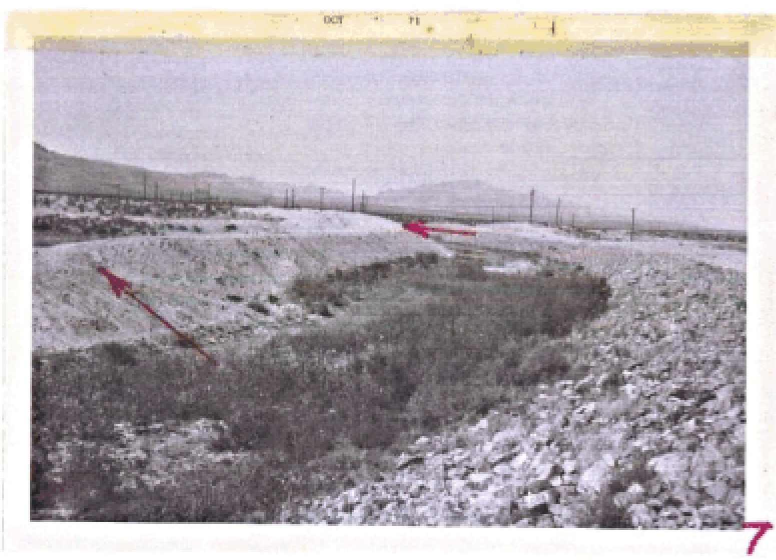

Photo 10.4. Inlet blocked

Think locally.

Drainage

Lesson 11

Gaging
 Lost histories

Few *Lessons Learned* tie to actual flood magnitudes. Not knowing the flow rate, or even stage, a project's success (or lack thereof) adds little to design improvement. Were floodworks designed with streamgaging in mind, numerical theory might be weighed against historical reality.

For many projects, high water marks may be sufficient to compute discharge. The key to the data is the sponsor's commitment to promptly note the levels. By the time of scheduled inspection, evidence is lost. Every project needs some component to remember the water. If that evidence is mud on a wall or vegetation caught in wire mesh, the observation must be timely. Elevation benchmarks may help photographing the record.

Some projects include crest stage recorders. Simple though the technology seems, few survive flood flows and vandals. If not employed with creative thought, gages are wasted effort. Theoretical hydrology and hydraulics yet reign.

The staff gages of Photo 11.1 were vandalized and removed.

Photo 11.1. Gages removed

The original staff gages of Photo 11.2 could not be read and were removed. Instruments suspended from cableways bounced on top of the water.

The gage was recessed into the channel wall sufficiently to weaken the slab. The wall failed.

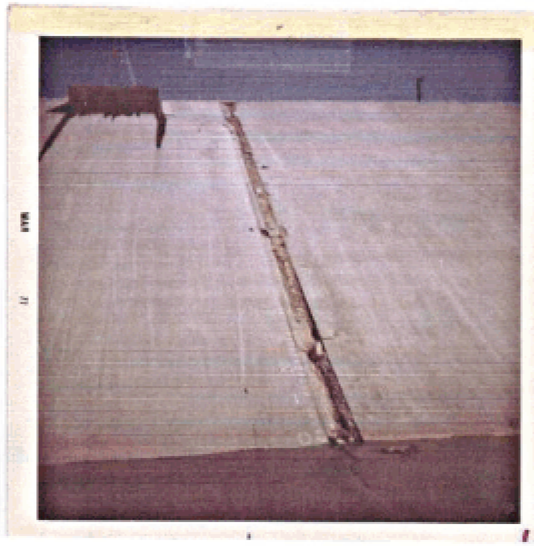

Photo 11.2. Wall failure

Flow tore out the gages of Photo 11.3.

Gages have been deleted from project design by Value Engineering, a misnomer in this case.

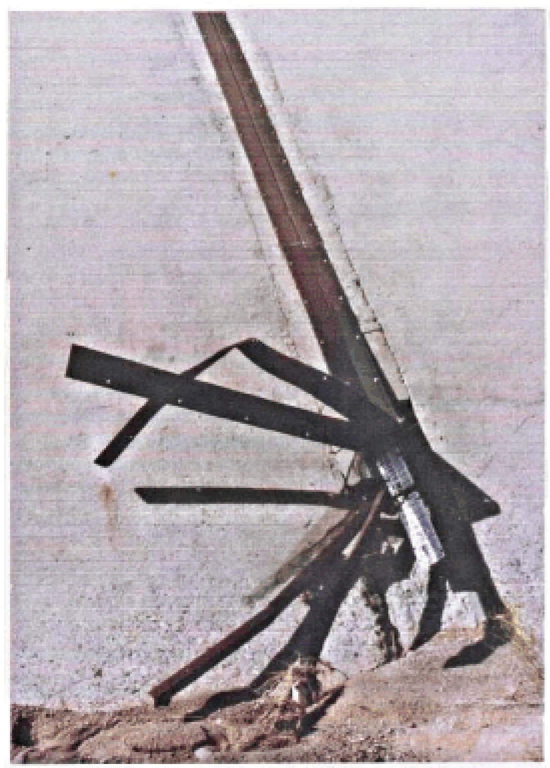

Photo 11.3. Ruined

Spend what is needed to gage correctly.

Lesson 12

Urban Development

The Corps as a player

The "emergency" aspect of Emergency Flood Control Works is more and more often the pressure of urban growth. Structural solutions are more and more often an invitation to yet more expansion. The Corps plays both sides of urban development.

As long as the Corps' urban role is understood, the Corps can be agent for efficiency and benefit. Floodways can serve multiple purposes. Hydraulic structures can enhance urban aesthetics. When the Corps' role is obscured, the magnitude and permanency of works can hinder the urban process. Floodways encumber, or worse yet, endanger development. Structures beckon graffiti. Planners rely on emergency rescue for anticipatable problems.

Photos 12.1 and 12.2 reveal a dilemma of urban dams. An engineered conduit or channel contains the 100-year outflow. Emergency spillway overflow is by definition at a greater recurrence interval. That floodplain is not in FEMA mapping, and thus is opened for development. The project invites downstream victims.

Photo 12.1. No exit

Urban

Water and wastewater works tend to be adjacent to channels. If the Corps stands ready to rescue poorly sited facilities, there is little incentive to place them at prudent elevations. Photo 12.3 illustrates the problem.

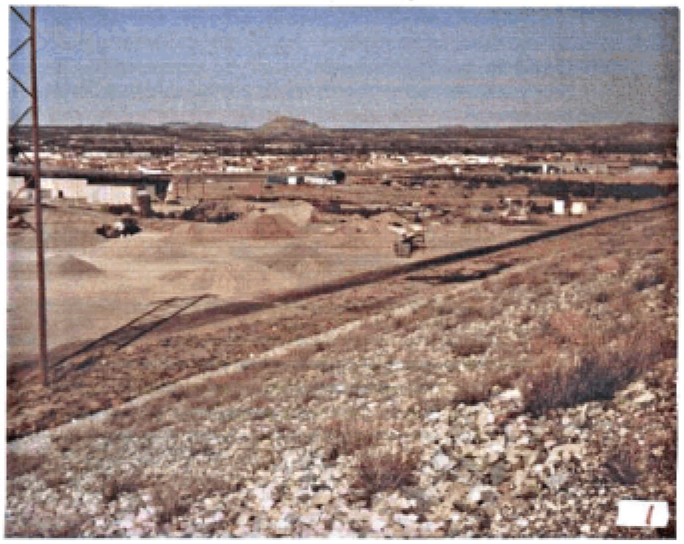

Photo 12.2. Legal, but imprudent, development

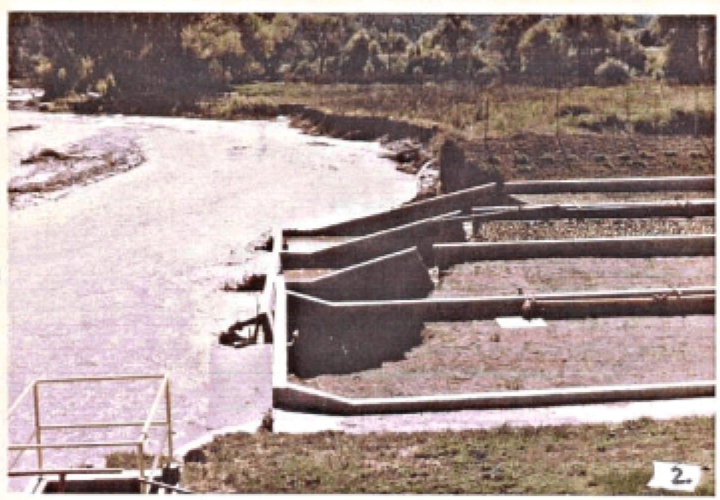

Photo 12.3. Sludge beds saved by Corps

Urban

Photo 12.4. Graffiti

Concrete beckons the urban "tags" of Photo 12.4. Riprap or gabions are less inviting than slab construction.

Photo 12.5 illustrates urban landscape enhancement. Widening the channel and adding natural boulders creates a fishing hole.

Think like a player.

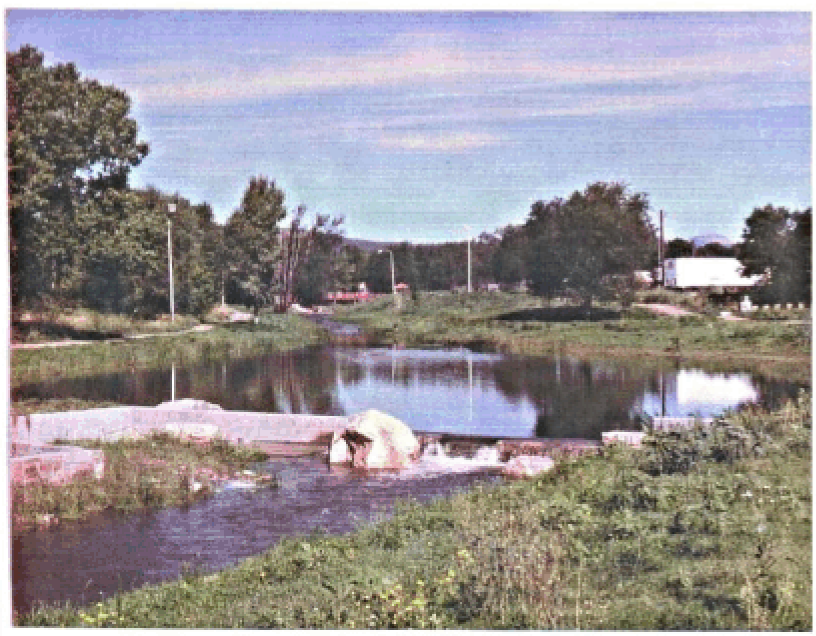

Photo 12.5. Fishing hole

Urban

Lesson 13

The Sponsor:

The best of intentions and the reality of resources

At project onset, the sponsor has the best of intentions. Unfortunately, sponsorship fades in many ways.

Inspection cessation

No Corps requirement seems to have fewer teeth than the sponsor's acceptance of annual (or in some cases, even semi-annual) inspection responsibility. Sponsors inspect for a few years, then send an observer when a Corps' employee performs the task (no longer an annual event). Then, too often, face-to-face continuity with the sponsor is lost.

Maintenance default

The sponsor is typically a well-intentioned public body whose intransigence is revealed only when funds are scarce. Channel repair competes with roadwork, dogcatching, sewage treatment, and the like.

Project planning must unofficially consider implications of sponsor default. If the sponsor is well established, has sound financing and engineering understanding, the issue may be moot. If the sponsor has demonstrated responsibility with Corps' projects in the past, the issue again may be negligible. But if the sponsor is not so certified, consequences of inattention should be an issue of forethought, not hindsight.

Personnel turnover

Employees and political leadership change. New players may not know their responsibilities. In some cases, they may not know of the project's existence.

Entity reformation

To government agencies, public resources and responsibilities are commodities. Cities and counties exchange bridges. Pueblos exchange duties with the Bureau of Indian Affairs. It is not uncommon for project sponsorship to so migrate. From a legal perspective, all may be proper. From a management perspective, projects can suffer.

Don't count on prudent inspection and maintenance by the sponsor.

Lesson 14

Operation and Maintenance Manual:
Death by Xerox

ER 1130-2-304 and its Appendix A provide basic guidance for the O&M manual. Synopsized sections describing content include:

General

O&M manuals are essential to insure that projects are operated in the most efficient manner possible and are maintained to maximize serviceable life. Manuals should be short and concise and should be in plain language, avoiding highly technical terms. Diversity in size and functions of projects requires careful evaluation of the material included. Many projects do not have full-time staff, are small and are operated and maintained on an "as needed" basis by street, fire and water departments or similar organizations.

Materials to include:

a. Operating limits and criteria of the major project equipment and facilities. Do not describe equipment or features in detail if common knowledge to operating personnel. More description may be necessary for local personnel. Avoid a voluminous document of details having limited value to O&M personnel.
b. Operating instructions and explanations of critical and complicated project equipment and systems; i.e., remote control.
c. Photographs and sketches of selected equipment where such representations make explanations easier. Reference manufacturers' drawings if available.
d. Procedures for National Emergency Situations in the event of nuclear, biological or chemical fallout hazards.

Materials to exclude:

a. Detailed references to regulations, project policy, fire prevention, safety and information furnished to local personnel through normal channels.
b. Operating and maintenance instructions for simple and familiar equipment such as pumps. Use judgment where personnel do not work with the equipment on a daily basis.
c. Detailed descriptions of features and equipment with which local personnel are familiar, such as generators.
d. Information readily available in manufacturers' instructions and drawings and in equipment files. Reprint simple paragraphs or small drawings to avoid laborious search from one document to another.
e. Maintenance procedures, frequencies and data available in the records for larger projects. Include some information for local protection projects where maintenance control systems may be limited.

Outline for O&M Manual

Chapter 1 - Introduction

a. Authority.
b. Purpose. (Suggested wording). *This manual provides basic guidance and instructions to the project personnel for proper O&M of the facilities at ...*
c. Parts of Manual
   Part I. General. Information about the manual and the project.
   Part II. O&M. Brief descriptions of major facilities and equipment. Basic O&M instructions. Omit administrative functions, reservoir management and reservoir regulation.
d. Scope of Manual. (Suggested wording). *This manual contains only basic essential O&M instructions. It is not all-inclusive but does reference other publications where appropriate. This manual is not a training manual. It is insufficient for personnel who have no knowledge of the project facilities and equipment. This manual is written for trained project personnel and all assigned project personnel should familiarize themselves with its contents, frequently reread it*

Manual

to maintain familiarity, and refer to it during times of emergency or when there is any question.

Chapter 2 - Project Description

a. Authorization. Documents and dates.
b. Location. General location, e.g., nearest town, river mile, etc.
c. Agreements. Agreements with other agencies or local interests.
d. Brief Description of Project. One page narrative.
e. Pertinent Data. Pertinent data, e.g., elevations of features or pools, acreage, acre-feet of storage, length of levee.
f. Photographs and General Plans.
g. History. Chronology of starting, completion, operation, turnover.
h. Project Contracts. Number, title, contractor, date of award, date of completion.

Chapter 3 - General

a. Operation. General statements. References especially for operation under emergency conditions.
b. Maintenance. General statements and pertinent references.
c. Maintenance Quality. Needs for high quality maintenance, clean working areas, trained personnel.
d. Maintenance Control System.
e. Roads. Responsibilities, especially if split between agencies
f. O&M of Recreation Areas.
g. Lubrication. Responsibilities. Development, review and update of schedules.
h. Painting/Repainting. Responsibility. Recording information. Colors and paint types or appropriate coordination to determine such information.
i. Operating Logs. Responsibility and format.
J. Safety. Responsibilities for review of O&M with respect to safety. Safety meetings at proper frequency
k. Unusual Occurrences. Notification procedures. List some of the occurrences such as movement of riprap, cracks in embankment, slumps, bulges, seepage.
l. Public Relations. Responsibilities. Treatment of visitors. Degree of protection information.
m. Deviations. Requirement for O&M without deviations from the manual except in cases of extreme emergency. Process for suggesting O&M improvement.
n. Prevention, Control and Abatement of Environmental Pollution. Executive orders, acts, regulations.

Chapter 4 - Dam, Equipment and Facilities.

Subdivide chapter by types of facilities or equipment, e.g., "Levee, Floodwall, Equipment and Facilities".

a. Descriptive Title or Name. Purpose, if needed. Omit if obvious.
b. Operation Limitations. Loadings, settings, tolerances established by design or other criteria.
c. Normal Operations. Step-by-step procedures and checklists. If long, include as appendix. Complete sequence from total shutdown to full operation and reverse.
d. Abnormal Operations. Key points. Steps to be taken.
e. Protective Devices.
f. Cautions and Warnings. Include in the paragraph on operations, or include here. For emphasis, include in both.
g. References.
h. Photographs. Use to clarify instructions. Avoid clutter with unnecessary, expensive photographs. However, "One picture is worth a thousand words."

Chapter 11 - Procedures for National Emergency Situations.

Chapter 12 - Dams and Reservoirs Contingency Plan for Emergencies.

a. Purpose. Responsibilities and procedures in the event of evidence of distress or potential dam failure.
b. Applicability. Develop at beginning of construction as a separate document and convert to an O&M manual chapter. Dams should have a contingency plan during construction.

Manual

c. Responsibilities. Practicable precautions to minimize property damage or loss of life as a result of uncontrolled releases of water.

d. Authorities. The District Engineer shall assign responsibility to insure that decisive action is taken quickly. If critical conditions are brought to the attention of the local responsible person and time does not permit contacting higher authority, the local responsible person shall take independent action in accordance with the emergency plan.

e. Advance Preparation: Procedures coping with potential failure, evidence of distress or actual failure. Include:
   1. Detection of structural weaknesses by field personnel.
   2. Action to be taken at field level in the event of imminent failure.
   3. Notification procedures at field level and higher headquarters.
   4. Supplies and equipment required in anticipation of failure.
   5. Procedures for coordinating with other agencies.
   6. Available contractors' support.
   7. Emergency contract authority for field personnel.
   8. Monitoring procedures for potential problem areas.
   9. Problems which may result from failure of upstream dams.
   10. Maps showing areas flooded by specific releases and dam failure.

The primary problem with the above instructions is that they are not read. What's said is valid. A secondary problem is that the proscribed structure encourages a fill-in-the-blank writing style.

The O&M manual is too often a moribund replication of self-evident technical goals, authorization minutia and legal specification. If the construction blueprints are reprints, so can be the manual. If the project contains new thought, let the manual reflect it.

Write for the sponsor's maintenance supervisor.

This supervisor is most likely a hands-on technician hired since the project was built.

Assume that the sponsor lacks institutional memory and the field crew knows nothing of the project.

Include:

Access instructions. Who keeps the key?

Layout drawings identifying particular locations. What is the "middle bridge"?

Sufficient description to convey how the project technically functions. Are the gabions intended to slump? How much?

As-built photographs for benchmarking performance.

Suggested O&M technologies. Maccaferri instructions for gabion maintenance may be new information to the sponsor. Use drawings.

Common sense motivation. The crew has it.

The sponsor's legal commitment to O&M. Show the signatures.

The financial consequence of maintenance default. This becomes the Corps' leverage.

An appropriate inspection form in matrix format:
- One line per specific concern (*e.g.*, gabion wire)
- Three columns:
  - Observations
  - Recommendations
  - Status of previous recommendations

Exclude:

- Items not directly relevant to job-site O&M.
- Paragraphs containing "whereas", "hereof", of "aforementioned", literary stop signs.
- Construction cost or cost-sharing data or rational. The crew doesn't audit.
- Definitions.
- Real estate explication.
- Calculations, unless as examples for an O&M task.
- Instructions and forms for future applications to the Corps or other authorities. Procedures become outdated.

Say it fully.
Say it clearly.
Say it once.

- O&M requirements buried within a complex document are overlooked.
- Bullet the action items.

A manual of explicit O&M effort should rarely exceed ten pages. If it is uninteresting to the author, it is anesthesia for the reader.

Write to be read. If the manual looks like filled in blanks, the reader will blank out.

Photo Sources

Photo	Title	LL	Title	Page
1	A $598,528 lesson	38	Gila River, NM, Local Protection Projects	10
1.1	New jacks	12	Trinidad Emergency Project and Emergency Bank Protection, Purgatorie River, Trinidad, CO	3
1.2	Jack steel	24	Jetty Jacks on the Rio Grande	4
1.3	Eight-foot jacks	23	Seven Ineligible Projects	20
1.4	Eroded line	23	Seven Ineligible Projects	15
1.5	Inadequate tieback	24	Jetty Jacks on the Rio Grande	13
2.1	Levee erosion	3	Fountain Creek Projects	18
2.2	Levee erosion	30	Sierra County, NM, Local Protection Projects	15
2.3	Remnants	32	Mimbres River, NM, Local Protection Projects	9
3.1	No footing	3	Fountain Creek Projects	17
3.2	Undercutting	5	Canyon City Projects	5
3.3	End erosion	20	Channel Stabilization in Santa Fe, NM	1
3.4	Rocks at end	23a	Streambank Protection, Black's Arroyo at Southern Blvd., Rio Rancho, NM	5
4.1	Spalling at construction joint	25	North and South Diversion Channels, Albuquerque, NM	10
4.2	Uplift	27	Socorro Diversion Channel	20
4.3	Thrust failure	25	North and South Diversion Channels, Albuquerque, NM	8
4.4	Spall at joint	34	Las Cruces Dam, NM	20
5.1	Masonry	17	Repair and Restoration of Flood Control Works, Raton, NM	8
5.2	Grout failure at waterline	15b	Creede, CO	10
5.3	Grout over rock	3	Fountain Creek Projects	5
5.4	Grout canopy	20	Channel Stabilization in Santa Fe, NM	25
6.1	Pier scour	20	Channel Stabilization in Santa Fe, NM	14
6.2	Headcut	20	Channel Stabilization in Santa Fe, NM	12
6.3	Lost abutment	18	Projects near Las Vegas, NM	10
6.5	Sand on overbank	23	Seven Ineligible Projects	9
7.1	1985	1	Pleasant View Estate	1
7.2	1990	1	Pleasant View Estate	2
7.3	1993	1	Pleasant View Estate	3
7.4	Trees holding gabions	20	Channel Stabilization in Santa Fe, NM	19
7.5	Wood at Cuchillo	33	Cuchillo Dam, NM	5
7.6	Post trees	38	Gila River, NM, Local Protection Projects	33
8.1	Target	34	Las Cruces Dam, NM	8
8.2	Concrete products	2	Templeton Gap Floodway	3
8.3	Encroachment	2	Templeton Gap Floodway	9
8.4	House	30	Sierra County, NM, Local Protection Projects	23
8.5	Junk in channel	17	Repair and Restoration of Flood Control Works, Raton, NM	4
8.6	Tanks in channel	27	Socorro Diversion Channel	7
8.7	Playhouse	27	Socorro Diversion Channel	21
9.1	Goats eating a dam	14	Pinon Canyon Dam, Trinidad, CO	4
9.2	Road crossing	24	Jetty Jacks on the Rio Grande	11
9.3	Pipeline crossing	24	Jetty Jacks on the Rio Grande	10
9.4	Riprap removed	27	Socorro Diversion Channel	13
9.5	Off-road vehicle trail	34	Las Cruces Dam, NM	6
9.6	Levee gate	43	Rehabilitation of Levee (Cibolo Creek),	

9.7	Locked gate	27	Socorro Diversion Channel	12
			Presidio, TX	7
9.8	Ribs	25	North and South Diversion Channels, Albuquerque, NM	5
9.9	Hard to clean	42	El Paso, TX, Local Protection Projects	19
10.1	Rundown	20	Channel Stabilization in Santa Fe, NM	20
10.2	Pipe inlet	20	Channel Stabilization in Santa Fe, NM	21
10.3	Headcut	26	Pottery Mound	3
10.4	Inlet blocked	27	Socorro Diversion Channel	5
11.1	Gages removed	42	El Paso, TX, Local Protection Projects	35
11.2	Wall failure	25	North and South Diversion Channels, Albuquerque, NM	6
11.3	Ruined	27	Socorro Diversion Channel	16
12.1	No exit	42	El Paso, TX, Local Protection Projects	22
12.2	Legal, but imprudent, development	34	Las Cruces Dam, NM	5
12.3	Sludge beds saved by Corps	37	Miscellaneous Sites, SW NM, Local Protection Projects	14
12.4	Graffiti	42	El Paso, TX, Local Protection Projects	31
12.5	Fishing hole	18	Projects near Las Vegas, NM	28

+++++++++++++++ **The End** ++++++++++++++

Any questions, please contact info@pdhnow.com

QUIZ for Best of Lessons Learned

1. Failure to maintain levees by repairing levee toe erosion can

a. Result in more erosion from new floods

b. Be easily deferred until next year since most of the levee is still in place

c. Is an unnecessary financial burden on public sponsors

d. With the addition of more damage from future floods make the levee vulnerable to breaching

e. “a” and “d”

2. Jetty Jack use by the Albuquerque District Corps of Engineers has been

a. An unsuccessful use of the government’s money

b. A huge success

c. A model for erosion protection for all other rivers

d. An expensive form of bank protection

e. A good design for steep streams with fast-moving water

3. Inventor of the Jetty Jack was

a. Henry Ford

b. Elon Musk

c. Henry Kellner

d. Ben Franklin

e. Bob Johnson

4. Jetty Jacks

a. Are self-repairing

b. Have a design life of 50 years and have exceeded that with only minor repairs

c. Can be made in different sizes

d. Are so robust in jack lines that even if a few are stolen, the line continues to do its job

e. “a”, “b”, “c”, and “d” are true

5. It is ok to anchor jetty jack lines to trees.

a. True

b. False

6. The most common form of levee failure in the Albuquerque District is

a. Overtopping

b. Bank erosion

c. Piping through the levee

7. Emergency “push-up” levees frequently made with material found in the river

a. Are a great idea because it saves money to use nearby material

b. Will likely fail in bank erosion because “If the river brought it down, the river will take it away.”

c. May prevent damage from a few small floods but tend to be sacrificial

d. “a”, “b”, and “c” are true.

e. “a”, “b”, and “c” are false.

8. Resistance to toe erosion is a levee’s most important design parameter

a. True

b. False

9. Gabions and wire wrapped riprap

a. Work well in high-velocity streams

b. Tend to get undercut and sidestepped

c. Are easily stolen

d. May be placed directly on the streambed

e. “c” and “d” are true

10. Wire Wrapped riprap protecting erosive soil banks in fast-moving streams

a. Will usually work well if keyed into the channel bed three feet

b. Is historically successful

c. Will likely require riprap on both upstream and downstream ends

d. “a” and “b” are true

e. “a”, “b”, and “c” are true

11. Precursing gross joint failure are concrete spalls at construction joints

a. True

b. False

12. Grout is usually successful as a long-term repair of flood control channels

a. True

b. False

13. Encouraging scour at bridge abutments is

a. A low-cost way to achieve greater flow capacity under existing bridges

b. A quick way to increase flow capacity under existing bridges

c. A bit tricky, because bridge support structure might be undermined

d. Allowable if the project is inspected annually

e. “a”, “b”, and “d” are true

14. Vegetation in arid channels

a. Is always a design concern

b. May help or hinder project functioning

c. Might trap sediment or debris, lower capacity, and cause the levee to overtop

d. Can be planted between the main channel and levee to protect the levee

e. All of the above are true.

15. Corps Local Protection Projects (levees, dam, channels, and bank protection) are designed to accommodate the public. Therefore,

a. We conduct annual inspections to see if vandalism has occurred

b. We have painted red Corps castles in the centers of metal signs for target practice

c. We have placed large amounts of decorative riprap at the toe of dams for local residents to borrow for landscaping their yards.

d. We have designed dams near or in cities with slopes safe enough for recreational four-wheel vehicles

16. Placing storage tanks in a Corps channel

a. Is dangerous because it lowers channel capacity

b. Is a wise of free land by learned academic administrators since it never rains in the desert

c. Could cause a blockage of a bridge downstream if the tanks float away

d. Could cause water pollution if the tanks rupture during a flood

e. “a”, “c”, and “d” are correct

17. Building a house on a levee

a. Offers a great view

b. Is life-threatening if the levee erodes

c. Will block flood fight effort since trucks containing riprap cannot get past the house

d. All of the above are true

18. Entrepreneurial encroachment into a levee toe by businesses

a. Is a smart move to extend an equipment yard

b. Decreases the width of the levee

c. Will unlikely be noticed during the annual inspection

d. Will decrease the designed seepage length and potentially cause levee failure flooding the business, surrounding neighborhood, and entire city

e. “b” and “d” are true

19. Goats eating vegetation off the sides of a gently sloped dam are a safe form of weed control.

a. True

b. False

20. Jetty Jack lines

a. Can be safely cut to make roads or trails

b. Should not be cut because a loose line can clog a major road bridge

c. Cuts should be repaired to avoid compromising channel performance

d. “a” and “b”

e. “b” and “c”

21. It is ok to move riprap on the side of a levee bank to make an access road to the channel.

a. True

b. False

22. Privately owned gates on Corps built levees

a. Prevent Corps inspectors from inspecting that reach of levee

b. Are justified to prevent four-wheelers from entering private property

c. Are justified to prevent road noise near residential areas

d. Prevent flood fight transport of riprap

e. “a” and “d”

23. Removal of sediment is a factor to consider in project design

a. True

b. False

24. Concentrated side drainage into large channels usually requires some bank protection to minimize main channel bank erosion

a. True

b. False

25. Gages installed at Corps Local Protection Projects (levees, dam, and channels) have

a. Been damaged by vandals

b. Failed by being beaten with large rock in the flood water

c. “a” and “b”

26. Urban development below a Corp dam spillway is

a. Legal and imprudent

b. Legal because it is outside the 100-year floodplain

c. Imprudent because it can be flooded by flows larger than the 100-year flood

27. Public sponsors of Corps built Local Protection Projects face many problems, including

a. Funding shortfall periods where there is no money for maintenance

b. Personnel turnover (new administrations don’t know they are responsible for maintenance of the project)

c. Lack of qualified personnel to perform an inspection

d. All of the above are true