Ft. Pearce Wash

River Mining Plan

Washington County, Utah

DRAFT

Prepared by:
JE FULLER
HYDROLOGY & GEOMORPHOLOGY, INC.
8400 S. Kyrene Rd., Suite 201
Tempe, AZ 85284
www.jefuller.com

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1. INTRODUCTION

1.1. Fort Pearce Wash Mining Plan Objectives

The Virgin River/Ft. Pearce Wash Master Plan scope of services (Task 7) requires development of a river mining plan for Fort Pearce Wash. The river mining plan task is described as follows: "*The team will develop mining guidelines to be used to regulate in-stream mining, primarily along Ft. Pearce Wash and to assess likely impacts to flood and erosion hazards along the wash corridor*." Based on this description, as well as discussions with City and County agency personnel, the following objectives were defined for the mining plan:

- Minimize the potential for erosion and flood damage to residential development.
- Facilitate production of aggregate materials which are vital to the local economy.
- Minimize the risk to, and cost of, future and existing road crossings.
- Minimize the risk to public and private utilities.
- Minimize environmental impacts and permitting concerns.

It is intended that the mining plan have the support of the mining and the regulatory communities, as well as the general public. Like many planning studies, the mining plan evolved during the course of its development, from basic guidelines for in-stream mining to a recommendation for a constructed, multi-use, channel corridor. Further engineering analyses, landowner coordination, and implementation planning are needed prior to finalizing the channelization project. This document establishes the framework and outlines the goals, opportunities and constraints of such a project.

1.2. River Impacts from Mining

Impacts from in-stream mining are well documented in the literature,[1] and include the following:

- Scour and Erosion. Physical changes in stream beds and banks caused by mining have damaged adjacent properties, as well as public infrastructure like roads and utilities, primarily due to increased scour and erosion upstream and downstream of the mining operation.
- Decreased Water Quality. Discharge of water used for material processing often has high turbidity which may impact riparian or aquatic ecology. Mining in perennial streams also causes increased turbidity.
- Dust and Noise. Mining inherently generates noise and dust, which leads to complaints from residential and non-industrial neighbors.

[1] Documented accounts of river-system impacts from in-stream mining, as well as a bibliography of related literature, are provided in the *Sand & Gravel Mining Floodplain Use Permit Application Guidelines*, Flood Control District of Maricopa County, 2003. This document is available digitally at the following URL: www.fcd.maricopa.gov/Services/SandGravel/SGguidelines.asp

- Truck Traffic. Delivery of mining products is most often by large commercial trucks, which can lead to wear of road surfaces and complaints from non-commercial drivers and local residents and businesses.
- Landscape Aesthetics. If not properly screened, or where zoning results in incompatible types of development, mine features such as material stock piles, batch plants, or excavations may have adverse impacts on the viewsheds of surrounding properties.

In-stream sand and gravel mining can have significant impacts on channel stability, and the stability of public infrastructure constructed along the stream corridor. In-stream gravel mining alters the natural channel form, which in turn leads to instability (Smith and Patrick, 1991). Changes in the natural channel geomorphology can impact the stability of the bed elevation, the bank position, and the structures that cross the channel (US Army Corps of Engineers, 1987). The ecology of the channel and riparian habitats may also be impacted as a result of geomorphic changes induced by in-stream mining (Pringle, 1987; Brown et. al., 1998; Meador and Layher, 1998). Geomorphic impacts of in-stream and floodplain sand and gravel extraction operations are not limited to changes immediately surrounding the pit, as the changes caused by the pit migrate upstream and downstream of its location. The geomorphic impacts of sand and gravel mining on a river system may include:

- Upstream degradation (headcut erosion)
- Downstream degradation (tailcut erosion)
- Increased probability of channel migration and pit capture
- Changes in sediment size distribution
- Increases in channel capacity

Gravel pits located in the channel will initiate degradation both upstream and downstream of the pit (Boyle Engineering, 1980; Heede, 1986; Sandecki, 1989; Kondolf, 1994a; Mount, 1995). Degradation upstream is a result of the lowering of local base level due to pit excavation. It is a well-established fact that, over time, streams will erode to the base level elevation (c.f., Gilbert, 1870). If the base level is lowered due to excavation in the channel bed, the stream will eventually reach that level unless the pit is filled and base level is restored to the pre-mining condition. Degradation works its way upstream from a gravel pit by the process of headcutting, also known as knickpoint migration or incision. Headcuts have been known to extend upstream of the pit, often undermining structures crossing the channel. The distance headcuts have migrated upstream in a single event has ranged from 90 meters (Bull and Scott, 1974) to 700 meters (Kondolf, 1997). On Tujunga Wash in southern California, a headcut migrated 915 meters upstream of a gravel pit over the course of three storms in January and February 1969, and undermined three bridges (Scott, 1973). On the Russian River in California, gravel mining initiated 3 to 6 meters of degradation over an 11 kilometer reach within a 40 year period (Kondolf, 1997). Degradation upstream of a gravel pit has the potential to extend as far upstream as the headwaters in extreme circumstances (Heede, 1986). Some of the key factors controlling upstream migration of headcuts from sand and gravel mines include the sediment supply rate, the size of the bed material, the duration and frequency of flooding, the depth of the mine below the natural stream bed elevation, the presence of other mines in the stream, and continuation of mining after initial flooding.

Degradation downstream of sand and gravel mines is mainly a result of the pit acting as a sediment trap. Water and sediment flow into a gravel pit during a flood. The sediment, particularly the coarse bed materials, is deposited in the pit due to decreased velocities in the ponding area. After the pit fills, water leaving the pit has a reduced sediment load and increased capacity to erode the channel bed and banks (Boyle, 1980). Downstream degradation may occur gradually over time or rapidly during a large flash flood (Sandecki, 1989). Degradation tends to be more severe in ephemeral channels than in perennial channels. Degradation in ephemeral channels has been measured at 4 meters in an 8-year period (Bull and Scott, 1974); 3-6 meters over a 20-year period (Kondolf, 1997); up to 5 meters over a 23-year period (Kondolf and Swanson, 1993); and about 3.5 meters over a 1-year period (Sandecki and Crosett-Avila, 1997). In contrast, degradation on a perennial stream was estimated at 0.9 meter over a 30-year period (Collins and Dunne, 1989).

Pits located in the floodplain outside the main channel are known to have captured the main channel during erosive floods (Sandecki, 1989; Mossa and McLean, 1997). Off-channel mines may also capture flow if protective levees fail or the erosion buffer is compromised. Channel form may also change due to in-stream mining. For example, downstream degradation caused by in-stream mining can turn a braided system into an incised single channel (Kondolf and Swanson, 1993). In the case of braided rivers, the capture of multiple channels in a single pit may lead to a more incised single channel. Alternately, large pits may widen the channel making the stream more braided (Sandecki, 1989).

Sediment size distribution on the channel bed can also be altered by sand and gravel extraction. In most cases, removal or disturbance of the largest clasts reduces the potential for armoring, thereby increasing the chance for bed erosion and headcutting (Lagasse et. al., 1981; Parker and Klingeman, 1982). In-stream mining often increases the conveyance capacity of the main channel due to the excavation itself as well as the subsequent degradation (Boyle Engineering, 1980). While the increased conveyance capacity may have apparent positive impacts for flooding (narrower floodplain, less frequent inundation of the floodway fringe, etc.), it is noted that the increased conveyance may also lead to accelerated rates of lateral erosion and increased peaks downstream due to loss of floodplain storage and attenuation.

1.3. Economic Benefits of Mining

There are a variety of significant economic benefits to the community of St. George provided by the aggregate mining companies working along Fort Pearce Wash. Besides the direct employment of heavy equipment operators, drivers, office personnel, managers, sales staff, geologists, and surveyors working for the mining companies, there are also important ancillary benefits from aggregate mining to the local economy. Rock products such as sand and gravel, as well as the concrete and asphalt derived from the basic raw materials, are basic needs for the construction industry. Approximately 100 tons of aggregate are required for each 1,600 square foot home. One mile of freeway requires about 10,000 tons cement, 40,000 cubic yards of concrete and 64,000 tons of aggregate.[2] For a rapidly growing community like Washington County, a reliable source of aggregate is vital to continued growth and construction. Finally, the tax revenues generated from sales and wages are an important economic benefit to the community.

1.4. Mining Plans in Other Communities

Master plans for aggregate mining in the floodplain have been developed in a number of communities in the Southwest.

- **St. George, Utah**. In 2003, St. George City prepared a mining plan for a portion of Fort Pearce Wash upstream of River Road. The objectives of the mining plan were to increase channel capacity and reduce the width of the regulatory floodplain in the Horseman's Park area east of Fort Pearce Wash, to control tamarix growth, and to facilitate removal of high quality aggregate from the river corridor. The plan was successfully implemented over a period of slightly more than one year. Areas of over-excavation below planned levels have since been filled by sediment deposition during the small floods which occurred since 2003.

- **Maricopa County, Arizona**. In 2001, the Flood Control District of Maricopa County developed a river master plan for the Agua Fria River that proposed to utilize in-stream mining to build an excavated, terraced flood control channel that would narrow the regulatory floodplain, eliminate lateral erosion hazards by construction of engineered and bioengineered bank protection, and protect bridge and utility crossings by constructing grade control structures to prevent long-term scour. In exchange for the corridor right of way, the aggregate miners' remaining property would be removed from the regulatory flood and erosion hazard zone. In addition, the miners could sell materials excavating while grading the channel corridor. To date, the master plan has not been implemented. The issues delaying implementation include acquisition of right-of-way, cost share and responsibility for capital expenses such as grade control and bank protection, identifying a lead agency for funding and implementation, and coordination among the seven affected municipalities and local/state/federal regulatory agencies along the project reach.

- **Pima County, Arizona**. In 1996, the Pima County Regional Flood Control District, the City of Tucson, and local rock products producers jointly developed a mining master plan for a multi-jurisdictional, rapidly developing portion of Pantano Wash located in Pima County, Arizona. The master plan identified past impacts from in-stream mining, identified acceptable levels of mining using a "red-line" approach, and recommended permitting processes and constraints. However, subsequent to completing the plan, Pima County placed a moratorium on in-stream mining and never implemented the Pantano Wash plan.

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[2] From "Impacts of the Rock Products Industry on the Arizona Economy" October 2003 by the WP Carey School of Business, Arizona State University.

The most common objectives of these mining master plans are to limit flood and erosion hazards along the stream corridor, to facilitate mining of economically important resources, and to minimize risk to public facilities such as roads and utilities. Most communities surveyed in the western United States have not developed or implemented river-specific mining plans. Instead, most communities either manage in-stream mining through individual zoning or floodplain use permits, or simply do not allow any type of in-stream mining. Over the past two decades, there has been a strong trend in large urban communities to eliminate and prevent in-stream mining, and to limit mining to overbank or upland areas.

2. STAKEHOLDER COORDINATION ISSUES

2.1. Existing Mining Permit Processes

Within St. George City, sand and gravel mining is permitted through a zoning conditional use permit (CUP). The City has broad latitude in assigning conditions to the CUP, which may range from hours of operation, to limits on mine depth and extent, to reclamation plans. CUP's are issued with specific renewal periods, which may range from 18 months to several years.

Other agency permits which must be obtained for sand and gravel mining include stream alteration permits (Utah Division of Water Rights, Stream Alterations Branch), 404 permits (US Army Corps of Engineers, Regulatory Division), air quality (Utah Division of Environmental Quality), and NPDES permits (Utah DEQ).

2.2. Stakeholder Coordination

The mining plan was developed in coordination with key agency stakeholders as well as the representatives from the mining community. The Virgin River/Fort Pearce Wash Master Plan team met with agency personnel at a series of meetings, field visits, and teleconferences held between July 2006 and March 2007. Agencies participating in stakeholder communication included the following:

- St. George City
- Washington County Water Conservancy District
- Washington County Public Works
- U.S. Army Corps of Engineers Regulatory Division
- State of Utah Stream Alteration Permit Group
- Utah School and Institutional Trust Lands Administration

Stakeholder meetings were held with rock products producers in January and February, 2007. A group meeting was held on January 30, 2007 to introduce the study, solicit input, and to identify specific concerns. Individual meetings were conducted with mining representatives on February 1, 2007. The following firms were invited to participate in the mining stakeholder coordination meetings:

- Quality Excavation

- Sunroc
- Russell Limb
- Western Rock Products
- Bryce Christensen Excavation

A summary of stakeholder concerns was provided in the preceding section.

2.3. Stakeholder Concerns

2.3.1. Mining Industry Concerns

At the stakeholder meetings in January 2007, the following issues were identified by the mine operators working along Fort Pearce Wash:

- General Concerns:
    - Amenity. The river should be able to be used as a community amenity after the period of mining. This includes an aesthetic element, i.e., the river should look like a desert wash. Use of the river and floodplain for trails and recreation should be a goal of the plan.
    - Flood Control. The river corridor should be able to safely convey flood flows up to the 100-year event without significant damage or need for maintenance.
    - Science-Based Guidelines. The stakeholders would like whatever mining guidelines that are developed to be based on sound science, with a rational explanation for any restrictions on mining.
    - Equity. The plan should be applied and enforced equitably for all parties with mining and development interests. All parties should participate in the plan equally according to cost and benefit.
    - Adjacent Reaches. The mining plan should identify potential impacts, maintenance needs, and opportunities in adjacent stream reaches, especially through the City's golf course downstream of River Road.
- Implementation:
    - Implementation. Several stakeholders suggested that construction of any channelization included in the mining plan could be implemented as part of the conditional use permit for mining. Alternatively, channelization could be implemented through the whole mining reach as a single, separately funded project.
    - Site Specific Plan. The mining plan should reflect the short- and long-term mining and development plans of each individual operator.
    - Enforcement. The mining plan should include some method to assure full participation and adherence by all parties to the approved plan.
    - Maintenance. The mining plan should allow for and plan on the need for periodic maintenance of the channel. Expected maintenance activities would include removal of tamarix and periodic or post-flood removal of accumulated sediment. The stakeholders felt that the sediment deposited in the channel would probably be too fine for most commercial aggregate uses, but that it could be used or sold as clean fill or used in site reclamation.

    - Tamarix Control. The mining plan should include steps to remove tamarix and control its future growth. Tamarix chokes the channel, reduces flood conveyance, and traps fine-grained sediment. Several of the stakeholders indicated that they would be willing to remove tamarix in exchange for the ability to mine some of the channel materials.
    - Nuisance Water. Nuisance water is any non-natural source of water discharged to the wash. Nuisance water should be controlled and is one of the causes of tamarix growth.
    - Channel Ownership. If the proposed compound channel cross section (described later in this report) is constructed, the mining plan should address who owns the land. The stakeholders raised questions about compensation for land within the channel, whether land would be obtained in fee or by easement, and who would have maintenance responsibility for the channel in whatever ownership scenario.
    - Non-Mining Land Owners. The mining plan should address ownership gaps between mining properties. Proposed channelization plans should address access, right of way, and funding for work on land not controlled by the existing mining interests.
- Channelization:
    - In-Stream Mining. There is a strong interest on the part of all mining interests who participated in the stakeholder meetings for mining in the main channel of Fort Pearce Wash because of the high quality material source.
    - Channel Cross Section. The proposed width of the constructed channel cross section was of concern. The project team proposed a compound channel, as described later in this report, with a total width of approximately 300 feet. Stakeholders noted some areas where the proposed width would be difficult to achieve due to existing utilities or geologic constraints, but had no significant objections to the concept.
    - Use of Channel Terrace. Proposed uses of the terrace if the proposed compound channel is constructed included golf, parks, active recreation, buried utilities (especially sewer), and lakes or constructed wetlands associated with water treatment.
    - Wash Realignment. At least one of the larger land owners has an interest in exploring options to relocate the wash to facilitate future development.
    - Past Channelization Plan. The stakeholders liked the concept of the channelization plan implemented in 2003 because it facilitated recovery of high quality channel bed materials and has contained flood waters during subsequent floods, but felt that there was some inequity in how the plan was implemented by individual owners.
- Mine Reclamation:
    - Reclamation Plan. The mining plan should include guidelines for site reclamation after mining is completed. Currently, reclamation plans address slope stability and reseeding, but do not address issues such as long-term lateral erosion, pit capture, filling of pits, or future land use in excavated areas.

  - Filling Pits. Some of the mining overburden and fines are used to partially fill excavations at some pits. A minor amount of imported fill is used. None of the stakeholders reported that tip fees were being charged for dumping clean fill.
- Mining Practices
  - Material Source. The Fort Pearce Wash is one of the few sources of quality aggregate in the St. George area. Other off-channel sources reportedly have very high gypsum content which limits the economic viability of mining. The economically viable material along the Fort Pearce Wash is limited at depths ranging from 30 to 80 feet by hardpan, clay and bedrock layers, and laterally by bedrock and land ownership.
  - Mine Design Life. The stakeholders agreed that the existing resource along the current mining district on Fort Pearce Wash would probably be depleted within 20 years. Individual operators suggested that the resource may be depleted as soon as five years.
- Permitting:
  - Permitting. Adherence to the mining plan should facilitate local, state and federal permitting. The mining plan should be coordination with and approved by local, state and federal permitting agencies.
  - State Land. Coordination with the Utah School and Institutional Trust Lands Administration (SITLA) is required for trust lands, especially in the area of site reclamation and mineral lease restrictions.

Meetings with several of the individual mining stakeholders were held in February 2007.[3] The following site-specific issues were raised during the individual stakeholder meetings:

Quality Excavation/Desert Canyon Development

- Quality Excavation (QE) is permitted for a number of off-channel excavations located at the southern end of the mining district on both sides of Fort Pearce Wash.
- Desert Canyon Development (DCD) is preparing a land use master plan for properties currently mined by Quality Excavation, and intends to use mining as means to achieve long-term flood control goals for the future master planned community.
- DCD intends to place fill to remove land along the stream corridor above the base flood elevation. Fill will be derived from mining spoils as well as from cut/fill balance from grading of the non-mining portions of their land holdings.
- DCD intends to construct several road crossings of the Fort Pearce Wash and is aware of other probable utility crossings within their project limits. DCD would like design guidelines for bridge and utility crossings to be included in a long-term plan.
- DCD is willing to construct engineered structural measures to prevent lateral erosion and long-term scour.

[3] All mining interests were invited to individual stakeholder meetings. Only those listed requested such meetings with the project team.

- DCD expects to transfer ownership of the constructed channel to the homeowners association.
- DCD expects to implement whatever channelization plan is adopted as a single phase prior to phasing of the development units located near the channel corridor.
- DCD would like the mining/channelization plan to include a plant palette to guide re-vegetation of the main channel, banks and floodplain terrace.
- QE indicated that their maximum pit depths are expected to be 40 to 50 feet due to the poor quality material (clay) at greater depths.

<u>Bryce Christensen Excavation</u>

- Bryce Christensen Excavation (BCE) is permitted for an off-channel excavation located at the northern end of the mining district on the east side of Fort Pearce Wash.
- BCE noted potential conflicts of the proposed 300-foot constructed channel width on his property with an existing sewer line, as well as with the width between bedrock outcrops immediately downstream of his property.
- BCE noted that the proposed total channel corridor width is greater than the existing channel width through his property which would require loss of developable land on one or both sides of the wash. In lieu acquisition of the entire corridor, BCE suggested that they be allowed to use of the terrace for non-residential commercial use (nursery plant storage), that compensatory density trades with properties elsewhere within the City be considered, and that ownership of the floodplain terrace be retained by BCE.
- BCE stated that they would not be likely to pay to “scalp” the channel for maintenance purposes due to the low volume of material recovered, the potential for contamination of the aggregate by fines, and cost of hauling the material to a processing plant. They would, however, consider performing the scalping maintenance for a fee.

<u>Sunroc</u>

- Sunroc noted that some of their critical infrastructure, including a well and settling ponds, is located near the channel and would need to be accounted for in design of a constructed channel corridor.
- Sunroc periodically discharges clear water from a clarifying machine into Fort Pearce Wash. These discharges would need to be accounted for in the mining plan channelization design.
- Sunroc favors a narrower channel cross section than the 300-foot width discussed in the stakeholder meetings. The wider channel would adversely impact their mining and processing activities.
- Sunroc regards their batch plant as a permanent facility, which will remain functional long after the mineral resources in the Fort Pearce Wash mining district are depleted.
- Sunroc stated that they would not be likely to pay to “scalp” the channel for maintenance purposes due to the low volume of material recovered and the potential for contamination of the aggregate by fines. They would, however,

consider performing the scalping maintenance for a fee and strongly prefer to have responsibility for any maintenance in the reach abutting their property.

- Sunroc advocated for City enforcement of any required maintenance by operators within a set time period. If the time period expired, maintenance would be performed by others to prevent transport of excess material from adjacent upstream properties.
- Sunroc recommended that a final alignment for the constructed compound channel be selected as part of the mining plan to facilitate planning by affected stakeholders as well as city infrastructure planners.

<u>Western Rock Products & Russell Limb</u>
These stakeholders chose not to attend individual stakeholder meetings.

2.3.2. St. George City Concerns

City staff identified the following opportunities and concerns regarding existing and future mining along Fort Pearce Wash:

- Opportunities –
  - Control of tamarix and invasive species
  - Maintenance of constructed channel through the golf course downstream of River Road
  - Increase channel capacity (decrease floodplain inundation) in developed areas and golf course
  - Control of irrigation tailwater and industrial processing water
- Concerns –
  - Adverse impacts on adjacent properties, especially increased lateral erosion near existing and future residential development.
  - Adverse impacts on bridge crossings, such as increased long-term scour
  - Implementation of long-term reclamation plans to provide stable, useful sites after completion of mining.

2.3.3. Permitting Agency Concerns

<u>US Army Corps of Engineers (USACE)</u> Steve Roberts/St. George Office
In Utah, Clean Water Act Section 404 permitting is processed through the Utah Division of Water Rights Stream Alternations Branch. The State solicits USACE input during the review process. USACE staff was unavailable to provide specific input regarding the proposed mining plan during the course of this study. A copy of the draft report was submitted to the USACE St. George regional office via email in March 2007.

<u>Utah Division of Water Rights, Stream Alterations Branch</u> Chuck Williamson
The USACE issues a “Regional General Permit 40” (GP40) to the State of Utah on a five-year renewal basis which allows the State process 404 permits for many proposed activities on Utah watercourses. While recent court decisions make USACE jurisdiction over the ephemeral Fort Pearce Wash questionable in the future, the State has previously had an interest in permitting activities along the watercourse due to its large watershed and riparian habitat areas downstream of River Road. Aside from issues of jurisdiction, the State (or the USACE) may have a permit interest in the mining plan because of the

reach length and extent of impact. In the past, the State has granted some leeway along Fort Pearce Wash because it is ephemeral. Stream Alterations Branch staff supported the concept of a mining plan for Fort Pearce Wash and identified the following opportunities and concerns:

- The low-flow channel should mimic natural channel geometry to assure sediment continuity and long-term channel stability.
- Re-vegetation requirements would probably be minimal given the low density of natural vegetation in the ephemeral stream.

Utah School and Institutional Trust Lands Administration (SITLA) Tom Faddies
SITLA controls land currently mined by Sunroc. SITLA staff strongly supported the concept of a mining plan for the Fort Pearce Wash and identified the following opportunities and concerns:

- Reclamation. SITLA requires their permittee to execute a site reclamation plan upon completion of mining operations. Site reclamation activities consist of grading excavation side slopes to a stable slope, typically 3:1, site grading to assure positive drainage, scalping and placing top soil, and encouraging revegetation of disturbed areas.
- Post-Mine Land Use Plan. The post mining land use plan for lands along Fort Pearce Wash calls for using the site for flood control, open space and trails. Currently, there are no plans for any other type of site development for the SITLA/Sunroc site.
- SITLA anticipates that the available aggregate resource at the Sunroc site will be depleted within five to six years.

3. RECOMMENDED MINING PLAN

3.1. Issues Potentially to be Addressed by Mining Plan

A variety of issues could be addressed by a mining plan for the Fort Pearce Wash. These issues could include the following, some of which are not within the scope of this study and others of which conflict with each other:

- Reduce potential riverine erosion damage to homes and businesses
    - Enforce erosion zone setbacks
    - Channelize wash to reduce regulatory floodplain and erosion zone width
- Facilitate safe and economic production of important aggregate resources
- Establish a template channel cross section to be implemented with future mining and development along the stream corridor
- Construct a flood and erosion control channel that
    - Contains the 100-year floodplain within the constructed channel
    - Confines lateral erosion to the constructed channel section
    - Connects to existing channelization downstream of River Road
- Assure stability of existing and future road and utility crossings by
    - Limiting the headcut/tailcut potential by isolating mines from flooding
    - Providing grade control where/if needed
    - Defining expected long-term scour depths for crossing designs
- Preserve or improve Virgin River water quality through control of

  - Mine processing water discharge containing fine sediments
  - Fine sediments and salts delivered from upstream watersheds
- Provide flood water detention and reduce peak discharges
- Eliminate non-natural nuisance flows in the watercourse
  - Irrigation tailwater
  - Mine processing water releases
  - Industrial outflows
- Establish zoning districts compatible with proposed mining and processing as well as future industrial, commercial, and residential development, trails and recreation, and the new airport.
- Manage dust and noise
- Minimize public cost to implement and maintain mining plan
- Plan for future maintenance and monitoring of sediment deposition or scour
- Provide guidelines for mine reclamation that address
  - Public safety
  - Aesthetics
  - Future land use, e.g., open space, parks, golf, ball fields, trails
  - Fill of excavations – timing, methodology, goals
  - Inert landfill

3.2. Mining Plan Alternatives

Given the issues outlined above, the following alternative mining plans were considered.

3.2.1. Alternative A: No New Mining Plan (Status Quo)

Currently, there is no overall plan for mining along the Fort Pearce Wash. Sand and gravel mines are permitted and regulated on an individual basis through conditional use permits and zoning. In the recent past, St. George City worked with several of the mining operations to excavate an unlined channel that was intended to reduce the floodplain width. The channelization plan ultimately achieved this goal, although some implementation difficulties occurred. At the present time, the City does not allow mining in the main channel of Fort Pearce Wash, but does allow mining in the floodplain and erosion hazard zone (EHZ) with minimal setbacks from the main channel.

The principal advantages of the status quo alternative are that the regulatory framework is in place and the existing channelization has effectively reduced overbank flooding and limited lateral erosion, at least within a short reach for the small floods that have occurred over the past several years. The disadvantages of the status quo include the potential for adverse impacts to adjacent properties and infrastructure from erosion when the off-channels excavations breach, the lack of bank protection along the excavated channel to prevent lateral channel migration, and the lack of a channel maintenance and inspection plan. There is also some legitimate concern about the long-term stability, impacts, and utility of the large excavations that will remain after the reach is mined out over the next decade.

Alternative A is feasible, but has significant long-term liabilities. More importantly, Alternative A may miss the key opportunity to transform Fort Pearce Wash into a community amenity, and may require substantial back-end investment to achieve a stable channel corridor along Fort Pearce Wash.

3.2.2. Alternative B: In-Stream Mining Moratorium

Currently, there are no operators continuously mining in the main channel of Fort Pearce Wash. Overbank mining in the floodplain has been limited by the City via the condition use permit process. The only adverse consequence to Alternative B is the lost economic opportunity for the sand and gravel operators, along with any residual impacts to the local economy caused by increased rock product costs. In addition, in-channel mining could be a means to control tamarix, perform required channel maintenance, maintain adequate flood capacity, and implement construction of a flood control channel. It would be more desirable to adopt an alternative that clearly identifies the conditions under which in-channel mining could occur.

Alternative B is feasible, but misses opportunities to stimulate economic activity and implement a broader river management plan. Alternative B also does not address liabilities associated with long-term impacts from the existing excavations.

3.2.3. Alternative C: Construct Bypass Channel

Relocating and constructing a flood control channel away from the areas with the best aggregate resources was suggested as a potential alternative. However, none of the mining operators favored this alternative, although Quality Excavating/Desert Canyon Development may consider some degree of channel realignment as a means to facilitate their long-term development plan. The cost of acquiring channel right-of-way, potential impacts to non-mining adjacent landowners, and difficulty of environmental permitting were cited as the main detractors.

Alternative C is not feasible as part of an overall mining plan for the Fort Pearce Wash.

3.2.4. Alternative D: Construct Regional Flood Control Dam

A regional dam constructed near the Utah-Arizona state line could lower flood peaks on Fort Pearce Wash to the degree that future flood and erosion hazards would be insignificant within City limits, could allow increased mining within current channel areas in the existing mining district, and could potential serve as a sediment trap that would provide a long-term regional source of aggregate materials.[4] The dam would also decrease delivery of fine-grained sediments and gypsic salts to the Virgin River, improving water quality downstream, and would potentially provide an additional source of water supply to Washington County. Given the current regulatory climate regarding construction of new dams, there would be significant schedule concerns with implementing the alternative prior to the time when the existing resource is mined out.

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[4] The Bureau of Land Management estimated an annual sediment yield of approximately 1,410 acre-feet per year (2.1 million tons; 2.3 million cubic yards) for Fort Pearce Wash. Assuming that 10% of the total sediment yield is marketable aggregate, the BLM estimate is equivalent to 200,000 yd3 of aggregate per year of renewable aggregate materials.

Alternative D may be feasible, although the planning and engineering necessary to design, permit, and construct a regional flood control dam on Fort Pearce is far beyond the scope of this analysis.

3.2.5. Alternative E: Implement Terraced Channelization Plan

The recommended alternative along the Fort Pearce Wash is construction of a terraced channel (a.k.a, a compound channel) that would contain flood and erosion hazards to a defined corridor through the City limits.

3.3. Recommended Mining Plan Elements

The following elements of the recommended mining plan are discussed below:

- Channel Cross Section Templates
- Guiding Principles for Channel Stability
- Channel Corridor Alignment
- Mine Reclamation Guidelines
- Corridor Maintenance Plan
- Implementation Plan
- Enforcement Plan
- Considerations for Modifications of the Mining Plan Elements
- Considerations for Application of the Mining Plan to Other Watercourses

3.3.1. Channel Cross Section Templates

Templates for the constructed channel cross section were developed by Natural Channel Design, Inc. (NCD) based on field reconnaissance, field measurements of stable channel reaches, and basic principles of fluvial geomorphology. The materials provided in this section were developed by NCD for use in the mining plan. Flood magnitude frequency data for Fort Pearce Wash are summarized in Table 1. The bankfull discharge estimate listed in Table 1 was developed by NCD from field measurements.

Table 1 Ft Pearce Wash Flood Magnitudes and Frequencies		
Watershed Area	1350	sq miles
Bankfull Discharge	650	cfs
2-Year	1,310	cfs
5-Year	4,240	cfs
10-Year	7,940	cfs
25-Year	14,700	cfs
50-Year	21,200	cfs
100 Year	25,000	cfs

The basic recommended channel cross section mimics the natural channel features observed and measured by NCD along undisturbed portions of Fort Pearce Wash, and incorporates the City's flood control objectives within the desired right-of-way width. The basic stream corridor cross section consists of the following elements shown in Figure 1:

- Geomorphic Floodplain. The geomorphic floodplain contains the low flow (main) channel and a frequently inundated floodplain. No development occurs within the geomorphic floodplain, which is intended solely for flood conveyance and open space. Trails may be located within the geomorphic floodplain, but they will be subject to damage during small to moderate flow events and during periodic channel maintenance activities. The geomorphic floodplain should contain the 10-year flood without inundating the terraces, and also contains the USACE jurisdictional area (waters of the United States).
- Flood Terrace. An elevated flood terrace will be constructed on one or both sides of the geomorphic floodplain. The flood terrace may be stepped with one or several levels, all of which will be sloped to drain toward the geomorphic floodplain at a minimum cross slope of two percent. A wide variety of flood-tolerant activities may occur on the flood terraces, including road construction, parallel utility alignments, active recreation facilities, storage of inert materials, recharge basins, constructed wetlands, and parking. 100-year flood velocities and depths on the flood terrace should be low to limit scour and erosion, although unless erosion protection is provided at the edge of the geomorphic floodplain, the flood terraces are considered to be within the Fort Pearce Wash erosion hazard zone (EHZ).
- Upland Areas. Upland areas are the lands located outside the flood terrace which are elevated above the 100-year flood elevations. Upland areas are outside the regulatory floodplain, but may be located within an erosion hazard zone (EHZ) depending on local conditions. The upland areas are potentially developable if located outside the erosion hazard zone or if erosion protection is provided.

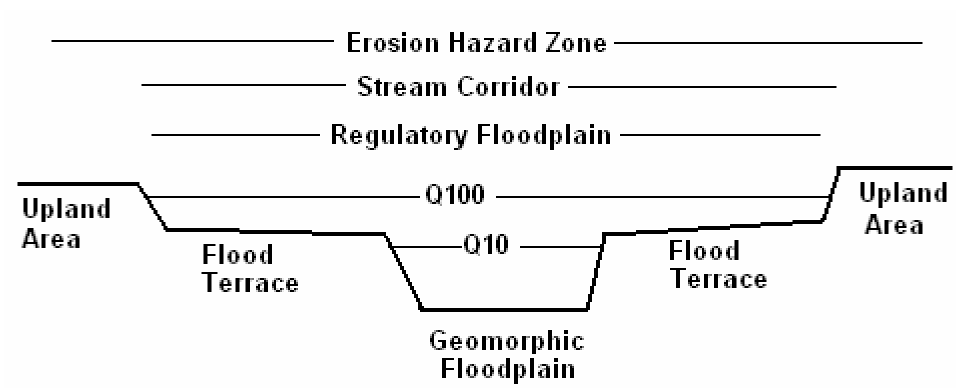


Figure 1. Schematic Drawing of the Recommended Channel Corridor Template Elements. (NTS)

The constructed channel cross sections geometry is described in Table 2 and shown in Figure 2. Hydraulic data for a 300-foot and 350-foot wide corridor are provided in Tables 3 and 4, respectively. Allowable or desired vegetative cover is listed in Table 5. The template cross section geometry should be considered as draft only, since more detailed analyses are recommended prior to construction. Some of the issues to be considered in final design include increasing the geomorphic floodplain capacity, lowering terrace velocities, corridor freeboard, and erosion protection.

Table 2 Channel Template Dimensions					
Cross Section Element	Zone (Figure 1)	Elevation Above Bed	Channel Width	Side slopes	Comments
		(ft)	(ft)		
Channel					
Bottom width		0	30	na	Jurisdictional Area
Top width	A	3	60	5:1	Jurisdictional Area
Geomorphic floodplain	B	6	140	13:1	Jurisdictional Area
Low Terrace	C	9	200	10:1	Low Terrace (10-year flood hazard)
High Terrace	D	12	300	17:1	Potential developable area
Daylight to natural grade			40:1	> 100-year flood hazard	

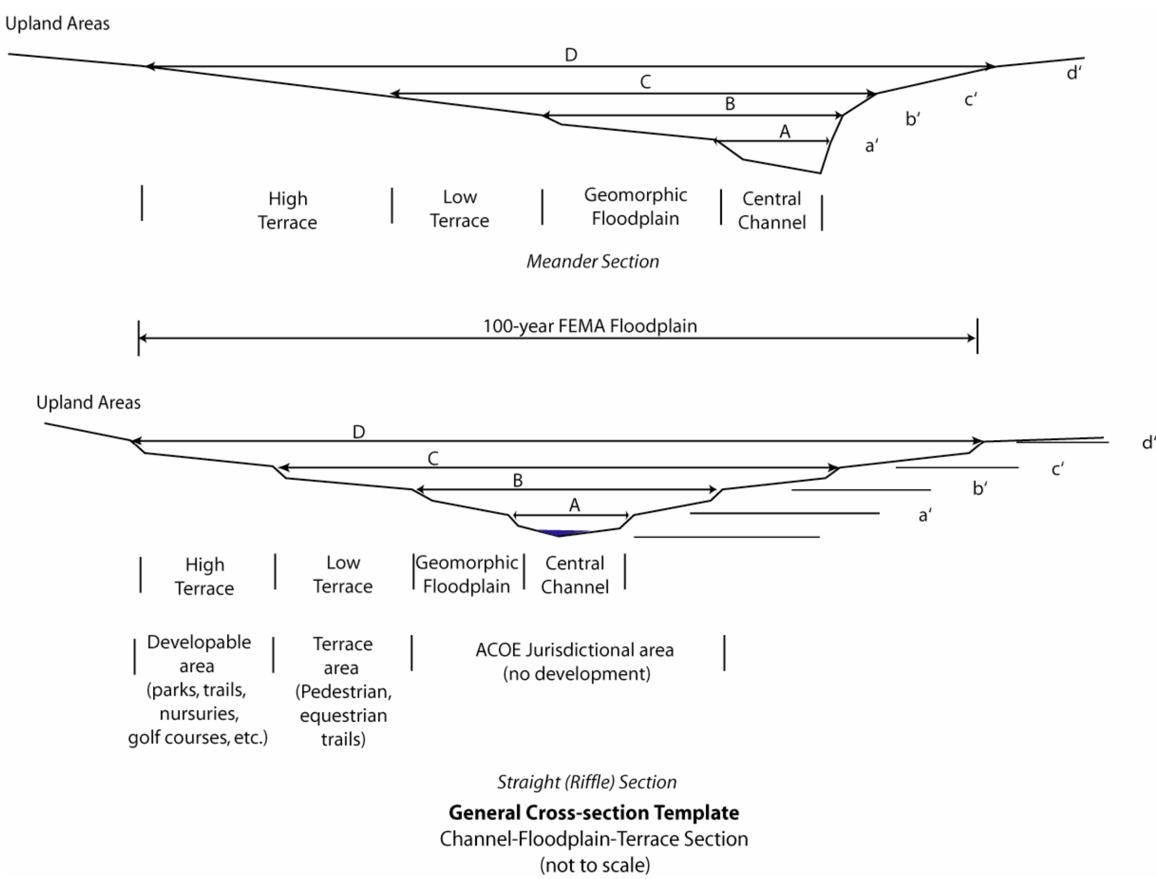


Figure 2. Ft. Pearce Wash Channel Template for the 300-foot Cross Section

Table 3. Hydraulic Rating for the 300-Foot Corridor Width Section							
Return Interval	**Discharge**	**Computed Discharge**	**Stage**	**Central Channel Velocity**	**Floodplain Low Terrace Velocity**	**High Terrace Velocity**	**Mean Velocity**
(years)	(cfs)	(cfs)	(feet)	(fps)	(fps)	(fps)	(fps)
Bankfull	650	635	3.0	4.7			4.7
2	1,310	1,216	4.0	6.2	1.1		5.8
5	4,240	3,840	6.5	9.6	3.3	1.0	7.6
10	7,940	7,920	8.5	12.4	6.1	3.3	9.3
25	14,700	14,700	10.5	15.2	9.7	5.6	11.6
50	21,200	22,500	12.0	17.5	13.4	7.5	13.9
100	25,000	25,770	12.5	18.3	15.0	8.2	14.8

Table 4. Hydraulic Rating for the 350-Foot Corridor Width Section							
Return Interval	**Discharge**	**Computed Discharge**	**Stage**	**Central Channel Velocity**	**Floodplain Low Terrace Velocity**	**High Terrace Velocity**	**Mean Velocity**
(years)	(cfs)	(cfs)	(feet)	(fps)	(fps)	(fps)	(fps)
Bankfull	650	635	3.0	4.7			4.7
2	1,310	1,216	4.0	6.2	1.1		5.8
5	4,240	3,840	6.5	9.6	3.3	1.0	7.5
10	7,940	8,090	8.5	12.4	6.1	3.3	9.0
25	14,700	13,390	10.0	14.5	8.7	5.3	10.5
50	21,200	21,200	11.5	16.7	12.0	7.4	12.5
100	25,000	24,510	12.0	17.5	13.4	8.2	13.3

Table 5. Vegetative Properties for the Constructed Channel Elements			
	Elevation Above Bed	**Zone Width**	**Typical Vegetation Type**
	(ft)	(ft)	
Central Channel	3	60	Free of woody species
Geomorphic Floodplain[1]	6	80	Shrubby willows/baccharis (< 2-inch diameter)
Low Terrace[1]	9	60	Native tree and shrub species
High Terrace[1]	12	100	Arroweed, saltbush, Desert willow, mesquite, acacia (Cottonwood, Black willow, Box elder, others with irrigation)
Total Stream Corridor Width		300	feet

3.3.2. Guiding Principles for River Stability

The following principles for stable channel design were developed by NCD as part of the Virgin River/Fort Pearce Wash Master Plan, and should be considered for the Fort Pearce Wash mining plan.

- **Bank stabilization required for high velocity, frequently flood zone.** The margins of the geomorphic floodplain will be subject to erosive high velocities during moderate to large floods. Depending on the final design of the flood terrace portion of the channelization corridor, portions of the flood terrace may experience high velocities during large floods. Therefore, land areas near the geomorphic floodplain and terrace may still be subject to lateral erosion hazards unless engineered erosion protection is provided.

- **Elevations should rise away from the central channel**. The central channel flowline must be the lowest point across the riparian area and the channel banks, floodplains, and terraces should slope upward continuously away from the channel. The outer banks of the stream corridor will be most stable if the terraces can be stepped as they rise away from the channel (Figure 3). All existing flat areas should slope toward the river. If they are level or slope away from the river they will tend to divert overbank flows away from the main channel and could contribute to greater erosion. Surfaces on the outside of meanders should rise in elevation more rapidly than those on the inside but should still be stepped when possible.

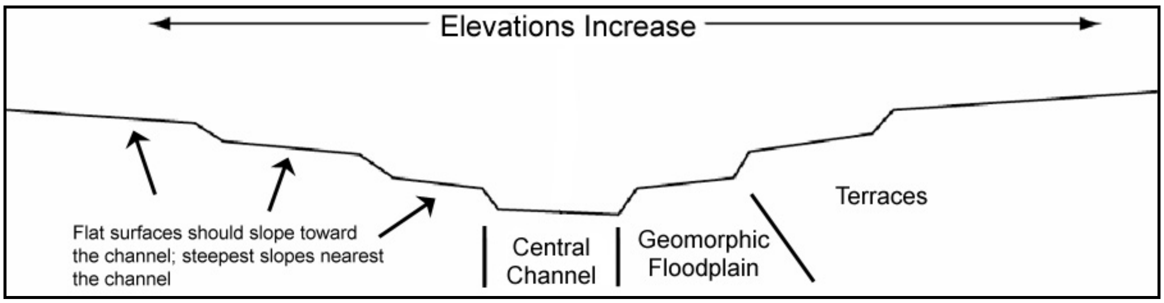
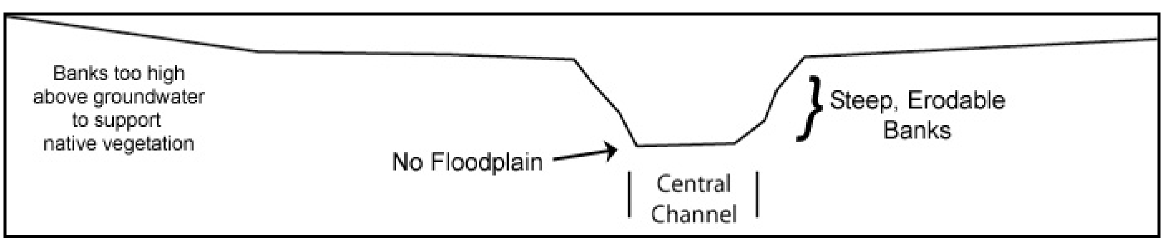


Figure 3. Appropriate channel/floodplain elevations

Diagrams of some common problematic river/floodplain cross sections are shown in Figure 4.

In this example, overbank areas are not sloped toward the central channel. Flow that overtops these banks may be trapped away from the channel and create erosion along the surfaces or gullies as the flow reenters the channel downstream



In this example, lack of a set of stepped floodplain/terrace features contains the flows but increases the velocities and erosion potential within the central channel. Once the banks begin to give way, the erosion can be extreme and unpredictable. Eventually flow will overtop the high banks and create erosion across the surface as well. High banks are often well above permanent ground water and cannot sustain robust plant communities.

Figure 4. Incorrect channel/floodplain characteristics that lead to channel erosion.

- **Roughness should increase away from the central channel.** Roughness is resistance to flow contributed by vegetation, uneven surfaces or structures that block flow. Increasing roughness away from the central channel tends to center high flows and slows velocities against the outer banks and terraces. For example, the central channel should be relatively free of vegetation and other obstructions. The areas immediately adjacent to the channel (floodplains) should support dense thickets of shrubby vegetation (i.e., willows, etc) that bend with the flows (Figure 5). Areas further away from the channel (terraces) support stiffer woody vegetation (cottonwoods, Black willow, etc) that further slows flows. It should be noted that roughness implies a slowing of the flow not necessarily stopping the flow. Structures that completely stop or redirect flow across the floodplain/terrace should be avoided.

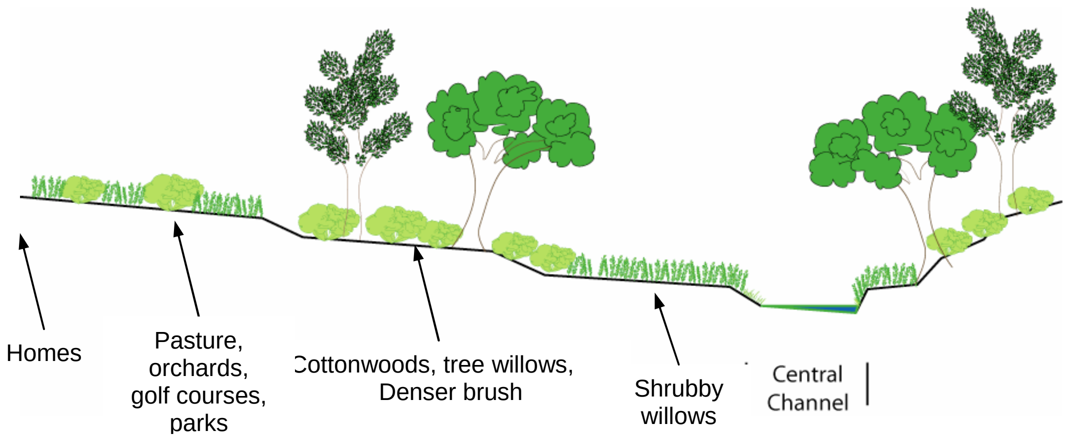


Figure 5. Appropriate Roughness Distribution. Vegetation provides increasing roughness to keep high velocities in the central channel.

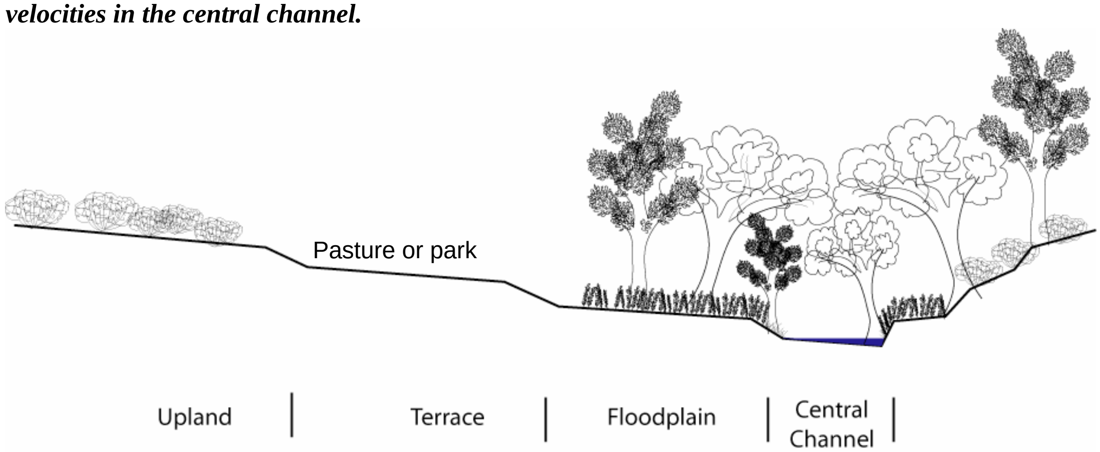


Figure 6. Incorrect Roughness Distribution. Dense stiff species choke channel the stream channel forcing flows to the vulnerable outer banks. Smooth surface of pasture creates high velocities and erosion.

- **Transitions should be gradual.** In order to minimize the risk of lateral bank erosion, water should flow smoothly through the stream corridor. While meander is a natural part of stream processes, tight turns can create excessive pressure to weak stream banks and increase erosion. Meanders should be gradual and within the dimensions described in specific recommendations. Floodplains and terraces should not be suddenly narrowed by buildings or other structures (Figure 7). Such constrictions force increases in velocity and water elevations that can increase erosion.

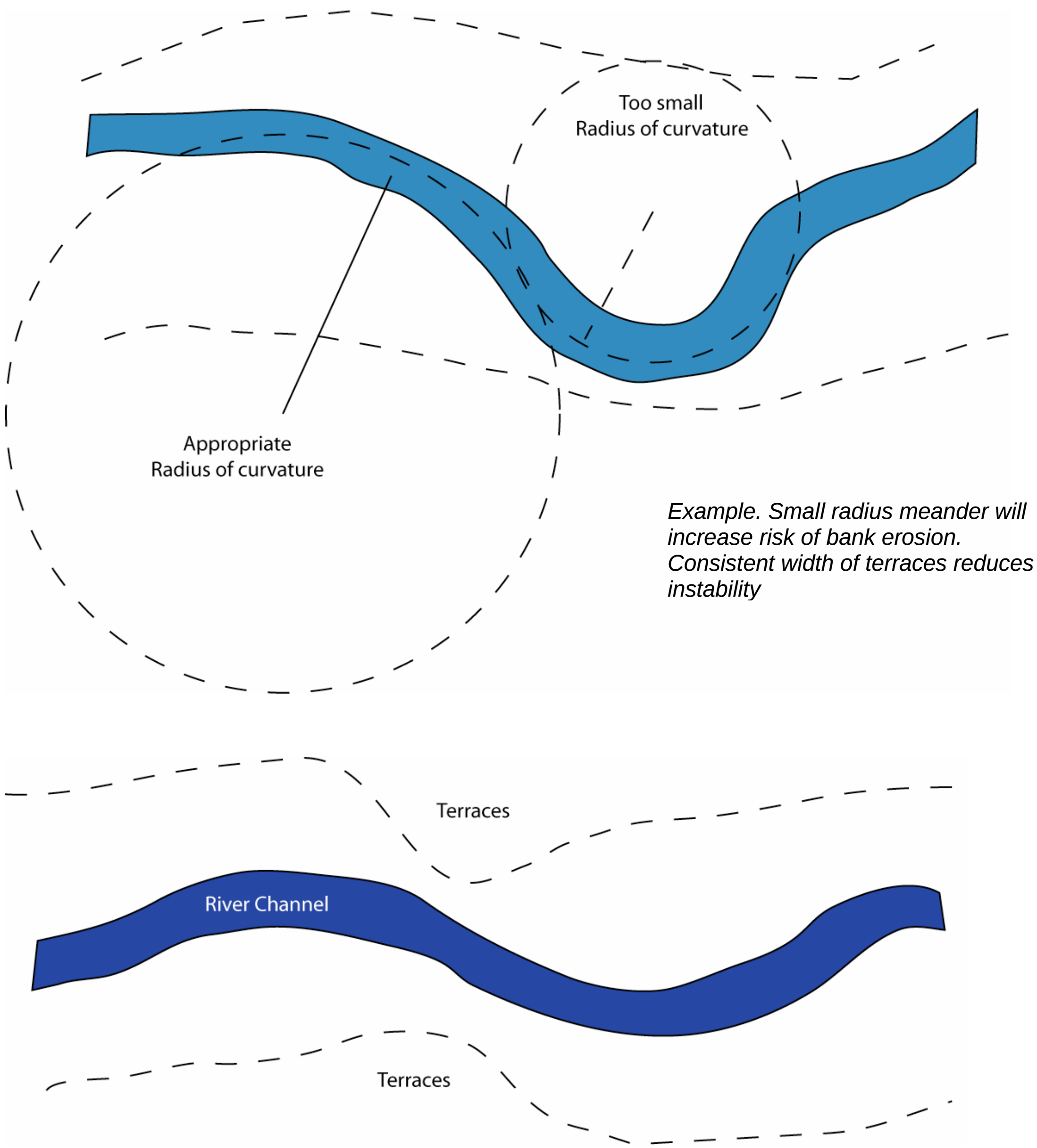


Figure 7. Incorrect transitions. Sudden narrowing of terrace or floodplain increases potential for erosion.

3.3.3. Channel Corridor Alignment

A preliminary channel alignment for a 300-foot corridor is shown in Figure 8.[5] The preliminary alignment generally follows the existing "natural" thalweg, except where individual landowners indicated that they may realign portions of the stream as part of a development plan (e.g., Desert Canyon Development). Wherever possible, the preliminary alignment is located within the regulatory floodway and the zone of active sediment transport, as delineated for the Fort Pearce Wash erosion hazard delineation. An attempt was also made to align the preliminary corridor to take advantage of existing bank stabilization, bedrock outcrops, and stable surfaces. Also, where information on existing utilities was available, the alignment attempts to avoid utility conflicts.

It is important to note that some modifications to the proposed alignment will occur as the mining plan is finalized and implemented as a result of negotiations with individual landowners, coordination with utilities and roads, and accommodation of physical barriers. The proposed alignment should be viewed as a starting point for finalization of the plan, should it be adopted and advanced by St. George City.

3.3.4. Mine Reclamation Guidelines

Stakeholder consensus was that active mining along Fort Pearce Wash is likely to cease in as soon as five years, but no longer than 20 years. Since more material is mined and sold than is available to refill the mined areas, excavated pits will be left behind. Current reclamation guidelines address pit slope stability, i.e., the sidewalls of the pits must be graded to a safe, stable slope, as well as some aesthetic aspects, i.e., removal of mining equipment and material/waste stockpiles. However, no reclamation guidelines with respect to long-term stream stability currently exist. Inadequately reclaimed mines located close to the channel have the potential to breach if Fort Pearce Wash experiences lateral channel movement. If breached, the excavations will capture the wash which will lead to upstream and downstream scour and erosion. Given that all of the pits are located within the Fort Pearce Wash erosion hazard zone (EHZ), the mining plan must address reclamation practices to assure long-term lateral channel stability.

Therefore, the following site reclamation guidelines are proposed as part of the Fort Pearce Wash mining plan:

- Refill Pits. There is a strong preference to completely refill the pits and restore natural grades in mining areas. Pits can be filled with imported clean fill and/or inert materials, as well as with fine-grained sediments left over from aggregate processing. In some communities, mine owners charge by the ton to dump fill in abandoned mines. In the St. George area, a potential source of fill materials is gypsic soils removed prior to development. In addition, material excavated from the main channel during corridor maintenance can be used to fill at-risk excavations.

[5] A digital version of the corridor was provided to St. George City in ArcGIS format.

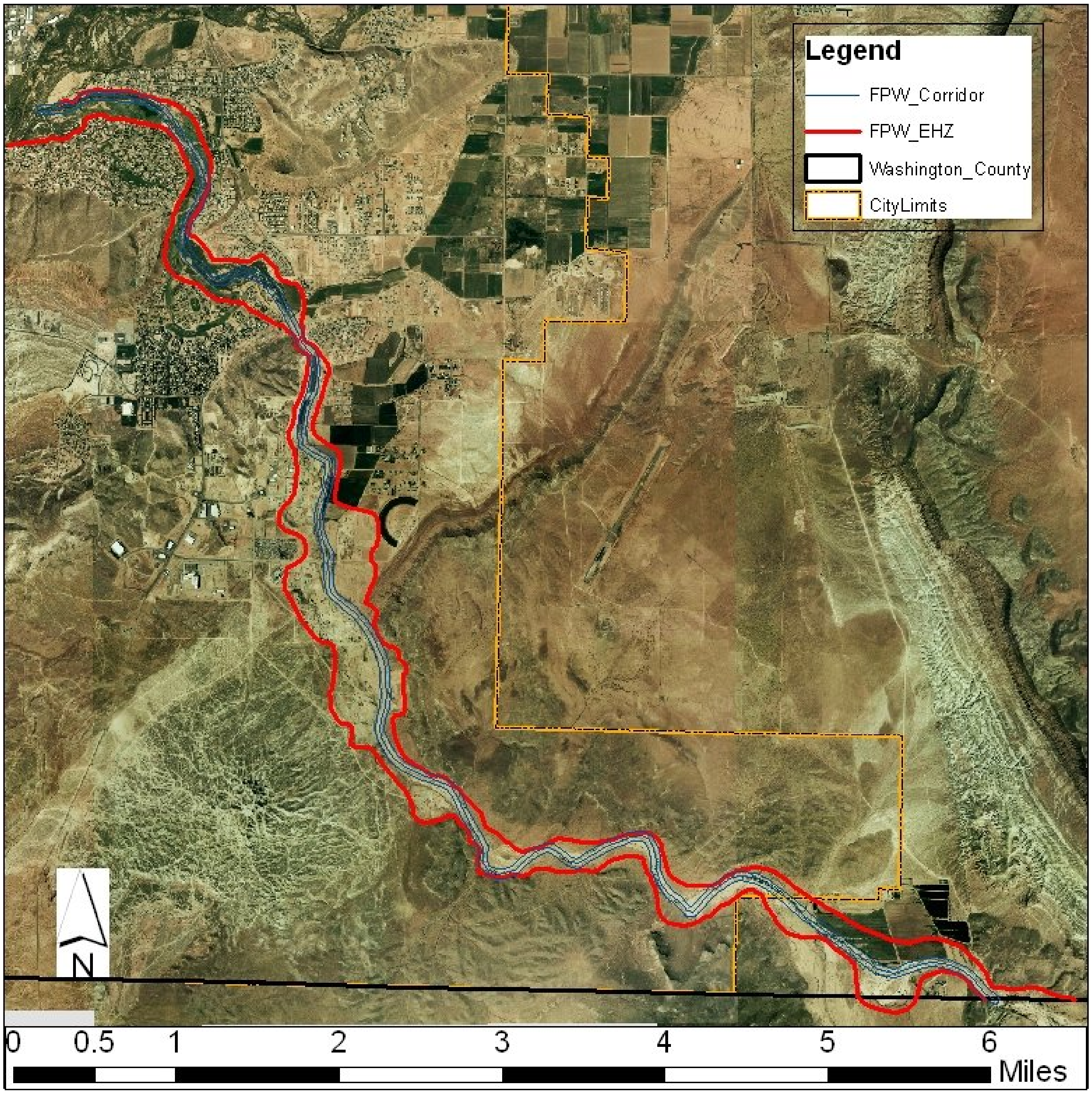


Figure 8. Preliminary channelization corridor alignment along Fort Pearce Wash.

- Partially Refill Pits. Where insufficient fill is readily available to completely fill the pits and restore natural grades, the pits should be filled in the following manner:
    - The areas nearest the channel corridor should be filled first to help prevent accidental breaches.
    - Erosion-resistant materials (rock, concrete rubble, clay) should be placed closest to the channel corridor to provide erosion protection.
    - Once a buffer of at least 200 feet from the edge of the main channel is established by placed fill material, the remaining portions of the pit that are lower than the main channel invert should be filled to at least the main channel invert elevation. The risk and severity of headcut erosion is directly related to the depth (and volume) of the excavation below the channel invert.

  - In some cases, it may be advantageous to place fill in large excavations in a honeycomb fashion to create isolated zones of lesser volume. The risk of headcut erosion decreases significantly with decreased pit volume.
- Stable Slopes. Excavated sidewalls should be regraded to a stable slope, usually 3:1 or flatter. For deep excavations, it may be necessary to create terraces to break up long slopes.
- Revegetation. Regraded slopes should be re-seeded with appropriate native plant mixes to help prevent slope erosion (rilling), prevent invasive species from growing, to provide habitat, and to control dust and air quality.
- Land Use Plan. St. George City should identify expected future post-mining land uses as part of the condition use zoning permit. Reclaimed abandoned mines have been incorporated into land use plans by constructing below grade parks and ball fields (the lower elevation helps offsite lighting and noise impacts on adjacent neighborhoods), recharge basins, constructed wetlands, regional retention basins, agricultural fields, pasture land, golf courses, and parking. In some communities, residential developments have been built in abandoned sand and gravel mines.

3.3.5. Corridor Maintenance Plan

Every constructed channel requires regular inspection and periodic maintenance. The proposed Fort Pearce Wash channelization corridor is no exception. The following maintenance plan elements are suggested as part of the long-term implementation and operations plan:

- Establish Red-Line Elevations. A red-line elevation profile should be established over the length of the corridor channelization project. The red-line elevation profile represents the stable slope of the channel. Deposition above the red-line elevation should be removed by excavation. Scour below the red-line elevation should be addressed through construction of grade control facilities. A two-foot threshold differential from the red-line elevation is recommended as the level of change required to trigger maintenance. The two-foot threshold should be built into channel freeboard calculations and design scour depths.
- Establish Monitoring and Inspection Control Points. Monumented elevation points should be established at 500-foot intervals along the channelization corridor, in the geomorphic floodplain and on the terraces, from which to measure channel elevation changes. Graded markers can be placed on bank slopes or on poles to facilitate rapid assessment of channel change, although experience has shown that such markers have been subject to flood damage.
- Establish an Inspection Program. Channel inspections should occur regularly each year, preferably in early spring so that any needed channel maintenance can occur prior to the late summer flood season. A post-flood channel inspection should occur after any flood that exceeds the five-year recurrence interval.
- Tamarix Control. Regular removal of tamarix should occur prior to the late summer flood season. If not removed, excessive tamarix growth will tend to induce sediment deposition, deflect flooding toward non-vegetated areas, and provide debris that reduces bridge capacities and causes channel overtopping.

- Eliminate Nuisance Flows. Perhaps the best means of controlling tamarix is to eliminate irrigation tailwater, mining process releases, and industrial discharges from Fort Pearce Wash. If these nuisance water sources cannot realistically be eliminated, then they should be captured and conveyed or stored on the terraces in defined channels that will effectively transmit away from the flood conveyance areas. It is likely that these water sources could be used to create natural habitat amenities on the terraces.

3.3.6. Implementation

Implementation activities take a plan and turn it into reality. The following implementation activities will be required prior to construction of the recommended mining plan:

- Corridor Ownership. St. George City must decide whether they will acquire the corridor footprint in fee, as an easement, or whether the corridor will remain in private ownership. Alternatives to acquiring the land in fee include land exchanges, density trades, or granting special use easements. Over the long-term, acquiring the right-of-way in fee, or at minimum as an easement, will provide better assurance of performance and will eliminate maintenance and enforcement challenges. Experience has shown that private landowners and/or homeowners associations are not equipped to deal with long-term channel maintenance and operation of regional flood control facilities.
- Funding Analysis. A mechanism for funding right-of-way acquisition, construction, inspection and maintenance must be identified. Stakeholder input indicates little interest in constructing the channel as part of normal mining activities unless they are allowed to mine significant volumes of material below the existing channel invert.
- Allowable Uses. St. George City should establish a special use overlay for the channelization corridor that outlines acceptable uses and activities within the geomorphic floodplain and terraces.
- Road Crossings. Guidelines for crossing the constructed corridor should be established by St. George. Ideally, road crossings should be one of the following:
    - Bridges. Bridges are the preferred crossing type, and should span the entire corridor including the terrace. If the bridge does not cross the entire corridor, it should span the geomorphic floodplain and either provide relief culverts on the terrace or cross the terrace at grade. Obstruction of the terrace conveyance by a bridge approach will lead to excessive channel scour and sediment transport discontinuities, in most cases.
    - At-Grade Crossings. At-grade low flow crossings that mimic the channel cross section topography are acceptable for low traffic volume roads with alternative routes for all-weather access. Where at-grade crossings are used, a flood warning system consisting of staff gauges, telemetry communication systems, and upstream flow monitoring stations is recommended to allow public officials to close roads prior to floods.
- Utility Crossings. Critical underground utilities (water, sewer, electric) should be buried below the main channel scour depth, including long-term scour, over the

entire width of the corridor unless structural erosion protection is provided to prevent lateral migration of the geomorphic floodplain through the terrace. If utilities are located in the terrace parallel to the corridor, they should be buried beneath the main channel scour depth or protected with structural measures to prevent damage if they are exposed by lateral erosion.

3.3.7. Enforcement Plan

Several stakeholders requested that the City develop a plan to assure conformance with plan elements to ensure that any burden placed on individuals is equitably distributed and to ensure that compliant landowners are not burdened with extra requirements to compensate for non-compliant landowners. For example, if the channelization corridor remains as private land, and maintenance is required, lack of maintenance by an upstream owner could result in additional sediment deposition on downstream owners' property. Conversely, if a downstream landowner over-excavates the channel during maintenance, it could initiate headcutting or scour on upstream properties which may adverse impact channel stability. Therefore, St. George City should identify mechanisms to enforce maintenance needs and plan compliance in a coordinated and timely manner.

3.3.8. Considerations for Modifications of the Plan Elements

Some changes in the recommended plan should be expected with time. Any request to change the recommended plan should be coupled with an engineering and geomorphic analysis to assess the potential for adverse impacts to adjacent stream reaches. Guidelines for the types of analyses required to assess adverse impacts were provided in previous versions of the river master plans and updates, and are also available in the *Sand and Gravel Floodplain Use Permit Guidelines* attached as an appendix to this report.

3.3.9. Considerations for Application of the Plan to Other Watercourses

The recommended mining plan channelization option was developed specifically for Fort Pearce between the Virgin River confluence and the Utah/Arizona state line. The basic concepts of the mining plan should be applicable to any stream system in the vicinity of St. George, but the recommended cross section should be adjusted for each stream's unique hydrologic and geomorphic conditions. Specifically, the following should be considered for any other river system:

- Geomorphic floodplain geometry. Principles of natural channel design should be applied using field data from stable reaches to identify the bankfull channel geometry and cross section.
- Stream corridor width. The recommended width of the corridor is a function of the stream's tendency to meander, floodplain sediment characteristics, flow duration, flood hydrograph peak and shape, sediment supply, and level of watershed disturbance.
- Grade control. The need for grade control should be assessed, particularly where significant narrowing of the natural floodplain is proposed and the stream bed is composed of sandy materials.
- Alignment. The channel alignment and sinuosity should mimic natural channel patterns and tendencies.

4. TECHNICAL REFERENCES

4.1. Engineering Analysis of Mining Impacts

Guidelines for engineering analysis of mining within flood and erosion hazards is given in Sand and Gravel Floodplain Use Permit Application Guidelines, 2004, Flood Control District of Maricopa County. This document has been accepted for use in Maricopa and Pinal Counties, Arizona and recommended as a guidance document in Washington County, Utah on Fort Pearce Wash and other regional drainage systems.

4.2. Sand & Gravel Mining Resource Documents

A bibliography of literature related to in-stream mining is provided in the *Sand and Gravel Floodplain Use Permit Guidelines* attached as an appendix to this report

4.3. Additional Technical Analyses

Additional technical analyses may be required to fully implement the recommended mining plan for the Fort Pearce Wash, including the following:

- CLOMR/LOMR. A revision of the effective floodplain delineation study for Fort Pearce Wash should be prepared to demonstrate the proposed change in the regulatory floodplain/floodway along the channelization corridor reach.
- Hydrologic Modeling. Currently, no detailed hydrologic model of Fort Pearce is available for the watershed. A detailed hydrologic model would provide estimates of flood volumes, flow duration, and other information required for detailed sediment transport modeling and to assess long-term channel stability.
- Sediment Transport Analysis. A detailed sediment transport study would evaluate the expected long-term channel response to the proposed channelization, establish design scour depths for bridges, and road and utility crossings, provide estimates of safe yield (mining) of sediment from the active channel, and estimate sediment maintenance needs. Other elements of the sediment transport analysis would include an equilibrium slope analysis to establish the red-line elevation profile and need for grade control, as well as a headcut/tailcut profile analysis for various pit breach and mining scenarios.
- Erosion Protection Design. Templates for acceptable means of providing structural erosion protection for the margins of the geomorphic floodplain and the terraces are required if development will be located near the corridor.

5. SUMMARY

A mining plan for the Fort Pearce Wash was developed by the project team, in conjunction with agency personnel and key stakeholders. The recommended mining plan consists of a constructed channel corridor intended to contain the 100-year flood and lower the potential for lateral erosion. Prior to fully implementing the recommended mining plan, St. George City should continue to regulate mining in the floodplain and erosion hazard zone using the conditional use permit process and well as mining guidelines provided as an attachment to this report.

Attachments

The following example document is provided in entirety:

Sand and Gravel Mining - Floodplain Use Permit Application Guidelines, Maricopa County, Arizona.

Sand and Gravel Mining

Floodplain Use Permit Application

1982

1983

1979

2002

Guidelines

Sand and Gravel Mining Floodplain Use Permit Application Guidelines

February 2004

Flood Control District of Maricopa County
2801 W. Durango St.
Phoenix, AZ 85009

Prepared by:
JE Fuller/Hydrology & Geomorphology, Inc.
6101 S. Rural Rd., Suite 110
Tempe, AZ 85283

Flood Control District of Maricopa County
Sand and Gravel Mining Floodplain Use Permit
Application Guidelines

Table of Contents

Section 7 Guidelines are in Progress.

Terms defined in the glossary are denoted at their first occurrence by SMALL CAPS font.

Section 1: Overview

Statement of Purpose

The primary purpose of regulation of sand and gravel mining in WATERCOURSES[1] is to comply with Federal Emergency Management Agency (FEMA) requirements. Federal laws require the Flood Control District of Maricopa County (District) to manage and regulate all FLOODPLAIN DEVELOPMENT within the County. Aggregate mining is included in the Federal definition of development. The DISTRICT looks to Federal law if State law is not specific.

The District has regulated sand and gravel mining within watercourses since February 25, 1974, when the County's first FLOODPLAIN REGULATIONS were established. Like all other floodplain activities and development, sand and gravel mining permitting is based on federal and state requirements for floodplain management:

> 44 CFR, Chapter 1, Part 59.1 "Development *means any man-made change… including… mining, dredging, filling, GRADING, paving, excavation or drilling operations or storage of equipment or materials."*

> ARS 48-3613 Authorization is Required for Construction in Watercourses: *"…a person shall not construct any STRUCTURE which will divert, retard or obstruct the flow of water in any watercourse without securing written authorization from the BOARD of the district in which the watercourse is located… This paragraph does not exempt those sand and gravel operations which will divert, retard or obstruct the flow of waters in a watercourse from complying with and acquiring authorization..."*

The Floodplain Regulations for Maricopa County define development standards and permit requirements for sand and gravel excavation within FLOOD and EROSION HAZARD ZONES

> Article I, Section 101.3. *Pursuant to the authority granted in A.R.S. §48-3609(B), judicious* floodplain *management requires the permitting of* development *within a watercourse or contributing watershed that have flows greater than 50 cfs (cubic feet per second) during a 100-year flood event so as not to cause OBSTRUCTION retardation or diversion of flows within the area of jurisdiction*.

> Article IX, Section 902.7 and Article X, Section 1002.12. [Applicants must] "*show that excavations will not have cumulative ADVERSE IMPACT nor be of such depth, width, length, or location as to present a hazard to life or property or to the watercourse in which they are located and they will comply with any applicable WATERCOURSE MASTER PLAN adopted by the Board of Directors*."

In the past, the review of sand and gravel operations had been conducted on a case-by-case basis. These guidelines for sand and gravel FLOODPLAIN USE PERMITS will update the existing sand and gravel permitting policies to achieve the following regulatory and management objectives:

- Protect public health, safety, and welfare
- Provide consistency and continuity of District review of floodplain use permit applications
- Create a streamlined process for sand and gravel floodplain use permit approval
- Integrate floodplain permitting with watercourse and drainage master plan recommendations

[1] Terms defined in the glossary are denoted at their first occurrence by SMALL CAPS font.

Application of these guidelines will provide consistent development of sand and gravel operations without compromising the function of the floodplain, flood control features, or infrastructure. These guidelines supercede all other District permitting guidelines and policies for sand and gravel mining in flood and erosion hazard zones.

Sand and Gravel Mining Policies

The District has established the policies listed below to protect public health, safety, and welfare, to fulfill local, state, and federal mandates for floodplain management, to protect the NATURAL AND BENEFICIAL FUNCTIONS OF FLOODPLAINS, and to minimize the expenditure of public funds for repair of infrastructure in the riverine environment. Mining operations located in the floodplain that meet the intent and criteria described in these policies will be viewed as consistent with the regulatory purpose of the District and may qualify for streamlined permit approval.

1.) Aggregate mines should be located outside of the REGULATORY FLOODWAY whenever feasible.

2.) Aggregate mines should be located outside of the erosion hazard zone whenever feasible.

3.) If aggregate mines are located within the regulatory floodway or erosion hazard zone and no STRUCTURAL FLOOD CONTROL MEASURES are provided, the maximum excavation depth should be no greater than the natural CHANNEL INVERT elevation shown on the EFFECTIVE FLOODPLAIN DELINEATION study (Figure 5-1).

4.) If aggregate mines within the floodplain or erosion hazard zone are excavated below the natural channel invert elevation shown on the effective floodplain delineation study, then engineered GRADE CONTROL STRUCTURES should be provided at any point where the 100-year flood could enter the excavation, or ENGINEERED FLOOD CONTROL STRUCTURES shall be provided to prevent the 100-year flood from entering the excavation.

5.) Aggregate mines shall have no adverse floodplain, EROSION, or sedimentation impacts on any adjacent or off-site property.

6.) Aggregate mining operations must have a RECLAMATION plan that assures the long-term stability of the excavation and the adjacent river system.

7.) Aggregate mining operations shall be compatible with the recommendations and policies specified in the approved watercourse master plan for that watercourse.

8.) Technical reports submitted in support of aggregate mining floodplain use permits should be prepared by experienced Arizona-registered professional engineers with relevant expertise in hydrology, hydraulics, sediment transport, river mechanics, FLUVIAL GEOMORPHOLOGY, and local stream systems.

The District has determined that in-stream mining in flood and erosion hazard zones can damage public infrastructure, private property, and public welfare. This determination is based on the District's experience gained from repair of flood damages, engineering studies, research, technical reports, historical documentation, and practical experience.[2] Therefore, more detailed engineering analyses will

[2] Case histories of flood and erosion damages related to in-stream sand and gravel mining are provided in Section 12 of this document. Additional references describing mining-related stream impacts are provided in Section 11.

be required to support any floodplain use permit application that does not meet the intent and criteria of the policies listed above.

Sand and Gravel Mining Floodplain Use Permit Process

All sand and gravel excavations located in a flood or erosion hazard zone must receive a floodplain use permit or FLOODPLAIN CLEARANCE, excluding LEGAL NON-CONFORMING (a.k.a., grandfathered) operations that existed prior to adoption of the Floodplain Regulations for Maricopa County. Legal non-conforming operations require assurance that their mining operation has remained within the original, legal non-conforming mining limits as defined in Section 4. Figure 1-1 outlines the permit application and approval process described in these guidelines.

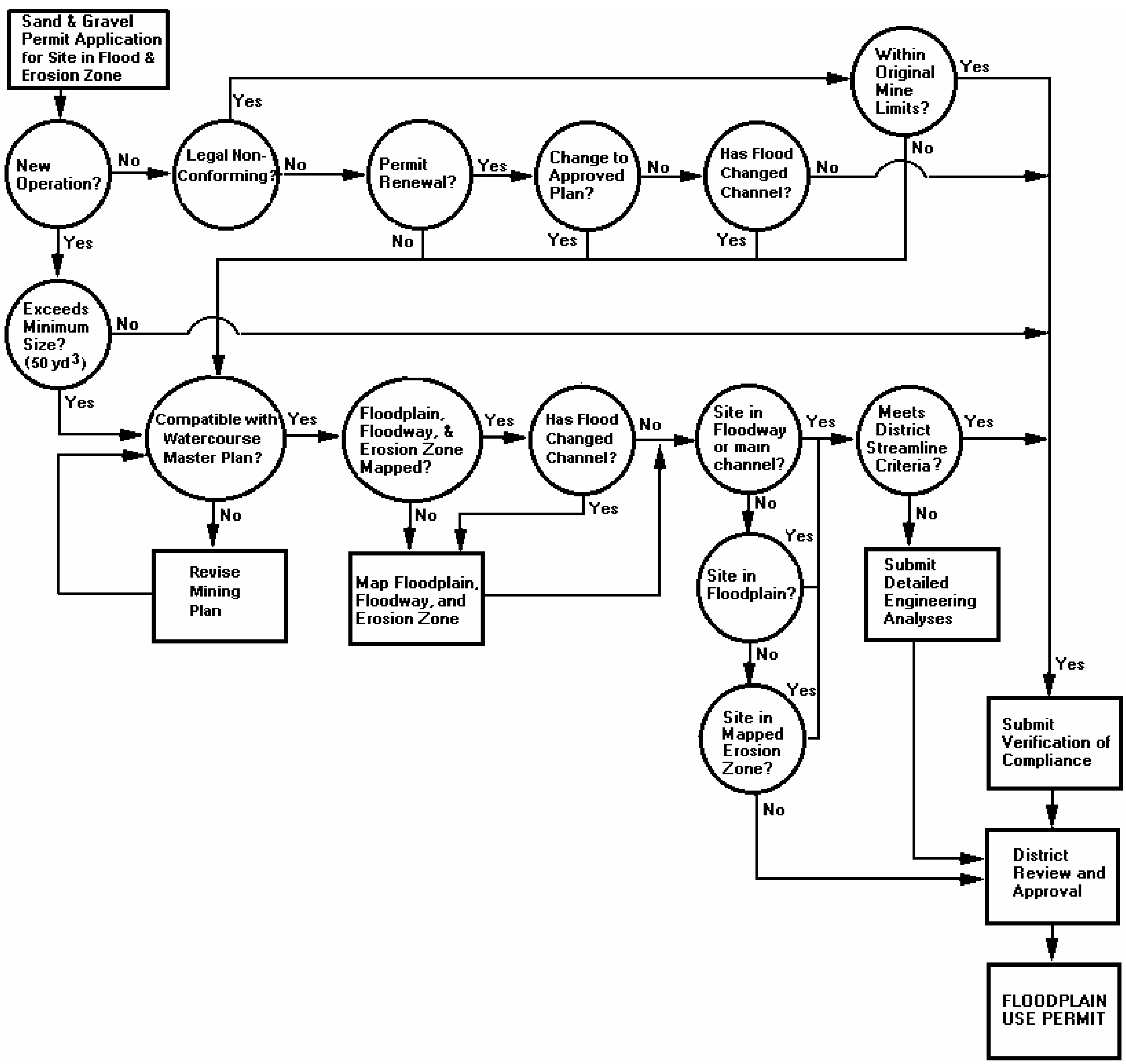


Figure 1-1. Flow chart showing the floodplain use permit *application process for sand and gravel mines.*

As shown in Figure 1-1, the application approval process can be streamlined by excavating outside the flood and erosion hazard zone, by limiting the size of the excavation to less than 50 yd^3 or by meeting the District's "streamlined criteria" for excavations in the FLOOD HAZARD ZONE, as described in Section 4, or by documenting compliance with the conditions of a previously approved floodplain use permit.

Section 2: Review Submittal Checklist
Sand and Gravel Mining Floodplain Use Permit

The checklist below will be used as a guideline to determine if a floodplain use permit application is complete. Additional data or analyses may be required depending on the complexity of the proposed design or the location of the excavation, as described in the following sections.

Floodplain Use Permit Application Form

____1. Application form completed including narrative description of mining operation

Site Plan Cover Sheet

____1. Project name and address
____2. Legal description or assessor's tax id of property
____3. Firm name, address, contact name and phone number of firm operating mine
____4. Property owner name, address and phone number
____5. Mine supervisor name, address and phone number
____6. Engineer of record name, address and phone number
____7. Site location and vicinity map
____8. Map showing ownership of adjacent parcels
____9. General notes and legend, if applicable
____10. Benchmark information – description, location, and on-site horizontal and vertical datum
____11. Arizona registered professional engineer's seal, date and signature

Site Plan Sheet(s) **(Detailed Information in Section 3)**

____1. Map information - north arrow, scale, property lines and dimensions
____2. Existing condition topographic mapping
____3. Proposed excavation and grading
____4. Locations of proposed flood and erosion control structures and features (if any)
____5. Location of existing and proposed BUILDINGS, processing, stockpiling, storage areas and haul roads
____6. Flood hazard zone boundary - floodplain, FLOODWAY, EROSION HAZARD ZONE LIMITS (cite source)
____7. Topographic cross section(s):
   a. Perpendicular to watercourse through site and adjacent watercourse(s)
   b. Parallel to watercourse through excavation at deepest points
____8. Project phasing plan for permit period and ultimate build out of mine
____9. Arizona registered professional engineer's seal, date and signature

Engineering Report* **(Detailed Information in Section 6)**

____1. General Information
____2. Floodplain Analysis
____3. Lateral Erosion Hazard Analysis
____4. Impacts Analysis
____5. Local Drainage Analysis
____6. Structural Measure Design
____7. Statement of Findings
____8. Documentation - engineering calculations and modeling to support results and design
____9. Registered engineer's seal, date and signature

Reclamation Plan Sheet(s)* **(Detailed Information in Section 7)**

____1. Proposed final contours, elevations, slopes. Meets District requirements
____2. Arizona registered professional engineer's seal, date and signature

Certification Forms **(Detailed Information in Section 8)**

____1. Completed certification form sealed by Arizona registered engineer
____2. Statement of compliance with other agency permits (404, 401, ADOT, AZPDES, etc.)
____3. Property owner's notarized authorization letter
____4. Certification of right-of-entry and access

* Not required for streamlined mining permit (Section 5) or legal non-conforming operations (Section 4).

Section 3: Required Information
All Sand and Gravel Floodplain Use Permit Applications

All applications for new or renewed sand and gravel mining floodplain use permits must include the information listed below. For permit renewals, only updated or modified information is required. Inclusion of the information listed below on the cover sheet and site plans, and in the Engineering Report will assure a complete submittal and facilitate District review.

3.1 General Information (Submitted in Report Format)

- 3.1.1 Project name and address
- 3.1.2 Legal description of property to be mined
  - a. Assessor's Parcel Number (APN)
  - b. Metes and bounds survey data
- 3.1.3 Applicant information
  - a. Property owner name, address, and phone number and proof of ownership
  - b. Mining operator legal entity and primary contact name, address, and phone number
  - c. Non-owner applicants: Property Owner's Letter of Authorization (See Section 8). A lease agreement may be substituted for the Letter of Authorization from the property owner.
- 3.1.4 Engineer of record
  - a. Name, address, phone number
- 3.1.5 Location maps for sand and gravel operation property
  - a. Adjacent land ownership, Assessor's parcel number, and current zoning
  - b. Aerial photograph showing property and proposed excavation limits
  - c. Geographic feature map
    - i. Watercourses and tributaries
    - ii. Streets, bridges, utilities, FLOOD CONTROL STRUCTURES located in a flood and erosion hazard zone within one mile of the proposed excavation
- 3.1.6 Site access
  - a. Description of access route to site to be used by District staff
  - b. Description of any restrictions to site access
  - c. Name and telephone number of person to contact for access notification

3.2 Site Plan Requirements (Submitted as Plan Sheets)

- 3.2.1 Map and site information
  - a. North arrow, engineering scale, and legend
  - b. Easements and right-of-way
  - c. Utility alignments within the property limits
  - d. Property boundaries with description of property corner markers
- 3.2.2 Boundary survey
  - a. Required for all new permit applications
  - b. Boundary survey must comply with Arizona Board of Technical Registration current minimum standards for land boundary surveys.
- 3.2.3 Topographic mapping
  - a. General requirements
    - i. Spot elevations and contours shall comply with current national map accuracy standards for 2 foot contour mapping as published by the American Society for Photogrammetry and Remote Sensing, whether performed by aerial methods or ground surveys.
  - b. Contour lines – existing and proposed
    - i. Contour interval of no more than 2 feet

c. Spot elevations
d. Location of on-site TEMPORARY BENCH MARK(S) -
e. Horizontal and vertical datum
   i. Tie-in to FEMA or District floodplain map datum must be provided
   ii. 1929 NGVD datum required for temporary benchmark
f. Mapping date and source
g. Tributaries and drainage paths
h. Registrant's name, address, and professional seal for topographic mapping
i. Site grading cross sections oriented perpendicular to the primary watercourse and spaced at no more than 500 feet intervals - show watercourse, excavation limits, side slopes, pit depth, stockpile areas, structures, 100-year water surface elevation

3.2.4 Mining operation information
a. Maximum pit depth - existing and proposed
b. Maximum excavation limits - existing and proposed
c. Pit side slopes
d. Stationing, offset, or coordinates for excavation boundaries
e. Building(s) and processing equipment locations
f. Tailings, waste, stockpiling, and material storage locations
g. Location and type of fencing and access control features
h. Location of berms and screening features

3.2.5 Flood and erosion control structures
a. Profile sheets showing all proposed flood and erosion control or engineered structures
b. Stationing for all linear structural measures
c. Engineering detail drawings for all structures

3.2.6 Phasing plan – a written description is required for COMPLEX MINING OPERATIONS
a. Anticipated schedule for each phase – onset and closure
b. Boundaries for each phase
c. Locations of constructed features and excavation elements
d. Plan for final closure

3.2.7 Engineer of record seal, date and signature on all plan and profile sheets

3.3 Flood Hazard Zone Boundaries Map (Submitted as Plan Sheets)

3.3.1 North arrow and engineering scale
3.3.2 Property boundaries and dimensions
3.3.3 Topographic contour lines
3.3.4 Proposed and existing mine limits
3.3.5 Floodplain and floodway boundaries
a. New floodplain delineations
   i. Floodplain limits
   ii. Floodway limits
   iii. Cross section locations, station labels, and water surface elevations
b. Existing effective floodplain delineation (District will supply data to applicant):
   i. Floodplain limits
   ii. Floodway limits
   iii. Cross section locations labeled identically to District work maps
c. Floodplain delineations are required for all tributaries with 100-year flows greater than 50 cfs

3.3.6 Erosion hazard zone limit
   a. Label indicating method used to delineate erosion hazard zone
   b. Erosion hazard zone delineations are required for all tributaries with 100-year flows greater than 50 cfs

3.3.7 Locations of structural flood and erosion control measures that alter floodplain and erosion hazard zone limits

3.3.8 Engineer of record seal, date and signature

The Site Plan and FLOOD HAZARD ZONE BOUNDARY Map may be combined into a single map for simple mining operations when few or no structural flood control measures are proposed.

3.4 Reclamation Plan **(Submitted in Report Format with Plan Sheets)**

The District intends to develop specific reclamation plan guidelines. Applicants should check with District staff to determine the status of the reclamation plan guidelines. At minimum, the reclamation plan shall include the following:

3.4.1 Written description of the reclamation plan, phasing, and proposed final condition of the site

3.4.2 Reclamation phasing plan including an anticipated timeline and projected schedule

3.4.3 Finished contours

3.4.4 Backfilled pit elevations

3.4.5 Cross section(s) showing finished side slopes and backfilled elevations

3.4.6 Location, stationing, and typical sections for permanent flood control structures (if any)

3.4.7 Bonding or financial assurance of compliance and reclamation
   a. Documentation of compliance with Floodplain Regulations
   b. Bonding plan data – description of performance assurance requirements (See Section 7)

3.4.8 Boundary survey
   a. Required upon abandonment of mining operation
   b. Boundary survey must comply with Arizona Board of Technical Registration current minimum standards for land boundary surveys.

Additional information on mining reclamation plan requirements is provided in Section 7.

3.5 Engineering Report **(Submitted in Report Format)**

An Engineering Report is required for any sand and gravel floodplain use permit application that exceeds the minimum size, as defined in Section 5, or does not meet the streamlined permit conditions, as described in Section 5. Requirements for Engineering Reports are outlined in Section 6.

3.6 Certification **(Submitted in Report Format)**

3.6.1 The standard engineer's certification form provided in Section 8 must be completed and sealed by an Arizona registered professional engineer. The certifying engineer shall have expertise in hydraulics, hydrology, sedimentation engineering, and river mechanics.

3.6.2 The permit applicant must certify that no mining will occur until all applicable regulatory and environmental permits have been obtained. The certification form is provided in Section 8.

3.6.3 Non-owner applicants must submit an Owner's Authorization Letter using the language provided in Section 8.

3.6.4 Applicant shall certify that legal access to the proposed mining operation is available.

3.6.5 If any submitted product contains both engineering and survey specific data such as property descriptions, metes and bounds courses, monumentation, control, or vertical and horizontal datums, the signature, seal and certification of each responsible registrant is required.

3.7 Notification **(To Be Done by the District)**

Per ARS 48-3610. 2, the District will advise any city or town in writing and provide a copy of any sand and gravel mining floodplain use permit application for sites within one mile of the boundary between the District's area of jurisdiction and that of the city or town.

Section 4: Permit Renewal Process
Existing Sand and Gravel Operations

Floodplain use permits for existing sand and gravel excavations in flood hazard zones require periodic renewal, as well as regular assurance of compliance with permit conditions. Existing sand and gravel excavations may be legal non-conforming, permitted, or out of compliance.

4.1 Legal Non-Conforming (Grandfathered) Mining Operations

4.1.1 Definition. Legal non-conforming (a.k.a., grandfathered) excavations are sand and gravel operations that were excavating materials prior to July 17, 1975 and that have been in CONTINUOUS OPERATION since that time. Specific conditions are described in Title 48, Chapter 21, Article 1 of the Arizona Revised Statutes and Article V, Section 505 of the *Floodplain Regulations for Maricopa County*.[3]

a. Legal non-conforming status is not transferable to adjacent properties or land areas outside the excavation limits that existed on July 17, 1975, regardless of the current ownership of the adjacent land areas.
b. Expansion beyond the property parcel boundaries present on July 17, 1975 upon which excavation was occurring on July 17, 1975, is not a GRANDFATHERED activity and requires a new floodplain use permit. Excavation to a depth greater than that which existed on July 17, 1975 may not be a grandfathered activity and requires review by the District.
c. Continuous operation means that the operation was not discontinued for longer than twelve (12) consecutive months.

4.1.2 Assurance of Compliance. Owners of legal non-conforming excavations are required to submit documentation annually showing that the excavation has not extended beyond the legal non-conforming excavation limits and that it has been in continuous operation. Documentation shall consist of the following:

a. Aerial photographs at a known scale from on or before July 17, 1975 and for the date of assurance, which show the mining limits on July 17, 1975 and at the date of assurance. Aerial photographs at identical scales are preferred. OR
b. Surveyed data sealed by an Arizona-registered land surveyor showing the excavation limits on July 17, 1975 and at the date of assurance. OR
c. A combination of aerial photographs and survey data that documents compliance. AND
d. Documentation of material excavation or sales that demonstrate continuous operation during the assurance period.
e. Assurance of compliance must include review and signature by the property owner or authorized representative.
f. Submittal of Assurance of Compliance Form 9-3 (See Section 9).

4.2 Existing Permitted Sand and Gravel Excavations

4.2.1 Permit Renewal. Sand and gravel floodplain use permits must be renewed every two or five years, depending on the stipulations of the original floodplain use permit.

a. If the existing permitted mining plan has not been modified, annual assurance of compliance has been submitted, no MAJOR FLOODS have occurred, and no watercourse master plans have been adopted by the Board of Directors of the Flood Control District (Board), floodplain use permits may be renewed by providing the following information:

[3] See also: Pima County v. Cardi, 123 Ariz. 424, 600 P.2nd 37 (Ariz. App.1979).

i. Letter signed by the property owner or an authorized representative, and the engineer of record that the mining operation is:
   1. In compliance with all conditions of the original permit, and
   2. In compliance with applicable watercourse master plans and/or AREA DRAINAGE MASTER PLANS, and
   3. River conditions are substantially unchanged since the original floodplain use permit was approved. Substantially unchanged means that topography, land use, vegetative cover, and channel morphology have not changed enough so that the 100-year water surface elevation has not changed by more than 0.5 feet, and the 100-year channel velocity has not changed by more than 10%.

ii. Field verification of permit compliance by District inspectors, and

iii. All applicable data listed in Section 3.

b. New permit guidelines apply (Section 5) where the previously approved mining plan has been or will be significantly modified, or where the mining operation has lost its legal non-conforming status.

c. A major flood is considered a significant modification to a previously approved mining plan. A major flood is defined as a flood that reaches, breaches, or otherwise enters the sand and gravel excavation, or a flood that causes lateral channel migration toward the excavation of more than 10 percent of the total pre-flood distance between the excavation and the primary channel bank.

d. If a major flood has occurred, the applicant must submit documentation demonstrating that no SIGNIFICANT CHANGES to the watercourse have occurred. Information on flood flow rates for specific watercourses may be obtained from the Flood Control District or the U.S. Geological Survey District Office in Tempe. Documentation must include the following:

   i. Pre- and post-flood aerial photographs showing channel position, or

   ii. Surveyed pre- and post-flood channel bank locations, and

   iii. Pre- and post-flood surveyed channel and floodplain cross sections showing bank locations and a thalweg profile adjacent to the excavation.

e. Survey data must be sealed by an Arizona Registered Land Surveyor.

f. If a watercourse master plan has been adopted by the Board, the applicant must demonstrate compliance with the recommended management plan.

4.2.2 Assurance of compliance. Property owners or their authorized representative and owner/operators of permitted sand and gravel operations may be required to submit documentation annually showing that the excavation comply with the stipulated permitted conditions. Documentation may consist of the any of the following:

a. Aerial photograph or survey data showing the present and permitted mining limits

b. Survey data sealed by a registered land surveyor showing:

   i. Pit depth(s) for each actively mined part of the phasing plan

   ii. Pit side slope for reclaimed areas

While reasonable attempts will be made by District inspectors to verify compliance of the mining operation with the floodplain use permit conditions, mine owners or operators may be required to provide additional or supplemental information as requested by the District.

4.3 Non-Complying Excavations

Sand and gravel mines that do not have legal non-conforming status, have not obtained a floodplain use permit, exceed the grandfathered areal extent, or no longer comply with the permitted conditions **<u>must cease operations</u>** and apply for a floodplain use permit, as described in Section 5 of these guidelines.

4.4 District Inspection

District inspectors may conduct semi-annual or post-flood inspections to assure compliance with permit conditions, or to identify flood related damages, as described in Section 9. Any conditions or restrictions on site inspections shall be clearly described on the floodplain use permit application, as well as a plan for allowing periodic access by District inspectors. A contact number for the mine supervisor must be provided with the permit application.

4.5 Transfer of Floodplain Use Permit

A floodplain use permit for a sand and gravel mining operation is not transferable without the District's written authorization. The new property owner and operator shall, upon application with the District, verify that they have read and understand, and shall stipulate in writing to the terms, conditions, and requirements of the existing permit approved by the District by submitting the transfer of permit agreement provided in Section 8. Assurance of compliance is required at the time of the permit transfer. If the new property owner or operator seeks to change or modify any previously approved permit conditions, they shall submit the requested changes to the District for review **prior to** commencing excavation and mining operations by the new owner or operator.

Notes:

1. Recent digital ortho-rectified aerial photography may be available from the Flood Control District of Maricopa County. Historical aerial photography is available from a variety of vendors, including the U.S. Geological Survey EROS Data Center website at http://edc.usgs.gov/products/aerial/napp.html.

Section 5: Permit Requirements
New Sand and Gravel Operations

Floodplain use permits for new sand and gravel excavations in flood hazard zones will be issued only after an engineering analysis is conducted and approved that documents that the District's floodplain management objectives and statutory regulations are met, except for the following two conditions:

5.1 Minor Excavations

A floodplain use permit is required for all sand and gravel excavations in flood and erosion hazard zones. However, if the cumulative volume of material to be excavated is less than 50 yd^3 over the life of the excavation AND the excavation within the floodplain or erosion hazard zone is SETBACK from all property boundaries a distance of no less than 25 times the pit depth, a floodplain use permit can be issued without an Engineering Report. Pit depth is measured as the difference between the average natural (pre-mining) ground elevation at the point vertically above the minimum elevation within the excavation.

5.1.1 MINOR EXCAVATIONS are subject to all the requirements identified in Section 4.
5.1.2 IF A MINOR EXCAVATION EXTENDS BEYOND THE CONDITIONS IDENTIFIED ABOVE, IT SHALL BE SUBJECT TO THE APPROPRIATE REVIEW REQUIREMENTS IDENTIFIED IN THIS SECTION.

5.2 Streamlined Permit Application

No detailed engineering analyses by the applicant are required if a new sand and gravel mine qualifies for a streamlined floodplain use permit. The streamlined permit application process applies if all of the following conditions are met:

5.2.1 An engineer certifies and documents that the proposed excavation meets recommended guidelines for sand and gravel mining in an approved Watercourse Master Plan for the watercourse in which the excavation is proposed, AND
5.2.2 If no floodplain, floodway, and erosion hazard zone delineation has been approved by the District for the watercourses impacted by the proposed mining operation, the applicant must complete those delineations as part of the permit application process, AND
5.2.3 Owner covenants to prevent and repair off-site erosion attributed to the mining operation, AND
5.2.4 A reclamation plan is provided, AND
5.2.5 An engineer certifies and documents that the proposed mining plan meets all of the applicable following conditions:

5.3 Excavations Within the MAIN CHANNEL, Floodway or Erosion Hazard Zone (Figures 5-1 and 5-2):

5.3.1 Setbacks. The excavation must be setback:
- a. From the lateral property line – a minimum of 25 feet plus three times the difference between the natural ground elevation at the property line and the minimum elevation of the excavation (Figure 5-1), and
- b. From the upstream property line, the setback is equal to the greatest of the following:
  - i. A minimum of 500 feet from any bridge or utility crossing, or
  - ii. A distance equal to 50 times the excavation depth (pre-excavation grade to excavation depth) at any point (excavation depth may vary laterally within the pit), or

iii. If the excavation extends outside the erosion hazard zone, it must be set back from the upstream property line (Figure 5-2) a distance defined by a 45° angle from a line perpendicular to the channel centerline (equivalent to the commonly used 1:1 upstream contraction angle).

c. From the downstream property line, the setback is equal to the greatest of the following:

i. A minimum of 500 feet from any bridge or utility crossing, or

ii. If the excavation extends outside the erosion hazard zone, it must be set back from the downstream property line (Figure 5-2) a distance defined by a 76o angle from a line perpendicular to the channel centerline (equivalent to the commonly used 4:1 downstream expansion angle).

5.3.2 Depth of excavation. The depth of the excavation must be at or above natural channel thalweg elevation, as determined by the District and based on one of the following databases (in order of preference):

a. District watercourse master plan study, or

b. FEMA floodplain delineation study minimum channel elevation, or

c. A baseline elevation established by the District or a profile provided by the applicant.

5.3.3 Excavation geometry. The mining excavation shall have the following geometry:

a. Minimum of 0.5% pit bottom cross slope directed toward the channel centerline.

b. The excavated area must allow for a 3:1 slope from the buffer zone to the bottom of the excavation (Figure 5-1; minimum 25 ft.). For the streamlined permit, it is not acceptable to excavate vertically to the buffer zone and propose to backfill the excavation to achieve the required 3:1 slope.

5.3.4 Reclamation Plan. A reclamation plan is required for streamlined permit applications.

Note: Deviation from approved slopes and setbacks will be cited as violations by District inspectors and may trigger the requirement for detailed engineering analyses.

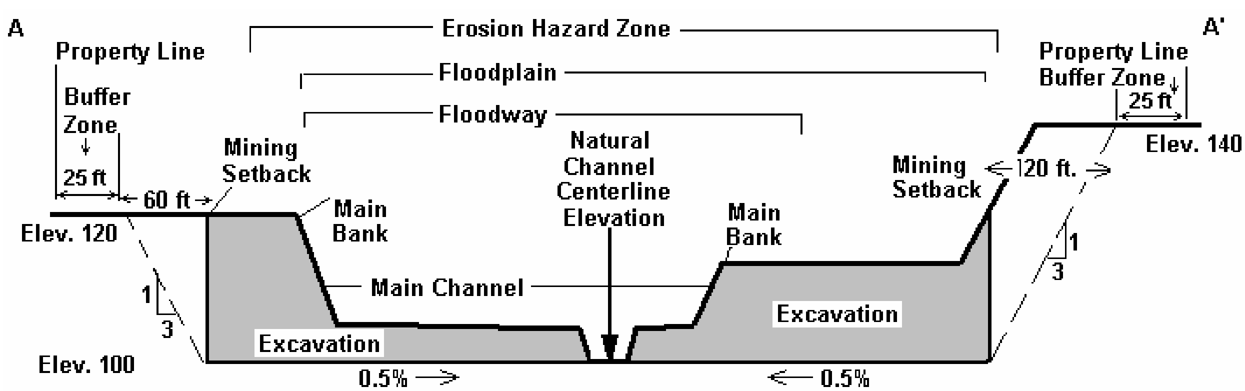


Figure 5-1. Main channel and floodway excavation geometry for streamlined floodplain use permits. Plan view is shown in Figure 5-2. This pit is 20 feet deep (Elev. 120 – Elev. 100). The shaded area marked "Excavation" is the area that can be mined under the streamlined permit process. Material may not be excavated from areas outside the shaded zone unless an engineering analysis is submitted.

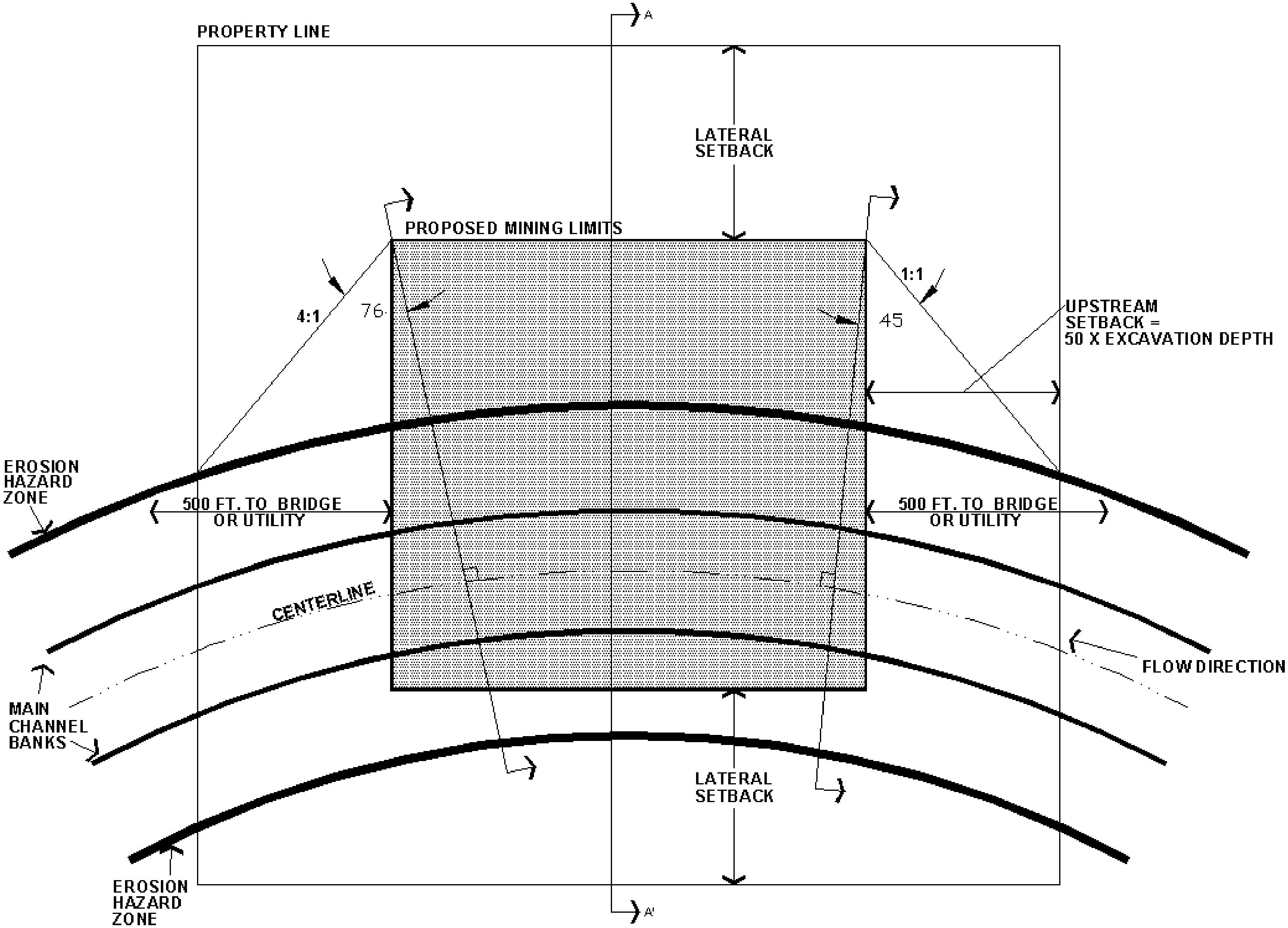


Figure 5-2. Upstream and downstream setbacks from property lines for excavations that extend outside the erosion hazard zone.

5.4 Excavations Entirely Outside the Main Channel, Floodway and Erosion Hazard Zone (Figure 5-3):

5.4.1 Setbacks. The excavation must be setback a minimum of:
- a. 25 feet from the erosion hazard zone, and
- b. 100 feet from main channel bank, and
- c. 500 feet from any bridge or utility crossing, and
- d. Three times the difference between the natural ground elevation at the mining buffer line (25 ft. from the property line) and the minimum elevation of the excavation.

5.4.2 Depth of excavation. The maximum depth of excavation is determined by a 10:1 line drawn from the elevation of the toe of the main channel bank, as shown in Figure 5-3.

5.4.3 Excavation geometry. For the streamlined permit, it is not acceptable to excavate vertically to the buffer zone and propose to backfill the excavation to achieve the required 3:1 slope.

5.4.4 Reclamation Plan. A reclamation plan is required for streamlined permit applications (See Section 7).

5.4.5 Notes:
- a. Excavations within the floodplain are subject to inundation. If inundation occurs, mine owner covenants to repair breaches and restore main channel banks to pre-flood positions and condition, or construct engineered flood control structures.
- b. If no approved erosion hazard zone exists, one shall be delineated based on an engineering analysis completed by the applicant, as described in Section 6.3.
- c. Deviation from approved slopes and setbacks will be cited as violations by District inspectors and may trigger the requirement for detailed engineering analyses.

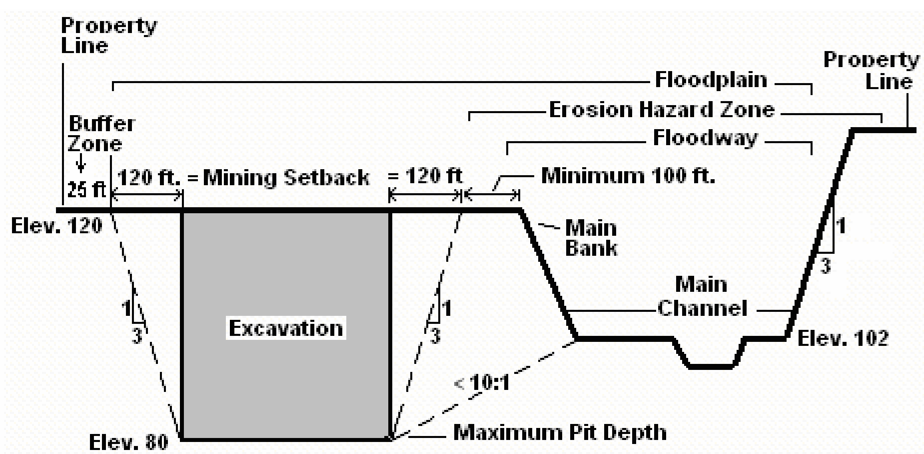


Figure 5-3. Floodplain excavation pit geometry for streamlined floodplain use permit. Pit is 40 ft deep.

5.5 Major Excavation Not Meeting Streamlined Criteria

Floodplain use permit applications for sand and gravel mining operations that do not qualify as minor excavations (Item #1 above) or do not meet the streamlined permit conditions, shall include an Engineering Report, as described in Section 6, in addition to the requirements of Sections 3 to 5.

5.6 Sand and Gravel Excavations Outside the Regulatory Floodplain and Erosion Hazard Zone

Floodplain use permits are not required for excavations that are located outside the regulatory floodplain limits and outside the erosion hazard zone. If the District has not approved regulatory flood and erosion hazard zones, see Section 6 for requirements for delineating the 100-year floodplain and erosion hazard zone. In some cases, structural flood control measures may be constructed to remove the sand and gravel MINING SITE from the regulatory floodplain and erosion hazard zone, but such structures require detailed engineering analyses as described in Section 6.

Section 6: Engineering Report
Requirements

Detailed engineering analyses are required for sand and gravel mines located within the regulatory flood and erosion hazard zone that are not legal non-conforming operations or do not meet STREAMLINED CONDITIONS described in Section 5, as well as for those sites that will be protected by structural flood control measures. The Engineering Report shall be submitted with the floodplain use permit application and approved prior to any excavation in the regulatory floodplain or erosion hazard zone.

The Engineering Report should contain the following sections and types of analyses:

- General Information (Section 6.1)
- Floodplain Analysis (Section 6.2)
- Lateral Erosion Hazard Zone Analysis (Section 6.3)
- Structural Measure Design (Section 6.4)
- Impacts Analysis (Section 6.5)
- Local Drainage Analysis (Section 6.6)
- Statement Of Findings (Section 6.7)
- Documentation (Section 6.8)

A description of each of the objectives and typical components for the eight elements listed above is provided below. It is not necessary to provide all of the detailed analyses listed below in every case if site conditions dictate otherwise. For example, there is no need to perform floodplain and floodway modeling (Section 6.2) or floodplain impact analyses (Section 6.4.1) if the proposed site is located outside of all approved regulatory floodplains. Similarly, there is no need to determine an erosion hazard zone (Section 6.3) if engineered bank protection is proposed and approved. Applicants and their engineers are advised to coordinate closely with District reviewers to determine what types of analyses will be required during the preparation of and prior to preparing or submitting the Engineering Report for review.

6.1 General Information Section

The objective of the General Information Section of the Engineering Report is to provide District reviewers with a basic description of the proposed mining activity, and enough information to identify potential regulatory issues. A General Information Section is required in every Engineering Report, regardless of site conditions. The following information should be provided in the General Information Section:

6.1.1 General Project Information

a. Project name and address
b. Applicant information – primary contact name, address, and phone number
    i. Applicant legal entity
    ii. Mine operator legal entity
    iii. Property owner of record
    iv. Engineer of record
    v. Surveyor of record
    vi. Mapping consultant
c. Project Location
    i. Legal description of property to be mined
    ii. Location maps
        1. Adjacent land ownership, assessor codes, and current zoning

2. Location map at a regional scale (~1:63,360)
3. Property ownership map showing assessor codes for adjacent parcels (~1:12000)
4. Recent aerial photograph showing property and proposed excavation limits, photo date, and scale. A recent aerial photograph is defined as one which accurately depicts existing site conditions in the project reach and does not pre-date any on-site mining or major floods.
5. The excavation and property limits should be plotted on a flood photograph, if available. Aerial photographs of some of the major watercourses during large floods are available from the District's GIS Department or from local commercial aerial photography vendors.

iii. Geographic features map
1. Watercourse and tributary names
2. Municipal and jurisdictional boundaries
3. Flood Hazard Zone Boundaries Map – See Section 3 for requirements

iv. Site access information
1. Description of access route to site to be used by District staff
2. Description of any restrictions on site access
3. Name and telephone number of person to contact for access notification

6.1.2 Description of Mining Plan

a. Proposed operation size
   i. Property and excavation acreage
   ii. Maximum expected depth of excavation
   iii. Maximum expected volume of excavation
   iv. Site plan – See Section 3 for site plan requirements.
b. Proposed phasing plan (include anticipated time line)
   i. Phasing and expected timing of mining stages
   ii. Phasing of flood protection structure construction
   iii. Reclamation plan map – See Section 3 for requirements

6.1.3 Structure Inventory. List all structures within the floodplain and erosion hazard zone located within one mile upstream and downstream of the site, including tributaries. The inventory of structures shall include, but not be limited to the following:

a. Roads – name, type, and ownership
b. Bridges – type, construction date, as-built plans, and ownership
c. Utilities – water, power, sewer crossings, canals – as-built plans and ownership
d. Landfills – existing or abandoned
e. Bank protection – type, extent, location, and as-built plans
f. Flood control structures – grade control, levees, dams, etc. – type, extent, and location
g. Floodplain development – subdivision names, zoning, and land use
h. Other existing sand and gravel mines – location and ownership

6.1.4 Existing Published Information. List published reports relevant to the project reach for the watercourse and its tributaries, including the following:

a. Watercourse Master Plans
b. Floodplain Delineation Studies
c. Erosion Hazard Zone Delineation Studies
d. Previous sedimentation or erosion studies
e. Engineering reports for sand and gravel mines in adjacent reaches of watercourse

A bibliography of published documents stored at the District library can be accessed on line at http://www.fcd.maricopa.gov/Resources/Library.asp.

6.2 Floodplain Analysis Section

The objectives of the FLOODPLAIN ANALYSIS SECTION of the Engineering Report are: (i) to document changes in the regulatory floodplain or floodway; (ii) to demonstrate that the proposed mining operation does not threaten public health, safety, and welfare; (iii) to show that the proposed mining activity has no offsite floodplain impacts; and (iv) to document compliance with all relevant FEMA requirements and the District's Floodplain Regulations. The following items should be addressed in the Floodplain Analysis Section:

6.2.1 No Existing Floodplain Delineation. If no District-approved floodplain delineation exists for the watercourse(s) impacted by the sand and gravel operation, new floodplain delineations must be prepared by the applicant. Guidelines for floodplain delineation studies and required documentation can be obtained from the following sources:

a. Flood Control District of Maricopa County
   i. Publications: www.fcd.maricopa.gov/Resources/Publications.pdf
   ii. Information: Flood Delineation Branch: 602-506-1501
b. Arizona Dept. of Water Resources. *State Standards for Floodplain Management*. State Standards 1-97, 2-96, 3-94, and 9-02 relate to floodplain delineation. Available at www.water.az.gov/adwr/Content/Publications/files/List0802.pdf
c. FEMA: *Guidelines and Specifications for Flood Hazard Mapping Partners* (2002). Available at www.fema.gov/mit/tsd/dlcgs.htm

6.2.2 Existing Floodplain Delineation. If an approved floodplain delineation study is available for the watercourse, the most recent District-approved delineation must be used to evaluate potential floodplain and floodway impacts. The following elements should be included in the analysis:

a. **Evaluation of channel conditions**. The engineer should document and certify that channel and floodplain conditions have not changed significantly since the approved floodplain delineation study was completed by submitting any or all of the following:
   i. Comparative topographic cross sections of the channel and floodplain near the proposed mining site, or
   ii. Comparative aerial photography of site and adjacent stream reaches, and
   iii. Gauge records demonstrating no significant floods since the floodplain delineation was performed

   If significant channel changes have occurred, the existing floodplain delineation will require revision to reflect existing conditions. Approval by the District must be obtained prior to proceeding.
b. **Evaluation of hydraulic model**. The engineer should evaluate and certify that the hydraulic model for the existing floodplain delineation can be used to adequately depict the proposed mining conditions. The following hydraulic information should be provided:
   i. Revised hydraulic model. It may be necessary to add cross sections or make other changes to the existing floodplain delineation model so that pre- and post-project conditions can be compared in the hydraulic model. For example, a proposed mine may be located between cross sections used in the effective floodplain delineation model, and therefore would not be reflected in the model geometry unless new cross sections were added. The Engineering Report must list, describe and justify every change made to the existing floodplain delineation hydraulic model.
   ii. Discharge. Changes in the discharge used in the hydraulic model are not permitted without prior approval by the District and by FEMA. FEMA will

require that a Letter of Map Revision be submitted and approved prior to use of a reduced discharge.

iii. Comparison Table. A table comparing the existing floodplain delineation study and modified (pre-project) hydraulic model water surface elevation, depth, velocity, and channel area at all cross sections adjacent to the project must be provided.

6.2.3 Floodplain/Floodway Evaluation. The hydraulic model must be used to document the degree of impact on the regulatory floodplain and floodway by comparing pre- and post-project conditions. The engineer should perform sufficient modeling to document that the following conditions are met:

a. **Floodway**. No increase in the regulatory floodway water surface elevation is allowable as a result of the proposed project or any related storage, stockpiling, processing, or other facilities.

b. **Floodplain**. At minimum, changes in the water surface elevations and channel and overbank velocities at each cross section in the hydraulic model shall be documented for use in the Impacts Analysis (Section 6.4). Increases in the BASE FLOOD (100-YEAR) WATER SURFACE ELEVATION must be less than one foot, and must not increase on any property not owned by the applicant, unless the affected property owner provides a written statement consenting to the increase in water surface elevation.

c. **Documentation**. Documentation shall include the following:

   i. Cross section plots. Side-by-side plots of pre- and post-mining cross section topography, bank stations, ENCROACHMENT, effective flow boundaries, and roughness coefficients should be provided where any changes occur.

   ii. Tabular data. Tables showing pre- and post-project water surface elevations, floodplain limits (start and end stations), channel velocity, overbank velocity, and maximum depth should be provided.

   iii. Photographic data. Photographic evidence to support any changes in hydraulic roughness or other channel parameters.

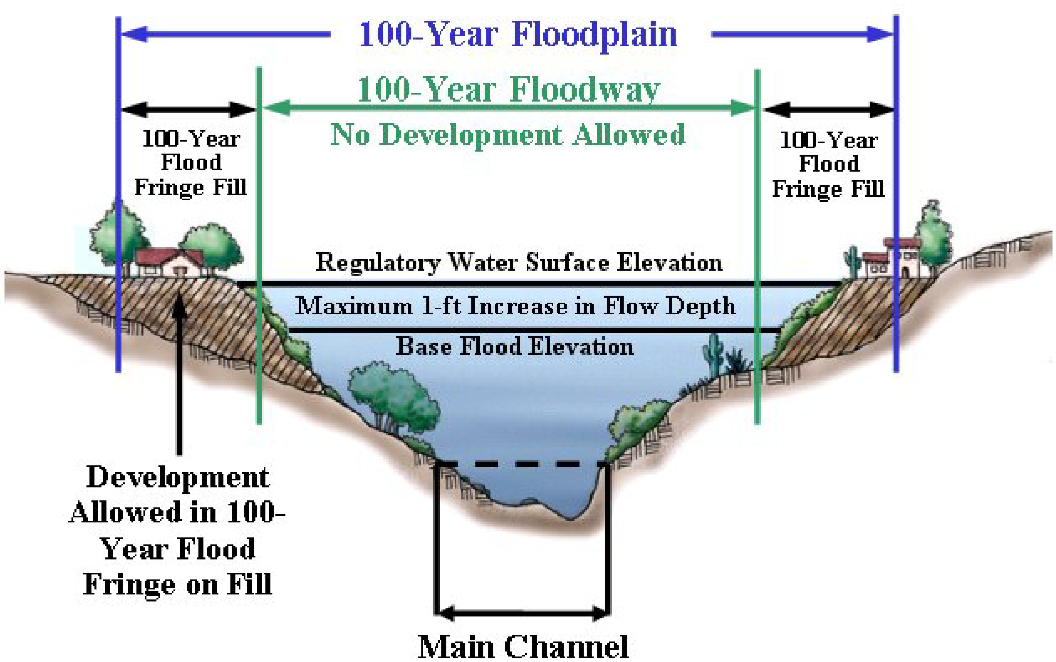


Figure 6-1. Illustration of Floodway, Floodway Fringe, Base Flood Elevation, and Regulatory Water Surface Elevation for a typical riverine floodplain.

6.2.4 Floodplain/Floodway Revisions. In some cases, applicants may wish to revise the effective floodplain or floodway boundaries to reflect proposed flood control improvements or other changes in the floodplain. The following conditions apply:

a. FEMA approval. Until revisions in the effective floodplain delineation are approved by FEMA as part of a Letter of Map Revision (LOMR), the District will regulate the floodplain using the most conservative floodplain delineation. Therefore, structural improvements intended to remove a mining site from the flood and erosion hazard zone do not remove the requirement for a floodplain use permit until the floodplain revisions are approved by FEMA.
b. District approval. The District must approve any floodplain revisions prior to submittal to FEMA. During the review process, the District will consider the cumulative impacts of floodplain encroachment, channelization, or structural flood control.

NOTE: If a sand and gravel operation and its associated facilities are located completely outside all regulatory floodplains for watercourses with 100-year discharges greater than 50 cfs, the Floodplain Analysis Section can be omitted from the Engineering Report. However, a Floodplain Analysis Section is required if any of the following conditions apply: (i) the sand and gravel operation is going to be removed from the regulatory floodplain by structural measures; (ii) if the mining operation is located in a regulatory floodplain that has not yet been mapped; or (iii) if the channel or floodplain has been modified significantly since the floodplain delineation was completed. District staff are available to determine whether a Floodplain Analysis will be required.

6.3 Lateral Erosion Hazard Analysis

The objectives of the LATERAL EROSION HAZARDS ANALYSIS Section of the Engineering Report are: (i) to determine the limits of expected LATERAL EROSION; (ii) to demonstrate that the proposed mining operation cannot be impacted by lateral erosion; (iii) to document that the proposed mining operation meets all relevant FEMA and District regulations for activity within the watercourse; and (iv) to document that the proposed plan protects public health, safety, and welfare. The Erosion Hazards Analysis Section must include an evaluation of potential lateral channel erosion for all watercourses that impact the project site.

6.3.1 Watercourses with District-Approved Erosion Hazard Zones (EHZ). The following options are available for streams with approved EHZ:

a. Use the approved EHZ. Use of the approved EHZ will facilitate permit approval.
b. Modify the approved EHZ. An approved EHZ may be modified under the following conditions:
    i. **Correct errors**. If errors in the original EHZ are identified and can be clearly shown to be errors by detailed engineering and GEOMORPHIC analyses, the EHZ may be revised accordingly. The District will not consider subjective reinterpretation of the results and conclusions from previous EHZ delineations as sufficient proof of an error.
    ii. **Perform more detailed analysis**. Some District-approved EHZ were delineated using reconnaissance-level techniques, while others were based on detailed engineering and geomorphic analyses. More detailed, site-specific engineering, geomorphic, or geotechnical analyses that exceed the level of detail used in the approved EHZ study may be submitted to justify modification of approved EHZ. The more detailed analyses or data must clearly demonstrate that different conclusions regarding the approved erosion hazard zone delineations are

justified. The applicant bears the burden of proof for any modification of an approved EHZ.

iii. **Demonstrate compatibility with District planning documents**. The applicant must demonstrate that any changes to an approved EHZ are compatible with the goals and management objectives of any approved or draft watercourse master plan or area drainage master plan, as well as with the technical data from any approved floodplain delineation study.

iv. **Construct structural measures**. Properly designed structural erosion control measures can modify an EHZ. Specific requirements for structural measures are outlined in Section 6.4 below.

6.3.2 Watercourses without Erosion Hazard Zones (EHZ). The following options are available for streams without a District-approved erosion hazard zone:

a. Provide structural erosion control. Engineered erosion control may be constructed in lieu of delineating and locating the mining operation outside the EHZ. Specific requirements for structural measures are outlined in Section 6.4 below.

b. Delineate the erosion hazard zone. More detailed information on delineating erosion hazard zones is provided in the District publication EROSION HAZARD ZONE DELINEATION AND DEVELOPMENT GUIDELINES. The following information applies to delineation of erosion hazard zones for a sand and gravel floodplain use permit application:

i. General information

1. Philosophy. The regulatory erosion hazard zone consists of the channel and floodplain area likely to be eroded by a "typical" series of floods over a 60 to 100 year period, including a 100-year flood, as well the natural channel movement due to geomorphic processes such as MEANDER MIGRATION or CHANNEL AVULSION. The erosion hazard zone is not intended to be limited to the distance the main channel banks might move in a single design flood. Therefore, the erosion hazard zone should be delineated based on consideration of a typical flood series over a long-term period.
2. Resources. Information on delineating erosion hazard zones can be obtained in the following documents:
    a. Flood Control District of Maricopa County. *Draft* Erosion Hazard Zone Delineation and Development Guidelines.
    b. Arizona Department of Water Resources. *State Standard 5-96 – Requirement for Watercourse System Sediment Balance*.
    c. FEMA. *Riverine Erosion Hazard Area Mapping Feasibility Study* (1999).
3. SEDIMENT TRANSPORT MODELING. In general, information provided by sediment transport computer models such as HEC-6 is not directly relevant to delineating lateral erosion hazard zones, although such modeling sometimes can be used to evaluate impacts of flood control alternatives, identify trends in sediment movement along a watercourse reach, or to predict reaches with SEDIMENT DEFICITS. More detailed information on computer sediment transport modeling is provided in Section 6.5.3.
4. Verification. Historical and field data are required to support any new EHZ delineation. In general, if historical or field data indicate that lateral erosion will occur, any contrary results from mathematical or theoretical analyses will be considered subordinate to verified historical and field data on stream behavior.

ii. **Required analyses**. At minimum, an erosion hazard zone analysis prepared in support of a sand and gravel mining floodplain use permit may include some or all of the following elements (* indicates required elements):

1. Engineering analyses*
   a. Bank stability assessment*
      i. ALLOWABLE VELOCITY/TRACTIVE FORCE/TRACTIVE STRESS
   b. Channel avulsion potential*
      i. Overbank flow DEPTH-VELOCITY-FREQUENCY ASSESSMENT
      ii. Identification of potential overbank flow paths
   c. STREAM BED STABILITY ASSESSMENT*
      i. General and local scour equations
      ii. Equilibrium channel slope
      iii. Armoring potential
   d. SEDIMENT CONTINUITY MODELING*
      i. Sediment yield (supply)
      ii. Sediment transport capacity
      iii. Sediment deficit/surplus analysis
   e. Geotechnical analyses
      i. Slope stability analysis
      ii. Resistance analysis
2. Geomorphic analyses*
   a. Field investigation*
      i. Main channel – evidence of erosion or stability
      ii. Floodplain – evidence of erosion, deposition, AVULSION
      iii. Comparison to adjacent reaches
   b. Bank stability assessment*
      i. Identification of LATERAL EROSION MECHANISMS
      ii. Bank characteristics – erodibility
      iii. Floodplain characteristics – avulsion potential
   c. Mapping of geomorphic surfaces*
      i. Delineate channels, floodplains, terraces and uplands
      ii. Delineate HOLOCENE and pre-Holocene surfaces
   d. Quantification of historical channel changes*
      i. Lateral channel change
         1. Maximum single event channel movement
         2. Maximum long-term channel movement
      ii. Vertical channel elevation changes
   e. Stream classification analysis
   f. Longitudinal profile analysis
   g. Channel pattern analysis
      i. MEANDER GEOMETRY EQUATIONS
      ii. Channel pattern evolution
      iii. HYDRAULIC GEOMETRY/REGIME EQUATIONS

More detailed information and technical references regarding these types of erosion hazard analyses can be obtained from the District's *Draft Erosion Hazard Delineation and Development Guidelines*, as well as from the citations listed above or from reports prepared for District-approved erosion hazard studies on file in the District library cited in Section 11.

NOTE: A Lateral Erosion Hazard Analysis Section is not required in the Engineering Report if the proposed sand and gravel operation is located on a stream reach that has an existing District-approved erosion hazard zone delineation for that reach, or if the entire sand and gravel operation is located outside the regulatory floodplain and erosion hazard zone.

6.4 Structural Measure Design

The objective of the Structural Measure Design Section of the Engineering Report is to demonstrate that any structural measures proposed in support of the mining operation are designed according to standard accepted procedures, will withstand flooding and erosion, meet all relevant FEMA and District regulations for activity within the floodplain, and will protect public health, safety, and welfare. The following criteria will be used to review and evaluate structural flood control measures:

6.4.1 District Design Guidelines. Hydraulic design criteria for channels and *flood control structures* adopted by the District are specified in the *Drainage Design Manual for Maricopa County – Hydraulics*. Additional structural mitigation measures are described in the following documents:
  a. Effects of In-Stream Mining on Channel Stability (Li et. al., 1989)
  b. Sand and Gravel Mining Guidelines (Boyle Engineering, 1980)
  c. Technical Review Guidelines for Gravel Mining Activities (Wright Water Engineers, 1987)

6.4.2 FEMA Requirements for Flood Control Structures. If the applicant intends to revise the FEMA-approved floodplain or floodway delineation, FEMA criteria outlined in 44 CFR Parts 60, 65, and 70 must be used in addition to District guidelines to assure FEMA acceptance of the revision.

6.4.3 General Design Guidelines for Flood Control Structures. The District will evaluate proposed flood control structures using the following general guidelines:
  a. Structures must withstand the design event (Q100 or as specified in WCMP).
  b. Structures must function for the projected life of the excavation.
  c. Structures must be incorporated into the reclamation plan.
  d. Structures must be maintained and inspected by the owners.
  e. Structures should have no adverse impact on adjacent properties (Section 6.5)

6.4.4 Specific Design Guidelines for Flood Control Structures. The District will evaluate the design of proposed flood control structures using the following specific criteria:
  a. Channel conditions. Because structures located within the EHZ may be exposed by lateral erosion, they must be designed using hydraulic data for the main channel. Where the main channel is wide and complex, the maximum rather than the average channel depth and velocity should be used as the basis of design.
  b. Toe-down. Structures should be toed-down below the 100-year depth of scour plus the long-term scour depth. Structures located within the EHZ should be toed down below the main channel scour depth.
  c. Lateral tie-in. Structures should be laterally tied in to stable, non-erosive surfaces to prevent flanking.
  d. Freeboard. Freeboard requirements for structures are listed in the *Drainage Design Manual for Maricopa County – Hydraulics*.

6.4.5 Documentation. Engineering designs should be thoroughly documented by computations, design drawings, typical sections, standard details and specifications included in the Engineering Report appendixes.

6.5 Impacts Analysis

The case histories documented in Section 11 describe disastrous and costly flood damages linked to in-stream sand and gravel excavations. The objective of the Impacts Analysis Section of the Engineering Report is to demonstrate that a proposed mining operation does not adversely impact adjacent properties or nearby structures, to document that relevant floodplain regulations are met, and to demonstrate that the proposed project poses no threats to public health, safety, and welfare. In general, the proposed mining operation should have no adverse impacts or changes in floodplain characteristics on adjacent properties without written permission of all affected landowners and approval by all relevant public agencies.

6.5.1 Regulatory Floodplain/Floodway Impacts. Hydraulic modeling of the pre- and post-project channel and floodplain conditions must be submitted and approved by the District to document the following:

a. **Floodplain**.
   i. Changes in the base flood (100-year) water surface elevation must be less than one foot within the property limits.
   ii. No changes in the base flood (100-year) water surface elevation may occur on adjacent properties.

b. **Floodway**.
   i. No changes in the regulatory floodway elevation are permitted, either within or adjacent to the proposed project limits.

6.5.2 Stream Stability and Sedimentation Impacts. Engineering analyses must be submitted to document that no adverse impacts occur on adjacent properties due to the proposed sand and gravel excavation. It is recommended that the applicant's engineer meet with District staff prior beginning any analyses to discuss and review the engineering methodologies to be used to evaluate sedimentation impacts. References describing the methodologies and procedures outlined below are provided in Section 11 of these guidelines.

a. **Streamlined review criteria**. Based on findings documented in previous District studies, mining activities in the flood and erosion hazard zone will be considered to have no significant sedimentation impacts if all of the following conditions are met:
   i. 10-year floodplain –
      1. No activity within, or alteration of, the 10-year floodplain.
      2. No change in 10-year width, depth, velocity or water surface elevation.
   ii. 100-year floodplain –
      1. Increase in water surface elevation and depth of less than 0.1 foot.
      2. Increase in channel or overbank velocity less than 10% and/or 1ft/s.
   iii. Erosion hazard zone –
      1. The excavation is located entirely outside the erosion hazard zone, or
      2. The excavation is protected from lateral erosion or capture of the main channel by engineered flood control structures.
   iii. Reclamation plan –
      1. The reclamation plan prevents inundation of the abandoned excavation during a 100-year flood (or the return period specified in an applicable watercourse master plan), or includes structural measures to limit erosion caused by pit inundation.

b. **Sedimentation impacts from floodplain encroachment or channelization**. The engineering analysis must address each of the following types of sedimentation impacts:
   i. Deflection scour. Deflection scour occurs on a stream bank when the channel or floodplain alignment is changed causing changes in flow direction, or where only one bank is protected, thus limiting the available sources of sediment in the reach. The following conditions can lead to reflective scour:

1. Change in the main channel alignment
2. Change in the overbank flow path alignment
3. Concentration of overbank flow
4. Increase in percentage of flow carried in the main channel due to overbank encroachment or deflection
5. Protection of only one channel bank
6. Severe contraction of the channel or floodplain

The evaluation of potential deflection scour should account for development of adverse channel alignment caused by exposure of proposed flood control structures following long-term channel movement. Channelization or structural measures located within the EHZ should be designed with smooth transitions.

ii. Contraction scour. Floodplain encroachment increases flow velocity and depth, which results in increased channel bed erosion and sediment transport capacity. Hydraulic data from the pre- and post-project hydraulic models should be used in conjunction with an approved sediment transport function to demonstrate that the proposed mining plan does not increase scour, erosion, or deposition on any adjacent property.

c. **Sedimentation impacts from pit capture or inundation**. The engineering analysis must address each of the following types of sedimentation impacts:

i. Upstream scour and degradation. Upstream scour occurs when floodwater enters a sand and gravel mine excavated below the grade of the surrounding floodplain or channel. Upstream scour consists of two primary elements: (1) a HEADCUT that migrates upstream as floodwater falls into the pit and erodes the upstream face of the excavation, and (2) LONG-TERM DEGRADATION as the watercourse adjusts to a new base level provided by the bottom of the excavation. More detailed descriptions of headcut and degradation processes are provided in the technical references provided in Section 11. The engineering analysis of upstream scour should include the following elements:

1. Headcut movement during the design hydrograph.
    a. Headcut movement during the design hydrograph shall be limited to the property owned by the mining operator, unless all potentially affected adjacent property owners provide written consent to allowing their property to be impacted by a headcut.
    b. Headcut modeling procedures are provided in Li et. al. (1989, “The ADOT Report”).
2. Headcut movement during other flow events. The rate of headcut migration can be slowed by rapid filling of the excavation by floodwater. Therefore, headcut movement may be more severe during a long-duration, low magnitude event than during the design event. The engineer should document whether the design event or another flow event controls the headcut migration process by investigating headcut migration under various inflow hydrographs.
3. Headcut movement during multiple flow events (long-term degradation). Unless sediment removed from the upstream channel during headcut migration is replaced, and the pre-flood channel conditions are restored, the headcut will continue to deepen and extend upstream during subsequent floods. In effect, the bottom of the excavation will become the stream’s new base level to which the upstream reaches will adjust. Furthermore, in most mining scenarios, sediment deposited in the excavation during a flood will be mined, returning the excavation depth to the pre-flood depth and establishing a condition favorable to continued

headcut formation. Therefore, the engineering analysis should document the potential headcut migration and characteristics over the design life of the excavation. The engineer should model the potential upstream headcut and degradation over a series of floods, with consideration of likely post-flood mining practices, and incorporation of the proposed reclamation plan.

4. Headcut modeling notes:
   a. Headcutting is affected, but not prevented, by a high water table. The technical references listed in Section 11 document numerous instances of headcut formation and degradation on perennial streams. The engineer should not assume that headcut depth is limited to the water table. Where the engineering analysis relies on the depth of the water table, the engineer should provide documentation regarding the historical and future stability of water table elevations.
   b. Headcut analysis, as described above, is required for any excavation located in the EHZ or that is subject to capture by the main channel.
   c. Headcut analysis for an excavation located outside the EHZ, but within the floodplain, should be based only on the part of the hydrograph intercepted by the excavation.
   d. No headcut analysis is required for excavation not subject to capture by the main channel or not subject to 100-year flood inundation.
   e. In general, headcutting analyses should show that long-term degradation will occur upstream of in-stream excavations unless structural erosion control measures are provided.

ii. Downstream degradation. Downstream degradation is caused when sediment is trapped within an excavation, and sediment-deprived water flows out of the excavation into downstream reaches. Downstream degradation can be estimated using procedures outlined in technical references listed in Section 11.
   1. ADOT Procedure. The methodology described in Li et. al. (1989; Volume II, Chapter X, p. 72-86) is recommended for most applications.
   2. Sediment modeling. If the excavation does not intercept the entire active channel and floodplain, computer sediment models of downstream degradation may significantly underestimate downstream impacts. The engineer should use alternative methods, such as the ADOT long-term procedure, to evaluate potential downstream scour.

iii. Channel deflection or realignment. If a sand and gravel excavation is subject to capture by lateral erosion or inundation by FLOODWATERS, the engineer should demonstrate the following:
   1. Floodwater cannot exit the flooded excavation. In this case the flooded excavation will be a slackwater zone subject only to deposition and ponding.
   2. The proposed excavation design accounts for potential inundation. In this case the engineer must demonstrate that floodwater will maintain its pre-capture characteristics and conditions, and that flow will exit the mining site in a manner that will not affect adjacent stream reaches, will not enter the main channel or floodplain at a skew or cause a deflection of floodwater toward an adjacent stream bank.

d. **Cumulative impacts analyses**. The District will consider the effect on the river system, adjacent properties, and public infrastructure if all landowners along the watercourse were allowed the same degree of impact on the river system as the permit applicant. On streams lacking a watercourse master plan, the District may require a cumulative impacts analysis as part of the floodplain use permit application Engineering Report.

6.5.3 Guidelines for Use of Computer Sediment Transport Modeling. In the past, many engineers have attempted to evaluate the impacts of sand and gravel mining using sediment transport computer models, such as the U.S. Army Corps of Engineers' HEC-6 model. However, the District's experience with such models is similar to that of the American Society of Civil Engineers (ASCE, 1998, Journal of Hydraulic Engineering, p. 881), which concluded that existing computer models have numerous deficiencies, including the inability to accurately predict lateral bank erosion. Therefore, sediment transport computer modeling is not required to support most floodplain use applications and should be used with caution according to the following guidelines:

a. **Model assumptions**. The engineer should explicitly address in the Engineering Report all the limitations and assumptions typically in the computer model user's manual to assure that model is being applied appropriately. Typical limitations and assumptions of sediment transport computer models for stream conditions in Maricopa County include the following:
    i. Inability to simulate the magnitude of lateral erosion known by historical data
    ii. Inability to simulate lateral erosion by avulsion processes.
    iii. Inability to simulate the effects of soil cohesion, vegetation, or local variations in soil characteristics on transport rate and erodibility.
    iv. Inability to simulate natural floodplain processes, such as simultaneous overbank deposition and channel scour (or vice-versa).
    v. Inability to simulate sediment transport where two-dimensional flow, braided flow, or split flow occurs.
    vi. Inability to simulate transport of large diameter sediment sizes, such as cobbles, which are known by field evidence to be transported.
    vii. Inability to simulate the effects of base level adjustments such as headcutting.

   The engineer should determine and certify whether and how any of these or other model limitations affect the proposed application or impact analyses.

b. **Modeling Approach**. The engineer should describe the proposed modeling approach. Specifically, the engineer should demonstrate how the localized impacts of the pit will be analyzed using the selected computer model(s), and how the model algorithms will simulate locally variable sediment transport characteristics across individual cross sections, between adjacent cross sections, and within impacted and non-impacted portions of the floodplain and channel, as well as how model results will be interpreted for assessing sedimentation impacts.

c. **Selection of flood hydrographs**. If sediment transport models are used, the following range of hydrographs should be modeled:
    i. Design event. Typically, a 100-year hydrograph is used. However, the engineer should determine whether another event could have more significant impacts than the 100-year event and should be considered as the design event in addition to the 100-year event.
    ii. Flood series. Modeling should be performed using an assumed series of multiple small and large floods that attempts to simulate long-term channel responses to the expected range of floods that would occur over a 100-year period.
    iii. Long-duration flow. Flow duration is often more important than peak discharge in determining channel changes. Some engineers have attempted to predict

expected long-term channel response by modeling a constant bankfull discharge over durations of up to several years.

d. **Verification**. The engineer must provide information that verifies the results of the sediment transport computer model. The verification information should include the following:

   i. Water surface elevations. The step-backwater hydraulic modeling component of the sediment transport model should be verified by comparing water surfaces established by the appropriate floodplain delineation study with those from the sediment transport model.

   ii. Lateral erosion. Lateral erosion predicted using the computer model should be comparable to magnitude of single event and long-term lateral erosion identified from historical data.

   iii. Scour estimates. The magnitude of single event scour predicted by the sediment transport computer model should be comparable to channel and long-term scour estimates computed using equations outlined in publications listed in Section 11. In addition, long-term scour predicted by the sediment transport computer model should be comparable to long-term scour estimated from historical topographic information and field data.

   If the computer model results cannot be verified or cannot simulate known historical channel responses, the modeling approach should be modified or abandoned.

e. **Interpretation of model results**.

   i. Trend analysis. In general, sediment transport modeling results are best interpreted as order-of-magnitude indications of the potential trend of channel behavior, rather than precise estimates of the actual response.

   ii. Comparative analysis. Sediment transport modeling can be effectively used to compare the relative predicted pre- and post-project trend of response, or to compare the relative response of various flood control alternatives.

f. **Coordination with District review staff**. To facilitate the permitting process and to prevent any wasted effort and funds by permit applicants, engineers are strongly advised to coordinate any computer modeling efforts with District staff prior to undertaking the modeling effort and prior to submittal of results.

6.6 Local Drainage Analysis

The objective of the Local Drainage Analysis Section of the Engineering Report is to demonstrate that local runoff flowing into and out of the project area is addressed. Local runoff should be safely conveyed around the mining operation or accounted for by engineering measures. The District regulates flood and erosion hazard zones for all watercourses with 100-year discharges greater than 50 cfs.

Specific drainage criteria for development are outlined in the following documents:

- Drainage Regulations for Maricopa County
- Floodplain Regulations for Maricopa County

Both of these documents are available at www.fcd.maricopa.gov.

6.7 Statement of Findings

The objective of the Statement of Findings Section of the Engineering Report is for the engineer of record to provide a concise summary of the results of each analysis, a definitive statement that all relevant County regulations are met, and that no adverse flood or erosion impacts are likely to occur to any off-site property due to the proposed plan. The Engineering Report Statement of Findings Section must include a definitive statement for each of the following areas:

- 6.7.1 Floodplain standards have been satisfied
  - a. FEMA
  - b. Local
- 6.7.2 Floodway standards have been satisfied
  - a. FEMA
  - b. Local
- 6.7.3 No offsite impacts will occur
  - a. Upstream
  - b. Downstream
  - c. Tributaries
  - d. Local drainage
  - e. Structures
  - f. Groundwater
  - g. Stream form and function
- 6.7.4 Need for structural flood control has been addressed
  - a. Vertical scour and degradation
  - b. Lateral erosion
- 6.7.5 A reclamation plan is provided
- 6.7.6 Compliance with regulations and guidelines
  - a. FEMA
  - b. Flood Control District of Maricopa County
  - c. Maricopa County Watercourse Master Plan
  - d. All State and Federal agency permits will be obtained prior to mining

6.8 Documentation

Thorough documentation of the engineering analyses used in the Engineering Report will facilitate the District's review. The following types of documentation are required:

- 6.8.1 Engineering Calculations
  - a. Calculation worksheets
  - b. Spreadsheets (digital version) with explanation of equations used in spreadsheet
  - c. References for all equations used
  - d. References for all methodologies used
- 6.8.2 Computer Modeling
  - a. Input files (digital version required)
  - b. Output files
- 6.8.3 Engineering Design
  - a. Typical sections and details
  - b. Plan, profile, and stationing
  - c. Supporting calculations
  - d. Design standards reference
- 6.8.4 Soils/Geotechnical Analyses

a. Sampling location map
b. Laboratory results

6.8.5 Survey
a. Field notes
b. Description of datum and coordinate system

6.8.6 Bibliography
a. Technical references used
b. Mapping sources
c. Previous studies
d. Floodplain delineation studies
e. Watercourse master plans
f. Area drainage master plans

Note that engineering analyses may require revision after a major flood to reflect changes in watercourse conditions.

Section 7
Reclamation Plans

Reclamation plans are required for all sand and gravel operations that require a floodplain use permit. The District intends to develop specific reclamation plan guidelines for sand and gravel mining operations located in flood and erosion hazard zones. Applicants should check with District staff to determine the status of the reclamation plan guidelines.

Until the District reclamation guidelines are completed, the following interim reclamation plan guidelines are recommended:

1. Proposed finished contour elevations should be provided for the mining site after excavation is completed.
2. Proposed minimum elevations for any backfilled excavations should be clearly marked.
3. The location, stationing, and typical sections for permanent flood control structure should be shown and detailed on the reclamation plan sheets.
4. Cross section(s) showing finished side slopes and backfilled elevations should be provided.
5. A description of the reclamation plan phasing should be provided, including an anticipated timeline and projected schedule.
6. Bonding or financial assurance of compliance and reclamation should be provided that includes:
    a. Documentation of compliance with Floodplain Regulations
    b. Bonding plan data – description of performance assurance requirements
7. Boundary survey
    a. Required upon abandonment of mining operation
    b. Boundary survey must comply with Arizona Board of Technical Registration current minimum standards for land boundary surveys.

In general, the reclamation plan should demonstrate that the final state of the excavation will be stable, will not result in increased flood and erosion hazards on adjacent properties, and will not be subject to flood and erosion damage. Reclamation plans should be developed considering the ultimate future use of the post-mining property, revegetation to natural conditions, and public safety.

Section 8
Certification Forms

Certifications may be required to support the Floodplain Use Permit application, depending on the specific conditions of the mining location, as indicated in Table 8-1. The following certification forms are provided in this section:

- Form 8-1: Certificate of Agency Permit Compliance
- Form 8-2: Property Owner's Letter of Authorization
- Form 8-3: Transfer of Floodplain Use Permit Agreement Form
- Form 8-4: Assurance of Compliance Form – Legal Non-Conforming Operations
- Form 8-5: Certification of Compliance Letter – Renewal of Existing Floodplain Use Permit

Table 8-1. Certification Forms

Type of Floodplain Use Permit Application And Site Characteristics	Form 8-1	Form 8-2	Form 8-3	Form 8-4	Form 8-5
Legal Non-Conforming Mining Operation	R	X	NA	R	NA
Permit for New Mining Operation	R	R	NA	NA	NA
Permit Renewal for Existing Mining Operation	R	X	X	NA	R
Renewal and Amendment of Existing Mining Permit	R	X	NA	NA	R

Codes
R = Form is required — NA = Not applicable
NR = Form is not required — X = Form may be required, contact Floodplain Administrator

Applicants may not modify the content of the certification forms without prior authorization of the FLOODPLAIN ADMINISTRATOR. Notary service is available at the District main office (2801 W. Durango St., Phoenix, AZ 85009) for forms that require notarization.

The fees for permitting, renewal and amendments to floodplain use permits for sand and gravel extraction shall be as approved by the Board of Directors of the FCDMC.

Certification of Agency Permit Compliance **Form 8-1**

This is to certify that no mining will occur at the site indicated in this floodplain use permit application until all applicable environmental and regulatory permits have been approved and have been obtained from local, state, and federal agencies, including, as applicable, the U.S. Army Corps of Engineers Section 404 Permit, Arizona Department of Environmental Quality 401 Certification, National or Arizona Pollutant Discharge Elimination System (NPDES/AZPDES), Arizona State Mining Inspector, and Maricopa County Environmental Services Air Quality and Construction general permits. Copies of all applicable permits will be submitted to the District upon issuance and shall be made part of the floodplain use permit file.

__________________________ _____________________________ ________

Signature Printed Name/Title Date

Affix Notary's Seal:

Note: As directed by 44 CFR 60.3(a), the District requires documentation that an applicant for a floodplain use permit is in compliance with applicable permits from other local, state, and federal agencies. The District will approve a conditional floodplain use permit if proof of application for other agency permits is provided with the floodplain use permit application. However, no excavation in floodplains and erosion hazard zones may be conducted until documentation of approval of all relevant permits from other agencies has been received and acknowledged by the District. A list of agency permits and internet links is provided on the District's web page at www.fcd.maricopa.gov/permitting.

Property Owner's Letter of Authorization **Form 8-2**

If the applicant for the floodplain use permit is anyone other than the property owner, the property owner shall submit a letter authorizing the applicant to conduct the proposed activities on their land, and giving the applicant permission to apply for the appropriate permits. The authorization letter shall include the following language:

> *The property owner acknowledges that they will not divert, retard or obstruct the flow of water in any watercourse without written authorization from the District, and shall be bound by any stipulations stated in the floodplain use permit, including no adverse impact on adjacent properties, no hazard to life and property or to the watercourse, any stipulated requirement for bonding, and site reclamation plans.*

Documentation of the proposed mining site ownership must be attached to the Letter of Authorization. A lease agreement with proof of ownership may be submitting in lieu of the Property Owner's Letter of Authorization if and only if the lease contains the language noted in italics above. The Letter of Authorization shall be notarized.

Transfer of Floodplain Use Permit Agreement **Form 8-3**

Floodplain use permits for sand and gravel operations are not transferable without the District's written authorization and submittal of the following agreement:

I/we________________________________ [NAME] am the authorized owner/operator of __________ __________________________ [AGGREGATE MINING OPERATION] verify that I/we have read, understand and agree to the terms, conditions, and requirements of the existing floodplain use permit ___________ [PERMIT NUMBER] approved by the District. No changes or modifications to the previously approved permit conditions will occur without prior review and approval by the District.

Affix Notary's Seal:

Assurance of Compliance – Legal Non-Conforming Operations **Form 8-4**

I/we___________________________[NAME] the owner of parcels _____________________________ [PARCEL TAX ASSESSOR CODE] on which a sand and gravel operation is being conducted certify that the operation has not exceeded the limits of excavation that were in effect as of July 17, 1975.

Signed: _______________________________________

Date: _______________________________________

Affix Notary's Seal

Certification of Compliance Letter
Existing Floodplain Use Permit Renewal or Amendment **Form 8-5**

I/we___________________________[NAME] the operator/owner of the sand and gravel operation permitted under permit number _____________________________ issued by the Flood Control District of Maricopa County on ___________________________ [DATE], do hereby request renewal of this permit for a period of _____________________ [DURATION] years. I/we certify that the operation has been conducted in accordance with the approved plan of development and that during the renewal period for this permit (if approved) I/we WILL / WILL NOT continue to follow the approved plan of development.

If "will not" is chosen, a revised plan of development must be submitted with this certification, along with the Application for Renewal or Amendment

Signed: _______________________________________
Date: _______________________________________

Affix Notary's Seal:

Notes:
1. If no change to the approved plan of development is requested, the application shall be treated as a RENEWAL. If the plan of development is changed, the application shall be treated as a renewal and an amendment.
2. An application for permit renewal or amendment may be downloaded from http://www.fcd.maricopa.gov/Permitting/Floodplain.asp. The Application to Floodplain Administrator and Warning and Disclaimer of Liability must be signed and returned with appropriate fee to:
   Flood Control District of Maricopa County
   2801 W. Durango Street
   Phoenix, AZ 85009

Section 9: Approval, Compliance and Site Inspection of Active Permits

Applicant and District Responsibilities

Assurance of compliance may be determined by aerial photograph interpretation for legal non-conforming sites if possible.

9.1 District Inspections (Provided by District)

9.1.1 Routine Inspections. Form 9-1

District inspectors will in most cases conduct semi-annual inspections of sand and gravel operations located in flood hazard zones to assure compliance with permit conditions. The intent of the inspection is to verify compliance with permit conditions, including the following:

1. Depth of excavation
2. Extent of excavation
3. Side slope
4. Reclamation phasing and condition
5. Structure condition
6. Watercourse condition
7. Evidence of recent channel change or bank erosion
8. Property boundary stakes or markers
9. Condition of on-site temporary benchmark
10. Environmental and agency permit status

Inspections by the District will be conducted in addition to the assurance of compliance to be submitted by legal non-conforming operations and permitted operations. Any restrictions to access by District inspectors should be clearly spelled out in the floodplain use permit application.

Note that property boundaries shall be clearly marked, staked, or fenced for use by District inspectors verifying excavation limits and setbacks.

Routine inspections are scheduled to occur in six month intervals.

9.1.2 Follow-Up Inspections After Notice of Violation Form 9-2

9.2 Assurance of Compliance (Provided by Permitee) Form 9-3

Assurance of compliance shall be submitted by the property owner or their authorized representative annually and shall include the following:

1. Verification of excavation depth
2. Verification of excavation limits

Assurance of compliance shall consist of a notarized statement by the property owner that the operation is in complete compliance with the stipulated conditions listed in the floodplain use permit as well as with the mining plan documented in floodplain use permit and/or engineering analysis. Documentation of assurance of compliance shall consist of an approved site plan showing the current excavation depth and limits sealed by an appropriate Arizona registered professional surveyor or engineer.

FORM 9-1

FLOOD CONTROL DISTRICT of Maricopa County
2801 West Durango Street
Phoenix, Arizona 85009
(602) 506-1501 (Office)
(602) 506-7346 (Fax)

COMPLIANCE INSPECTION REPORT

Permittee:		
Permit Number:	**Location:**	
Date:	**Time:**	**Inspector:**
Accompanied By (name, affiliation, title, phone #)**:**		

Synopsis

1) Activity:

2) Adverse Affects to Banks:

3) Material and Structures in Channel/Floodway:

4) Other Materials:

5) Maintenance of Drainage and Washes:

6) Pit Slopes:

7) Pit Setbacks:

8) Depth and Extent of Excavation/Operation:

9) Other:

Inspector's Signature:		**Date of Report:**	

FORM 9-2

District Inspector's Checklist

Project Name______________________________________ Floodplain Use Permit #_______________
Inspector Name_____________________________________
Date of Current Inspection____________________________ Date of Last Inspection________________

Follow-Up on Previous Non-Compliance Items

Watercourse Condition Documentation – describe changes
____ Attach recent aerial photograph (note changes from previous inspection)
____ Attach ground photographs (match photo location and aspect from previous inspection if possible)

Mining Operations Conditions
____ Excavation depth
____ Excavation limits
____ Property setbacks
____ Condition of flood control structures
____ Reclamation – progress vs. schedule

FORM 9-3

Assurance of Compliance

Permit Number ________________________________ Date _______________

I/we ____ [name], certify that the operation conducted on this site during the previous twelve (12) months has been in accordance with the approved plan of development.

Signed: ____
Date: ____

Notary Seal: _______________________________________

Required Attachments: documentation of current excavation depth and limits sealed by a registered professional engineer or surveyor.

Note: This form is to be submitted annually

Section 10: General Stipulations

Sand and Gravel Floodplain Use Permits

The following stipulations may be added to floodplain use permits for sand and gravel operations:

1. The property owner and their authorized representative (if applicable) have read, acknowledge and agree with all the stipulations and conditions of this floodplain use permit.
2. The Floodplain Use Permit shall be limited to five (5) years[4] from the date of approval, but may be renewed provided development has been in conformance to the approved plans, subject to modification made necessary by flow related changes in river morphology. Renewal will be evaluated for compatibility with the [Stream Name] Watercourse Master Plan if applicable.
3. Any substantial change, addition, alteration, modification, or deviation from the approved plan shall have prior approval of the District.
4. The use shall be subject to post-flood review. Modification of the permit may be necessary due to flood-related changes in river morphology.
5. The applicant shall apply for renewal at least six (6) months prior to the permit expiration date.
6. The applicant shall submit annual status reports, including the anticipated extent of activity during the next year.
7. Development shall be in compliance with the plan of development and mine plan report dated [date of plan] prepared by [Engineer] and reclamation plan dated [date of plan] prepared by [Consultant]. The reclamation plan shall be submitted along with the initial application.
8. Excavation depth shall not exceed [elevation or depth] as shown on the approved plan of development.
9. Excavation shall follow the slope(s) and depth(s) as approved on the plan of development.
10. Final reclamation when the mining operation is terminated must include removal of equipment and materials.
11. A reclamation plan is required for all new permit applications and permit renewals. The plan of reclamation and revegetation shall be reviewed at 50% of mining showing that it complies with the approved narrative report.
12. The plan of reclamation shall include backfilling to original ground elevations with inert construction waste material as specified in Section 1002.8 of the Floodplain Regulations for Maricopa County, or otherwise as approved by the Floodplain Administrator.
13. No stockpiling of tailings, overburden or sand and gravel shall obstruct, divert, or retard the natural flow of tributaries to the main watercourse.

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[4] The normal period of a permit is five (5) years. Under special circumstances, e.g., a period in which a Watercourse Master Plan or Watercourse Restoration is pending, a permit may be issued with a validity of less than five (5) years, at the discretion of the Floodplain Administrator, whose decision may be APPEALED in the normal manner.

14. Applicant shall comply and submit proof of clearance from the U.S. Army Corps of Engineers, if needed, prior to commencement of operation.

15. Applicant shall comply and submit proof of compliance with State water quality standards as administered by the Arizona Department of Environmental Quality prior to commencement of operation.

16. The applicant shall be responsible to stay informed of any flooding, storm runoff, or river flows that may be imminent, and for removing any portable equipment and structures, as required by this permit.

17. The applicant shall submit a signed Warning and Disclaimer of Liability Notice on a form provided by the District.

18. Approval of [permit #] does not convey any property rights, either real estate or material, and is not to be construed as consent, approval or authorization to cause any injury to property or invasion of rights or infringement of any Federal, State, or other local laws, rules or regulations nor does it obviate the requirement to obtain other permits. The floodplain use permit is not transferable without the written authorization of the floodplain administrator. Furthermore, the plan review by the District is solely for the purpose of determining that the application conforms with the written requirements of the Floodplain Regulations for Maricopa County and is not to be taken as a warranty that structural plans and specifications meet engineering requirements or standards or are free from failure to perform as described or designed in the application, reports or plans as submitted. Approval does not imply that the total drainage concept for the site has been reviewed or approved by the District.

Section 11: Technical References
For Engineering Analysis of In-Stream Mining

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Section 12: Glossary

Note: Terms defined in the Floodplain Regulations for Maricopa County are available at www.fcd.maricopa.gov/services/FCDMC_Fldpln_Regs_00.pdf.

Appendixes: Case Histories

Impacts of In-Stream Sand and Gravel Mining on Channel Stability

Documentation of flood damages attributed in in-stream sand and gravel mining is provided in the following four accounts from Arizona and the Southwest:

- Appendix A. Case History #1: Bridge Failure
  Indian School Road, Agua Fria River, February 1980
- Appendix B. Case History #2: Headcutting
  Tujunga Wash, February 1969
- Appendix C. Case History #3: Lateral Erosion
  Ina Road, Santa Cruz River, October 1983
- Appendix D. Case History #4: Long-Term Degradation
  Salt River, 1903-2001

Case History #1: Bridge Failure
Indian School Road, Agua Fria River, February 1980

Introduction

The Indian School Road Bridge over the Agua Fria River collapsed during the February 20, 1980 flood. The Indian School Road Bridge is located west of Phoenix in Maricopa County, Arizona (Figure 1). Post-flood engineering analyses and a lawsuit concluded that the bridge failure was due in part to channel narrowing and encroachment caused by sand and gravel operations located immediately downstream of the bridge.

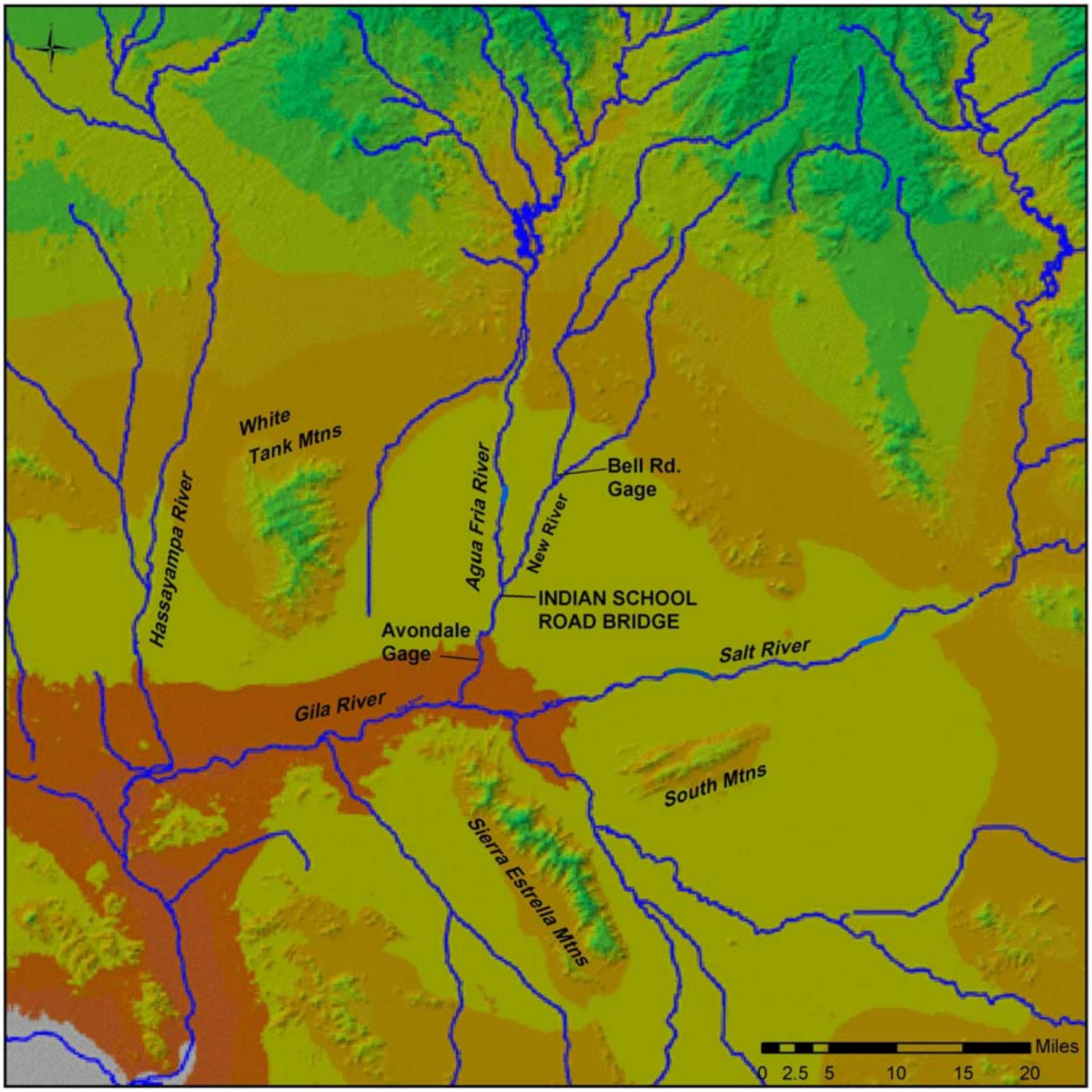

Figure 1. Shaded digital elevation model showing location of the Indian School Road Bridge failure site, USGS gages, major rivers, and mountain ranges.

Bridge Description

The Indian School Road Bridge was constructed in 1970 by the Maricopa County Department of Transportation. The original bridge was an 18 span, 1623-foot, two-lane bridge, which was widened to 4 lanes in 1977. The bridge was supported by pointed-nose wall piers on spread footings, with spill through abutments on pile footings. The piers were skewed 11 degrees from perpendicular to the bridge centerline. At the time of construction, the pier spread footings were located approximately 25 feet below the channel bed elevation. Piers 13 through 16, which are located near the east bank of the Agua Fria River (Figures 7 and 8), were damaged during the February 1980 flood, causing the collapse of several bridge spans. The bridge was designed for the 50-year flood, which was estimated at 73,800 cfs (MCDOT, 1966).

Reach Description

The Indian School Road Bridge is located over the Agua Fria River approximately nine river miles upstream of the confluence with the Gila River and about one mile downstream of the New River confluence (Figure 1). The Agua Fria River is an ephemeral sand and gravel bedded stream, with poorly defined and unstable banks, and subject to rapid and extensive channel change (SLA, 1982; JEF, 2001). Historically, prior to urbanization of the watershed, the Indian School Road Bridge reach of the Agua Fria River had a strongly braided channel pattern, with numerous wide channels divided around alluvial islands, a slope of about 0.003 feet/feet, and overall low sinuosity (SLA, 1982). Today, the Indian School Road Bridge serves as the upstream limit of a 4.4-mile channelized reach constructed by the U.S. Army Corps of Engineers in the mid 1980's. The Corps' channelization consists of 14-foot high raised soil cement levees and grade control structures that narrowed the natural floodplain from about 6,000 feet to the channelized width of about 1,100 feet.

Human impacts on the Indian School Road Bridge reach of the Agua Fria River have been significant. Construction of seven major flood control and water supply dams, introduction of urban storm water and irrigation return flows, urbanization of the lower watershed, bridge construction, channelization, and floodplain encroachment have altered the natural hydrologic regime, channel geometry, and floodplain characteristics. Many of these human impacts were present at the time of the construction and failure of the Indian School Road Bridge. In addition to channel change initiated by construction of the bridge itself, in-stream sand and gravel mining began downstream of Indian School Road as early as 1958. Extensive mining of the east side of the Agua Fria River by one operation (East Mine Site) and the west side by a second mining operation (West Mine Site) began around 1970 (SLA, 1982), the same year the Indian School Road Bridge was constructed (Figure 2). In 1973, at the request of Maricopa County, 135,925 cubic yards of waste rock was placed in the East Mine Site to fill in-stream pits located immediately downstream of the Indian School Road Bridge. Perimeter dikes built around the East and West Mine Sites between 1973 and 1975 narrowed the channel of the Agua Fria River to about 800 feet wide (SLA, 1982).

Figure 2. Historical aerial photography of the Agua Fria River at the Indian School Road Bridge alignment.

Figure 3. Aerial photograph showing channel conditions at Indian School Road prior to the 1980 flood.

Channel changes in the Indian School Road Bridge reach also occurred in response to flooding and natural river processes. Shifting of the low flow channel and braided stream segments is well documented by historical aerial photographs (JEF, 2001; Figure 2). Prior to 1967, the dominant low flow channel of the Agua Fria River was located on the east side of the floodplain. By 1970, when the Indian School Road Bridge was designed, the east channel had been nearly abandoned in favor of a channel located on the west side of the floodplain. The Indian School Road Bridge was designed to span the low flow channel and west side of the floodplain. However, the 1978 floods reestablished the east channel as the dominant flow path that sharply impinged on the bridge approach 800 feet east of the left abutment. Since 1980, natural channel changes in the Indian School Road Bridge reach have been muted by human impacts to the river. In addition, the Indian School Road reach was subject to net degradation from the 1950's to the 1980's, a somewhat uncharacteristic trend for a braided ephemeral stream.

Storm Summary

A prominent low latitude storm track brought record amounts of rainfall to central Arizona during the winter of 1979-1980. Nearly continuous precipitation from February 13 to 22, 1980 dropped between 2 and 15 inches of rainfall over the Agua Fria River watershed (Figure 4). While rainfall totals ranged from two to four inches in the Phoenix Valley, orographic effects increased rainfall yields in the upper watershed to up to a record 16.63 inches at Crown King (USACE, 1981), more than half of the average annual rainfall for that station. The February storms filled Lake Pleasant to the capacity of Waddell Dam, and resulted in 23 days of runoff at the normally dry Agua Fria River at Avondale (Li et al., 1989). Very heavy rain from 6 a.m. to 12 p.m. over central Arizona on the morning of February 19 caused runoff that exceeded the capacity of Waddell Dam (USACE, 1981).

By midnight on February 19, up to 66,000-73,300 cfs was being released over Waddell Dam (Arizona Republic, 1980; PRC Toups, 1981; Simons et al., 1982). The peak discharge at the Indian School Road Bridge was estimated at about 44,000 cfs, about a 25-year flood (SLA, 1982). The difference in peak discharge between Waddell Dam and Indian School Road is due to flow attenuation over the 25 miles from Waddell Dam to the bridge, and inflow of about 12,000 cfs from New River (SLA, 1982; Pope et. al., 1998). The estimated flood hydrograph for the 1980 event is shown in Figure 5. The 100-year discharge of the Agua Fria River at Indian School Road was 94,000 cfs, according to the US Army Corps of Engineers (SLA, 1982).[1]

[1] Construction of New Waddell Dam in 1992 and other flood control structures on the Agua Fria River has reduced the 100-year discharge to 54,400 cfs at Indian School Road, and reduced the effective watershed size from 2,243 square miles to 392 square miles.

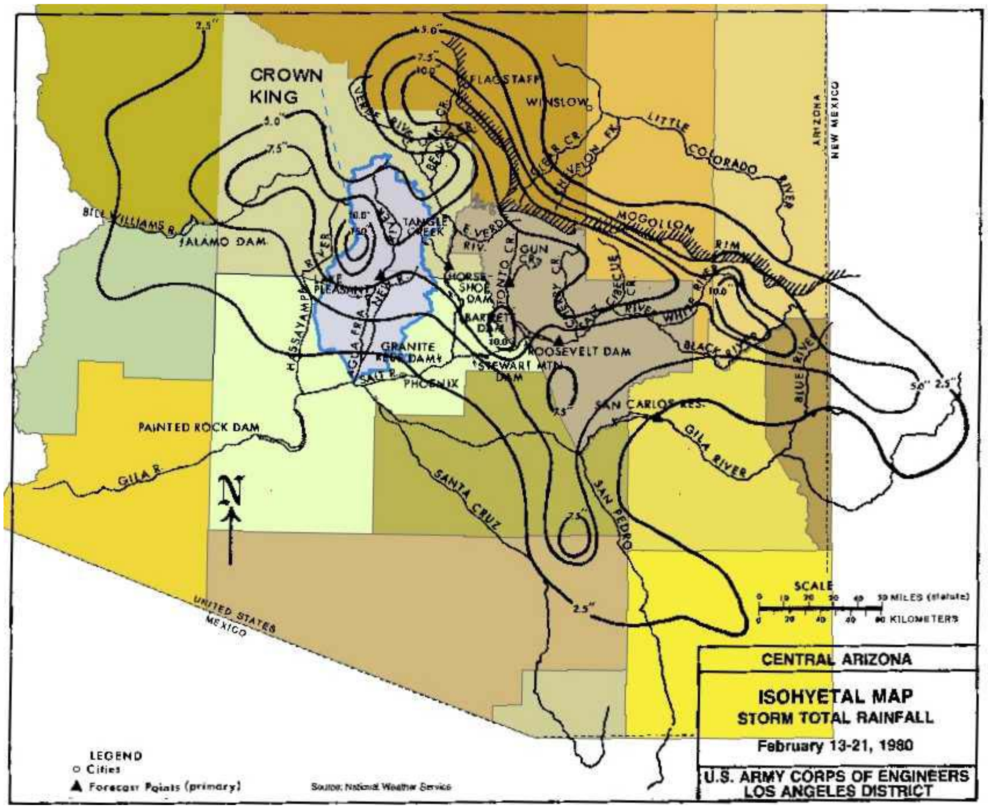

Figure 4. Isohyetal maps showing total rainfall depths for the February 13-21, 1980 storms over Arizona. The Agua Fria River watershed is shown in blue (Source: USACE, 1981).

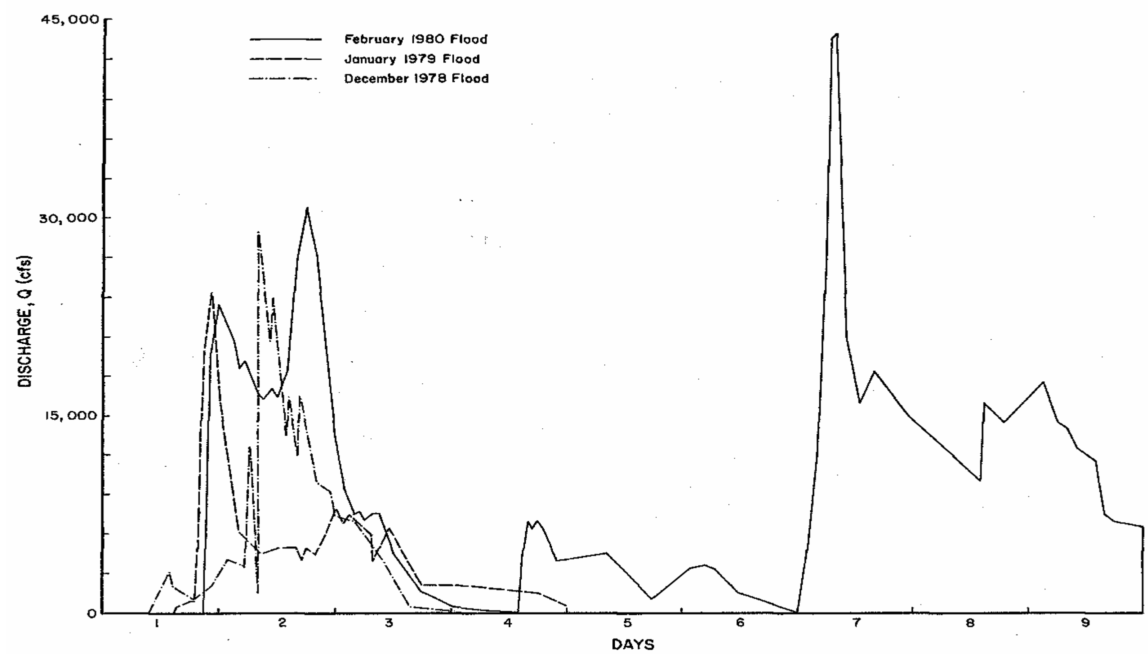

Figure 5. Estimated flood hydrographs for the 1978, 1979, and 1980 floods on the Agua Fria River at the Avondale gauge (Source: USACE, 1981). Note the rapid rise of the hydrograph on Feb. 20th 1980 where discharge jumped from 18,000 to 44,000 and back to 18,000 in less than 8 hours.

At 8:15 a.m. on February 20, Maricopa County highway workers noticed a sag in the Indian School Road Bridge. Within 10 minutes, a section near the eastern end of the bridge had dropped by 2.5 feet. About an hour later the bridge span between piers 15 and 16 collapsed into the river, leaving only two intact crossings over the Agua Fria River and tying up traffic for weeks (Arizona Republic, 1980). Photographs of the collapsed bridge are shown in Figures 6 to 8.

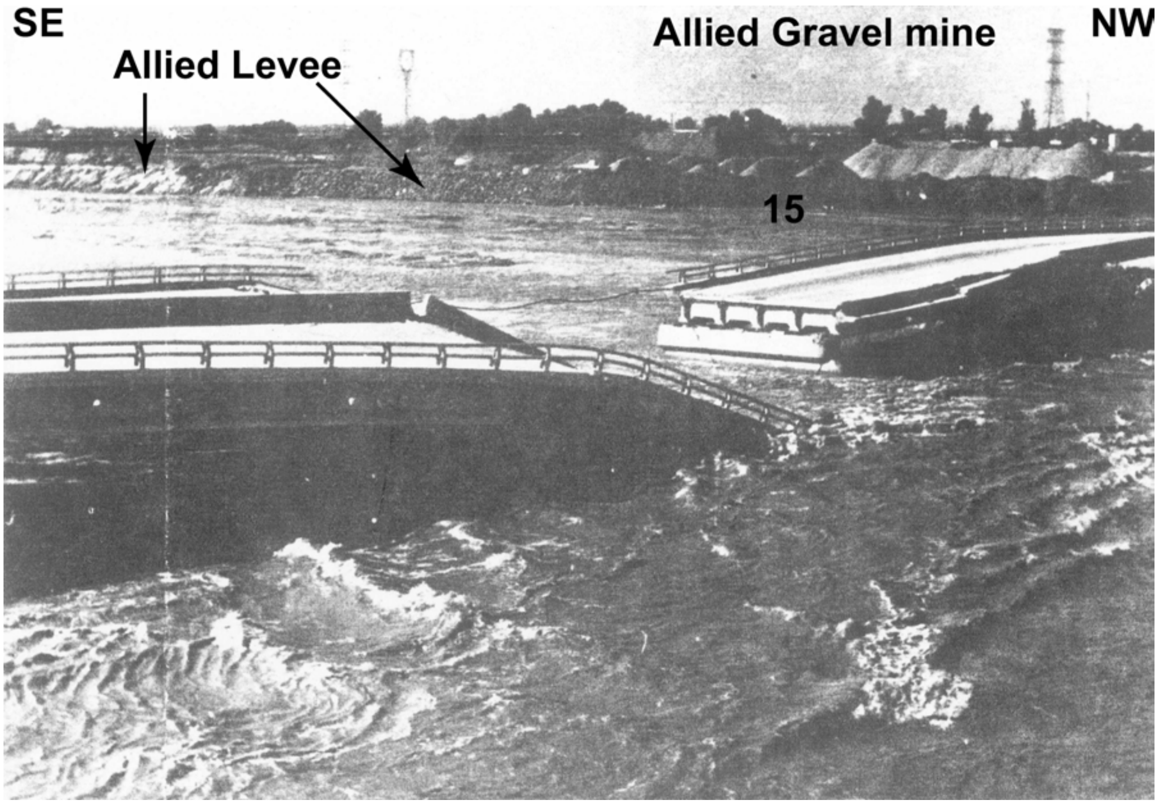

Figure 6. Photograph looking downstream at the Indian School Bridge collapse during the 1980 flood.

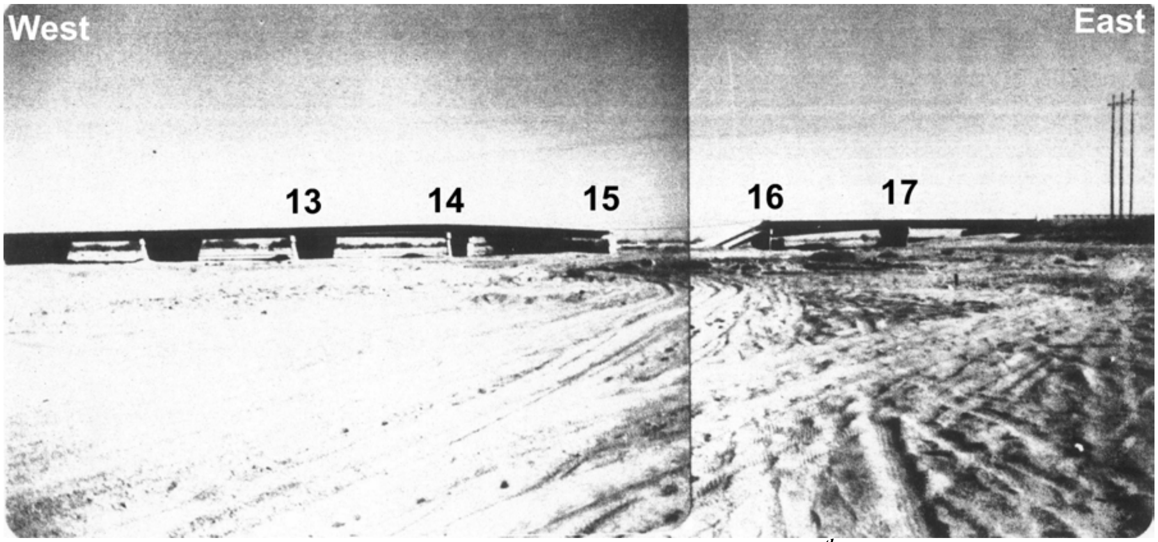

Figure 7. Photograph looking upstream at failed bridge after February 26th. Pier numbering indicated.

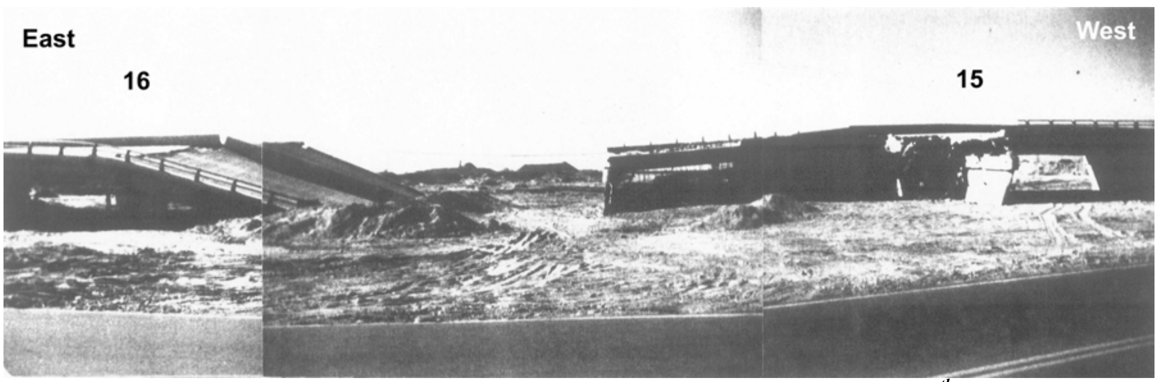

Figure 8. Photograph looking downstream (south) at failed bridge after February 26th.

Indian School Road Bridge Failure Investigations

After the Indian School Road Bridge collapsed in 1980, a number of agencies, attorneys, and engineers prepared forensic engineering reports to document the causes of the failure (Schultz, 1980; PRC Toups, 1981; SLA, 1982). The cause of the bridge failure was determined to be due to undermining of piers 13 to 16 near the east end of the bridge, resulting in collapse of one span and settlement of the adjacent spans. While these reports assigned different degrees of importance for the causes of the increased scour that led to the bridge collapse, they all consistently cited the following two basic causes:

1. Causes Related to In-Stream Sand and Gravel Mining. Sand and gravel mining had the following impacts on the stability of the Indian School Road Bridge:
   - *Channel Constriction*. Perimeter levees built around the East and West Mine Sites located 300 feet downstream of the Indian School Road Bridge constricted the Agua Fria River channel and floodplain to a width of 800 feet, 50 percent

narrower than the Indian School Road Bridge opening, and about 10 percent of the natural floodplain width (Schultz, 1980; PRC Toups, 1981; SLA, 1982).

- *Channel Narrowing*. Narrowing of the bankfull channel and floodplain width by in-stream and overbank mining increased scour depths due to increased channel velocities, turbulence, flow depths, water surface elevations, and sediment transport rates. These increases led to greater local scour as well as regional degradation that progressively lowered the channel bed elevation and changed the Agua Fria River from a braided stream to a degrading single channel (PRC Toups, 1981; SLA, 1982).
- *Decreased Bridge Capacity*. The West Mine Site perimeter levee effectively reduced the capacity of the Indian School Road Bridge by blocking the western cells of the bridge and increasing the unit discharge through the remaining cells on the east side of the bridge. Increased unit discharges resulted in increased scour depths (Schultz, 1980; PRC Toups, 1981; SLA, 1982).
- *Removal of Coarse Sediment*. In-stream mining tended to selectively remove large sediment sizes from the river, which increased scour in two ways. First, the potential for armoring that could limit regional and local scour depths was reduced. Second, backfill of local scour holes with finer, looser sediment during the receding limbs of previous floods made those areas more susceptible to future scour due to the lack of coarse sediment sizes (SLA, 1982).
- *Headcutting*. Settlement of poorly compacted or low quality sediment used to partially fill an in-stream excavation located 600 feet downstream of Indian School Road may have initiated a headcut that migrated through the bridge during the failure (SLA, 1982).
- *Channel Degradation*. Progressive lowering of the bed elevation of the Agua Fria River (Figure 9) due to direct excavation of the channel bed for sand and gravel mining, as well as regional degradation from the hydraulic and sediment supply impacts of regional in-stream mining in the Agua Fria River increased the depth of scour relative to the pier foundations (SLA, 1982).

2. Factors Related to Natural Channel Processes. Natural causes contributed to flood damages in the following ways:

- *Channel Migration*. Migration of the low flow channel and floodplain to the east dramatically increased the skew angle of flow through the Indian School Road Bridge (Figures 3 & 10). Increased skew significantly increases local scour due to increases in effective unit discharge and flow velocity (Schultz, 1980; PRC Toups, 1981; SLA, 1982).
- *Bridge Design*. Construction of the Indian School Road Bridge significantly narrowed the floodplain and blocked a historically active portion of the floodplain, resulting in a severe flow constriction along the east approach (SLA, 1982).

In addition, the forensic engineering reports determined that upstream development and historical construction of dams in the watershed had only negligible effects on channel conditions at the Indian School Road Bridge at the time of the failure (SLA, 1982).

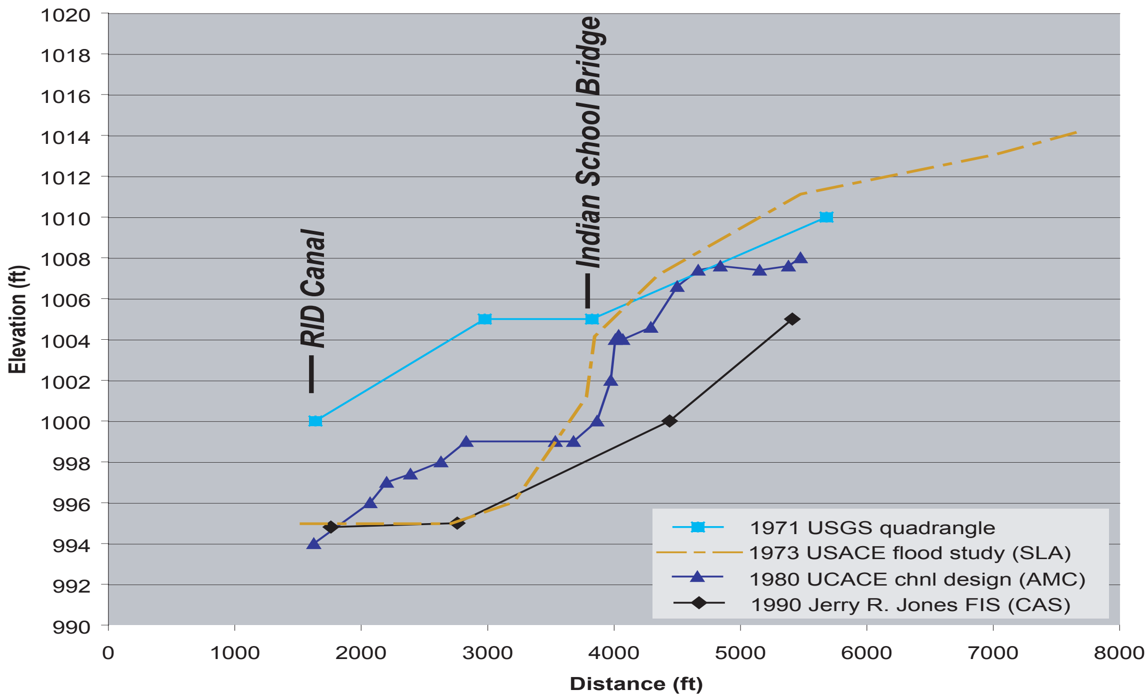

Figure 9. Thalweg profiles for the Agua Fria channel bed.

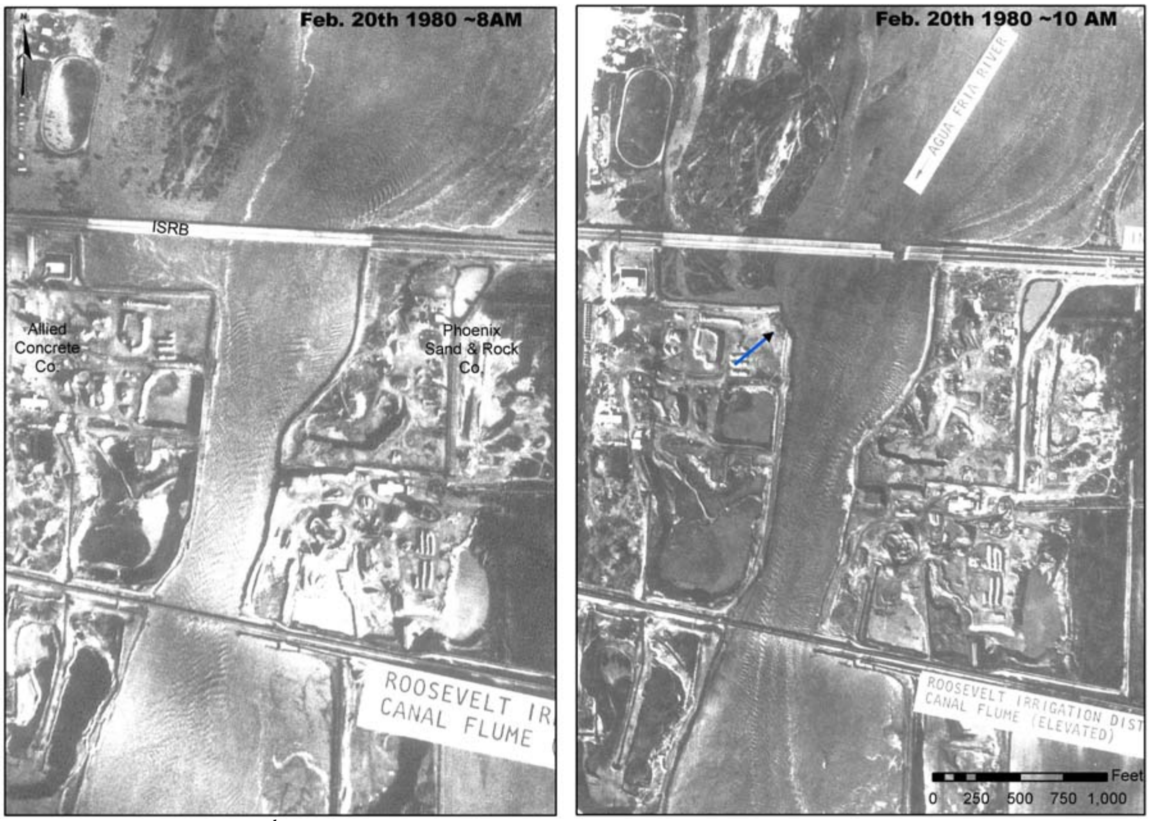

Figure 10. February 20th, 1980 aerial photographs taken before and after the Indian School Road Bridge collapse. Note the flow constriction at the ISRB, high angle of flow to the eastern piers, and erosion of the tip of the western levee (blue arrow).

Summary

The Indian School Road Bridge over the Agua Fria River failed during the February 1980 flood at a flow rate that was about half the discharge of the design flood for the bridge, or about a 25-year flood. Detailed scour, sediment transport modeling, and qualitative geomorphic analyses performed by SLA (1982) demonstrated that in-stream sand and gravel mining impacts increased scour depths sufficiently to undermine the pier foundations and cause the bridge failure. In addition to failure of the bridge, activities associated with sand and gravel mining were shown to have increased 100-year water surface elevations as much as 10 feet, initiated headcuts and regional channel degradation, and increased local and general scour in the Agua Fria River. A lawsuit filed by Maricopa County and the Roosevelt Irrigation District against downstream sand and gravel operators resulted in a $1.45 million settlement in favor of Maricopa County.

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Case History #2: Headcut Migration and Bank Erosion
Tujunga Wash – February 1969

Introduction

Capture of an inactive, off-channel sand and gravel pit on Tujunga Wash initiated a headcut that migrated 2,600 to 3,000 feet upstream and destroyed three bridges during back-to-back floods. The floods also caused bank erosion that destroyed seven homes, a residential street, and a long portion of a four-lane highway (Bull and Scott, 1974). This case history reviews the hydrologic, hydraulic, geomorphic, and anthropomorphic conditions that led to lateral and vertical channel change on Tujunga Wash during the floods of January and February 1969.

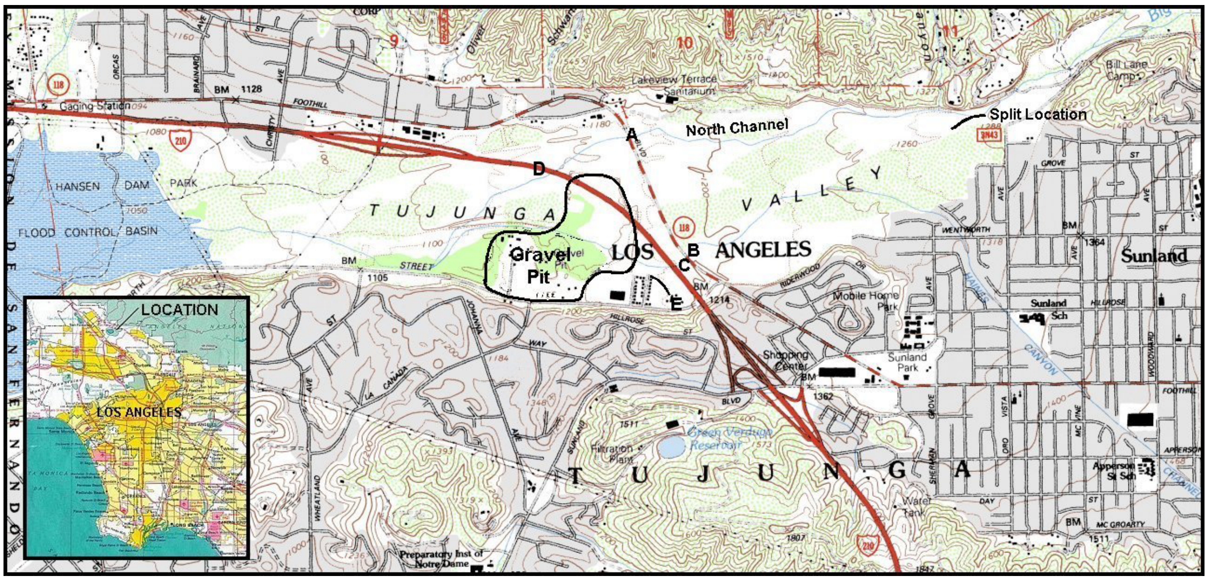

Figure 1. Map showing location of study area and points of interest.
A = Foothill Blvd. Bridge (North Channel) B = Foothill Blvd Bridge (South Channel)
C = Wentworth Place Bridge D = Interstate 210 (Built after 1969 flooding)
E = Bengal St. Terrace (7 homes and Bengal St. destroyed, also see Figures 7-8)

Site Description

The 115-square mile Tujunga Wash watershed drains the western San Gabriel Mountains and flows into the San Fernando Valley in Los Angeles County (Figure 1). As Tujunga Wash leaves the narrow canyons of the mountainous portion of the watershed, the floodplain widens significantly into a broad floodplain similar to an expanding alluvial fan. Prior to urbanization of the San Fernando Valley, the broad floodplain downstream of the mountain front was characterized by a sand-bed channel, multiple braided flow paths, and channels that migrated within the floodplain during floods. As urbanization proceeded, residential homes and development became more common along the Tujunga Wash floodplain fringe, particularly along the southern boundary of the floodplain. Intermittent sand and gravel mining began in 1925 in the southern portion of the floodplain. The 1,000 by 1,500 feet sand and gravel mining excavation that existed in

1969 was located in the floodplain, but well away from the main channel which was located up to 1,000 feet to the north of the pit (Bull and Scott, 1974). Three relief bridges were located roughly 1,000 feet upstream of the upstream edge of the pit. Two of these bridges were designed for motor vehicles, and the third was a footbridge (Figure 1).

Tujunga Wash is an ephemeral stream, meaning it only flows in response to significant periods of rainfall. Typically, large flow events and flash floods on Tujunga Wash occur during the winter and early spring. Long-term precipitation data were obtained for relevant portions of Los Angeles County and for the Tujunga Creek watershed from the Western Regional Climate Center.[1] Average annual precipitation values for four nearby gages are shown in Table 1. Gage locations are shown on Figure 2. For stations located on or near Tujunga Creek, the combined mean annual rainfall is approximately 18 inches for the periods of record, while the mean monthly precipitation for January and February at the Tujunga gage is 3.6 and 4.7 inches, respectively.

Table 1. Tujunga Creek and Adjacent Watersheds
Regional Long-Term Precipitation Stations

Station Name	Period of Record	Average Annual Precipitation (in)
San Fernando (1)	1927-1974	16.2
Canoga Park Pierce College (2)	1949-2001	16.6
Tujunga (3)	1966-1987	20.8
Burbank Valley Pump Pla. (4)	1939-2001	16.3

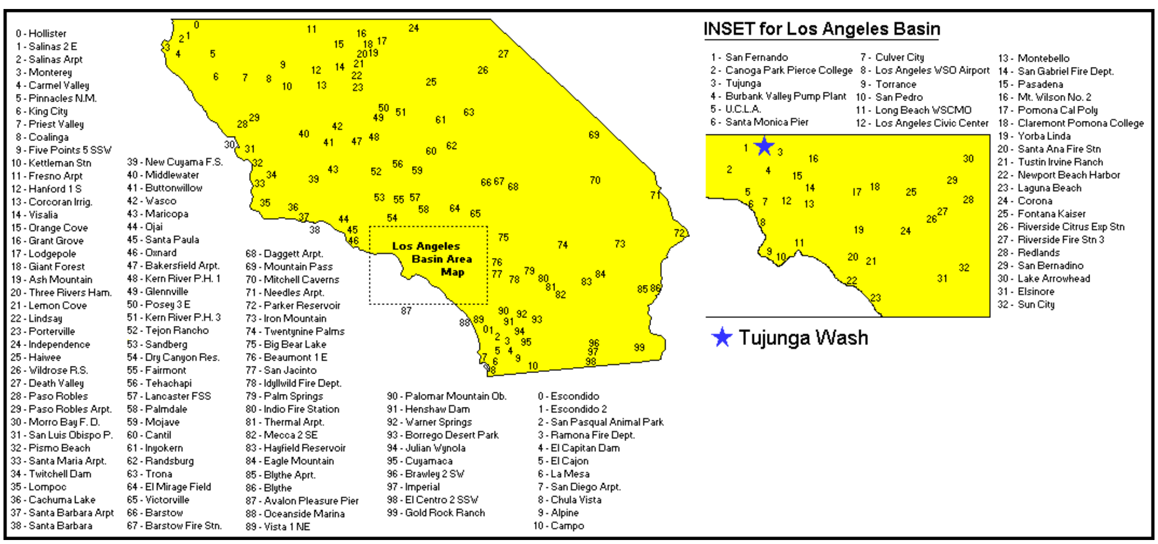

Figure 2. Location of regional long-term precipitation stations near Tujunga Wash.

Floods of 1969

Two storm events caused widespread flooding on Tujunga Wash in 1969. These storms occurred during the months of January and February, which had total monthly

[1] Western Regional Climate Center precipitation data are located at http://www.wrcc.dri.edu/index.html and mission and personnel data are at http://www.wrcc.dri.edu/wrccmssn.html.

precipitation of 17.1 inches and 16.3 inches, respectively, nearly equal to the mean *annual* rainfall for the gages shown in Table 1. Scott (1973) indicates that storms in January resulted in more rainfall than those of February, but saturated soil conditions during February caused runoff volumes and peaks comparable with the January event.

Hydrologic data for Tujunga Wash were collected from USGS stream gage records. Table 2 summarizes the results showing drainage area, 1969 discharge estimates, and the flood of record for each gage. Figure 3 shows the location of gages on or near Tujunga Wash. Note that the 1969 floods were about half the magnitude of the flood of record at the closest USGS gauge with the longest record (#11095500).

Table 2. USGS Stream Gage Records On or Near Tujunga Creek

Name	Station #	Period of Record	Drainage Area (mi^2)	Q 1969 (cfs)	Flood of Record	
					Q	Date
Tujunga Creek below Mill Creek Near Colby Ranch	11094000	1948-1970	64.9	20,700	20,700	1969-02-25
Tujunga Creek near Colby Ranch	11094500	1931-1950	67.5	-	14,800	1943-01-23
Big Tujunga Creek near Sunland	11095500	1916-1977	106	21,300	50,000	1938-03-02
Big Tujunga Creek below Hansen Dam	11097000	1933-2001	153	11,700	54,000	1938-03-02

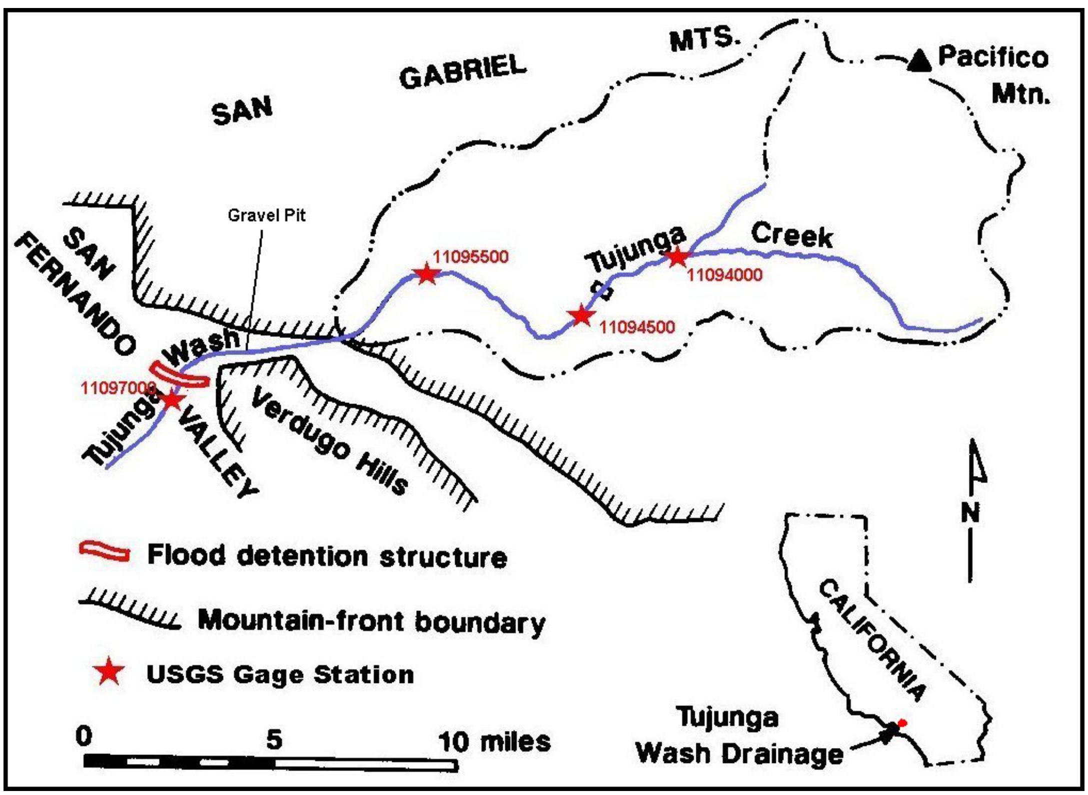

Figure 3. USGS gage station locations. Original figure taken from Scott (1973).

Gage records of annual peak flow indicate the occurrence of several major flood events during the combined period of record. The peak of the February 25, 1969 event was estimated at 21,300 cfs at the gage located closest to the Tujunga Wash study area and upstream of the flow split location shown in Figure 1. Scott (1973) reported an estimated peak of 20,600 cfs for the January flood at the USGS gage. Scott (1973) reported that inflow into Hansen Dam reached a peak of 26,000 cfs, although the USGS gage downstream of the dam recorded a much smaller peak discharge (11,700 cfs) due to flow attenuation behind the dam. Scott (1973) also determined that the recurrence intervals of the peak discharges for both storms exceeded the 50-year flood, and notes that the greatest amount of damage occurred during the February flood (Bull & Scott, 1974). For example, the northern Foothill Blvd. bridge failure did not occur until February despite significant scour during the January flow (Scott, 1973).

Volume calculations from mean daily discharge values recorded at the gage near Sunland show little variation between January and February flow events. The estimated volume of the January flood was approximately 40,000 acre-feet (AF), not significantly different from the February flood volume of 44,000 AF. Daily mean discharge during the days between the flood peaks in January and February remained relatively high at an average of 421 cfs per day (835 AF/day), with several smaller peaks between the large January and February events. Continuous flow, small and moderate floods, saturated conditions, and progressive erosion probably contributed to the bridge failure and avulsive channel changes that occurred in February, despite the similarity between the January and February peak discharges.

Flood Damage

Prior to 1969, flow in Tujunga Wash was confined to the main channel located in the northern portion of the floodplain, except for local runoff from the floodplain that was redirected by small levees (Figure 4). In response to the January and February 1969 storm events, flow entered the southern channel and flooded several homes along the banks of the upper reaches of Tujunga Wash. Later, a series of small levees located downstream of the Foothill Boulevard crossing were breached, allowing floodwaters to enter a 50 to 75 foot deep inactive gravel pit. As shown in Figure 4, flow from the northern channel also breached a second set of levees downstream of the highway bridge and entered the gravel pit, which caused the majority of the flood flow to concentrate in the southern channel (Bull and Scott, 1974). Breaching of the gravel pit and shifting of the channel location to the southern portion of the floodplain resulted in significant flood damages and channel change. Flood damages were caused by vertical channel changes (headcutting) and lateral channel changes (bank erosion) as described below.

Headcutting – Vertical Channel Change

Flood flow into the 50 to 75 foot deep gravel pit initiated a headcut that actively scoured the upstream channels (Bull and Scott, 1974). Scott (1973) confirmed headcutting on

Tujunga Wash by comparing pre- and post-flood topography[2] that showed significantly lower bed elevations upstream of the pit (Figure 5). Net channel degradation during the 1969 floods was about 11 feet immediately upstream of the gravel pit, with decreasing degradation depths in the upstream direction. Two pre- and post-flood cross section comparisons are shown in Figure 5 for locations at and upstream of the gravel pit. Scott (1973) reported that the thalwegs of both the north and south channels experienced headcut erosion that propagated as far as 3,000 feet upstream from the pit. Degradation from the headcutting resulted in the undermining and failure of three major highway bridges crossing Tujunga Wash upstream of the pit. The destruction of the southern channel bridge after the February flood is shown in Figure 6.

[2] Pre-flood topography date: June 10, 1968. Post-flood topography date: March 6, 1969.

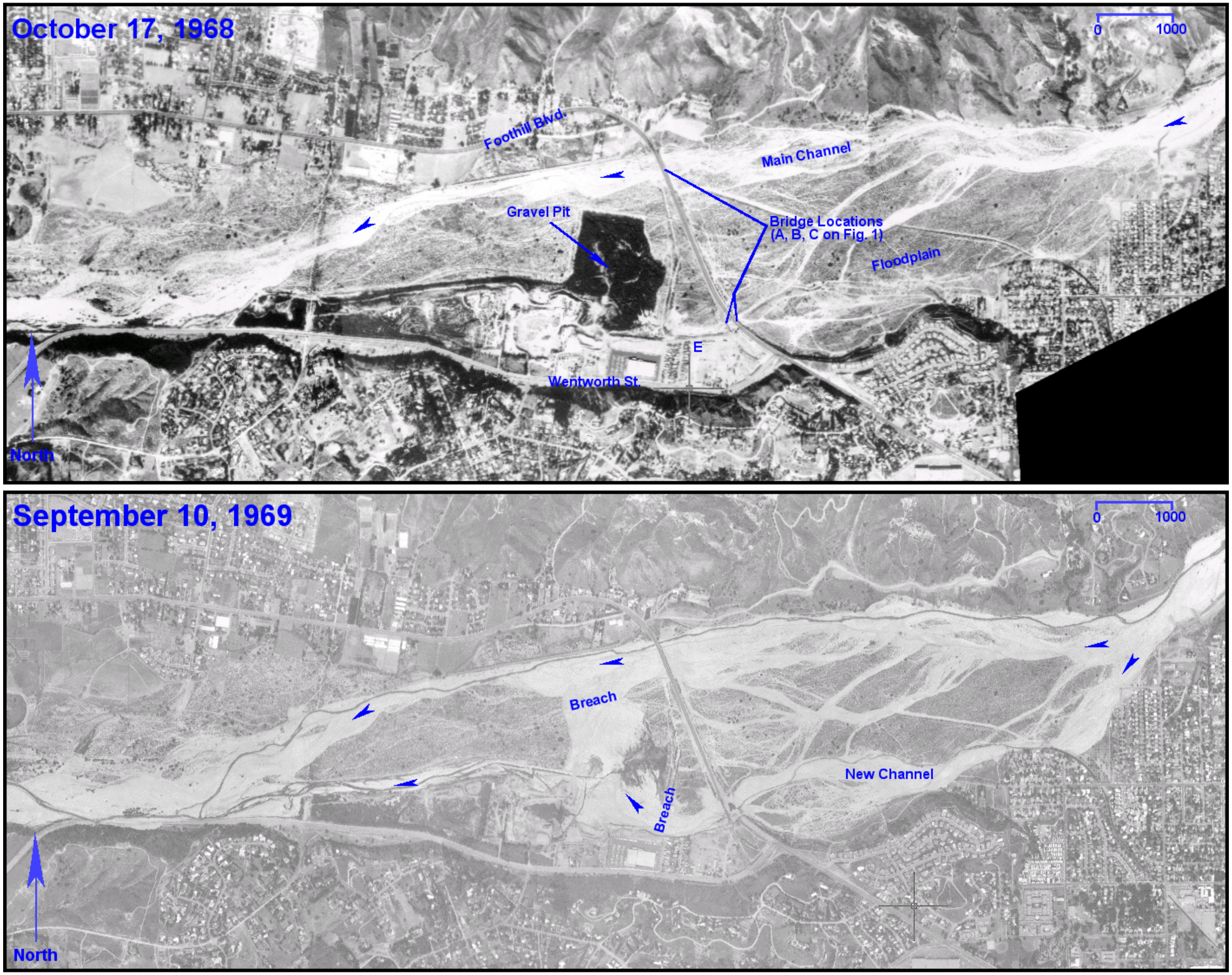

Figure 4. Pre- and post-flood view of entire reach. Note: 1969 photography was taken after two of the original three bridges were replaced.

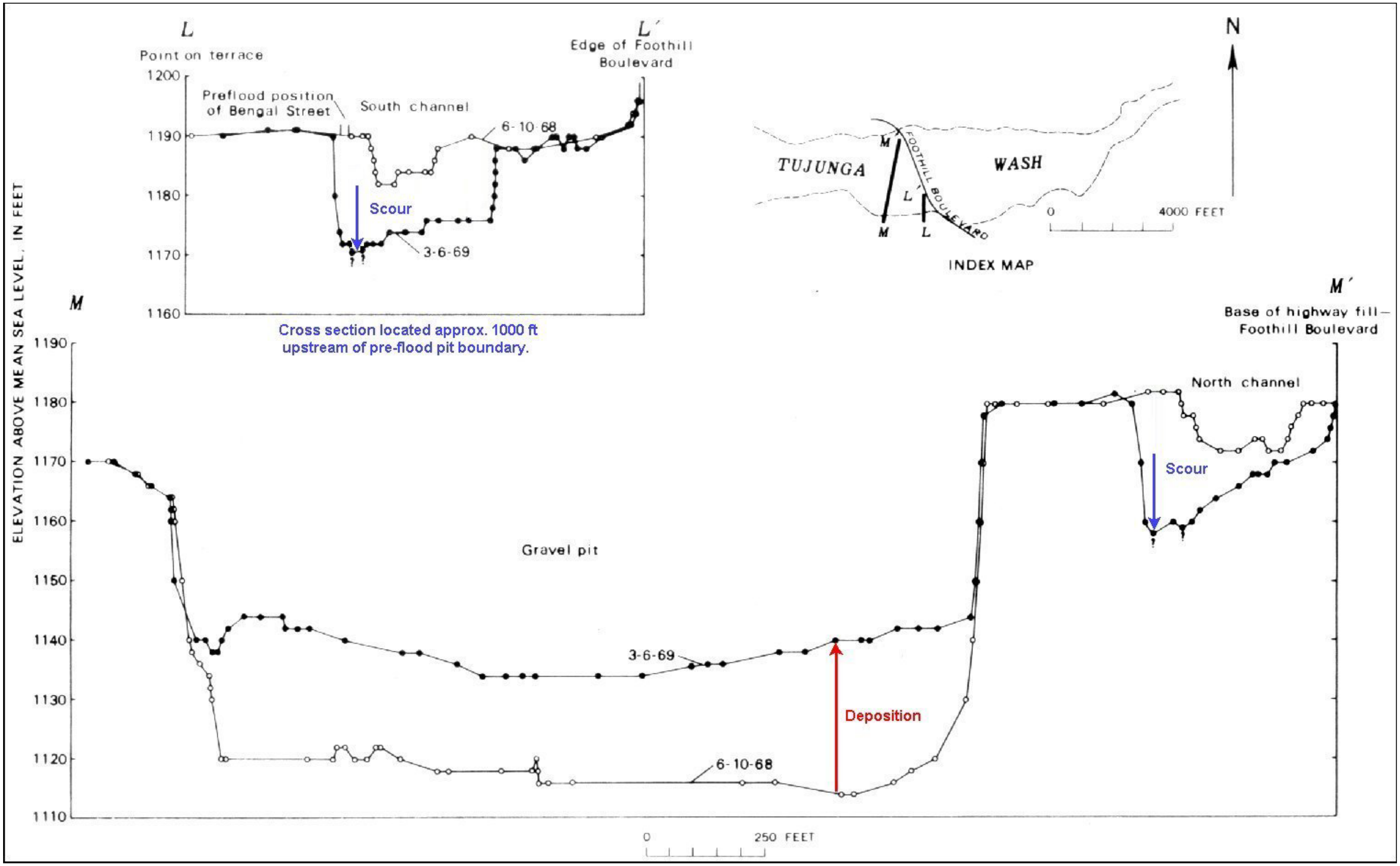

Figure 5. Figure showing example of bed elevation change at two locations on Tujunga Creek. Cross section M-M' is across gravel pit and cross section L-L' is located just upstream of the gravel pit (Original figure taken from Scott, 1973).

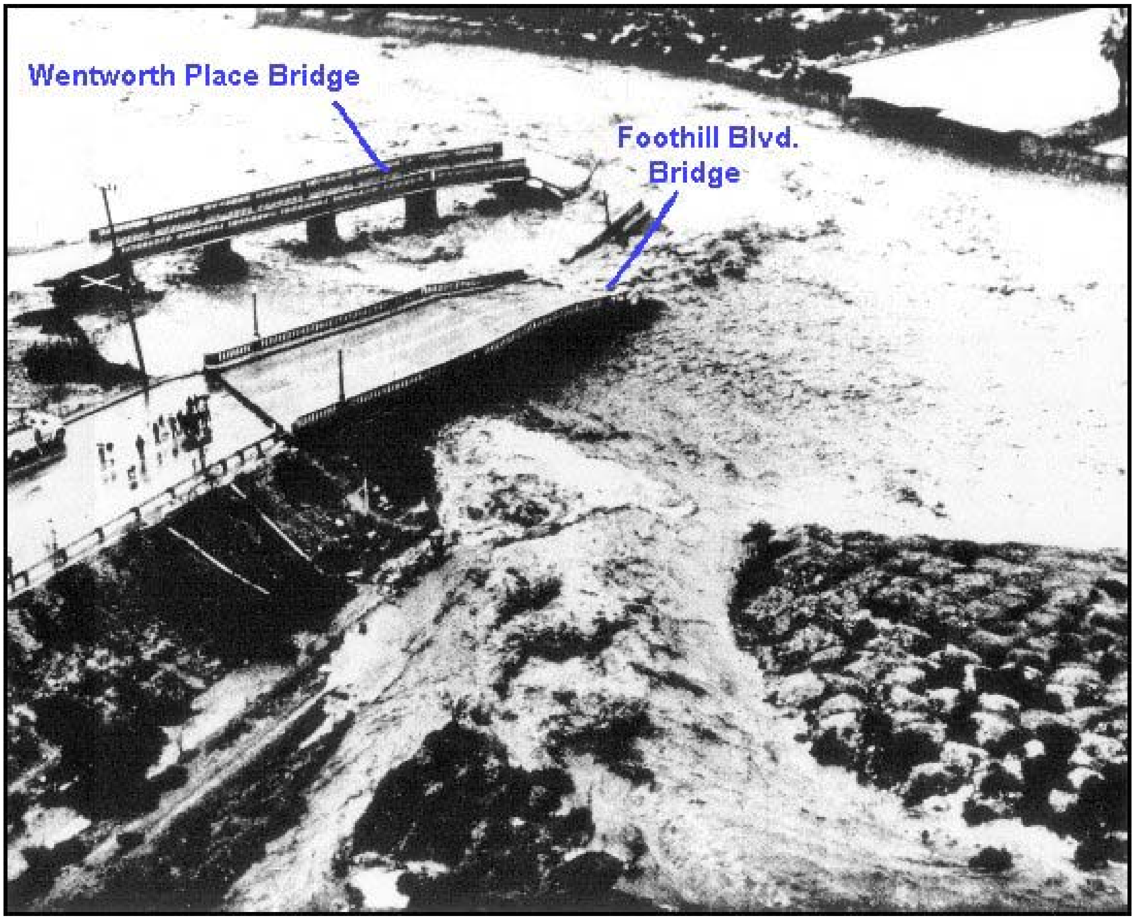

Figure 6. Picture by Harold Morby looking downstream (NW) at Foothill Blvd. and Wentworth Place bridge failures (from Scott, 1973).

Breaching the gravel pits by the 1969 flood caused significant deposition within the pit itself, as material eroded from the degrading upstream channel entered the low velocity pool in the excavated area. As shown in Figure 5, Scott (1973) reported that up to 24 feet of deposition, or approximately three million tons of sediment, was deposited in the breached pit. Interestingly, mining operations had ceased by 1960 because prior mining had depleted the aggregate reserves in the pit, and because the lessee was unable to acquire zoning clearance for mining the surrounding area. However, after 1969 flooding gravel mining was reinitiated due to the estimated 2-3 million tons of sediment that had been deposited in the abandoned pit after it had breached and captured the main channel. As Bull and Scott (1974) state: "Thus, the pit owners and operators were among the few beneficiaries, at the taxpayers' expense, of the disaster."

Lateral Bank Erosion – Horizontal Channel Change

Comparison of pre- and post-flood aerial photography reveals that significant lateral channel changes also occurred on Tujunga Wash. For example, at Cross Section L-L' in Figure 5, about 75 feet of the existing floodplain terrace was eroded resulting in the loss of seven homes along Bengal Street, as shown in Figure 7. The channel bank on river right was also eroded downstream of the southern channel bridge crossings in the same location (Figure 6). Scott (1973) stated that lateral erosion in excess of the natural rate of lateral erosion occurred near the sand and gravel pit due to two major factors. First, the channel widened to compensate for the significant increase in discharge capacity caused both by the large flood itself and by erosion and degradation that increased the percentage of flow conveyed in the channel instead of the floodplain. Second, bank stability decreased due to headcutting initiated by breaching of the gravel pit. Lowering of the bed elevation by headcutting increased the bank height, removed basal support at the bank toe, exposed unvegetated bank material to hydraulic forces, and increased the channel velocity. Pre- and post-flood aerial photography shown in Figures 4 and 8 can be compared to indicate the magnitude and extent of lateral channel changes.

Figure 7. Photograph by Harold Morby looking downstream (NW) at lateral erosion of left bank near Bengal Street. From Scott, 1973. See Figure 8 for photo location.

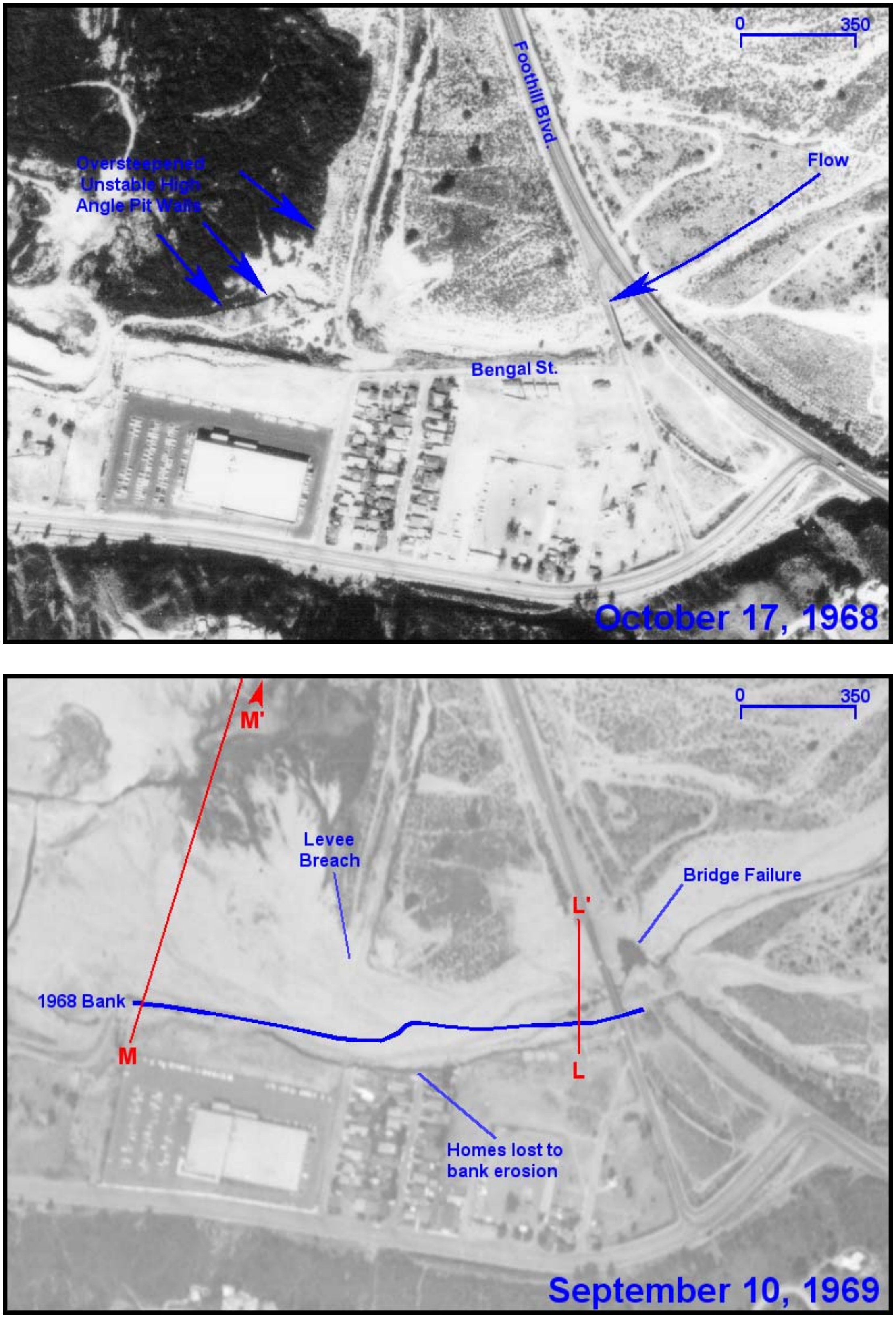

Figure 8. Lateral bank erosion that destroyed 7 homes and Bengal St. See Figure 5 for topography at cross sections M-M' and L-L'. Note: The bridge in the 1969 photography was built after the flood.

Summary

During the 1969 flood on Tujunga Wash, three bridges and seven homes were destroyed by erosion, bank erosion of up to several hundred feet occurred in some locations, a headcut up to 13 feet deep formed and migrated up to 3,000 feet upstream, and approximately three million tons of sediment was deposited in an abandoned sand and gravel pit breached by the flood. Flood damages were directly related to breaching of an inactive, off-channel sand and gravel pit located in the modern geologic floodplain of Tujunga Wash. The following easily implemented management policies and engineering and geomorphic analyses could have prevented the disaster and reduce flood damages:

- Recognition of the potential for alluvial streams to move within their geologic floodplain over time.
- Recognition of the inherent hazards associated with deep excavations located outside the main channel, but within the geologic floodplain.
- Requirement for engineering and geomorphic analysis prior to permitting sand and gravel operations in flood and erosion hazard areas.
- Geomorphic evaluation of potential lateral migration within the modern geologic floodplain using historical aerial photographs, interpretation of floodplain soils and stratigraphy, interpretation of channel pattern, and consideration of bank conditions.
- Engineering evaluation of bank stability, floodplain depth and velocity relative to sediment transport thresholds, and potential lateral channel movement.
- Adequate engineering design of flood control structures used to protect sand and gravel mining operations.
- Adequate engineering design of bridges and/or requirement for bridge scour mitigation near in-stream sand and gravel excavations.
- Requirement for reclamation plans to mitigate flood and erosion hazards after depletion of the aggregate resource.

Bull and Scott (1974) offer the following perspective on the lessons that could be learned from the 1969 floods on Tujunga Wash:

> *The [1969] event emphasizes the need for geomorphic considerations in the issuance of future gravel-mining permits in seemingly inactive channels, as well as the need for a survey of existing operations in similar geomorphic settings. Many similar gravel pits exist in inactive channels with flooding potential in urban areas… of the Southwest. There are sound economic reasons for permitting gravel mining in inactive channels, and there are valid practical reasons for using geomorphic principles to site the operations so as not to pose an environmental threat.*

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Case History #3: Lateral Erosion
Ina Road, Santa Cruz River, October 1983

Introduction

The Ina Road Bridge over the Santa Cruz River is located approximately 15 miles northwest of downtown Tucson (Figure 1). The current bridge spans over 600 ft. and contains nine pier sets, five of which were added in 1984 following a large flood event in October, 1983. Over 300 feet of the bridge was destroyed during the 1983 flood, as well as parts of both the east and west approaches (Pima County, 1984). During the flood, two sand and gravel operations near Ina Road were inundated, damaging Ina Road by accelerated lateral erosion.

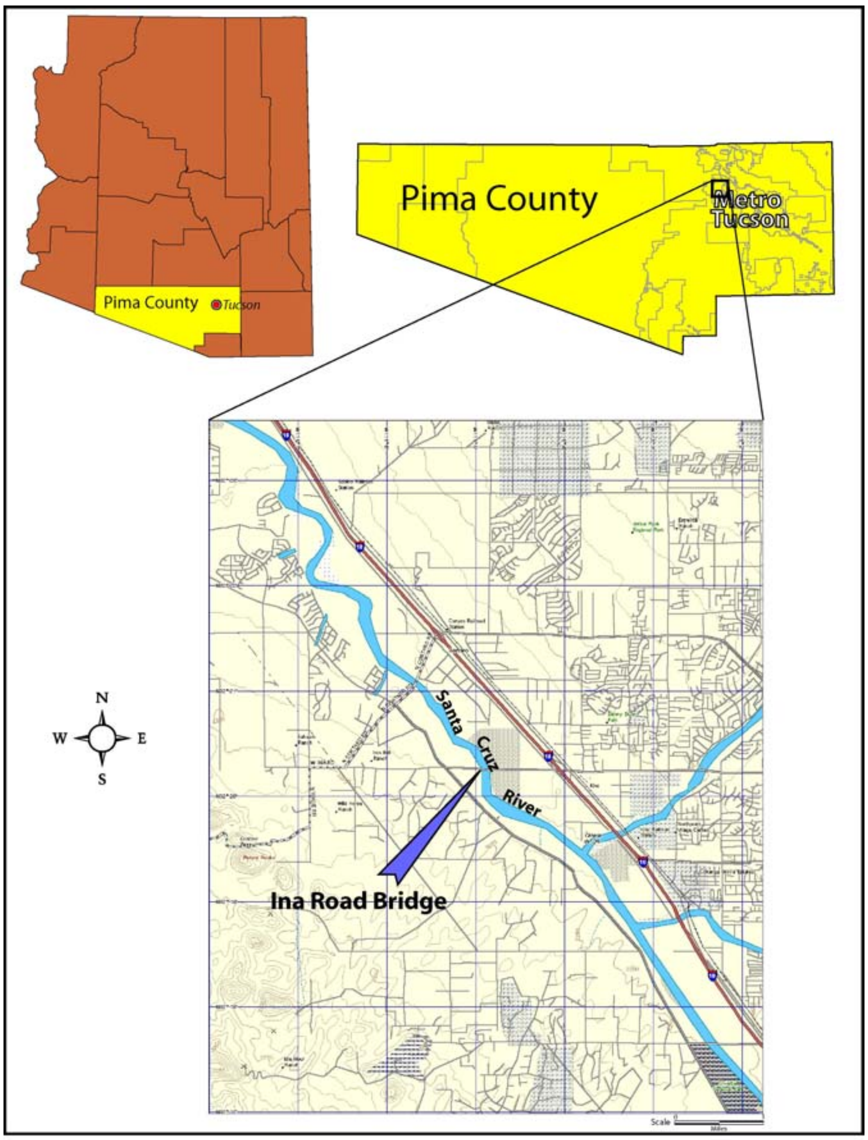

Figure 1. Vicinity map for Ina Road in Tucson, Arizona.

1983 Flood Characteristics

Tropical Storm Octave triggered heavy precipitation in Tucson beginning on September 28 1983 and continuing through October 3, 1983. On October 1st the National Weather Service (NWS) Tucson office issued the following statement:

> *Local inflow from very heavy and persistent showers and thunderstorm in the Tucson area has also dramatically increased the flow in the Santa Cruz River. The flow in the river has increased between Continental and Tucson. This flow is still far short of that which is needed to cause the river to leave its channel at Tucson. However…local inflow into the Santa Cruz in the Tucson Area from these heavy showers and thunderstorms has caused a sharp rise in the river.* ***While the river is still well within its channel…heavy lateral erosion of the riverbanks has…and will continue to take place through at least 9 a.m. this Sunday morning. Those persons affected by this erosion should move to a place of safety immediately****. (Saarinen et al., 1984)*

On the morning of October 3rd, 17 of the 18 bridges crossing the Santa Cruz River in Pima County were inoperable or unsafe for occupation (Saarinen et al., 1984). The Ina Road Bridge suffered extensive damage including failure of the west abutment as a result of erosion to the west bank, breaking off of the south wing wall and support pile, settling of the southwest corner of the west abutment, and loss of east and west approaches (Figure 2 to 4).

Figure 2. Aerial photograph of the Ina Road Bridge, Santa Cruz River, AZ, looking northwest after the 1983 flood (PCDOT, 1984). The gap in the roadway was due to failure of the west abutment by lateral erosion.

Figure 3. Aerial photograph of the Ina Road Bridge, Santa Cruz River, AZ, looking east (PCDOT, 1984)

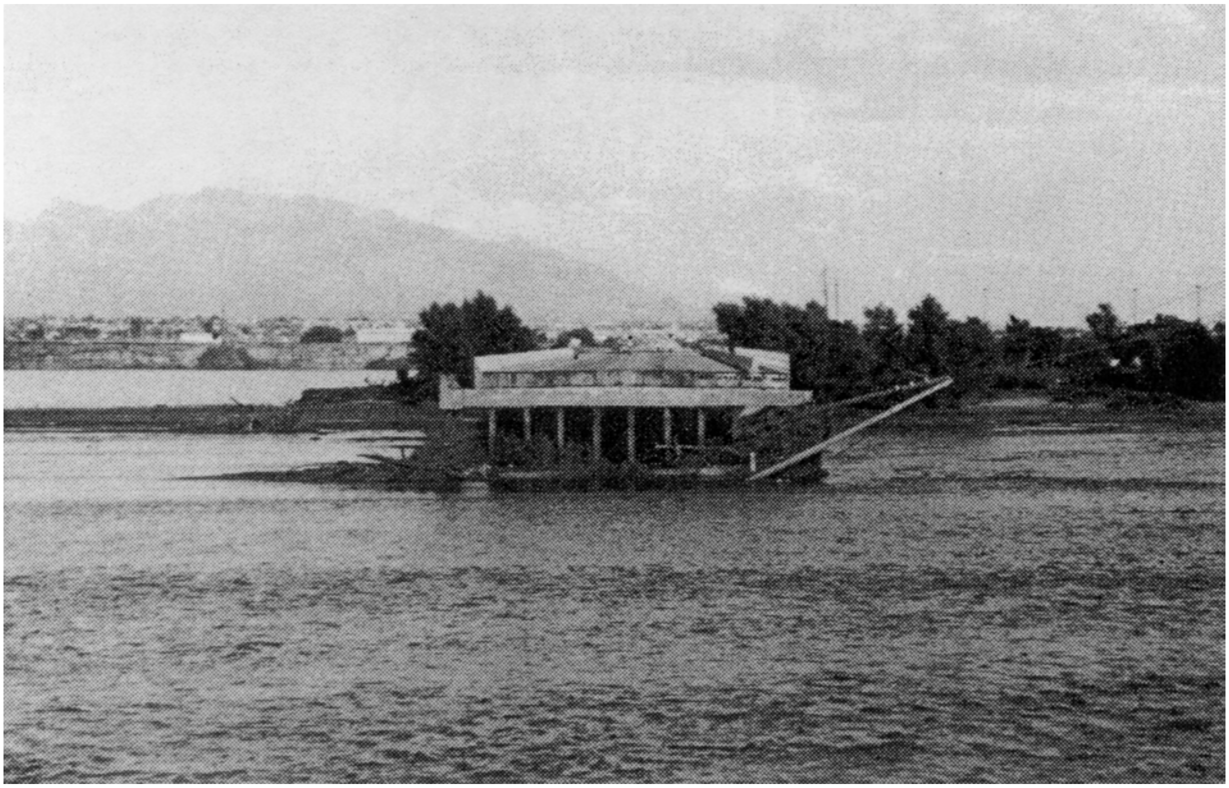

Figure 4. Photograph of the Ina Road Bridge, Santa Cruz River, AZ, looking east from the west bank of the river (PCDOT, 1984). Note the breached and flooded Site #5 pit in the upper left of the photograph.

Sand and Gravel Mining Near the Ina Road Bridge

The six sand and gravel operations located nearest the Ina Road Bridge prior to the 1983 flood are shown in Figure 5 and were described by SLA (1986) as follows:

- Site #2 – This small pit was active in October 1983, but occupied less than two acres and was located far enough from the Ina Road Bridge to have no known impact on the bridge failure.
- Site #3 – This pit was inundated by the October 1983 flood and was found to be a contributing factor to the major shift in the Santa Cruz River main channel alignment downstream of Ina Road.
- Site #4 – This pit was inundated by the October 1983 flood and was found to be a contributing factor to the major shift in the Santa Cruz River main channel alignment downstream of Ina Road. The pit was as much as 40 feet deep prior to October 1983, but flood deposition in the pit and subsequent lateral erosion of the main channel through the pit's footprint removed almost all traces of the excavation.
- Site #5 – This pit occupied about 35 acres of the east overbank immediately downstream of Ina Road and was separated from the main channel of the Santa Cruz River by a narrow unstabilized levee. Seepage and underflow through the levee, which breached during the 1983 flood, also had been a problem during past floods. Flood flow entering the pit through

the breached levee formed a reverse vortex current within the inundated pit that eroded the downstream side of Ina Road (Figure 6).

- Site #6 – This pit, located in the east overbank area immediately upstream of Ina Road, had flooded and partially filled during the October 1977 flood, so the depth below the Santa Cruz River thalweg at the time of the October 1983 flood was minimal. However, flow into and out of the abandoned pit resulted in a severe constriction, realignment of flow toward the west abutment, and subsequent failure of the Ina Road Bridge west abutment due to lateral erosion.
- Site #7 – This small pit located on the west bank of the Santa Cruz River upstream of Ina Road was breached resulting in about 400 feet of headcut migration upstream of the pit.

In addition, two historical landfills were located in Santa Cruz River floodplain upstream and downstream of Ina Road.

Ina Road Bridge Failure

Failure of the Ina Road Bridge has been directly linked to several impacts from in-stream and floodplain sand and gravel mining along the Santa Cruz River. First, failure of a narrow unstabilized levee caused the pit at Site #5 to rapidly fill with floodwater. Normally, off-channel pits that rapidly fill with floodwater become slackwater areas that have minimal impacts on main channel stability. However, a circulating clockwise current developed in the flooded Site #5 pit. The steep, unstabilized alluvium that formed the sides of the excavation became unstable when saturated and subjected to the low velocity circulating current, resulting in erosion of the excavation margins. Because the pit was not set back adequately from Ina Road (Figure 7), erosion of the pit side slopes removed large sections of the roadway (Figure 6). In addition, failure to design drainage structures to account for local runoff entering the pit from a channel located along the north side of Ina Road resulted in erosion, headcutting, and destabilization of the pit side slope prior to inundation of the pit by floodwaters from the Santa Cruz River (Hendricks, 2003). The headcut from local drainage entering the pit is visible in the lower right corner of Figure 6.

Second, the abandoned pit area located immediately upstream of Ina Road was also inundated (Figures 5 to 7). Even though the upstream pit had partially filled during October 1977 flood (SLA, 1986), the overbank material had not been replaced, resulting in an over widened main channel upstream of Ina Road. Floodwaters exiting the abandoned pit area were severely constricted by the bridge section, probably resulting in increased flow velocities at the bridge. In addition, flow leaving the abandoned pit area was at a high skew angle to the Ina Road Bridge, directly impinging on the west bank of the river. The velocity increase that was directed at the west abutment accelerated the river's already high tendency for lateral erosion, resulting in extensive lateral erosion of the west approach that widened the main channel by several hundred feet. While the bridge itself remained essentially intact, the channel widening stranded the bridge more than 200 feet from the new channel bank.

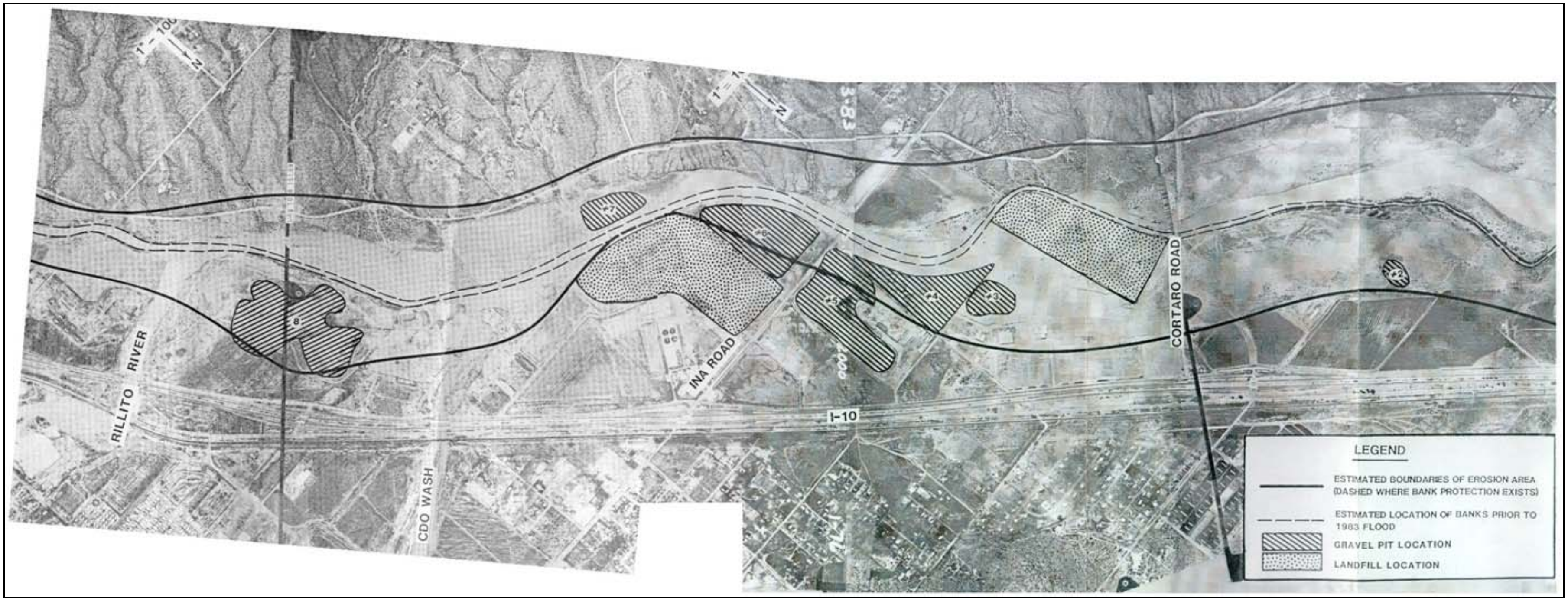

Figure 5. Locations of sand and gravel operations along the Santa Cruz River near Ina Road prior to October 1983.

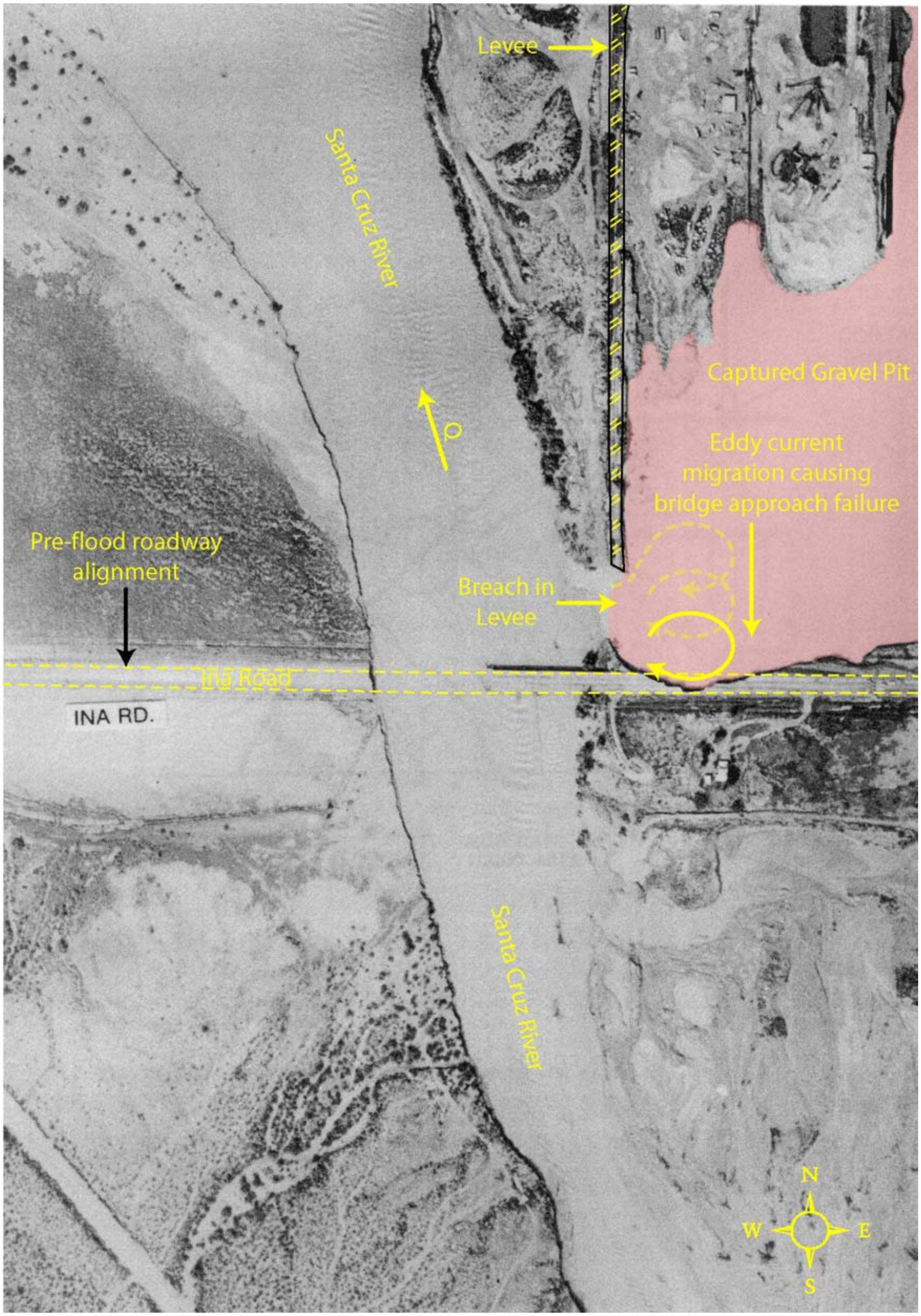

Figure 6. Ina Rd Bridge during the October, 1983 flood. Note the erosion of Ina Road east of the bridge and main channel due to circulatory currents and local inflow to the pit (PCDOT, 1984).

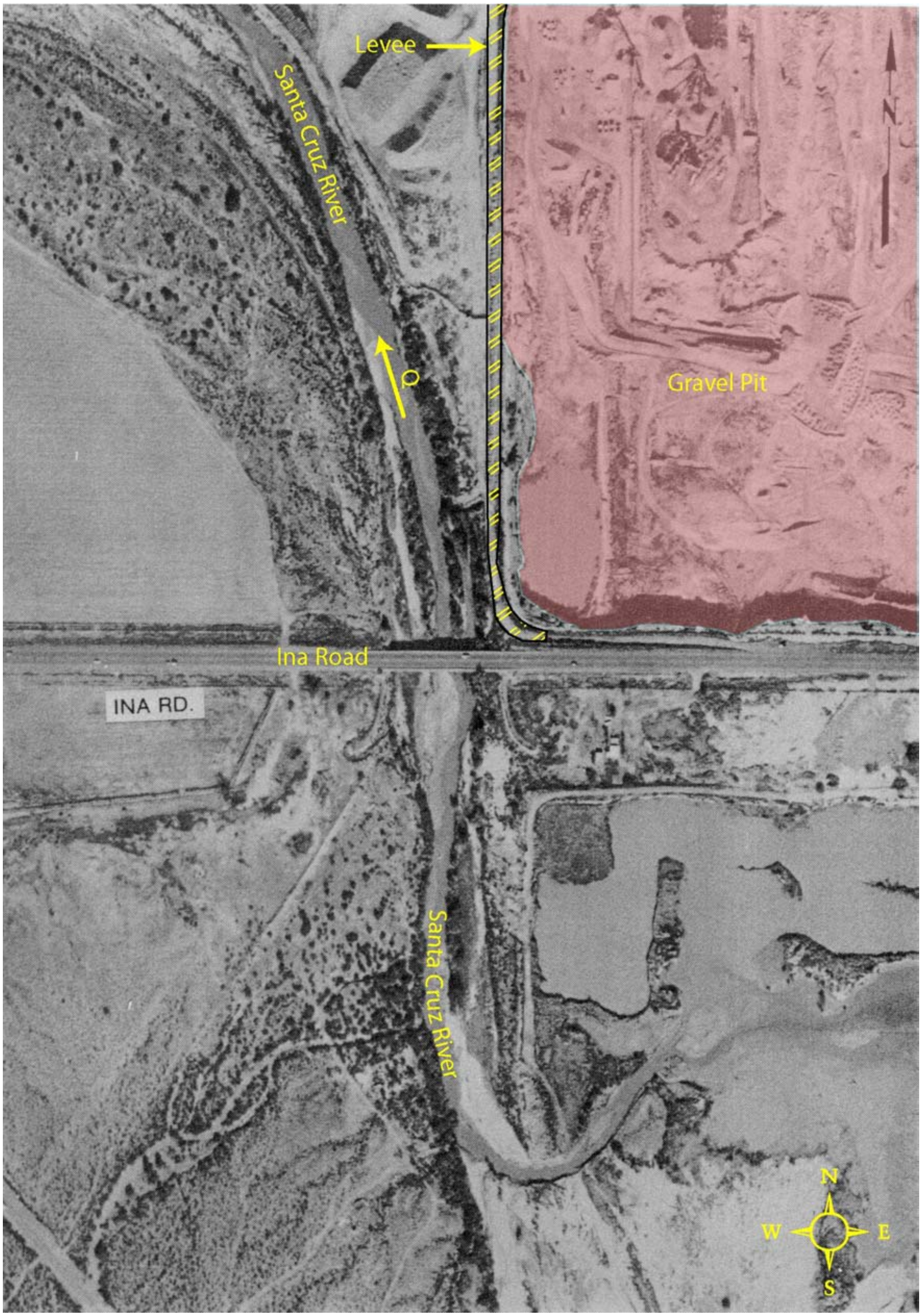

Figure 7. Ina Road Bridge site in December, 1982 (from PCDOT, 1984). Note the steep side walls and narrow setback from Ina Road at the Site #5 Pit, as well as headcut into the inundated pit south of Ina Road.

Historical channel degradation also has been attributed to extensive in-stream sand and gravel mining of the Santa Cruz River during the 1950's and 1960's (SLA, 1986). In ephemeral streams like the Santa Cruz River, much of the long-term degradation occurs during large floods like the 1983 event particularly when the main channel captures deep excavations in the floodplain. Channel elevation profiles of the Santa Cruz River shown in Figure 9 document the degree of long-term degradation that occurred near Ina Road. While pre- and post-flood topographic data are not available to determine how much headcutting occurred at Ina Road, the data in Figure 9 indicate the potential for future degradation at Ina Road caused by downstream excavations.

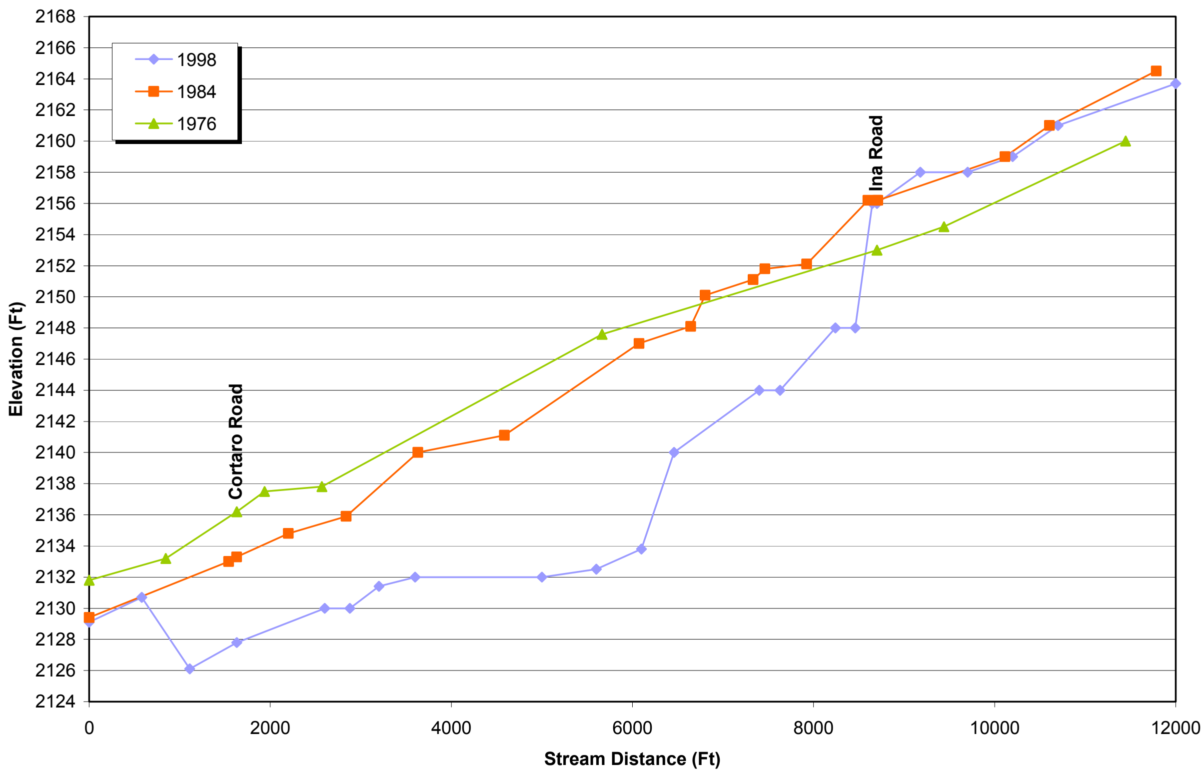

Figure9. Changes in channel minimum bed elevations in the Santa Cruz River from 1976 to 1998.

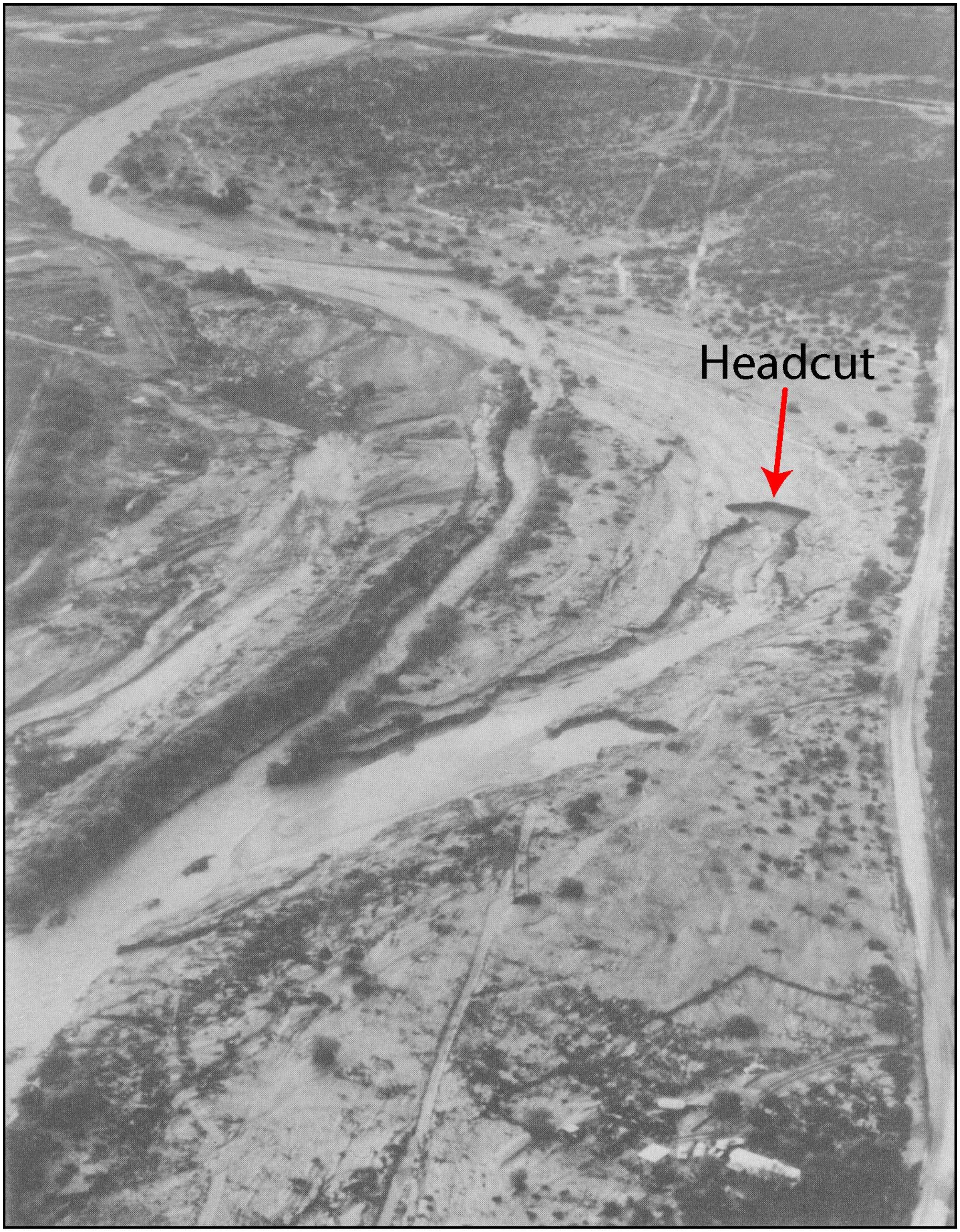

Figure 10. Headcut on the Santa Cruz River floodplain, October 1983 (Baker et al., 1988).

Summary

Lessons learned from the extensive lateral erosion and bridge failures that occurred in Tucson in the 1983 flood were summarized as follows:

> *Problems such as increased aggradation/degradation and lateral migration, which are a result of unregulated sand and gravel mining activities, have become much more apparent during recent decades, especially as more public and private development occurs within the river environment. Damages due to erosion/sedimentation problems caused by unregulated sand and gravel mining activities are becoming much more costly, and merely serve to underline the need for better enforcement and regulation of sand and gravel mining operations within the river environment.* (SLA, 1986)

Off-channel sand and gravel mining adjacent to the Santa Cruz River led to extensive lateral erosion, channel widening of several hundred feet, and failure of the east and west approaches to the Ina Road Bridge during the October 1983 flood. Flood damages could have been prevented by engineered bank stabilization that would have prevented the under-designed flood control levees from eroding and failing during the flood, and by implementation of reclamation plans that preserved natural river functions after mines were abandoned.

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Case History #4: Long-Term Degradation
Lower Salt River, 1903-2001

Introduction

Degradation is defined as general lowering of a river bed, usually by erosion of bed material by flowing water (Bates and Jackson, 1984). Stream degradation is caused by both natural and anthropogenic processes. Degradation rates are variable and are dependent on the characteristics of individual rivers. This study examines the effects of in-stream sand and gravel mining on the long-term degradation of a 38-mile reach of the Salt River near Phoenix, Arizona, from 115th Avenue to Granite Reef Dam (*Figure 1*).

The effects of sand and gravel mining in the Salt River study reach were previously described in a study conducted for the Arizona Department of Transportation (ADOT, 1989) entitled Effects of in-Stream Mining on Channel Stability (hereafter, "the ADOT Report"). The following excerpt from the executive summary of the ADOT Report illustrates the need for, and challenges of, understanding the effects of sand and gravel mining on river stability:

> *Sand and gravel constitutes one of the primary natural materials used in construction of the roads, bridges, and buildings required to support the needs of our society. The source of these materials, and the mining practices employed for harvesting them, can create problems for the very society that they serve. This is especially true in arid regions of the country where gravel mining operations are frequently located in the channel and overbank areas of floodplains historically known to be unstable during floods…The State of Arizona experienced several large floods during recent years. The presence of in-stream gravel pits fueled problems and may have been partly responsible for flood-related damage to roads/bridges and nearby riverbank property. The concern and speculation arising from this issue prompted the Arizona Department of Transportation to undertake research to study the problem, with the goals of developing technical procedures for analyzing the impacts of in-stream mining upon the river system and of recommending* legislative approaches to regulating the sand and gravel mining industry. (ADOT, 1989)

This study summarizes the conclusions of the ADOT Report and presents evidence of long-term degradation in the lower Salt River. The study includes a description of historical degradation in the Salt River, including upstream and downstream impacts from degradation.

Historical Long-Term Degradation

In-stream sand and gravel mining was the primary cause of historical long-term degradation of the lower Salt River, although it was not the sole cause of channel change. Alterations in the natural flow regime by upstream dams, channelization, and land use changes have also impacted river stability. However, as described below, the available

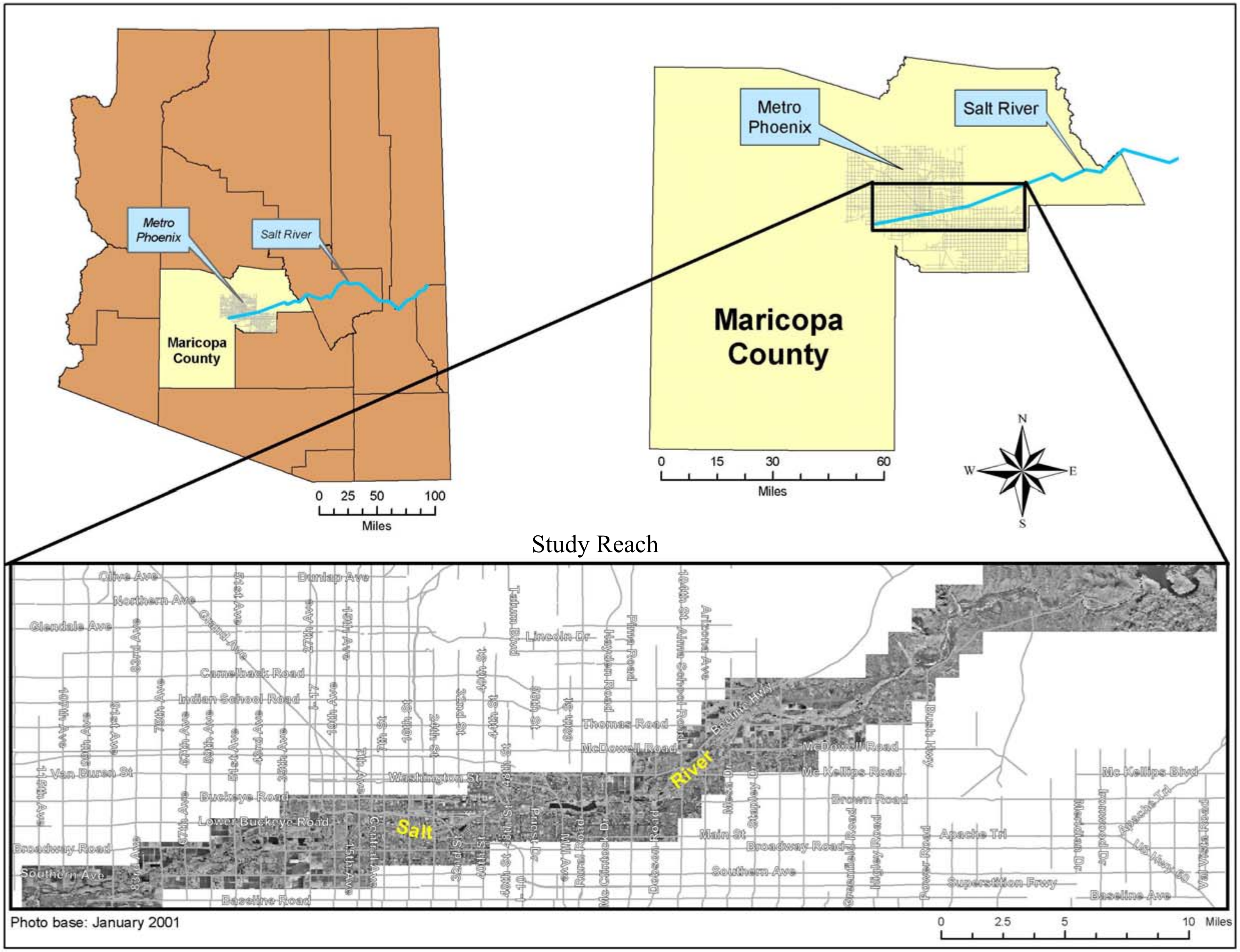

Figure 1. Vicinity map

data support the hypothesis that degradation is strongly linked to in-stream aggregate mining.

Dam Impacts. The Salt River's natural flow regime has been dramatically altered by upstream diversion and impoundment of runoff by a series of seven major dams (*Table 1*). The dams are located far enough upstream of the study reach to preclude direct impacts from clear water discharge.

Table 1. Major Dams in the Salt River Watershed

Dam	Year of Completion
Granite Reef (Diversion)	1908
Roosevelt	1911
Horse Mesa	1925
Mormon Flat	1925
Stewart Mountain	1930
Bartlett (Verde River)	1939
Horseshoe (Verde River)	1948
*Granite Reef Dam replaced Arizona Dam, which was built in 1883	

The following quote describes the annual flow regime change caused by dam construction in the Salt River watershed:

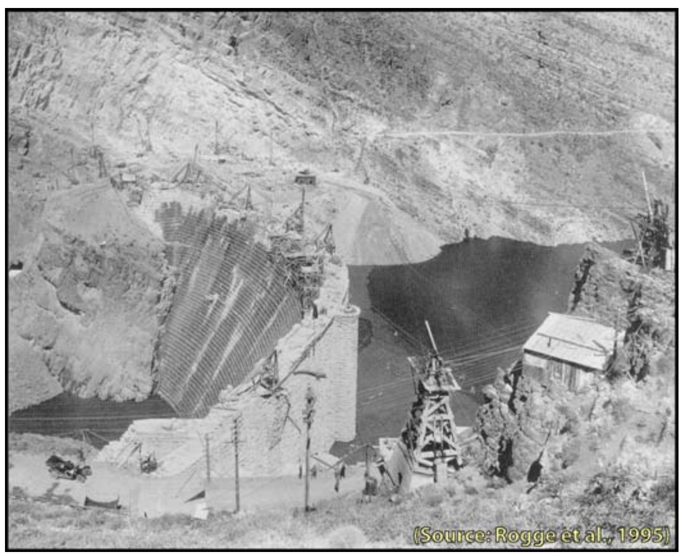

Figure 2. Roosevelt Dam near completion (1910)

The cumulative effect of the dams has been to completely change the character of the river. Before 1900, the river's flow was heaviest in the spring and early summer when snow melted in the mountains...Flows were generally low in fall and in drought years...The dams transformed some 70 miles of flowing river into a chain of lakes and changed the way water flowed downstream…. Diversions from Granite Reef Dam, a dam which diverts most of the water in the Salt River to the Phoenix area, effectively dewatered the river, turning it into a sandy expanse experiencing high flows only during unusually rainy years when flood waters had to be released from the dams upstream. (Source: Tellman et al., 1997)

There are several consequences of dam construction that relate to the impact of sand and gravel mining. First, as noted in the citation above, flow diversion and impoundment has left the Salt River essentially dry downstream of Granite Reef Dam, except during the largest floods. Second, the dry streambed allows in-stream sand and gravel mining to exist. Third, high river flows downstream of Granite Reef Dam occur infrequently, only during the largest flood events. Fourth, the lack of normal flow and small floods mutes the rate of response to in-stream mining because although large floods in the study reach are relatively rare temporally; it is during such events that large changes in river morphology can occur in a short expanse of time (c.f., Bull and Scott, 1974; Kondolf, 1997; Saarinen et al., 1984; Scott, 1973).

Historic Flow Data. Historical mean daily outflow records for Granite Reef Dam that describe changes in the lower Salt River natural flow regime between 1912 and 1998 were collected from Salt River Project (SRP). These data were used to approximate annual peak flows (*Figure*) and volumes (*Figure*) for the study reach. The total volume of flow from 1934-2001, the period of record for historical topographic and photographic data for the study reach, was 18.3 million acre-feet (AF), or 0.3 million AF/year. The U.S. Geological Survey (USGS) estimated the Salt River pre-development natural flow rate at 1.2 million AF/year (Thomsen and Porcello, 1991), nearly an order of magnitude larger than the modern average annual flow rate. Note that from 1942 to 1964, the period following closure of the last of the Salt River watershed major dams, there was almost no flow in the lower Salt River.

The reduction of water flow to the lower Salt River is not the cause of long-term degradation. In years of no flow, no degradation or other channel changes occur, except those caused by direct excavation or channelization of the river. Runoff is required to perform the geomorphic work of channel change. Therefore, in years where runoff occurred in the study reach, the rate of channel change was reduced, compared to the rate of channel change that would have occurred had the natural water supply flowed through the study reach. Given the reduced runoff rate, the magnitude of historical degradation in the study reach is remarkable. As discussed in the following section, the period of most intense mining of the river corresponds to a period of large flood peaks and high annual flow volumes.

Historical Photo Comparison. Side-by-side historical photo comparisons of river channels can provide important information regarding geomorphic changes over time. Photo comparisons from 1934 through 2001 were constructed for the Salt River study reach (). The 1932 and 1986 photos were semi-rectified to the 2001 ortho-rectified images. Historic photo comparison exhibits illustrating changes in the Salt River channel in 1934, 1986, and 2001 are provided at the end of this report.

Table 2. Aerial photo sources

Photo Date	Source
1934	Fairchild
November 24, 1986	Rupp Aerial Photography, Inc.
January 2001	Landata Airborne Systems

The photo comparisons show the extensive overall narrowing of the floodplain that has occurred due to encroachment, channelization, and mining, as well as the change from a wide, braided channel pattern to an incised single channel system.

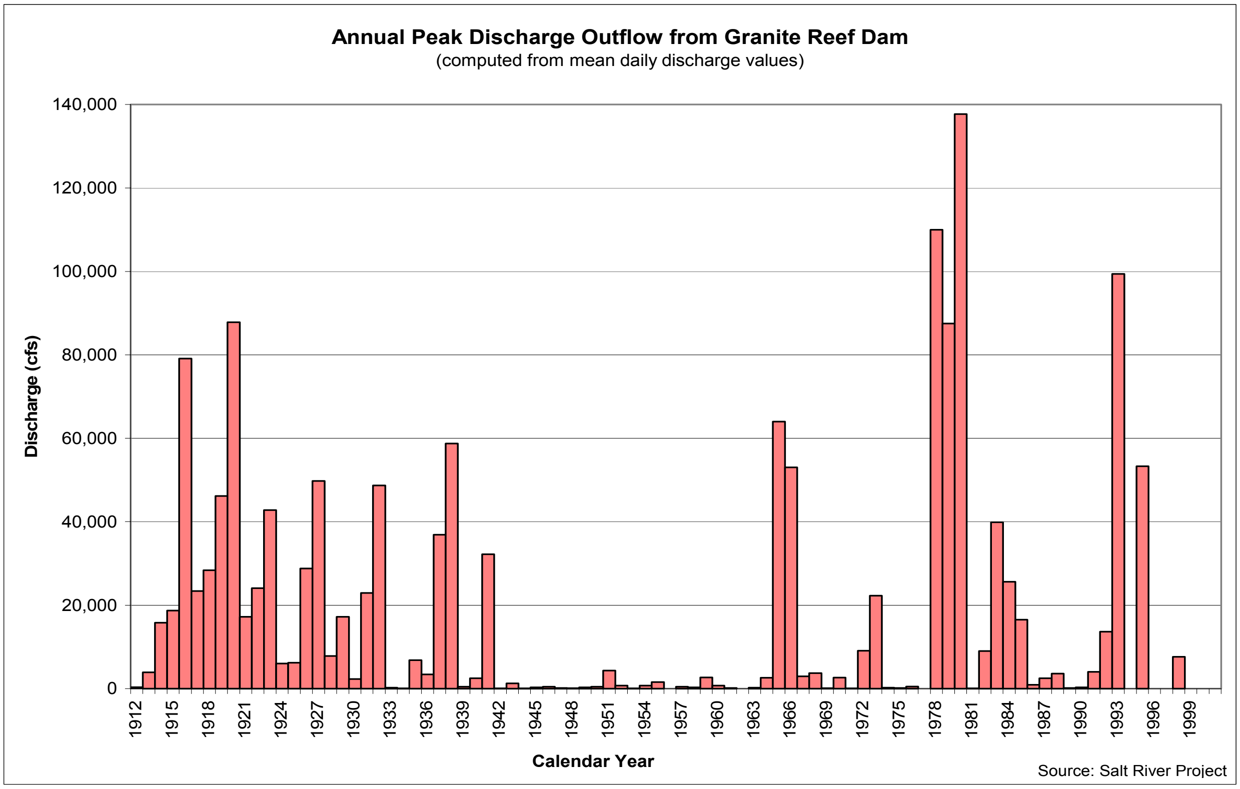

Figure 3. Estimated Salt River annual peak discharge downstream of Granite Reef Dam.

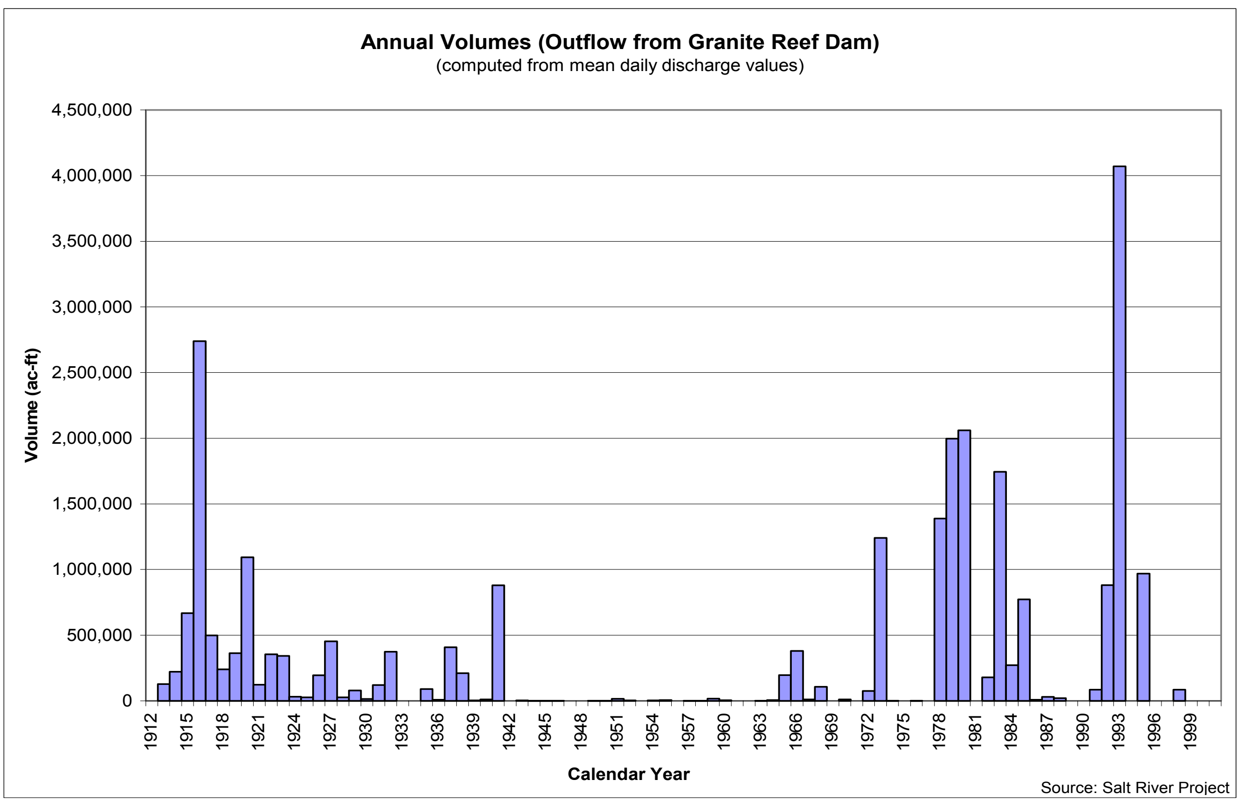

Figure 4. Estimated Salt River annual flow volumes downstream of Granite Reef Dam.

Regional Mining History. To determine the extent of channel degradation that occurred in the Salt River study reach, a longitudinal profile was developed using 1903 and 1999 topographic data (*Table*). The profile shown in Figure 5 is based on the minimum elevation at the thalweg where it crosses a fixed cross section at each section lines. The minimum elevation data from 1903 and 1999 at each point were plotted to show the long-term degradation that has occurred in portions of the lower Salt River study reach over the past 100 years (*Figure 5*).

Table 3. Topographic sources	
Date of Topography	**Source**
1903	Davis & Hawley (SRVWUA)
1993 (digital)	FCDMC
1999 (digital)	FCDMC

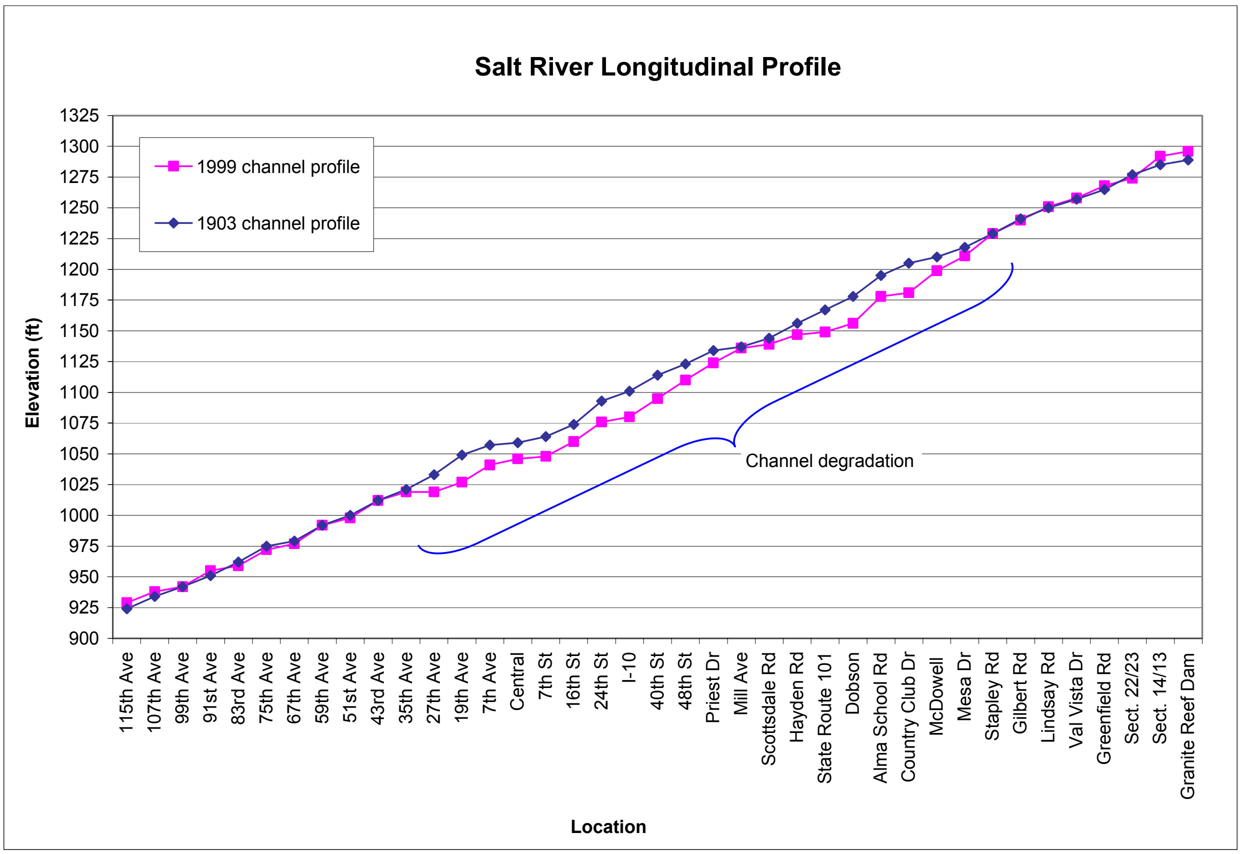

Figure 5. Longitudinal profiles of the Salt River in 1903 and 1999.

The longitudinal profiles shown in Figure 5 reveal that the most significant channel degradation occurred between 35th Avenue and Stapley Road, and that the reaches upstream and downstream experienced little long-term degradation. The lack of measurable long-term degradation at the upstream and downstream ends of the study reach indicates that watershed changes, such as urbanization or land use, systematic regional channel change, or upstream water impoundment cannot be the primary causes of long-term degradation.

The locations of existing and abandoned sand and gravel mines within the lower Salt River study reach were identified on historical aerial photographs to determine their spatial relationship to the reach of significant long-term degradation shown in Figure 5. To quantify the level of sand and gravel mining, an active channel corridor was identified and delineated on the 1934 aerial photographs. The limits of mining operations within the defined active channel corridor were then delineated on the rectified historical and

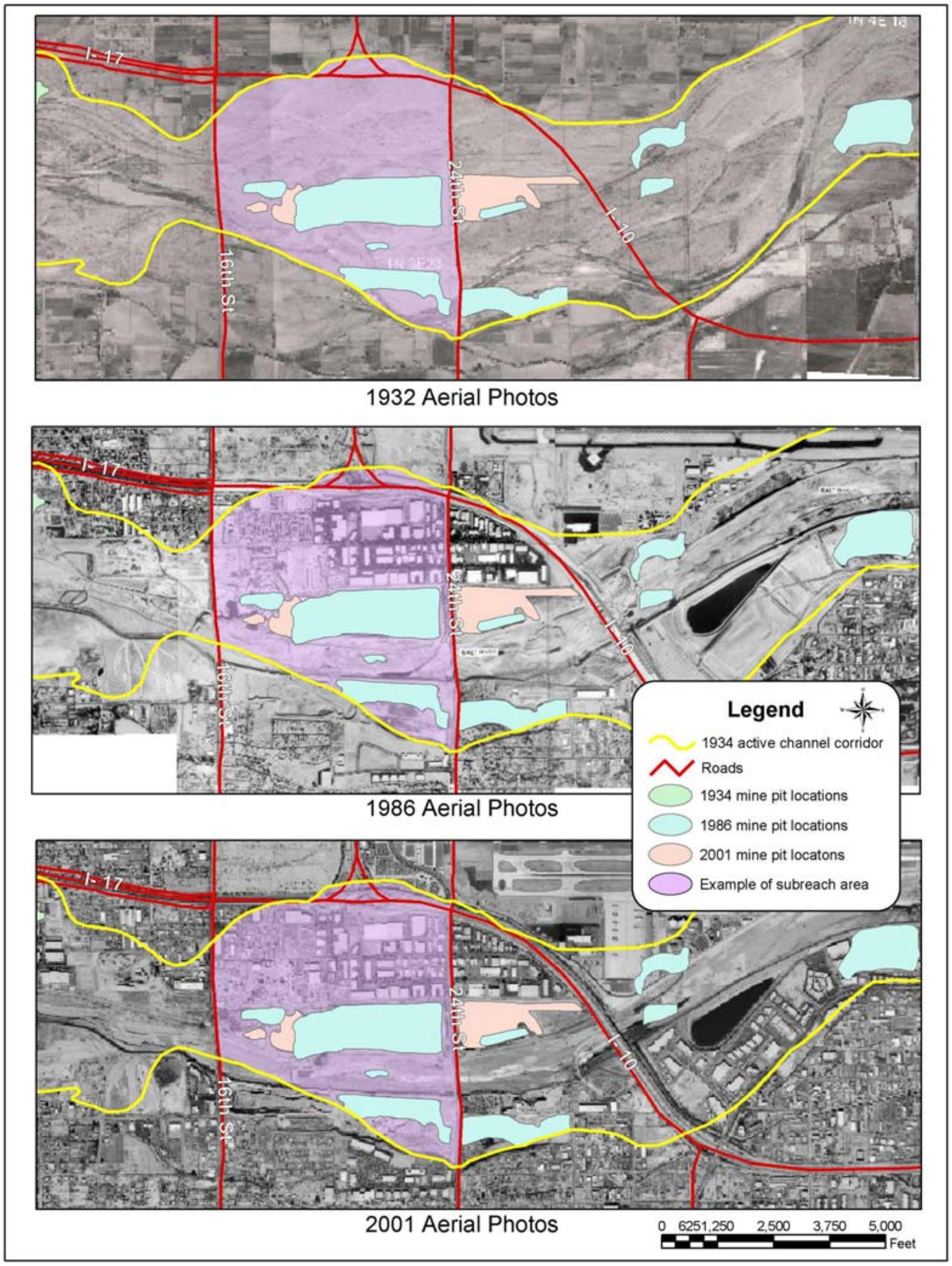

Figure 6. Example of mine pit delineations for a subreach of the study area.

recent aerial photographs. The study reach was divided into one-mile subreaches, and the surface area of the active channel corridor was measured for each subreach. Then, the surface area for each sand and gravel mine was measured to determine the percent of the subreach (by area) that was mined in 1934, 1986, and 2001. An example of the delineation and measurement technique is illustrated in Figure . Mine area delineations that overlapped from year to year were clipped to include only the area added to the excavation. The calculations of mining area shown in Figure 6 are cumulative, based on the assumption that an individual pit will have a geomorphic impact on the channel that extends beyond the life of the excavation.

The percent of each subreach that had been mined in each year of aerial photographic coverage compared to the change in longitudinal profile is shown in Figure 7. The slight difference in the photographic and topographic record (1999 vs. 2001) is considered insignificant because SRP flow records indicate that no flow over Granite Reef Dam has occurred since 1998. Therefore, no appreciable flood-related channel change has occurred in the study reach.

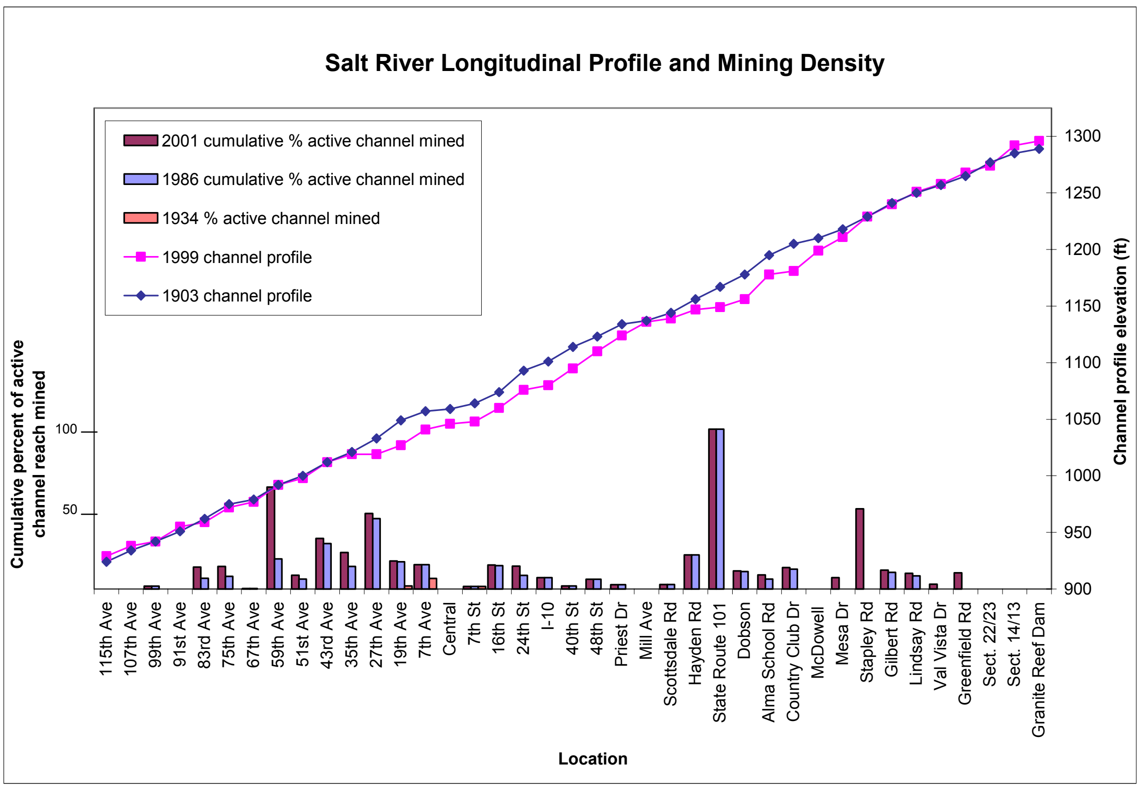

Figure 7. Mining density in 1934, 1986, and 2001 relative to long-term degradation.

As shown in Figure 7, the most intense in-stream mining of the study reach occurred in two primary mining clusters. One cluster extends from about 59th Avenue to 7th Avenue. The other cluster extends from about Hayden Road to Country Club Drive. Both mine clusters are located near the downstream ends of the most highly degraded reaches, at the

35th Avenue alignment and at Scottsdale Road.[1] The position of the mining clusters relative to the degraded reaches suggest that degradation of the channel upstream of the apex points may be caused by long-term headward erosion from the mining activity in addition to removal of material through excavation. However, it is no coincidence that the most heavily channelized and narrowed reach of the Salt River corresponds to the highly degraded reach located upstream of 59th Avenue and downstream of Gilbert Road.

Long-Term Degradation: Hayden Road to Country Club Drive

A detailed investigation channel change near the mining cluster located between Hayden Road and Country Club Drive was conducted to document an example of the potential impacts of in-stream mining on channel stability. Mining data for the Hayden Road-Country Club Drive area has been collected since 1962, in part for the ADOT Report. Sand and gravel extraction from 1962 to 1986 was estimated at 58.5 million tons, from in-stream pits that had average excavation depths of 10-30 feet (ADOT, 1989). Historic, individual mining operations at a particular location within the study reach were also identified in the ADOT report. These individual operations were grouped into smaller mining clusters, as illustrated in Figure 8. The reach was then divided into grid cells of equal area and numerically coded. The years of active mining for each grid cell, by numeric code, are listed in Table 4.

In the ADOT Report, the grid matrix was used to estimate the average change in bed elevation within each grid cell, using the topographic data sources listed in Table 5. The ADOT Report methodology was adopted for this study and was extended both spatially and temporally using additional photographic and topographic information described above and listed in Tables 2 and 3. A 101-cell grid was created in a digital GIS format for the Hayden Road-Country Club Drive mining cluster reach, as shown in Figure 9. Each cell is approximately 1,024 feet on a side and comprises an area of about 24 acres (0.04 mi.^{2}). Elevation data were collected at each grid corner and averaged to yield the cell elevation for each year of topographic coverage.

Changes in channel elevation were calculated for three periods: 1962 to 1986, 1986 to 2001, and 1962 to 2001. Elevation data for 2001 were collected from digital terrain model (DTM) data obtained from the District's Floodplain Delineation Study of the Salt River. These topographic data were used to generate digital topography with a 1-foot interpolated contour interval that was then superimposed over the 2001 topography. Following the ADOT Report methodology, elevations were measured at each grid cell corner to derive a mean cell elevation. All topographic data were converted to the National Geodetic Vertical Datum of 1929 (NGVD 29). Mean grid cell elevations from 1962 to 1986 reveal that over 80 percent of the Hayden-Country Club mining cluster reach experienced a lowering of the base channel elevation by an average of 10.2 feet, as shown in Figure 10. From 1986 to 2001, only 28 percent of the reach experienced degradation, with a mean depth of 7.9 feet, as shown in Figure 11. Note that many of the grid cells in Figure 10 that experienced degradation from 1962 to 1986, had a positive net

[1] Shallow and exposed bedrock crops out in the bed of the Salt River near Mill Avenue and limits long-term degradation at that point.

change in channel elevation from 1986 to 2001. The rebound in channel elevation is primarily due to channelization associated with construction of the Loop 202 highway and the Loop 101-202 Interchange. Overall, from 1962 to 2001, the reach experienced an average of 14.0 ft. of channel lowering over 50 percent of the study reach (*Figure 12*). Grid cells with negative elevation changes in Figures 10 to 12, and that are located outside the actively mined areas indicate channel degradation typically extends well beyond the limits of the actual mining excavation.

A topographic map showing the net change in channel elevation from 1962 to 1986 is shown in Figure 13, as well as the immense volume of aggregate material removed from the floodplain. Given the volume of material removed from the channel and the depth of most excavation, part of the channel bed lowering shown in Figure 13 can explained by direct excavation of the channel during the mining process. However, given that only portions of the lower Salt River were mined (*Figure 7*), direct excavation cannot explain the measured lowering of the channel between mining areas, nor can it explain the long-term degradation observed upstream of the in-stream pits.

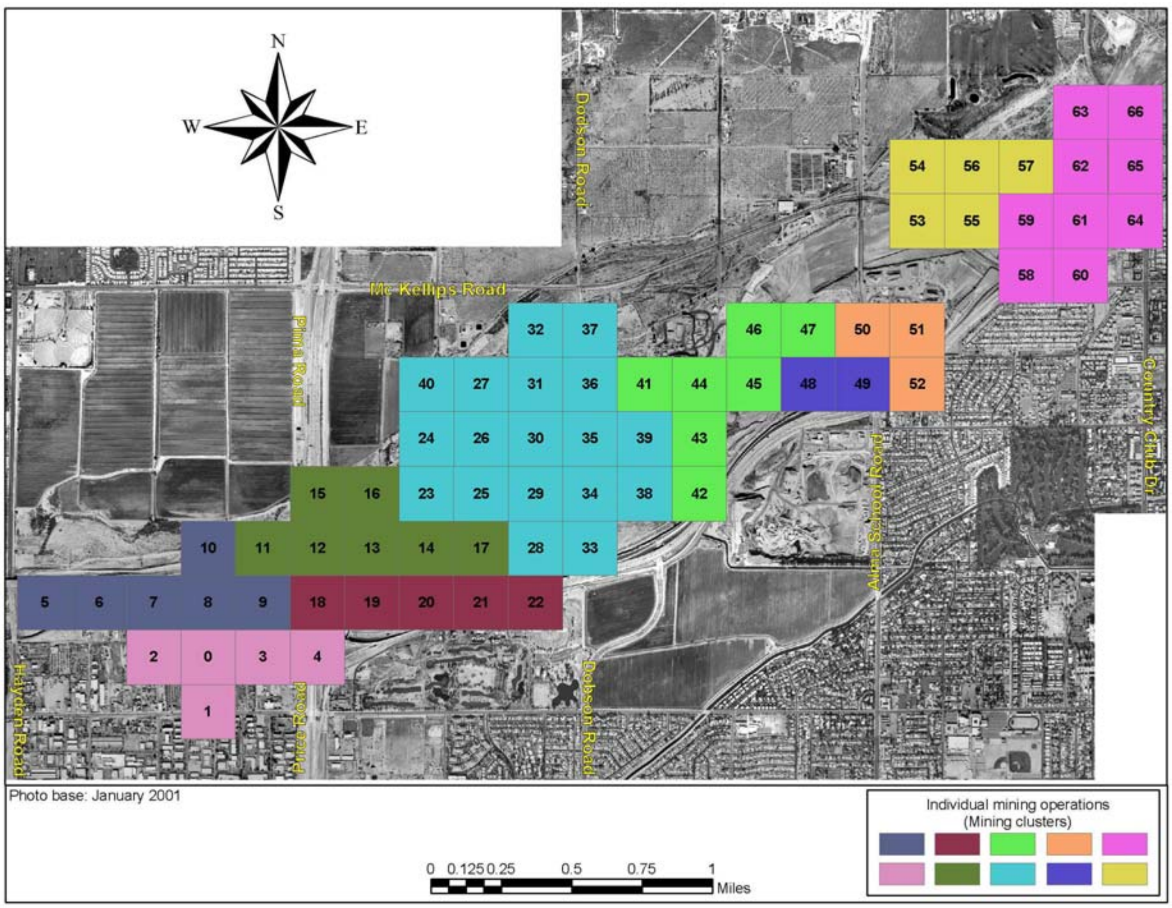

Figure 8. Historic mining clusters located between Hayden Road and Country Club Drive.

Table 4. Years of Active Mining Within the Hayden-Country Club Mining Cluster.			
Grid ID	Years of Active Mining	Grid ID	Years of Active Mining
0	1973,1977,1978,1980,1981,1982,1985	34	1984,1985,1986,1987
1	1973,1977,1978,1980,1981,1982,1985	35	1972,1980,1982,1983,1985,1986,1987
2	1977,1978,1980,1981,1982,1985	36	1980,1981,1985,1986,1987
3	1972,1973,1982,1985	37	1985,1986,1987
4	1982	38	1984,1985,1986,1987
5	No data	39	1972,1979,1980,1985,1986,1987
6	1985,1986,1987	40	1987
7	1980,1981,1984,1985,1986,1987	41	1979,1980,1981,1982,1985,1986,1987
8	1973,1975,19.77,1979,1980,1981,1982,1985,1986,1987	42	1973,
9	1972,1973,1978,1979,1980,1982,1985,1986,1987	43	1972,1973,1976,1978,1979,1981,1982,1985,1987
10	1973,1982,1985,1986,1987	44	1972,1975,1977,1978,1979,1982,1985,1986,1987
11	1973,1975,1976,1981,1982,1983,1984,1985,1986,1987	45	1969,1972,1973,1979,1982,1985,1987
12	1976,1978,1981,1982,1983,1985,1986,1987	46	1969,1972,1985,1987
13	1981,1982,1983,1984,1985,1986,1987	47	1969,1972,1985,1986,1987
14	1975,1985,1987	48	1969,1972,1977,1979,1982,1983,1985,1986,
15	1985	49	1969,1972,1977,1982,1983,
16	1982,1983,1985,1987	50	1969,1972,1987
17	1975,1987	51	1972,1973,1975,1676,1677,1678,1980,
18	1977,1978,1979,1980,1981,1982,1983,1985,1987	52	1973,
19	1978,1979,1980,1981,1983,1985,1987	53	1969,1972,
20	1975,1978,1979,1980,1981,1983,	54	1972,1976,1982
21	1978	55	1972,
22	1978	56	1969,1972,1976
23	1972,1984,1985,1986,1987	57	1969,1972,
24	1984,1986,1987	58	1973,1975,1976,1978,1980,
25	1984,1985,1986,1987	59	1973,1975,1976,1978,1980
26	1972,1984,1985,1986,1987	60	1973,1976,1978,
27	1985,1986,1987	61	1969,1972,1973,1975,1976,1978,1987
28	1985,1986,1987	62	1969,1972,1973,1975,1976,1977,1685
29	1984,1985,1986,1987	63	1969,1972,1973,1976,
30	1972,1982,1983,1984,1985,1986,1987	64	1976
31	1981,1982,1984,1985,1986,1987	65	1972,1973,1976,1977,1980
32	1985,1986,1987	66	1969,1972,1973,1976,
33	1984,1985,1986,1987		
Source: ADOT Report Grid cell ID's shown in Figure 8.			

Table 5. Topographic sources from ADOT report	
Topography Date	Source
1952	U.S. Geological Survey Tempe Quadrangle Map – 10 ft. contour interval
1952	U.S. Geological Survey Mesa Quadrangle Map – 10 ft. contour interval
1962	FCDMC – 2 ft. contour interval
1986	ADOT – East Papago and Hohokam Freeway Study – 2 ft. contour interval
1986	Salt River Floodplain Analysis – 2 ft. contour interval

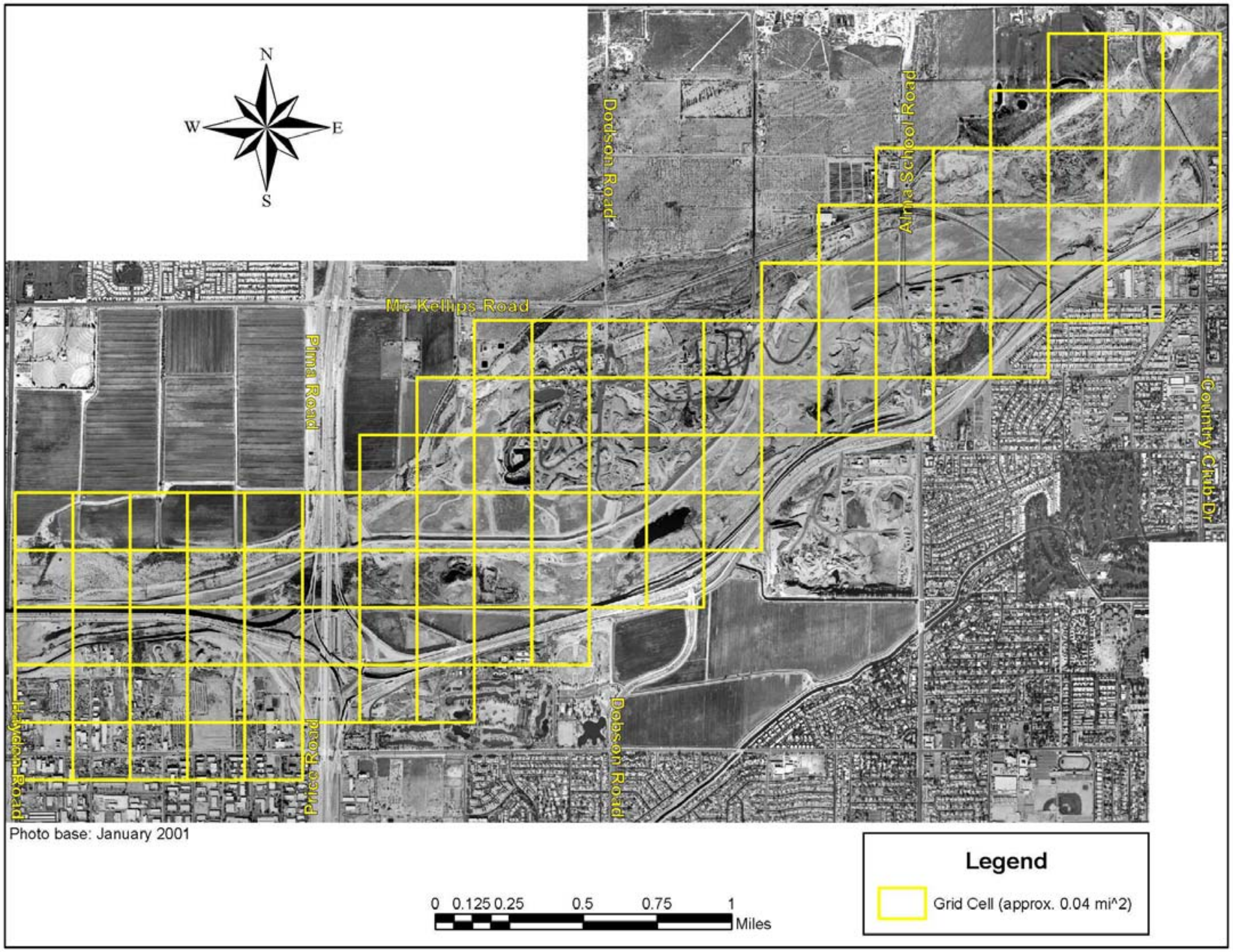

Figure 9. Grid matrix for Hayden Road-Country Club Drive Mining Cluster Reach.

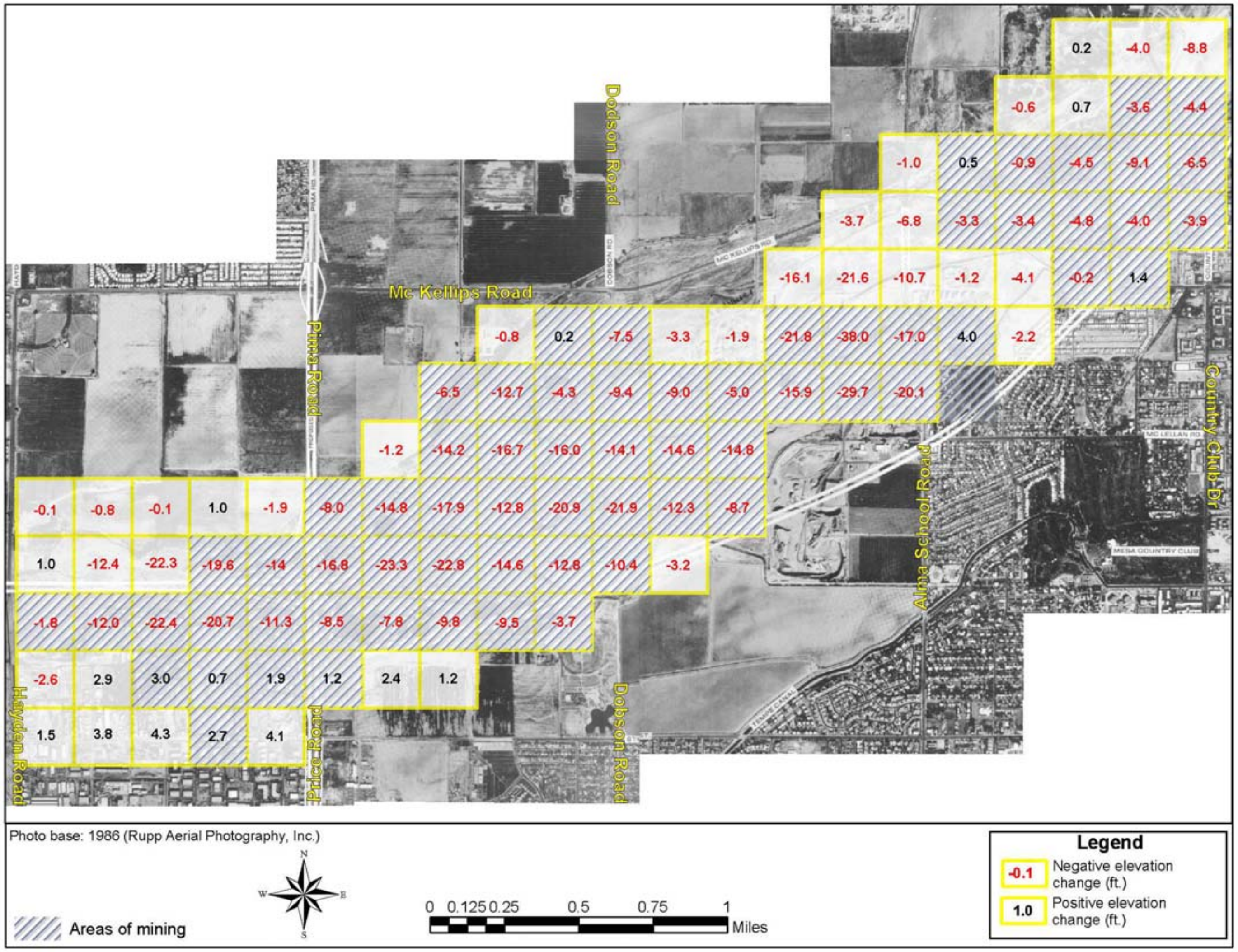

Figure 10. Mean elevation change from 1962-1986 in the Hayden-Country Club Mining Cluster.

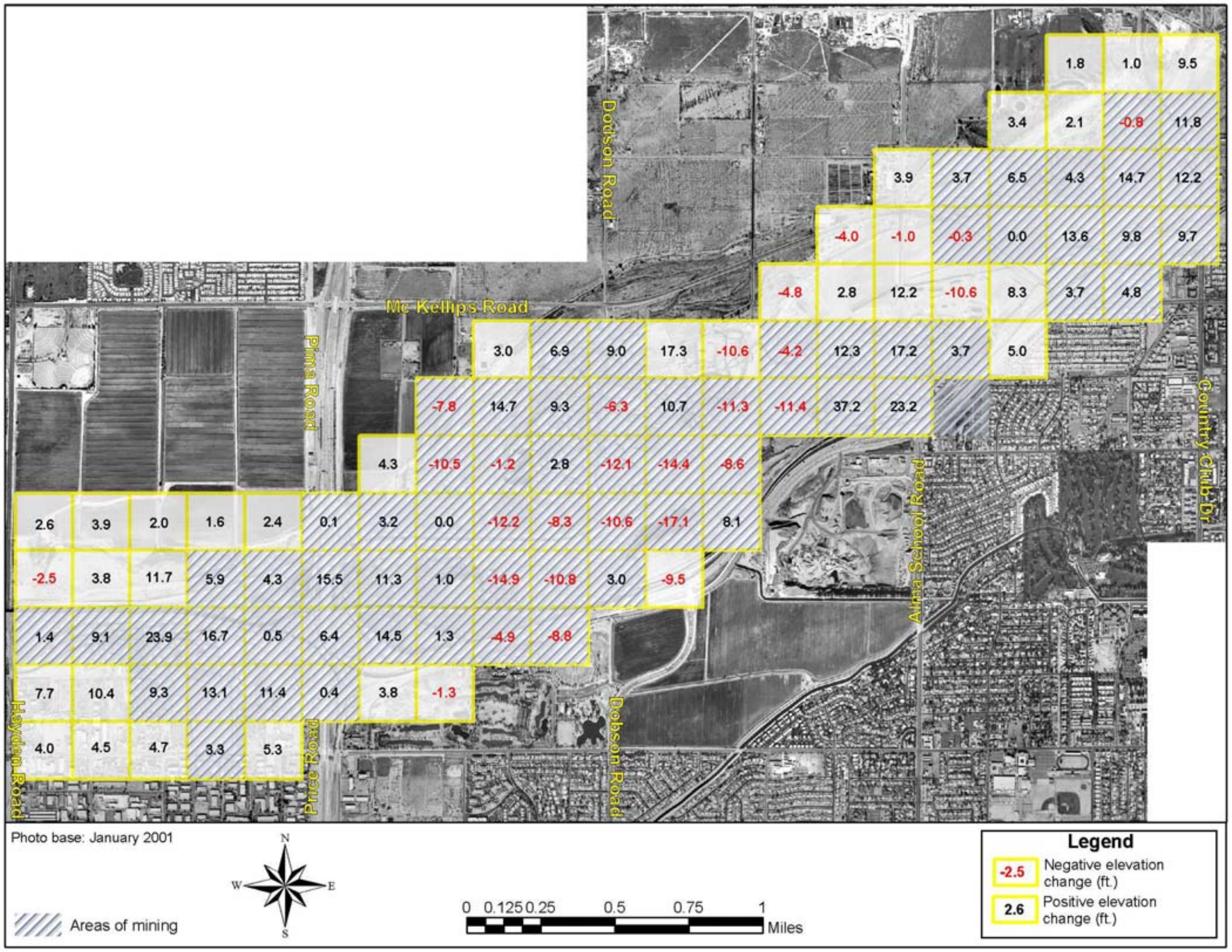

Figure 11. Mean elevation change from 1986-2001 in the Hayden-Country Club Mining Cluster.

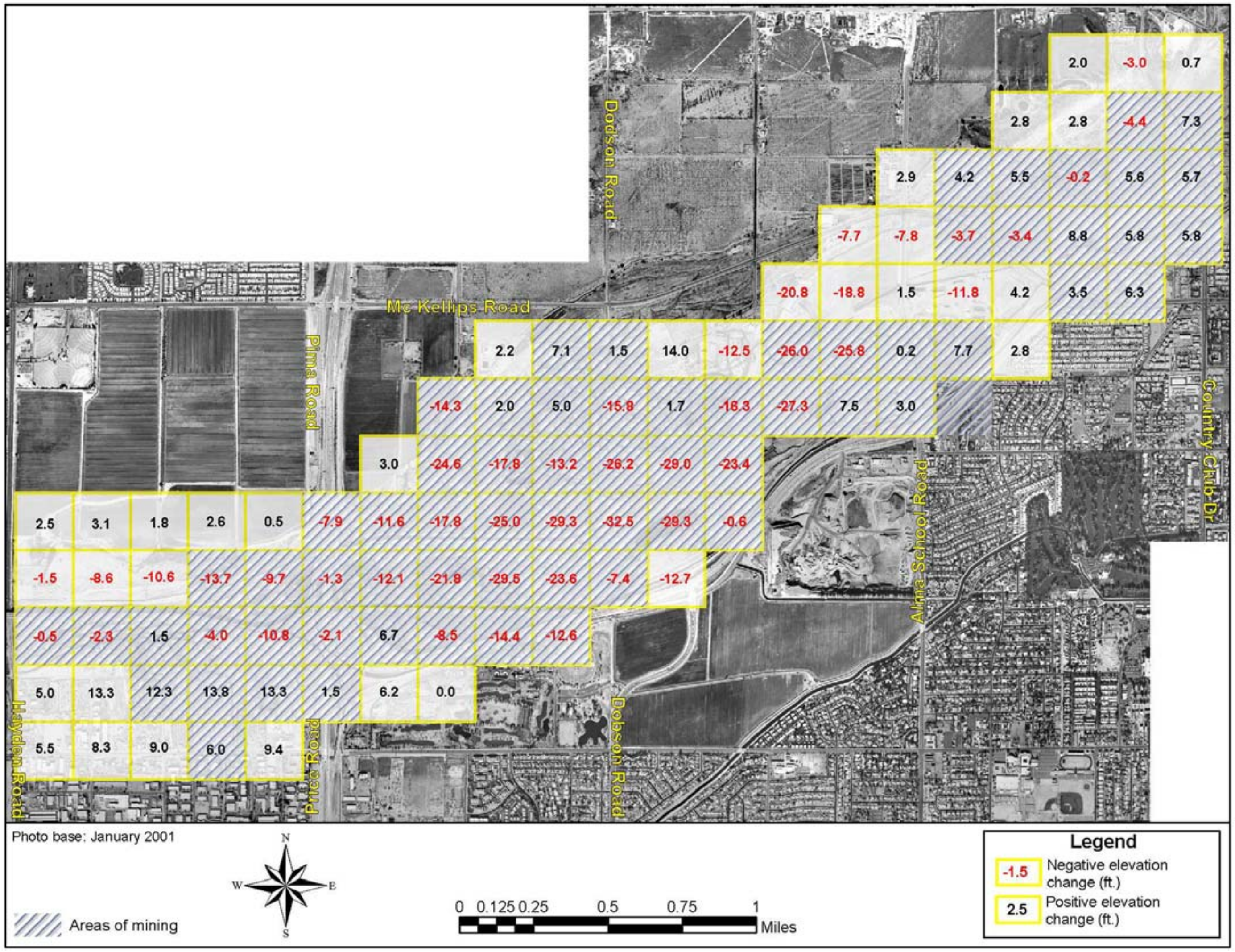

Figure 12. Mean elevation change from 1962-2001 in the Hayden-Country Club Mining Cluster.

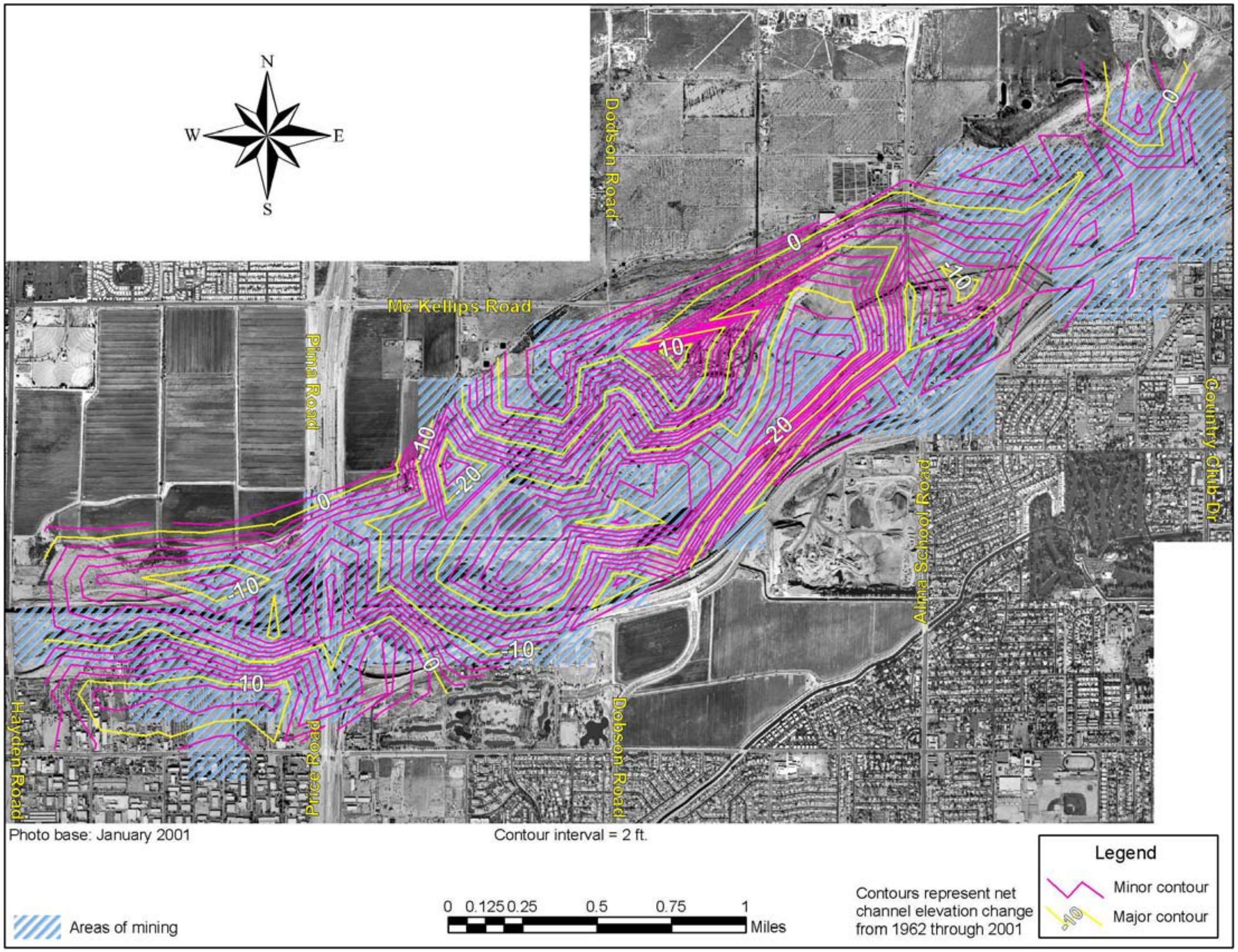

Figure 13. Topographic map of long-term channel elevation change (1962-2001) in the Hayden-Country Club Mining Cluster.

Long-Term Degradation Mechanisms

Upstream Impacts. The upstream effects of in-stream sand and gravel mining can be observed in both long- (decades) and short-term (single flood event) time scales. Headward erosion occurs on both time scales, and depends on the duration and magnitude of runoff. Headward erosion occurs naturally on rivers, such as when a river-fed lake experiences a lowering of the lake level, creating a nick point at the river mouth that propagates upstream through the delta. Headward erosion can also result from anthropogenic activity, such as in-stream sand and gravel mining that lowers the base level of the river by excavating material from the main channel or the floodplain. The lowered base level alters the natural sediment and energy continuity and creates erosive forces that alter channel morphology. Excavation of an aggregate mine within an active channel creates an over-steepened slope on the upstream pit wall. As water flows over the over-steepened slope, stream power increases, thus enabling sediment erosion (*Figure 14*). The locally steepened slope migrates upstream, lowering the streambed until an equilibrium slope and elevation is achieved, unless a manmade structure or a natural feature such as bedrock prevents such erosion. If no additional excavation or re-excavation occurs, the pit may eventually fill in with sediment. Photographs of headward erosion are shown in Figures 15 to 17.

As shown in Figures 7, 12, and 13, and as documented in the ADOT Report, headward erosion upstream of the Hayden-Country Club mining cluster is one of the primary causes of long-term degradation of the lower Salt River.

Downstream Impacts. Long-term degradation can occur downstream of in-stream sand and gravel operations, primarily due to the sediment deficit created when sediment is trapped and deposited in a flood excavation (Figure 14). The ADOT Report describes the downstream impacts of in-stream sand and gravel mining in the Hayden-Country Club mining cluster:

> *Since 1962, the channel invert at Hayden Road has degraded 14 feet, and immediately upstream of the bridge, the channel invert in existing mining excavations is 35 feet below the 1962 invert elevation. The reach of the Salt River below Hayden Road sustained a series of flood flows (1978, 1979, 1980, and 1983) and has not been re-channelized or disturbed by mining since. The channel profile at this location shows a distinct reduction in gradient from the prevailing 0.002 ft/ft to less than 0.001 ft/ft. The channel resumes the steeper gradient, one mile below the Hayden Bridge. The reduction of the channel gradient in this reach is indicative of clear water scour caused by a reduction in sediment supply. Trapping of sediments in upstream sand and gravel excavations is the cause of the reduced sediment supply. At Alma School Road the channel had degraded 6 to 7 feet since 1962, and 30 to 40 feet below the 1962 invert elevation in mining excavations located 1500 feet downstream of the bridge site. At Country Club Road, the channel invert is 15 feet below the 1962 elevation at the bridge site, and 30 to 35 feet below the 1962 invert elevation in the mining excavations located immediately below the bridge. (ADOT, 1989)*

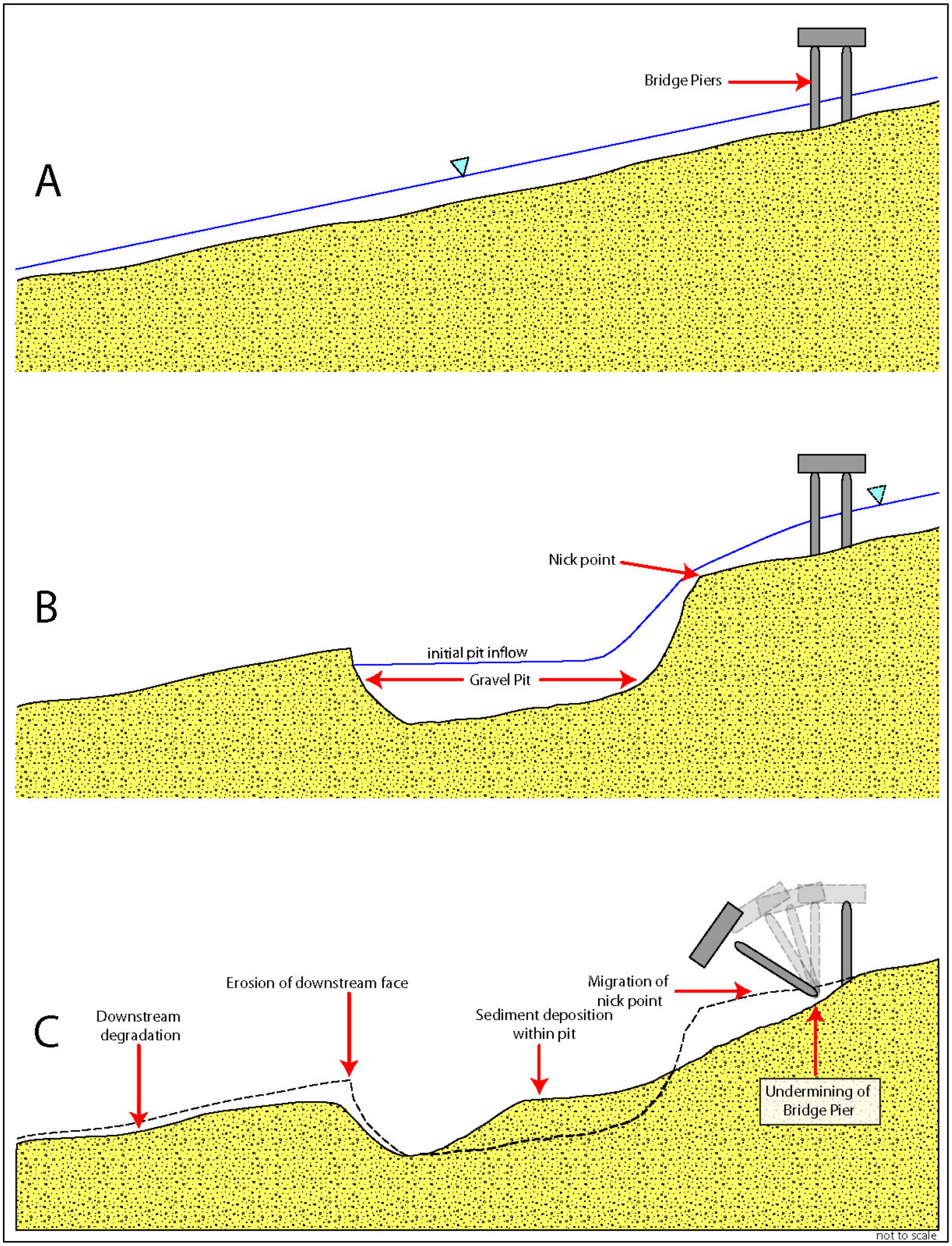

Figure 14. Schematic illustration of potential erosion due to in-stream mining. (A) Energy in is equilibrium, no net deposition or erosion occurs. (B) During flood, flow into the excavation creates a nick point and headward erosion begins. (C) Continued nick point migration upstream can undermine bridge piers, causing collapse. Also, note the erosion at the downstream edge of the excavation and deposition in the excavation due to sediment trapping.

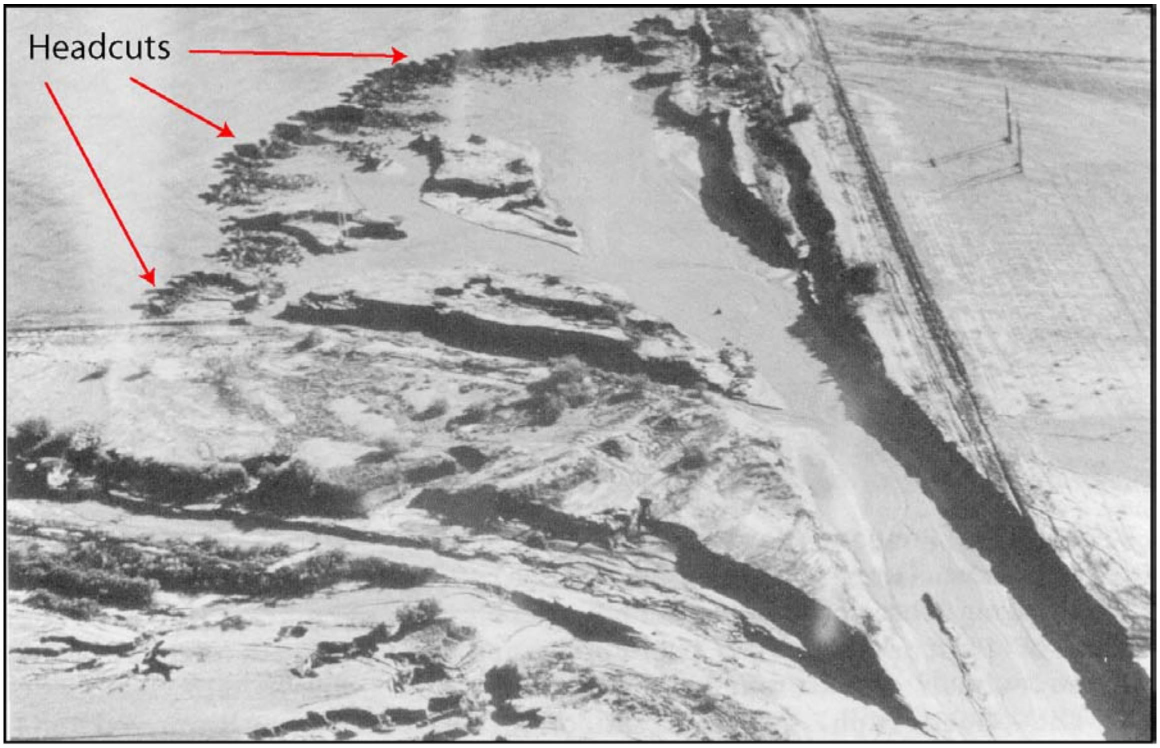

Figure 15. Headcutting on the Santa Cruz River 9 miles northwest of Marana, AZ, October 1983 (Saarinen et al., 1984) .

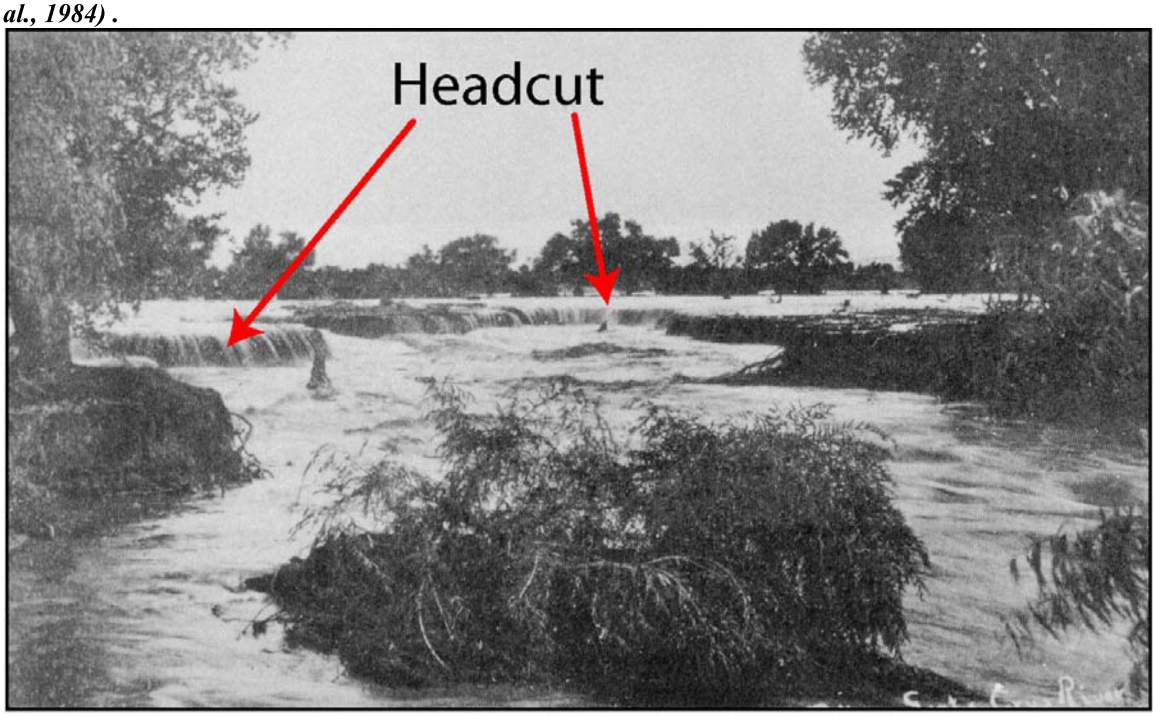

Figure 16. Historic photograph of headcuts on the Santa Cruz River in 1889 (Baker et al., 1988).

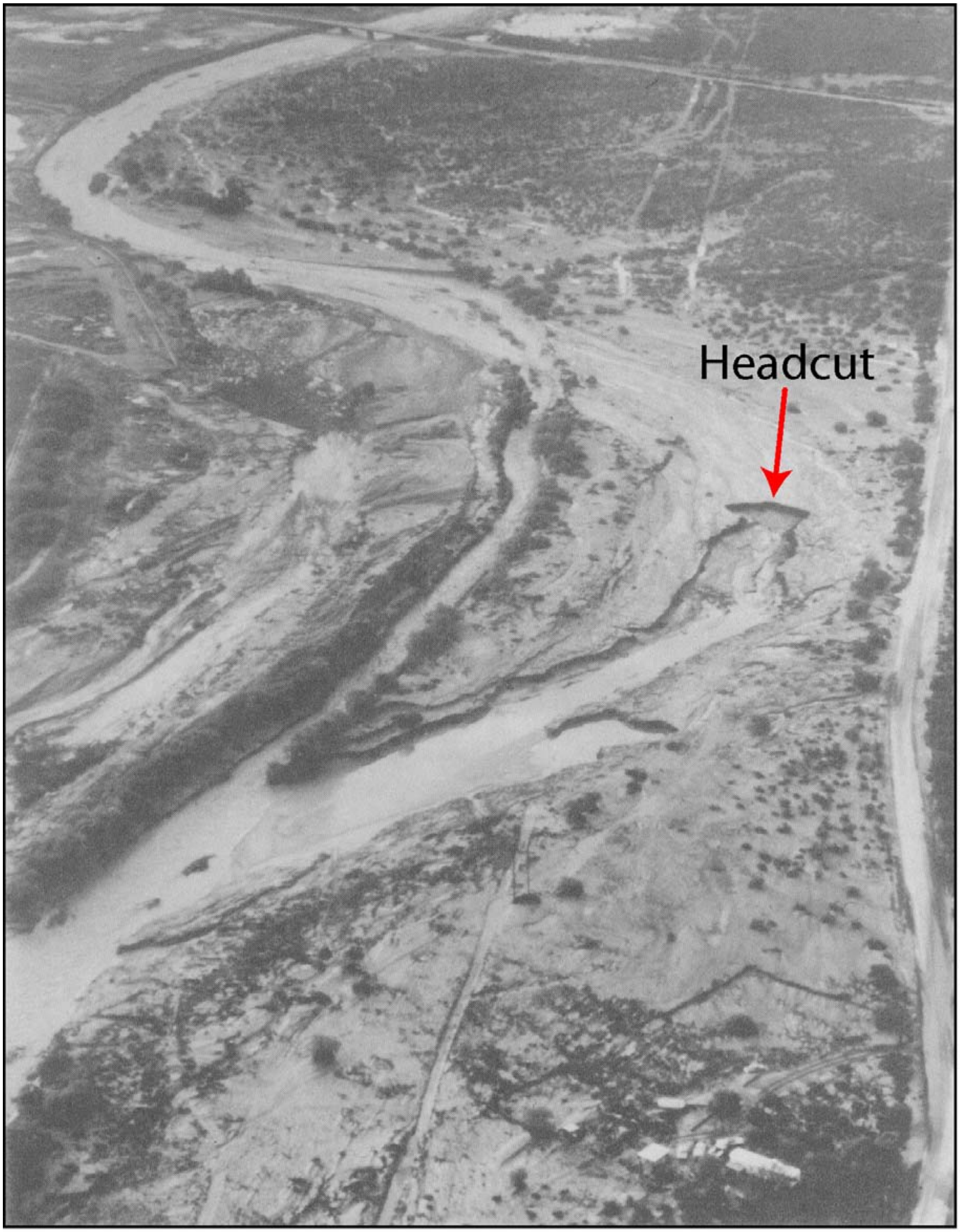

Figure 17. Headcuts on the Santa Cruz River floodplain, October 1983 (Baker et al., 1988) .

Bridge Inspection Reports. Conclusions regarding long-term degradation are supported by descriptions of the channel contained in 1983 to 1997 ADOT bridge inspection reports for the Country Club Drive Bridge.

Inspection Date: 11/10/1982	
Channel: 25 ft. deep borrow pit 200 ft. downstream. 12 ft. deep pit 100 ft. upstream.	
Inspection Date: 12/08/1983	
Channel: Degraded 1-2 ft. under span #5 during recent flow. Borrow pits were mostly filled in during recent flow; however, a new pit is now is progress 200 ft. downstream.	
Inspection Date: 10/07/1985	
No significant change in channel profile. Mining operation is back in business 100 yds downstream. Pit is 20 ft.± deeper than low channel.	
Inspection Date: 12/02/1987	
Channel: Thalweg is in span 5. At this point degradation is 7 ft.± in 2 years. There is a gravel mine upstream approx. 0.8 mi and one downstream approx 1.2 mi. The downstream mine is in the thalweg. Low point of thalweg is El.1189 ft.± at the Bridge. According to the plans, "max. allowable future channel excav." is El.1180.0 ft.. River profile from [staff] and field observation indicates that it would not take too many flows to reach El. 1180.0 ft.	
Inspection Date: 08/13/1992	
The channel near Pier #4 has degraded 4 ft. since last inspection, due to recent water releases. This thalweg is now at approx. El.1185 ft. and there is a headcut 500 downstream to the borrow pit which is approx. 18 ft. deep. Any flows will soon scour below the minimum allowable channel excav. (1180 ft. per plans). There are borrow pits upstream also.	
Inspection Date: 01/07/1997	
Channel has shifted causing degradation around pier 8 instead of pier 4 as noted before.	

Conclusion

Long-term channel degradation can dramatically impact channel stability and public infrastructure both near the source of degradation and a significant distance up and downstream. In-stream sand and gravel mining on the lower Salt River was demonstrated to have caused significant long-term degradation. The mining of large volumes of sediment from an otherwise dry channel bottom may show little regional impact for many years, but has steadily increased in magnitude and extent during the past few decades. Consequently, the ultimate extent of degradation may not be felt for several more decades.

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