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ARIZONA DEPARTMENT OF TRANSPORTATION
TRANSPORTATION RESEARCH CENTER

INTERIM REPORT

PRESENTING

THE INITIAL DATA BASE ASSEMBLED TO STUDY THE EFFECTS OF IN-STREAM MINING ON CHANNEL STABILITY

Simons, Li & Associates, Inc.
December 1986

sla

THE EFFECTS OF
IN-STREAM MINING
ON CHANNEL STABILITY

INTERIM REPORT

ON

INITIAL DATA BASE

Arizona Department of Transportation

Transportation Research Center

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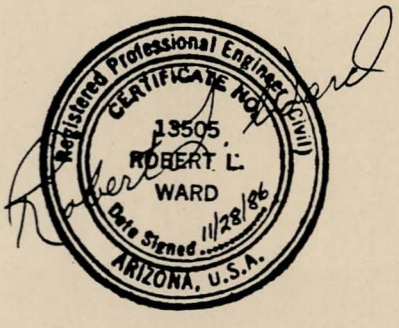

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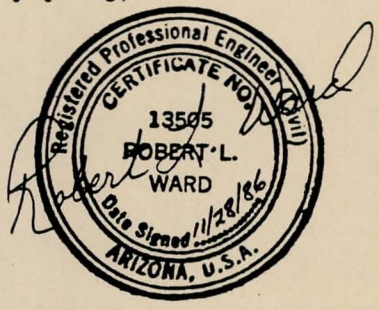

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I. INTRODUCTION

Sand and gravel constitute 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, frequently 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 historicaly known to be unstable during floods.

The alluvial river systems of the southwestern United States are typically ephemeral streams, flowing only in response to significant amounts of rainfall. As such, they are an easily accessible and economical source of sand and gravel. However, continual removal of these natural materials from a river system may change the hydraulic and sediment transport characteristics of the system. The river's response to such changes often take the form of accelerated degradation, aggradation, headcutting and lateral migration. The occurrence of these phenomena can endanger adjacent property, highways, bridges, or other structures located in the floodplain environment.

The State of Arizona has suffered several large floods during recent years. The presence of in-stream gravel pits has fueled speculation that such operations have caused river instability problems which may have been partly responsible for flood-related damage to roads/bridges and nearby riverbank property. The concern and speculation arising from this issue has prompted the Arizona Department of Transportation to fund an 18-month long research project to study this problem and to recommend possible regulatory procedures and technical guidelines for in-stream sand and gravel mining.

The Scope of Work for this project is organized in a format that provides time for an initial literature search prior to pursuing the detailed technical research that will lead to the development of recommended regulatory procedures. The purpose of this literature search is to provide the beginning of a data base that will be expanded upon and referred to throughout the course of the research project.

At this early stage of the research project, the data base emerging from the literature search will help provide insight into the historical severity of in-stream mining problems (related to river stability) and identify proce-

dures or programs that are currently being used to regulate in-stream sand and gravel mining operations. The data base will also include economic data related to the sand and gravel mining industry.

The purpose of this Interim Report is to: 1) provide an overview of the initial data base assembled by Simons, Li & Associates, Inc. (SLA); 2) identify areas where additional literature search is needed; and 3) determine if the data collected to date supports any revisions to, or changes in, the direction of the original Scope of Work prepared by SLA for this project.

II. FLOOD DAMAGE TO TRANSPORTATION SYSTEMS & IN-STREAM GRAVEL MINES IN ARIZONA

Floodplain encroachments by both transportation systems and gravel mining operations have resulted in substantial damage to both of these entities during recent years. Although there is relatively little quantitative data relating these damages to each other, there is a substantial data base listing monetary damages incurred by each of these entities during major floods on Arizona rivers. Table 2.1 itemizes such damage by: 1) river; 2) damage category; and 3) date of occurrence. It should be emphasized that these figures are presented for information purposes only, and that they are not intended to imply that in-stream sand and gravel operations were responsible for the monetary damages to roads and bridges during the listed floods.

TABLE 2.1

SUMMARY OF FLOOD DAMAGES TO TRANSPORTATION SYSTEMS

AND IN-STREAM SAND & GRAVEL MINES IN ARIZONA

RIVER	DAMAGE CATEGORY	1/ Dec 1965 Jan 1966	2/ Oct 1972	3/ Oct 1977	4/ Feb-March 1978	5/ Dec 1978	6/ Feb 1980	7/ Oct 1983
Salt River Granite Reef Dam To Gila River	Roads & Bridges Sand & Gravel	$1,686,000 1,967,000						
Gila River To Gillespie Dam	Roads & Bridges Sand & Gravel	91,000 32,000						
Gila River Safford Valley, Graham County	Roads & Bridges Sand & Gravel		227,000 N/A					
Gila River in Duncan & York Valleys, Greenlee Cty	Roads & Bridges Sand & Gravel		1,000 N/A					
San Francisco River @ Clifton	Roads & Bridges Sand & Gravel		184,000 N/A					
Nogales Wash Santa Cruz County	Roads & Bridges Sand & Gravel			69,000 N/A				
Santa Cruz River, Santa Cruz County	Roads & Bridges Sand & Gravel			682,000 N/A		9/		9/
Santa Cruz River, Pima County	Roads & Bridges Sand & Gravel			784,000 N/A		9/		9/
Santa Cruz River, Pinal County	Roads & Bridges Sand & Gravel			54,000 N/A		9/		9/
Salt River from Granite Reef Dam To 115th Ave.	Roads & Bridges Sand & Gravel				11,809,000 1,814,000			
Gila River, Maricopa County	Roads & Bridges Sand & Gravel				340,000 680,000			9/
Salt River, Metropolitan Phoenix	Roads & Bridges Sand & Gravel					17,985,000 3,921,000	16,399,000 1,710,000	
Gila River, Metropolitan Phoenix	Roads & Bridges Sand & Gravel					1,526,000 45,000	1,360,000 23,000	
Aqua Fria River, Metropolitan Phoenix	Roads & Bridges Sand & Gravel					1,999,000 1,277,000	4,242,000 62,000	
All rivers within Pima County	Roads & Bridges Sand & Gravel	9/				9/		28,000,000 8/
All rivers within Greenlee County	Roads & Bridges Sand & Gravel							4,320,000 8/
All rivers within Santa Cruz County	Roads & Bridges Sand & Gravel							3,879,586 8/
All rivers within Graham County	Roads & Bridges Sand & Gravel							1,660,000 8/

REFERENCES FOR TABLE 2.1

1/ Flood Damage Report on Flood of December 1965-January 1966
Salt and Gila Rivers, Granite Reef Dam to Gillespie Dam, Arizona
U.S. Army Corps of Engineers, April 1966

2/ Flood Damage Report, Flood of October 1972
Gila River Basin above San Carlos Reservoir, Arizona and New Mexico
U.S. Army Corps of Engineers, August 1973

3/ Flood Damage Report on Storm and Floods on 6-10 October 1977
Santa Cruz, Gila, and San Pedro Rivers, Arizona
U.S. Army Corps of Engineers, September 1978

4/ Flood Damage Report, 28 February - 6 March 1978
on the Storm and Floods in Maricopa County, Arizona
U.S. Army Corps of Engineers, February 1979

5/ Flood Damage Report, Phoenix Metropolitan Area, December 1978
Flood
U.S. Army corps of Engineers, November 1979

6/ Phoenix Flood Damage Survey, February 1980
U.S. Army Corps of Engineers, April 1981

7/ Federal/State Damage Survey Reports, October 1983
Federal Disaster Declaration
Arizona Division of Emergency Services

8/ Damages to sand and gravel operations undoubtedly occurred during this flood, but they are not reported on Federal Disaster Survey Reports.

9/ Damage is known to have occurred, but no data base listing monetary damages was found.

III. REVIEW OF REGULATORY PRACTICES RELATED TO IN-STREAM MINING

3.1 Introduction

This review covers literature supplied by federal, state, and local agencies responsible for the regulation of sand and gravel mining operations. The bulk of the literature was gathered by Mr. Ottozawa Chatupron in the period from February and March of 1986 and has been supplemented by SLA staff during the course of preparation for this report.

The literature was divided into four categories: (1) federal programs, (2) California state programs, (3) state programs other than California, and (4) Arizona programs. A large amount of regulatory information is associated with the state of California, in conjunction with the Surface Mining and Regulation Act (SMARA). Policy guidelines have been established for in-stream sand and gravel mining operations as a result of the enactment of SMARA. Counties have primary jurisdiction over sand and gravel mining operations in California.

3.2 Federal Programs

3.2.1 General

A paper by Mossa (1) provides an overview of the general regulatory environment for sand and gravel mining operators in the United States. At this time, there is no federal regulation of in-stream sand and gravel mining. Some federal laws could be interpreted as having an indirect affect on sand and gravel mining activities. These include the Rivers and Harbors Act of 1899 (Section 10), the Federal Water Pollution Control Act (FWPCA) Amendments of 1972 (Section 404), the National Environmental Policy Act, the Federal Land Policy and Management Act, and the National Flood Insurance Policy Act. Because federal law does not directly control in-stream mining operations, most of the responsibility is at the state and local government level. Local control takes the form of zoning ordinances, permits, plans, and variances. The focus of this regulation is primarily on operation and reclamation plans, not on planned resource development or environmental management. Mossa identifies the following issues related to in-stream sand and gravel mining:

- A decrease in channel stability with regard to position and gradient
- Impacts on flood rates and the flood boundary

° Impact on water quality

° Loss of floodplain habitat with impacts to fisheries and wildlife

The following general guidelines are put forth for in-stream sand and gravel development.

° Avoid removal of riparian vegetation.

° Excavation should not be permitted in channel bottoms or point bars.

° Post mining landscape should be left in a stable, non-hazardous, and useful condition.

° Encourage sand and gravel industry development in locations that will benefit (for example, where flood-control channelization is needed.)

3.2.2 Corps of Engineers Policies and Guidelines

The Corps of Engineers (COE) studied sand and gravel mining operations in the Phoenix/Tempe area (2), and found that extensive mining is taking place. Most of the mining is not subject to floodplain regulations because state law exempts floodplain users prior to enactment. However, additions or changes are subject to regulation. COE also noted that multi-jurisdictional responsibilities hinder enforcement of existing regulations. They propose minimum guidelines for sand and gravel operations based on a report by Boyle Engineering (3) (see discussion in Section 6.8.2). Defining the problem in the Phoenix metropolitan area, the COE notes that sand and gravel operations have followed the pattern of expanding urbanization. Streambed lands are under both public and private ownership. There is fragmented jurisdictional authority with involvement on the part of separate governments representing the Indian reservation, Maricopa County, and municipalities. Federal laws are not applicable to Indian reservations; but are followed on federal lands, or when federal grant monies to Indian tribes are involved. Maricopa County administers all unicorporated areas, and the municipalities administer within their corporate boundaries.

The current pattern of excavation is essentially random and has taken place in a leapfrog fashion. The COE estimated that planned excavation of the Salt River floodway could provide improved flood control. They recommend a channel excavated at a grade of 0.10% (approximately half the existing gradient), with 3:1 sideslopes to a depth of 30 to 40 feet below the floodplain. Maintenance of the channel grade will require grade control.

Five structures are proposed: Central Avenue, 16th Avenue, 24th Street, I-10, and Scottsdale Road.

The Federal Water Pollution Control Act, Section 404 is administered by the Corps of Engineers. Barnett (4) reviews the legislative history and the Corps administration of the permit process as it relates to the arid west. Barnett reviews the legislative history of Section 404, addressing the legislative intent related to several key issues in the Act. The 1972 amendments to the FWPCA adopted a broad definition of navigable waters, as follows: "waters of the United States, including the territorial seas". Barnett states that the 1972 legislative history shows that section 404 was created to protect the Corps of Engineers and private dredging operations from the more comprehensive water quality program (Section 402). Section 404 was intended to put pressure on the Corps to end the practice when alternatives to open water disposal were available. Barnett quotes Senator Muskie as saying that the use of the word "fill" was to make clear that if the specific disposal site agreed upon by the Corps and the Environmental Protection Agency (EPA) was on land in the form of a fill, that there would be no ambiguity on the question of whether or not it also was covered by Section 404. Implementation of Section 404 by the Corps required substantial clarification of the term "navigable water". The Corps initially published regulations in 1974 that limited the scope of jurisdiction to "traditional" navigable waters. After a great deal of public controversy and congressional review, interim final regulations were published in July 1975 based on the expanded definition of navigable waters. The 1977 regulation threw out the term "navigable waters" altogether in favor of exclusive reference to "waters of the United States" for jurisdictional purposes. The Corps implemented the concept of a nationwide permit at this time that permitted, by regulation, many routine activities not specifically exempted by definition. Exempted activities included agriculture, silviculture, and construction.

According to Barnett, the 1977 Amendments to the FWPCA did not change the broad definition of navigable waters for the purpose of water quality, but did make the following key changes: 1) the ability to issue general permits; 2) exemption for routine activities considered to be of insignificant impact; 3) exemption from regulation any discharge of dredged material which is determined to be a "best management practice" under an approved Section 208 plan;

4) procedures for the states to assume administration of the Section 404 program; 5) procedures to expedite permit processing; 6) exemption of Federal projects if the impacts were addressed in an EIS submitted to Congress prior to authorization; 7) procedures for handling violations; and 8) recognition of the state's authority to control discharges of dredged or fill material within its jurisdiction (including the activity of any Federal agency).

According to Barnett, the Corps revised their regulations in September 1980; the regulations were not promulgated by the Reagan administration. The Reagan administration felt that the Section 404 program had gone far beyond its originally intended scope. The Reagan administration issued their revised regulations in July 1982. The Presidential Task Force on Regulatory Relief, directed EPA to revise is regulations under section 404(g)-(1) to provide increased incentives and simplified procedures for state assumption of the 404 program.

Barnett states that the debate over the appropriateness of the current section of 404 program has focused on four major issues. Those issues involve: 1) whether the program, as administered is clearly what Congress intended; 2) whether administrative authority for the program should be with the Federal government, or delegated to the individual states; 3) whether the program represents Federal interference with state water allocations; and 4) whether the benefits derived from the program are worth the cost.

3.2.3 Federal Emergency Management Agency Policies and Guidelines

In their guidelines (5) the Federal Emergency Management Agency (FEMA) does not specifically establish standards for sand and gravel mining within designated flood-hazard areas. The National Flood Insurance program does require a floodplain-development permit. The standard for a floodplain-development permit prohibits development that will increase flood heights. A new sand and gravel operation would have to show that their operation would not have any significant adverse impact on flood elevations. If sand and gravel operations cause an alteration in a watercourse, modify the base (100-year) flood elevation, or alter the designated floodway, approval of any revision is required from FEMA. Revisions are in the form of either a Physical Map Revision (where selected map panels of the FHBW or the FIRM are modified to show the change), or a Letter of Map Revision (LOMR), which

describes the changes made and officially states that corrections to maps have been accepted by FEMA.

3.3 Regulation in California

The State of California has passed a fairly comprehensive piece of legislation that regulates surface mining (6). The Surface Mining and Regulatory Act of 1975 (SMARA) is administered by the Department of Conservation, Division of Mines, and the Geology Reclamation Board. The actual implementation of the act is a function of individual city or county governments in which the mining operations are located. The Reclamation Board reviews local actions and can intervene if they feel the act is not being enforced. The act sets standards for mining practice and reclamation. The act also seeks to classify mineral lands, and provides guidelines for mineral-resource management.

The Reclamation Board has a special policy for sand and gravel operations in floodways. The Board found that sand and gravel extraction near a levee can be detrimental to the integrity of the levee and/or can result in channel changes. The need to clear riparian vegetation during mining was found to be detrimental to flood management and wildlife habitat. Permit approval by the Reclamation Board is required before mining is allowed in a designated floodway. The following requirements must be met in order to obtain a permit.

General Requirements

1. Excavated material cannot be stockpiled within the limits of the designated floodway during the flood season.
2. Debris has to be completely cleared from the floodway.
3. Damage to levees or access ramps must be promptly repaired.
4. Excavation will not take place within 100 feet of the edge of a streambank.
5. Replanting of specified vegetation.
6. Extraction operations will not entrap fish or cause siltation of spawning gravels.

Specific Requirements

1. Excavation will not take place within 100 feet of the toe of a levee, toe of a streambank, or an adjacent property line.
2. Side slopes less than 3:1 (5:1 if excavation by dredge).

3. Excavation depth no lower than bottom of the low-water channel of the streambank adjacent to the excavation area (or not to exceed approved limit for excavation by dredge).
4. Uniform bottom excavation and, if in the floodway, clear and uniform excavation prior to flood season.

Examples of county implementation of SMARA associated with sand and gravel regulation are given by Orange County (7, 8), Sonoma County (9), Riverside County (10) and Sacramento County (11). Orange County has both zoning and mining regulations. The zoning ordinance (7) is administered by the county Environmental Management Agency, and has the following requirements:

° Limits pit depth to 150 feet from existing grade
° Requires reclamation of mined areas
° Requires a drainage and erosion-control plan
° Requires a plan of operations , including depth of all proposed excavation

The county ordinance (8) requires that all sand and gravel operations have a permit obtained from the county Department of Building and Safety. Standards are provided for inactive and active (or planned) operations. The following requirements are of interest:

° Setbacks - 50 feet, or as determined by the administrator based on the preservation of an adjacent flood-control channel.
° Slopes - inactive, 1.5:1
Active, if seepage problems exist (i.e., the pit is below the existing water table) a perimeter slope of 2.5:1; if not, then 1.5:1. In addressing more complex problems, Orange County contracted for detailed studies to assess the impacts of sand and gravel operations at the basin level. A study of San Juan Creek and Trabuco Creek in Orange County (12) was conducted to assess aggradation/degradation along river reaches in the basin. The study applied hydrologic, geologic, geomorphic, hydraulic and sediment transport analysis.

Methodologies used included:

° Hydrologic - at-gage statistical analysis (Log-Pearson III and Pearson III), and watershed modeling using programs HEC-1 and SWMM
° Geomorphic analysis - detailed geologic description of the basin,

description of channel reaches, bank-erosion history, aggradation/degradation history, evaluation of man's activity

- Hydraulic - water-surface profile determination using program HEC-2
- Watershed sediment yield - use of programs MUSLE and PSIAC
- Sedimentation - estimation of bed material transport, coarse-sediment yield, estimation of the dominant discharge, incipient-motion analysis (static equilibrium), equilibrium-slope analysis (dynamic equilibrium), and local scour at bridges
- Sediment transport - use of QUASED model, transport by size fractions, and determination of bed armoring.

The Sonoma County ordinance (13) regulates surface mining and was adopted June 1978. The following standards in Section 26A-6 pertain to gravel-mining operations:

- In-stream operations - required to avoid modification of the hydraulic capacity of the channel that would cause upstream or downstream erosion, or that would modify the streamflow (magnitude or direction) that would cause upstream or downstream erosion.
- Setbacks - 25-feet to property lines or public streets; may be required to submit a geotechnical report investigating the stability of excavation and the effect on adjacent property.

Substantial litigation over the effects of in-stream sand and gravel mining on river stability occurred in Sonoma County in the late 1970's. Newspaper articles (14) describe the outcome of this litigation and proposals for more restrictive regulation of sand and gravel operators. The litigation between sand and gravel companies and adjacent property owners along the Russian River and Dry Creek was settled out-of-court. The total settlement was $705,000. The proposed aggregate-resource management plan would curtail sand and gravel operations in in-stream and floodplain-terrace locations. Farmers and property owners were in favor of the plan. Gravel miners were opposed, saying the plan would result in unacceptable economic impacts.

One of the reports produced on the above litigation was by Slosson and Associates (15), which evaluated the impact of in-stream and terrace sand and gravel mining operations on bed and bank stability of the middle reach of the Russian River and Dry Creek in Sonoma County, California. The report presents data on gravel extractions volumes, topographic data (field surveys, including

measured cross-sections and river profiles), aerial photos (1940-1979), field investigations (soil types, existing erosion-control measures, types of riparian vegetation, locations of rock outcropping, and man-made structures such as dams and levees), existing reports and publications, and documentation of meetings with local, state, and federal agencies. The study concludes, based on a sediment bed-material mass balance, that sand and gravel extraction has caused a significant deficit in the sediment balance, resulting in property damage in these river reaches. Slosson estimated a replenishment rate of 0.27 Mtons/year. Another estimate of the replenishment rate was given in a report by D. B. Simons of 1.0 Mtons/year. Slosson considered their estimate more reliable than Simons, since it was based largely on actual measurements. However, Slosson does not include any estimate of the measurement error for this data. It is interesting to note that a measurement error of -25% for sand and gravel extraction and +25% for streambed volume change greatly reduces the difference between the two estimates. This error would revise estimated recharge based on a sediment balance to .71 Mtons/year. An error of +25 percent is typical of many fluvial measurements, and bias may have occurred in the sampling either as: 1) underreporting by the sand and gravel industry; or 2) by unintentional bias in selection of river cross-section locations.

Riverside County has addressed regulation of gravel mining on a pit-by-pit basis. Information on Riverside County's regulatory program was provided by the Chief Engineer for the Flood Control and Water Conservation District, Kennith Edwards (10). An example of the type of review given a large gravel-mining operation is given in intergovernmental correspondence regarding an operation on the San Gorgonio River located just south and west of I-10. Edwards stated the issues related to granting a permit for this operation in a letter to Carolyn Luna of the Riverside County Planning Department as: 1) the existing levee cannot be assumed to be sufficient to prevent the river from flowing into the proposed pits, the resulting erosion could undermine upstream railroad and highway bridges (it was assumed that headcutting erosion would occur at a grade twice that of the existing natural channel); 2) that pipelines are at risk due to potential headcutting; and 3) mining operations had caused local drainage problems. A letter from Norman Arno, Chief Engineer LACOE, stated the following COE guidelines: 1) on the excavated landward side

of a levee, the excavation should not extend below a plane passing through the present ground surface at a point 60-feet from the levee, and dropping at a ten percent slope; 2) on the floodway side of a levee, the excavation should not extend below a plane passing through the present ground surface at a point 200-feet from the levee and dropping at a slope of five percent, excavation should be made with a length to width ratio of about five (downstream length to cross channel width); and 3) headcutting is assumed to start at half the depth of excavation and to proceed upstream at twice the slope of the existing natural ground. Riverside County implemented SMARA with Ordinance No. 555, which requires the operator to submit mining and reclamation plans. Public hearings are held prior to granting a permit. Edwards, in a letter to the County Planning Director, Patricia Nemeth, proposed revisions to Ordinance No. 555 to incorporate COE guidelines and to restrict operations in the floodway that might increase flood damage.

Sacramento County conducted an aggregate resource study (11) that estimated sand and gravel demand based on population growth and per capita consumption. The study reviewed standard specifications for aggregate products, noting that emphasis on good quality products from the construction industry has increased in recent years. The potential locations and geologic sources of aggregate materials is presented. Areas where land-use conflicts are likely are noted. An estimate is made of the number of square miles that will need to be set aside to meet aggregate resource demand for 25 years. Areas were identified within the county that can be set aside for this land use without conflict. Land-use management is determined to be the best alternative for meeting aggregate resource demand and avoiding adverse impacts to adjacent land uses. Regulations were proposed that would require: 1) a mining plan, 2) a reclamation plan, and 3) property-line setbacks. Regarding runoff and flood control, proposed regulation would require that mining operations compliment the design and purpose of drainage-basin flood-control systems and local drainage improvements. Approval from the Sacramento Division of Water Resources would be required prior to issuance of a permit.

Ventura County (15b) has adopted a resolution establishing a "red-line" profile and width policy for mining and excavation in the Santa Clara river. The policy is comparatively simple and consists of the following requirements:

1. In-river mining will be considered on the basis of a river management

strategy which generally limits mining to the aggradational reaches of the river, with the constraint of protecting structures.

2. Excavation will be limited to the red-line profile and width standards, as determined by the Flood Control District, and be defined by a table of horizontal and vertical control data and excavation widths which have been plotted on drawings on file with the Public Works Agency.

The "red-line" boundaries were defined by a comprehensive engineering analysis of the Santa Clara River. Amendments to the "red-line" boundaries are possible, provided stabilization measurements for the vertical and lateral adjustment of the river are introduced. Adoption of the "red-line" boundary gives a common reference for all users of the river environment. In addition, since the boundaries are defined through a cummulative analysis of the river system both with and without gravel mining, the effect of joint operation of several sand and gravel mines on the river can be assessed.

In California, sand and gravel operations have also been subject to water-quality monitoring and waste-discharge requirements, as implemented by the California Water Quality Board. Issues identified (16) are related to impacts on in-stream biota from sediment deposition or turbidity, reduced ground-water recharge due to sealing of recharge areas by fine sediments, and increased flood potential from sand and gravel operations in the floodway. Water quality permits issued in the San Diego Region (17, 18) provide limits on the amount of sand and gravel that can be extracted, and set waste water discharge requirements for settling ponds. The California Division of Mines and Geology works with the various Regional Water Quality Boards to meet water-quality standards, as legislated by the Porter-Cologne Water Quality Control Act, as these relate to mining operations (19).

3.4 Regulation in Other States

Several other states, each with a significant coal-mining industry, have adopted legislation for regulation of surface mining. This allows these states to administer parts of the federal program rules implementing the Surface Coal Mining and Reclamation Act. While the federal legislation pertains to coal mining only, state laws tend to regulate all surface-mining activities, which includes sand and gravel extraction. Montana and Colorado's programs are

examples of state-level regulation of surface mining. Montana's regulations (20) require that a detailed permit application be submitted that includes a map of intended operations, a detailed reclamation plan, and a bond of at least $200 per acre. The emphasis in Montana's program is reclamation; no analysis of the impacts of gravel mining on river stability is required or implied. Colorado (21) requires a surface-mining operation to submit a detailed permit application with information on mining plans, reclamation plans, base-line data (water, wildlife, soils, vegetation, and climate), an estimate of reclamation costs, and various legal information (right of entry, property description). Colorado requlations do not specifically address in-stream sand and gravel mining.

States with significant aquatic habitat and/or in-stream recreational resources have adopted regulations on sand and gravel mining to protect those resources. Washington, Oregon, and Idaho have each adopted this type of regulation. Washington's aquatic land management plan (22) has a river-management component. The parts pertaining to sand and gravel mining include: 1) protection of braided and meandering channels from mining activity; 2) river channel relocation is permitted only when overriding public benefit can be shown; 3) sand and gravel removals are not permitted beyond the perimeter of navigable rivers, except as authorized under a department of fisheries and game hydraulics permit; 4) sand and gravel removal beyond the wetted perimeter of a navigable river is considered under the following conditions: a) no alternative upland source is available, b) pit configuration is designed to create improved river floodplain features, c) recreation benefits are provided, d) would reduce sediment deposition in downstream rivers and lakes, and e) would reduce damage to private or public land; and 5) sand and gravel removal beyond the wetted perimeter of a navigable river is not considered under the following conditions: a) below a dam, b) from detached bars and islands, c) if unstable hydraulic conditions will be created, d) if impacts to the esthetics of nearby recreation facilities will occur, and e) if negative water quality will result. Washington's general policy statement for sand and gravel extraction (23) states that upland deposits of sand and gravel are nonrenewable and have become less available. The industry is relying more on renewable river gravels than upland deposits. The use of river gravels can cause aquatic habitat damage to fishery and spawning areas and to gravel bars

that provide access for various aquatic-land recreational users. The policy is, therefore, to allow sand and gravel extraction on aquatic lands, but only when a more preferrable upland site is unavailable.

Oregon garners a royalty on sand and gravel extraction (24). The rules for this tax provide uniform methods with which to measure and verify the quantity of material extracted. Riverbeds are owned and controlled by the state. The regulations do not control operational or reclamation aspects of sand and gravel mining. The lessee is required to file a plan that gives a general volume and rate of extraction for the duration of the lease. A report by the Oregon Water Resources Research Institute (25) studied gravel mining practices on the Willamette River and outlined a comprehensive research plan addressing various issues. The report finds that sand and gravel mining is an important industry, but that the lack of quantitative information on sediment transport and erosion processes raise issues of streambank stability and potential impacts on recreational usage and fisheries. The objective of the study was to understand the sediment transport regime of the Willamette River, prioritize this information for decision making, and demonstrate how decisions can be made based on this information. Typical gravel mining techniques in Oregon are bar-scalping to the depth of the water surface, or mining in the floodplain to a depth equal to the water level in an adjacent water course. The study proposes a comprehensive attack on the problem, beginning with a thorough understanding of sediment budget and sediment transport rates, and development of river-management tools.

Idaho regulates the removal of sand and gravel below the mean highwater mark (26). The Division of Water Resources (DWR) requires the following construction procedures: 1) no construction equipment below the existing water-surface elevation without prior approval, 2) temporary structures should be designed to handle anticipated high flows during construction, 3) only the minimum necessary disturbance to the natural appearance, 4) fill material must be placed in horizontal lifts, and 5) DWR can limit the period of construction to minimize conflicts with fish spawning, migration, or with recreational use.

Contact with the Nevada Department of Transportation (NDOT) and the Nevada Legislative Council Bureau indicated there were no existing statutes regulating in-stream sand and gravel mining. With the exception of an isolated site on the Carson River, NDOT was not aware of any in-stream mining

operations within Nevada. At the present time, all sand and gravel extraction is taking place on alluvial fans. The absence of in-stream mining problems in Nevada is, no doubt, largely due to the fact that the two major metropolitan areas (Las Vegas and Reno) are not situated adjacent to major ephemeral rivers as are Phoenix and Tucson.

The New Mexico Department of Transporation (NMDOT) has also experienced very few problems with in-stream sand and gravel mining. As with Nevada, most of the sand and gravel operations in New Mexico are located on alluvial fans, rather than in river floodplains. NMDOT indicated there was no existing or pending legislation which would specifically regulate in-stream sand and gravel operations.

3.5 Regulation in Arizona

Arizona law relative to floodplain management was reviewed. Title 48, Section 3609 of the Arizona Revised Statutes mandates that the board of directors of a flood control district shall adopt and enforce regulations governing floodplains and floodplain management in its area of jurisdiction. This shall include regulations for all development of land, construction of residential, commercial or industrial structures; or a use of any kind which may divert, retard or obstruct floodwater and threaten public health or safety, or the general welfare. The regulations shall also establish minimum flood damage prevention requirements for land uses, structures, and facilities which are vulnerable to flood damage. The regulations shall be in compliance with state and local land-use plans and ordinances, if any.

The law does provide for variances from the regulations that do not result in danger or damage to persons or property in floodplains in the area of jurisdiction. Unless expressly provided, the adopted regulations will not affect existing legal uses of property or the right to continuation of such legal use. However, if a nonconforming use of land or a building or structure is discontinued for twelve months, or destroyed to the extent of 50% of its value, any further use shall comply with the regulations adopted by the district.

ARS Title 48, Section 3610 enables the governing body of an incorporated city or town to assume the responsibility for floodplain management. If the city or town declares by resolution that it no longer wishes to assume the

floodplain management and regulation function, then these functions shall be the responsibility of the flood control district.

In general, the regulation of sand and gravel operations in association with floodplain management is based on ARS 48-3613 which addresses the authorization required for construction in watercourses. The law provides that sand and gravel operations which will divert, retard, or obstruct the flow of waters in a watercourse must comply with adopted regulations governing floodplains and floodplain management and that operators shall secure written authorization from the board of the district in which the watercourse is located.

ARS Title 11, Section 251 allows the board of supervisors of a county to adopt and enforce standards for excavation, landfill and grading to prevent unnecessary loss from erosion, flooding and landslides subject to the prohibitions, restrictions and limitations as set forth in ARS 11-830.

ARS Title 11, Section 830 addresses restrictions on regulation through zoning ordinances. The law provides that nothing contained in any zoning ordinance shall prevent, restrict or otherwise regulate the use or occupation of land or improvements for "mining purposes", if the tract concerned is five or more contiguous commercial acres. A current court case examines the issue of whether the in-stream sand and gravel mining operation larger than five contiguous acres is exempt from zoning ordinance requirements.

Floodplain regulations for Yuma County, Pima County, the Flood Control District of Maricopa County, the City of Phoenix, and the City of Mesa were reviewed. To obtain a floodplain use permit in Yuma County (27) the sand and gravel operator must submit a permit application containing the following information: 1) excavation limits, location of stock piles, and pit depth; 2) phasing and method of operation; and 3) description of proposed watercourse alterations. The operation is not permitted to store materials within the floodway, nor is the storage of buoyant, flammable, explosive, or injurious materials allowed in areas subjected to flooding.

Pima County (28) requires that the sand and gravel operator submit a permit application containing a development plan, a reclamation plan, and assurance for reclamation costs. The development plan requires analyses of hydrologic, hydraulic, and sediment transport issues. The scope of work for the sediment transport analysis is determined on a case-by-case basis. The

development plan must show set-back distances, location of structures and equipment, and the phasing of operations. The reclamation plan requires that post excavation slopes be stable and that set-back distances from property lines be established.

The Flood Control District of Maricopa County (29) excludes certain types of sand and gravel activity from the floodplain. The regulations also require a development plan and a reclamation plan. Guidelines are given in addition to the regulations to assist the sand and gravel operator in preparing a permit application. The exclusions prevent permitting if the sand and gravel operation would be a hazard to life, property, the watercourse, or crossings (i.e., bridges or utility crossings). For sand and gravel operations within the designated floodway, the development plan requires a sediment transport analysis. The reclamation plan addresses the stability of the post-mining floodway. Guidelines help the applicant to identify operation and reclamation issues pertinent to the operation. These guidelines include questions relating to whether the operation is: 1) in the floodway or floodplain; 2)likely to affect channel form; 3) close to property or channel crossings; and 4) in a channel that is known to aggrade or degrade, or in a zone of channel headcutting.

The City of Phoenix ordinance allows (30) sand and gravel mining within the floodway provided that excavations do not present a hazard to other development and river crossings. The ordinance excludes stockpiling within the designated floodway but permits it within the floodplain.

The City of Mesa ordinance (31) allows gravel mining if the property is zoned for such use. Individual sand and gravel mining operations are subject to stipulations on a case by case basis. An example of such stipulations is the Shill-Biggs zoning case, for a gravel pit on the west side of Mesa Drive, north of Lehi Road. In this case, dikes or levees were not permitted and the excavation depth was limited to 100 feet below natural ground (with 1:1 sideslopes). The direction of excavation was specified as south to north with provisions to carry local runoff around the pit to the river. A requirement was also imposed that the pit be backfilled upon completing sand and gravel extraction.

An industry perspective on the political issues faced by sand and gravel operators was given by the magazine Southwest Contractor, in a July 1985

article entitled "River of Controversy" (2). The issues discussed relate to sand and gravel mining on the Salt River, and included development of Rio Salado, flooding and flood control, and ownership of river bottom property. The article points out that sand and gravel is a significant but finite resource. The Rio Salado project is considered the number one problem facing sand and gravel operators on the Salt River. The rock producers feel that the project, as proposed, has not properly taken into account their interests. The condemnation of private property owned by mining companies for this project is strongly questioned. Private development of previously mined land has been undertaken by several companies (CALMAT and Tanner). As an alternative to Rio Salado, the rock producers propose channelization of the Salt River with the excavation conducted by the producers. The project would be engineered by the Flood Control District of Maricopa County. The period of construction is estimated at five to eight years.

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IV. REVIEW OF LITIGATION RELATED TO IN-STREAM MINING

A review of litigation related to in-stream sand and gravel mining was performed in order to determine the general magnitude of this type of litigation and to investigate the factors that lead to such litigation. Due to difficulties encountered by Simons, Li & Associates, Inc. (SLA) in locating an attorney (for the research team) that was acceptable to the State Attorney General's office, research into specific details for all cases was not possible within the time allowed. The following is a partial listing of pertinent court cases. This information has been gathered by SLA staff through review of news articles and verbal discussions with people associated with the cases. Pending approval of an attorney for the research team, more detailed legal investigations will be performed.

A. Maricopa County Superior Court, Cause #C453677

Maricopa County and Roosevelt Irrigation District v. Allied Concrete, et. al.

Location: Agua Fria River downstream of Indian School Road Bridge
Phoenix, Arizona

Sand and gravel mining operations encroached into the river channel downstream of the Indian School Road Bridge and upstream of the Roosevelt Irrigation District (RID) canal flume. The in-stream gravel pits necessitated the construction of dikes to prevent inundation of these operations during periods of flow, thereby restricting the channel opening to approximately 500 feet. The Indian School Road Bridge failed during the flood of February 1980. The RID flume did not fail; however, significant degradation did occur at this location.

The County prevailed in an out-of-court settlement. The objective of the settlement was to return the river channel to a "natural state". The defendents agreed to 1) provide funds which would be used to channelize and stabilize the river at this location and 2) deed ownership of the river bottom over to the County.

B. Agua Fria River Materials v. Allied Concrete

Location: Agua Fria River downstream of Indian School Road Bridge
Phoenix, Arizona

Sand and gravel mining operations encroached into the river channel downstream of the Indian School Road Bridge. Property owned by the plaintiff was located downstream of the sand and gravel operation owned by the defendent. The plaintiff's property was inundated during the February 1980 flood, alledgely as a result of the upstream mining operation.

The defendent settled out of court.

C. Kane, Talent v. Maricopa County, United Metro

Location: Agua Fria River upstream of Glendale Avenue Bridge
Phoenix, Arizona

The Maricopa County Highway Department had constructed a bridge over the low-flow channel at Glendale Avenue. The approaches to the bridge consisted of fill which encroached into the floodplain. An in-stream sand and gravel mining operation was located upstream of the Glendale Avenue Bridge. The plaintiff owned a business located in the floodplain upstream of the approach roadway. The plaintiff's property was inundated during the flood of December 1978, alledgely due to the combined effect of flow diversions from the upstream sand and gravel operation and backwater caused by the roadway approaches and a restricted bridge opening.

The plaintiff prevailed in an out-of-court settlement.

D. City of Phoenix v. Union Rock & Materials

Location: Salt River at the Central Avenue Bridge
Phoenix, Arizona

A gravel pit was located at the northwest corner of the bridge and another mining operation was located upstream of the bridge on the south side of the river channel. The flood of December 31, 1965 damaged the bridge causing failure of a pier.

A negotiated settlement was reached restricting the limits of sand and gravel mining in the vicinity of the bridge.

E. Yavapai County v. Valley Concrete & Materials, Inc.

Location: Verde River in the vicinity of Cottonwood, Arizona

During recent years, increased gravel mining activity by the defendent in the Verde River floodplain upstream of the roadway crossing to Dead Horse Ranch State Park caused the plaintiff concern over river system changes allegedly related to the extraction of sand and gravel. This concern focused primarily on increased bank erosion, the shifting of the low-flow channel alignment, downstream channel degradation, and environmental damage to the riverbanks.

Following the flood of October 1983, the plaintiff filed a suit and a criminal charge against the defendent for diverting the course of the river. The criminal charge was dropped before going to court when the parties reached an agreement to implement, on a specified schedule, a bank stabilization plan to mitigate the damage. When it was ascertained that the defendent was not proceeding on schedule with the agreed upon mitigation plan, the plaintiff revoked the defendent's operating permit and secured a Temporary Restraining Order (TRO) from the court. The TRO was later overturned when the court decided that it was not convinced that the defendent's sand and gravel operation was the sole source of downstream property damage. The issue of damages is still to be heard.

F. Arizona State Land Department v. Valley Concrete & Materials, Inc.

Location: Verde River in the vicinity of Cottonwood, Arizona

The plaintiff owns the Dead Horse Ranch State Park located downstream of the defendent's sand and gravel operation on the Verde River. During the flood of October 1983, environmental damage occurred at the park site. The plaintiff has filed a suit seeking monetary damages. The issue of ownership of the river bottom is also being tested. The plaintiff seeks sovereign ownership of the land located between the river's ordinary high water marks as part of a statewide effort to claim lands given to Arizona at the time of statehood under the Equal Footing Doctrine.

G. Pima County Superior Court Case No. 217116

Addison/Philips v. Churchman Trucking, Cienega Ltd., and Columbia Mat-Materials

Plaintiff prevailed.

H. Pima County Superior Court Case No. 178620

Bohman v. Estes

Plaintiff prevailed.

I. Pima County Superior Court Case No. 162577

Pima County v. John Cardi

The ruling stated that if an existing use creates a hazard to life or property, a permit is required.

J. Pima County Court Case No. 1855856

Charles Cindrich v. Pima County

The court ruled that the plaintiff must obtain a Floodplain Use Permit to mine sand and gravel within the Tanque Verde Wash.

K. Maricopa County v. Phoenix Sand & Rock

The defendent paid monetary damages and deeded over fifteen acres for channelization.

L. Wooten v. Phoenix Sand & Rock

The defendent paid monetary damages.

M. Mulcher v. Phoenix Sand & Rock

The defendent paid monetary damages.

N. Maricopa County v. Phoenix Sand & Rock

The case involves condemnation of sixty-six acres of land. Outcome pending.

V. SUMMARY OF RESPONSES TO SAND AND GRAVEL MINING QUESTIONNAIRE

5.1 Introduction

In order to establish a comprehensive data base for this research project, questionnaires were developed to solicit relevant information from: 1) regulatory agencies; 2) sand and gravel operators; and 3) consulting engineers who have been involved in preparing technical studies for mining permit applications. This summary provides an overview of the input received from the questionnaire respondents.

5.2 General

Three different questionnaires were developed with questions oriented towards obtaining the type of data available from each of the three groups (i.e., regulatory agencies, sand and gravel operators, and consulting engineers). A total of 190 questionnaires were sent with the following results:

Respondent	No. of Questionnaires Transmitted	No. of Questionnaires Returned	% Returned
1. Regulatory Agencies	32	31	97
2. Sand & Gravel Operators	152	12	8
3. Consulting Engineers	6	5	83

5.2.1 General Issues and Trends

A review of the respondents' comments identified the following general issues and trends related to in-stream sand and gravel mining:

° Several respondents expressed concern regarding the feasibility of developing uniform guidelines at the State government level which would be justifiably applicable to all river systems within the State.

° Some disagreement exists among respondents regarding which governing body should be responsible for regulating sand and gravel mining operations; however, a general consensus is that regulation should be left up to local jurisdictions backed by a State enabling law and physically based engineering standards.

° At the present time, the primary vehicle for regulation of in-stream sand and gravel operations is through local zoning and floodplain ordinances applied on a site specific basis. Requirements for issuance of a Floodplain Use Permit are tailored to the specific operation under consideration.

° Enforcement is carried out first through contact with the operator and, if necessary, then through litigation in civil court. Several respondents have been or are currently involved in litigation both as defendents and/or plaintiffs. (A current court case examines the issue of whether the in-stream sand and gravel mining operation is exempt from zoning ordinance requirements.)

° The primary benefit of in-stream sand and gravel mining was seen as providing an economical, convenient source of quality construction material upon which virtually all development of public and private infrastructure depends. Other benefits mentioned included: 1) increased channel capacity; 2) reduced potential for overbank flooding in some areas due to channel degradation; 3) partial runoff storage; 4) minor, local groundwater recharge; and 5) profits for companies that leads to the creation of jobs and an increased tax base.

° It was noted that the issue of damaged transportation structures was not exclusively related to the impacts of sand and gravel mining. Also cited as a contributing factor to structure damage was a lack of proper planning on the part of engineers in predicting the magnitude of severe flood events and in designing structural foundations to withstand such flooding conditions. An in-depth study was called for to evaluate the cost effectiveness of designing new bridge foundations and/or refur-

bishing existing structures to handle 100-year flows versus the economic impacts of the loss of production of low-cost aggregates.

° It was suggested that environmental concerns and long-term consequences be considered as they relate to the benefit of mining a particular site. A benefit/cost approach to regulating in-stream mining would weigh the type, quality and need for material versus the cost of mitigating mining impacts (e.g., grade control structures, site restoration, etc.)

° A recommended technical approach would evaluate the long-term stability of the overall sediment system for a given river reach and then analyze the local effects resulting from in-stream mining within that system. The analysis should not always be based on the impacts of an individual pit, since such an approach might overlook the combined effect of adjacent operations on the overall system.

5.2.2 Basis of Regulatory Program

The questionnaires solicited respondents' input regarding the objectives, procedures and criteria upon which a state-wide regulatory program should be based.

The main objective of the regulatory program was seen as preventing/mitigating negative impacts (due to mining operations) upon stream stability, water quality, adjacent property owners, and in-stream structures and improvements.

The procedures by which this objective would be pursued were also addressed. The majority of regulatory agency respondents supported regulation of gravel operators through local zoning and floodplain ordinances backed by State law and subject to State audit to ensure compliance. New operations, or expansion of existing operations onto new land, would be restricted so that existing or planned improvements were not at risk, while existing operations could be accommodated through some type of "grandfather" clause.

Although respondents provided information regarding criteria currently used to evaluate impacts of sand and gravel mining on channel stability, in-stream structures and bank protection, they provided very little information

of specific technical procedures that were used to analyze the criteria. The following is a summary of respondents' comments regarding technical criteria that should be used in reviewing permits for in-stream mining:

1. Restrictions on distance from gravel pit to bridges, flood control structures, utilities and urban development
2. Restriction on pit depth and side slopes
3. Limitations on upstream headcutting, bank erosion, and downstream degradation
4. Determination of "safe yield" through analysis of material extracted versus sediment supplied to mined reach
5. Investigation of manner in which excavation will proceed (pit geometrics), excavation method to be used, and duration of mining activities
6. Restrictions on stockpiling in the floodway
7. Restrictions on diverting channels with diversion dikes at mining locations
8. Requiring sediment routing analysis to consider different flow frequencies and durations
9. Requiring grade control structures, as needed
10. Requiring environmental rehabilitation and restoration for aesthetic purposes

5.3 Questionnaire Response Summary

5.3.1 Regulatory Agencies

The regulatory agencies were asked to provide facts concerning the sand and gravel mining operations within their jurisdiction, regulatory guidelines/ policies, enforcement programs and litigation information. If they were involved in the design, regulation or maintenance of in-stream structures, input regarding design methodologies and considerations was also requested.

5.3.1.1 Federal Agencies

The federal agencies responding to the questionnaire do not regulate the sand and gravel mining operations within their jurisdiction. The USDA Soil Conservation Service does consider erosion/sedimentation processes in the

design of in-stream flood control structures and does account for the effects of sand and gravel mining upon the project design, as needed. Of concern to the U.S. Fish & Wildlife Service is the long-term impacts to fish and wildlife resources as a result of in-stream mining operations.

The U.S. Army Corps of Engineers (COE) Regulatory Branch administers a permit program under Section 404 of the Clean Water Act. Any person, firm of governmental agency planning work in "waters of the United States" must first obtain a permit from the COE. Activities related to sand and gravel mining which require permits are the disposal of fill or the discharge of dredged or fill materials in "waters of the United States" which cause the loss or substantial adverse modification of 10 acres or more. Under the provisions of Nationwide General Permit Number 26, for those discharges which adversely impact 1 to 10 acres, the COE District Engineer must be notified before work begins. This nationwide general permit eliminates the need for further permit processing by the COE for discharges which cause the substantial loss or adverse modification of less than 1 acre. In addition, sand and gravel operations outside the 20-year floodplain need not apply for individual permits.

5.3.1.2 State Agencies

The Arizona Department of Transportation (ADOT) does not directly regulate sand and gravel mining operations throughout the State. However, ADOT does control the use of materials on highway construction projects through their construction specifications. Section 106.03 of the 1985 ADOT Supplemental Specifications limits the use of material sources situated within the 100-year floodplain of a watercourse, and located within one mile upstream and two miles downstream of a highway structure or roadway crossing. Within these boundaries, existing commercial sources may not be utilized as a source of borrow nor will any new source or existing non-commercial source be approved for any materials.

> "The location of any new material source or existing non-commercial material source proposed for use on this project shall be reviewed by the appropriate agency having flood plain management jurisdiction for the area in which the proposed source is located. The contractor shall obtain a letter from the agency addressed to the Engineer certifying that the location of the proposed source conforms to the

requirements of the Specifications."[1]

In monitoring Department-owned sources in the floodplain, ADOT requires the Materials Section to evaluate potential risk to public or private improvements located one mile up and downstream of the materials operation. A mining plan and an environmental assessment, which includes a hydraulic study, is required under certain conditions.

The Arizona Department of Health Services (ADHS) principal authority related to mining is to control the discharge of pollutants from point and non-point sources. The point source control program is implemented by National Pollutant Discharge Elimination System (NPDES) permits, issued under Section 402 of the Federal Clean Water Act. The non-point program consists of compliance evaluations in waters potentially impacted by diffused source discharges. If standards are exceeded, or protected water uses are impaired in these waters, then corrective actions are required. Water line crossings for proposed projects for water supply and wastewater systems receive detailed engineering reviews before approval to construct is granted. If buried lines cross watercourses, the impact of gravel mining and channel scouring are considered on a site-specific basis.

None of the respondents from State agencies had been involved in litigation related to sand and gravel mining operations.

5.3.1.3 County Agencies

Two-thirds of the county respondents have in-stream sand and gravel mining operations within their jurisdiction. It is interesting to note that two-thirds of county respondents do regulate mining operations; however, those regulating are not necessarily the same counties as those with mining activity occurring.

The counties regulate sand and gravel mining through floodplain and zoning boards. Floodplain Use Permits are required for new mines and major expansions of existing mining operations. Enforcement may require legal action; one-half of county respondents are involved in litigation related to sand and gravel mining as both defendent and/or plaintiff.

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[1]Arizona Department of Transportation, Standard Specifications for Road and Bridge Construction, 1985 Supplement, Sec. 106.03)

Cochise County has budgeted funds for this fiscal year to commence a mapping and study program designed to more effectively regulate sand and gravel mining operation within their jurisdiction.

5.3.1.4 Local Agencies

One-half of the local respondents have in-stream sand and gravel mining operations within their jurisdiction. One-half of the respondents also regulate in-stream mining in the form of Floodplain Use Permits with supplemental extraction data supplied by the operator. One of the local respondents had been involved in litigation related to sand and gravel operations.

At the local level, there is concern that mining operations tend to have a negative impact on adjacent property values. There is support for environmental rehabilitation through proper site restoration in these areas.

The City of Peoria has stipulated that the City will receive, as a license fee, a per ton royalty for material which is extracted for commercial use at off-site locations. This fee is placed in the flood control budget. The operator is responsible for submitting monthly reports indicating the amount of material removed.

5.3.2 Sand and Gravel Operators

The sand and gravel mining operators were asked to provide facts concerning their facilities resources for all operations they have conducted in the State during the past five years. Also requested were data regarding the total amount of rock products they produce and sell in Arizona, and estimates of future annual extraction rates for the next five years. In addition, information was solicited concerning regulatory compliance requirements, permit application submittals, and design practices, if applicable. Responses were received from individual operators.

The operators felt that there are some inconsistencies on the part of regulatory agencies with regard to requirements for issuance of permits for sand and gravel operations. The operators feel the agencies are uncertain as to what is really necessary to assure indemnity from litigation, and that engineering firms have over-emphasized to these agencies the need for sophisticated, costly studies to adequately assess mining impacts. This results in increased cost of aggregate materials to the end user. The most

important economical factor in the total cost of gravel products is the transportation cost incurred in hauling material from pit to end user, thus making a case for maintaining gravel pits in close proximity to development sites.

The turnaround time for regulatory agencies to process permit applications varys from two months to more than one year. The average total cost to the operator for completion of a permit application was estimated to be $50,000. Major factors affecting the cost of submitting a permit application include:

1. operation location relative to in-stream structures
2. operation size
3. river characteristics
4. varying requirements of different regulatory agencies

The operators emphasize that a statewide program should consider the impact to the overall economy resulting from regulating or restricting the recovery of limited aggregate reserves which, in the major metropolitan areas, are centrally located to the market, therefore, providing low cost building materials for the State's growth. The operators are concerned about the economic impact on the sand and gravel industry as related to the cost of compliance with regulatory controls.

5.3.3 Consulting Engineers

The questionnaires sent to consulting engineers requested information concerning the criteria and procedures used in evaluating the effect of sand and gravel mining facilities on channel stability and the design of in-stream structural improvements. Input was solicited regarding the preparation of permit applications for sand and gravel mining operations.

Respondents identified the following as major hazards to in-stream structures caused by the presence of sand and gravel operations:

- degradation/scour potential
- headcut propagation
- significant lateral channel migration impacts
- concentration/diversion of flows at mining sites
- perpetuation of mining activities

The criteria used to assess these hazards included:

- sediment supply and balance
- upstream and downstream channel conditions
- pit geometrics/volume
- set-back distances
- proximity of structural improvements

The following procedures and methodologies are used to evaluate the effect of sand and gravel mining operations on channel stability and in-stream structural integrity:

- computer programs: HEC-2, HEC-6, FLUVIAL-11, IALLUVIAL, QUASED, PIT, SETTLE
- empirical sediment transport capacity equations
- qualitative geomorphic assessments
- hydrograph development techniques

In the preparation and submittal of permit applications for sand and gravel mining operations, it was estimated that approximately 70-80% of the applications were approved. The percentage approved increased with the operator's acceptance of modifications to the operating procedures or mining plan.

5.4 Interview Summary

As a follow-up to the questionnaire response, personal interviews were conducted with four regulatory agencies to solicit additional information relative to sand and gravel operations. The agencies interviewed include the Arizona Department of Transportation Structures Section, the Pima County Department of Transportation and Flood Control District, the Flood Control District of Maricopa County, and the City of Phoenix.

5.4.1 Interview Agenda

A brief synopsis of the general issues and trends identified from the questionnaire response (Section 5.2.1) was presented to interviewees. Their input and feedback on these issues was then discussed. Additional information

was requested on appropriate methodologies and technical procedures used in the analysis of the impact of sand and gravel operations on channel stability. The current status of regulation of mining operations at a federal, state, county, and local level was reviewed. The strong points and shortcomings of existing regulatory practices were evaluated. In addition, alternative approaches to regulation of sand and gravel operations were explored with attention to the appropriate means of administering and funding any recommended approach. The availability of technical data was discussed, especially in areas where damage has occurred in the past that was allegedly aggravated by the presence of sand and gravel operations. Data availability would impact the potential for use of these sites for case history studies. Finally, pertinent court cases, if any, within the area of jurisdiction of those interviewed were briefly reviewed.

5.4.2 Interview Response

A review of the questionnaire response indicated that very little information was received regarding specific technical procedures used in the analysis of in-stream pit impacts. Most respondents recognized that in-stream sand and gravel mining could impact channel stability, but few were able to provide details regarding appropriate methodologies for quantifying such impacts.

Those interviewed currently evaluate impacts on a case-by-case basis relying on various methodologies and engineering judgement. Two of those interviewed were cautious about relying solely on sediment routing model results and felt the regulations should allow for some simple, generalized guidelines and measures for use in analyzing sand and gravel mining impacts. The Flood Control District of Maricopa County (FCDMC) has relied on the use of design measures to mitigate impacts. Mitigation alternatives include: 1) low-flow side weirs or spillways which allow drowning of in-stream pits during periods of channel flow; 2) provisions for protection at the upstream side of a pit from headcutting by installing dumped or grouted riprap; and 3) conservative setbacks as an alternative to stabilization measures.

Those interviewed generally agreed there was a need to establish guidelines for proper use of analytical techniques and to implement a standardized approach so that consistency is maintained. Sand and gravel operators have been concerned that local board decisions have not been consistent nor based

on adequate techniques. The need to develop criteria and guidelines addressing several specific areas was identified. These areas include:

- appropriate flood events to use in sediment routing models
- evaluation of annual sediment yield
- determination of a profile line above which extraction is permitted
- setback distances and development plans for overbank pits
- guidelines for long-term sediment yield modeling
- proper analysis techniques for determining the cumulative impacts of several adjacent pits on the overall system.

The interviewees support more comprehensive study on a river basin level to evaluate an overall river system rather than relying on site specific analyses which do not consider cumulative impacts. FCDMC is currently planning several floodplain/environmental river system studies which might integrate well with river basin level studies of gravel mining impacts.

With regard to regulation, discussion centered on a workable regulatory approach to in-stream sand and gravel operations. A three-tier approach recommended by SLA was discussed with each of those interviewed and is summarized as follows:

1. Based on data to be collected by SLA during subsequent tasks of this research project, an effort will be made to develop regionalized envelope curves for major river basins within the State. Depending on the availability of data, these curves will be developed to provide guidelines relating pit depth to: 1) headcut length; 2) downstream degradation; 3) lateral migration distance; and 4) any other parameters that may be deemed necessary. Although these envolope curves will be based on data specific to different river basins within the State, they will have to incorporate a degree of conservatism that will permit their application to any site within the region for which they were developed. The factor of safety that would have to be included under such a scheme may make the envelope curves very restrictive in terms of allowable excavation limits.

2. At the county/local level, general river basin studies would be recommended for basins within county/local jurisdiction in order to develop an "optimal red-line standard" defining both the lateral and vertical limits for sand and gravel mining. These guidelines, which would be less conservative and more site-specific than the envelope curves developed under Level 1, would define the extraction slopes, elevations, and width along the mining reach. These studies could be funded through a tax on sand and gravel extractions (levied on a per ton basis) or possibly, through State appropriations similiar to those previously approved for flood control projects.

3. For those individuals who feel the envelope curves or "red-line" approach are too conservative, a third alternative would be available. This third level of this multi-tier approach would allow for a site specific engineering analysis to be performed at the sand and gravel operators' discretion and expense. This third level of analysis could be invoked in those cases where the sand and gravel operators feel the envolope curves and "optimal red-line standard" are unfairly restricting the volume of material that could potentially be excavated from a specific site. This third tier of analysis would provide a very detailed site-specific study of a pit. The objective of this study would be to provide technical documentation that would show the excavation limits established by the envelope curves or "optimal red-line standard" could be exceeded without causing damage to adjacent property.

With some reservations, those interviewed generally support the three-tier approach. At the present time, the regulatory approach at the County level is two-tiered using either conservative guidelines or detailed site specific studies. A middle ground, as represented by a "red-line standard", would help to reduce the number of site specific studies required.

The opinion of those interviewed was divided over the role of a State-level authority to monitor this program. It was recognized that a State-level authority would be needed to assist smaller counties (without the expertise in this field) by providing technical support and/or developing model ordinances.

However, one of those interviewed did not see a need for statewide resource identification and there was some concern that a State-level regulation could serve to interfere with local decisions regarding mining operations. It was felt such interference would be to the detriment of the local community. To circumvent this issue, it was proposed that the regulatory control be maintained at the county level while allowing the incorporated cities and towns to assume the responsibility of regulation of mining activities. Similar to floodplain management responsibility under ARS Title 48, Section 3610, the cities or towns could opt to let the county flood control district assume the gravel mining regulatory function for them. Thus large cities with adequate technical staff could support this regulatory function themselves while the flood control districts could support small cities and towns.

Other issues of concern to those interviewed are summarized below:

- FCDMC is concerned with the need to regulate in-stream gravel mining operations which are outside of official FEMA delineated floodplains. ARS Title 48 and the county floodplain ordinance do not cover these cases.

- The Pima County Department of Transportation and Flood Control District (PCDOT & FCD) is concerned with adequate enforcement of operator compliance with permit stipulations. PCDOT & FCD recommends consideration be given to requiring assurance of compliance by the operators through bonds, etc.

- "Grandfathering in" existing gravel mining operations can be problematic as to where to establish a cut-off point.

- Consideration should be given to requiring rehabilitation and restoration of the site following the termination of a mining operation.

- In general, current regulatory policy is not opposed to in-stream mining when there is a surplus in the sediment balance of the reach being mined. There is support for allowing the scalping of river bars and vegetation to restore channel conveyance. The use of sand and gravel mining as a channel clearing function is seen as beneficial,

realizing there are possible long-term degradational impacts on the river being mined.

5.5 Damage Inventory

This section includes an inventory of damage to public or private property allegedly due to, or in part from, in-stream sand and gravel mining operations. This information was taken from the questionnaires returned to SLA and is presented here for information purposes only. The respondents that provided this information do not indicate what proof, if any, has been developed to link the sand and gravel operations to the alledged damage. This information may be used as a source of data for case history studies that will be pursued in subsequent sections of this research project.

1. Gila River - damage to streets and adjacent lands in Goodyear, AZ
2. Salt River - I-10 bridge foundation (1979, 1980, 1981)
3. Agua Fria River - Indian School Road bridge failure (Feb., 1980)
4. Agua Fria River - Glendale Avenue crossing (Dec., 1978)
5. Agua Fria River - Rose Garden Lane crossing (Dec., 1978)
6. Agua Fria River - East overbank upstream of Northern Avenue crossing (Dec., 1978)
7. Verde River - I-17 bridge crossing
8. Verde River - Vicinity of Cottonwood, AZ, damage to downstream properties, destabilized banks, reduced riparian vegetation/biota
9. Verde River - upstream of Camp Verde, AZ
10. Santa Cruz River - Silverlake Road bridge pier exposure
11. Santa Cruz River - T13S, R12E, Sec. 1 and T12S, R12E, Sec. 35, capture of overbank pits resulting in increased channel width and lateral migration
12. Pantano Wash - increased lateral migration between Houghton Road and Rincon Creek (1983)
13. San Pedro River - impact upon fish and wildlife resources
14. Ehrenberg, AZ - some damming and ponding exacerbated damage due to flood of July 21, 1986
15. Cottonwood Wash - aggradation/degradation at SR77 bridge, Snowflake,

AZ

16. Granite Creek - damage to U.S. Highway 89 bridge near Prescott, AZ

17. Kingman, AZ - exposure of utility line crossings in channel

5.6 Recommended River Segments

The following river segments were recommended for detailed study of in-stream sand and gravel mining operations:

1. Gila River - Gillespie Dam to Salt River confluence

2. Gila River - Salt River confluence to Coolidge Dam

3. Salt River - Gila River confluence to Granite Reef Dam

4. Agua Fria River - Salt River confluence to Waddell Dam

5. New River - Agua Fria River confluence to Maricopa - Yavapai County line

6. Hassayampa River - U.S. Highway 60-89 bridge to 1/2-mile upstream of bridge

7. Verde River - Salt River confluence to Paulden, AZ

8. Oak Creek - limits unspecified

9. Wet and Dry Beaver Creek - limits unspecified

10. Santa Cruz River - I-10 bridge (Martinez Hill) to Avra Valley Road

11. Rillito Creek - Santa Cruz River confluence to Craycroft Road

12. Pantano Wash - Tanque Verde Wash confluence to 5-6 miles upstream of Houghton Road

13. Santa Cruz River, Sonoita Creek, Potrero Creek, and Harshaw Creek - within Santa Cruz County (limits unspecified)

14. San Pedro River - Hereford to Winkelman, AZ

15. San Pedro River, Garden Canyon Wash, and Cayote Wash - immediately outside Sierra Vista city limits

16. Rye Creek - 4 miles upstream to 4 miles downstream of SR87

17. Tyson Wash - 5 miles upstream to 2 miles downstream of Quartzite, AZ

18. Ehrenberg, AZ - site of flooding of July 21, 1986 (limits unspecified)

19. Cottonwood Wash - between SR277 and SR77 bridges in Snowflake, AZ

20. Sols Wash - in vicinity of River Street, Wickenburg, AZ

VI. REVIEW OF METHODOLOGIES FOR SAND AND GRAVEL MINING IMPACT ANALYSIS

6.1 General

Sand and gravel mining may induce local headcutting, sediment backfill, and clear-water scour upstream, within, and downstream of the gravel pit. The scour and fill processes induced by the pit will progress both upstream and downstream. In cases where sand and gravel extraction exceeds replenishment of sediments, net degradation of the river bed will result. The magnitude of river degradation can be analyzed by field measurements, physical models, and analytical methods.

6.2 Methods Using Field Measurements

Using conventional field surverys or topographic mapping, river changes due to sand and gravel mining can be measured by comparing the cross sections and channel profiles before and after mining. This technique has been applied to investigate sand and gravel mining effects in a number of cases.

This method requires a large number of measurements over time and along a river. Accuracy of the method is limited since maximum scour may occur between river sections or between measurement periods. Maximum scour measurements may be critical in assessing the impacts on floodplain structures. The method also requires a long-term commitment of resources to collect, reduce and record the data. The method is probably best suited to monitoring sand and gravel operations. Use of field data alone to predict future river response to mining activity is limited to statistical approximations.

Studies using field data have inferred that sand and gravel mining operations contributed to bank erosion and river degradation. Kira (1) showed a relationship between data on river degradation and the sand and gravel extraction quantity for the Yasu River, Japan. This relationship indicated that long-term degradation is proportional to the extraction quantities regardless of short-term river-bed fluctuation.

Scott (2) illustrated the scour and fill phenomenon near a gravel pit located in an inactive channel of Tujunga Wash in Southern California. The old channel was activated by flood water breaking out of the existing main channel. The headcut erosion extended about 3,000 feet from the gravel pit boundary and caused failure of three major highway bridges. In addition, lateral scour damaged the properties lying between the inactive south channel and the existing north channel.

Lagasse et al. (3) studied the effects of gravel dredging along the lower Mississippi and concluded that historical dredging in this river reach has caused reduction of bed material sizes and an increase in the number of divided-flow reaches, and has affected the overall stability of the river system and structures. Mossa (4) investigated changes of the channel meander and geometry in the middle Amite River, Louisiana, from 1941 to 1981. The increased channel width, meander cutoff and middle channel bars were attributed to intensive sand and gravel mining over many years. The extraction disrupted riparian vegetation and gravel bars, and increased bank erosion and channel cutoff.

To measure the maximum scour caused by a sand and gravel pit, Bull and Scott (5) installed a scour chain in the Rillito River, Arizona, in 1973. This technique is more economical than measuring entire cross sections and channel profiles, and can provide critical scour information during the flood. This technique, however, is limited to local application.

6.3 Physical Model Study

Chen (6) conducted a physical model study to investigate the gravel mining effects on the stability of the Salt River channelization system and the Interstate 10 channel. The physical model was applied to examine the headcut and backfill processes for thirteen hypothetical cases containing various combinations of gravel pit dimensions and flood hydrographs. A rectangular pit was assumed in these cases. Using the model results, the extent of headcut erosion, downstream scour and lateral scour (due to lateral inflow to the pit) were expressed graphically as a function of gravel pit depth. These relationships reveal that the scour depth and length increase proportionally to the depth of the pit.

Although the physical model study can provide valuable information on the potential sand and gravel mining impact, it may not be feasible for general planning and analysis because of the following reasons: (1) physical model facilities and operation are costly, (2) sediment discharge scaling problems, and (3) sediment inflow to the pit is hard to simulate and may affect the accuracy of the model results.

6.4 Analytical Methods Developed for Alluvial River Studies

6.4.1 Sediment Transport Technology

Sediment transport technologies developed for alluvial river studies are applicable to sand and gravel mining impact analysis. Publications by Shen (7, 8, 9), Simons and Senturk (10), Schumm (11), Simons, Li & Associates (12), and Wang et al. (13) document various methodologies available for studying hydrology, hydraulics, sediment transport and geomorphology of an alluvial river.

Specifically, the unit hydrograph procedure (14), HEC-1 model (15) and SWMM model (16) are typical methods for hydrologic analysis. Normal depth computations using the flow continuity principle and Manning's equation are applicable if flow depths are nearly uniform throughout a given river reach. The HEC-2 model (17), developed for solving the energy equation for gradually-varied flow, can be used to obtain the backwater profile. The hydraulic conditions in a river reach can also be assessed using the momentum equation.

Shields' criteria (18) are frequently referenced in the incipient-motion analysis of a sediment particle. This relationship can be utilized to estimate the armor size of bed materials for a given flow or to size riprap for channel scour protection. Once set in motion, sediment particles are transported by the flow in one or a combination of the following ways: (1) rolling or sliding on the bed (surface creep), (2) jumping into the flow and then resting on the bed (saltation), and (3) supported by the surrounding fluid during its entire motion (suspension). Based on these mechanisms and sources of sediments, bed load, suspended load, wash load, and bed-material load are defined for sediment transport analysis as follows.

The term "bed load" applies to sediments transported by surface creep or saltation. Sediments which are suspended by flow are referred to as "suspended load", "wash load" is the part of the total sediment load which consists of particle sizes finer than those represented in the river bed. Excluding wash load from total load (bed load plus suspended load) leaves the bed-material load. Wash load is mainly determined by watershed production and bank erosion, and may play an important role in changing river morphology. However, for sediment transport analysis and river response evaluation (considering sand and gravel mining impacts), only the bed-material load is of primary consideration.

The mechanism of sediment transport is very complicated. Although previous research work has made the computation of sediment transport capacity possible, improvements in this area are still needed, as each methodology has its limitations. Without a consistent calibration and verification procedure, a large difference may exist in the application of different computational methods. Careful selection and thorough understanding of the methodology may lead to a more successful application.

Of the bed-load equations, those derived by Duboy (19), Meyer-Peter Muller (20), Einstein (21, 22) and Toffaleti (23, 24) are frequently referenced. The Einstein method (22) also includes the suspended-load equation. Representative theoretical based methods for computing total load include the modified Einstein method (25), Toffaleti's method (24), and the Bishop et al. approach (26). Regression analysis of existing sediment transport data from flumes and field sites has lead to new formulas for total sediment load. Representative regression based methods include Shen and Hung's approach (27), Yang's method (28), Lu and Li (29), Zeller and Fullerton (30), and Karim and Kennedy (31).

6.4.2 Computer Models for River Response Simulations

In 1983, the Federal Emergency Management Agency, in association with the National Research Council conducted an evaluation of flood-level prediction using alluvial river models (32). Six computer models developed for alluvial river simulation were evaluated:

1. HEC-2SR, developed by Simons, Li & Associates, Inc. (1980d)
2. KUWASER, developed by Simons, Li and Brown, Colorado State University (1979),
3. UUWSR, developed by Chen and Simons, Colorado State University (1975),
4. HEC-6, developed by Thomas and Prasuhn, U.S. Army Corps of Engineers Hydrologic Engineering Center (1977),
5. FLUVIAL-11, developed by Chang and Hill, San Diego State University (1976), and
6. SEDIMENT-4H, developed by Ariathurai, Resource Management Associates (1980).

Model theories, computational methods, assumptions, data requirements, limitations and applicability were documented, and the results of application

to the San Lorenzo River (City of Santa Cruz, California), San Dieguito River (San Diego County, California), and the Salt River (Phoenix, Arizona) were compared. Table 6.1 summarizes the major features of each model. Although none of the alluvial-river models evaluated was found to yield wholly satisfactory results, considerations of the sediment redistribution and bed-armoring effect by HEC-2SR, expression of the sediment transport equation in a simplified power-law function by KUWASER and UUWSR, and simulation of channel widening by FLUVIAL-11 were evaluated favorably.

Since the completion of the NRC study, several new alluvial-river models have been introduced. They include IALLUVIAL, developed at the University of Iowa, and STARS, developed by the U.S. Bureau of Reclamation. Holly and Karim (33) applied IALLUVIAL to simulate bed degradation in the middle Missouri River as part of an evaluation of downstream environmental consequences due to man-imposed changes to the upper Missouri River basin. The STARS model was applied by the Bureau to describe water and sediment movement on the East Fork near Boulder, Wyoming (34).

The major function of the alluvial-river models just presented is large scale simulations of general river response. Assessment of the headcut and backfill processes of a sand and gravel pit requires the spatial and temporal resolution at a smaller scale. The sediment routing model, PIT, simulates headcut, sediment backfill and downstream scour adjacent to a sand and gravel pit. Model PIT was developed by Dr. Ruh-Ming Li and Lan-Yin Li of Simons, Li & Associates. The model was developed for investigating the headcut effect on San Juan Creek and Bell Canyon, Orange County, California, associated with the Consolidated Rock (Conrock) gravel mining operation (35). The model was calibrated for this study using the scour data measured after the January and February, 1969, flood. The applicability of the developed model was validated using the January, February and March, 1978, storm. Simulation of the headcutting process by Model PIT was further verified with physical model observations (6). The Model PIT was applied in the development of qualitative guidelines for sand and gravel mining in the Salt, Gila and Agua Fria Rivers, Arizona. The Model was applied to the Rillito River for evaluating the legal responsibilities of sand and gravel mining operators for damage to the Oracle Highway bridge in Tucson, Arizona (37) and to the Columbia and San Xavier sand and gravel pits on the floodplain of the Santa Cruz river near Cortaro Farm

Table 6.1 Summary of Characteristics of Alluvial-River Simulation Models.

Model	Hydraulic Computations	Sediment-Transport Computations	Armoring or Sediment Coarsening	Lateral Migration
HEC-2SR	- Flow continuity eq. (known discharge) - Flow energy eq. - Energy head loss	- Meyer-Peter, Muller (1948) and Einstein (1950) - Sediment continuity eq. - Routing by sediment size	Sediment redistribution during routing Simulation of river armoring	N/A
KUWASER	- Flow continuity eq. (known discharge) - Flow energy eq.	- Power-law function of velocity and depth - Sediment continuity eq.	N/A	N/A
UUWSR	- Flow continuity eq. (unsteady flow) - Flow momentum eq.	- Power-law function of velocity and - Sediment continuity	N/A	N/A
HEC-6	- Flow continuity eq. (known discharge) - Flow energy eq.	- Options for Laursen (1958, Toffaleti (1968), Yang (1973), (DuBoy (1879), Brown (1950) and a special function of depth and energy slope	N/A	N/A
FLUVIAL-11	- Flow continuity eq. (unsteady flow) - Flow momentum eq.	Graf (1971) or Engelund-Hansen (1978	N/A	One-dimensional flow assumption with limited coordination of channel width change
SEDIMENT-4H	- Flow continuity eq. (unsteady flow) - Flow momentum eq.	Rouse (1937)	N/A	N/A

Road, Pima County, Arizona (38, 39). The model has also been applied to assist the authorities of Ventura County, California, in evaluating various sand and gravel mining alternatives proposed along the Santa Clara River, and to develop a sand and gravel mining standard.

The HEC-6 program was modified in 1980 by MacArthurs and Montalvo (40) to simulate in-stream, sand and gravel mining operations. The modifications allow users to specify rates of mining for specific mining locations. Mining activity can also be indicated for different periods in the simulation. Application of the program was made to simulate sediment transport and flow conditions in the Kansas River.

6.4.3 The Three-Level-Approach

To date, methodologies for sediment transport computation and simulation of river changes are still in the process of refinement and improvement. Application of the sediment transport equations and sediment routing models presented above requires significant knowledge of the methodologies selected and the physical system and processes of interest. A three-level approach was suggested by Simons and Li (12) for analysis of a watershed and river system. The three phases or levels for assessing problems rleating to a watershed or river system are:

Level I: a qualitative analysis based on general geomorphic parameters.

Level II: a quantitative analysis based on specific geomorphic concepts and basic engineering relationships.

Level III: mathematical modeling to simulate the physical processes of river response.

The Level I approach is to understand the entire river system, instead of an individual site-specific observation. This approach requires significant data describing the past and present conditions of the river system and the historical changes due to Man's activities. In particular, evidence of bank cutting, thalweg shifting, lateral migration, channel downcutting, sediment deposition, and vegetation changes can be studied based on field investigations and using aerial photographs and channel geometry data for different years.

To quantitatively describe the hydrologic, hydraulic and geomorphic characteristics of a fluvial system, the Level II analysis is applied sub-

sequent to the Level I analysis. The Level II analysis relies mainly on the empirical, theoretical or experimental engineering relations and equations developed for fluvial system analysis, such as rigid boundary water surface profile calculations and the sediment transport equations mentioned previously. This analysis can provide more specific quantitative information to supplement the conclusions from qualitative investigations.

A Level III analysis is employed when more detailed information on river bed changes is needed. This level uses alluvial river models with their calibration based on the Level I and II analyses. The results of a Level II analysis provides a sound engineering base for preparation of model application.

6.5 Procedures for Developing Sand and Gravel Mining Regulations

6.5.1 The "Red-line" Procedure

The technical methods described previously can be applied to develop sand and gravel mining regulations. A procedure recommended by Simons, Li and Associates (38), which was applied in the development of an "Optimal Red-line Standard" for the Santa Clara River, Ventura County, California, is as follows:

1. Review sand and gravel mining and channel degradation history;
2. Evaluate qualitatively the stream morphology and identify the erosion or sedimentation pattern;
3. Determine quantitatively the hydraulic, sediment transport and erosion or sedimentation characteristics for the baseline (pre-mining) conditions, including model simulation if necessary;
4. Define specific erosion and sedimentation control objectives for each channel reach, considering the erosion and sedimentation features of the reach and the potential impact on the upstream and downstream reaches;
5. Repeat Step 3 for the proposed mining plans;
6. Estimate the scour potential (including local scour and general degradation) under the proposed mining conditions and compare the results with the available scour protection. Identify the critical structural elevations for sand and gravel mining control;
7. Based on the results of Steps 3, 4, 5, and 6, recommend optimal

"red-line" slopes, river control elevations, and lateral limits for sand and gravel extraction;

8. Perform degradation or aggradation analysis for the proposed mining condition based on the optimal "red-line" standard.

The optimal "red-line" standard was determined considering the following major factors:

1. Erosion and sedimentation characteristics of the existing channel;
2. Scour potential under worst mining conditions; and
3. Critical structural elevations.

In the case of Ventura County, stability of critical structures is the foremost of these factors.

6.5.2 U.S. Army Corps of Engineers Sand and Gravel Mining Guidelines

Operation, reclamation, and administrative guidelines for sand and gravel mining were developed by Boyle Engineering for the COE (39). It was recommended that these guidelines be implemented through a permit process. The operational guidelines call for extraction to be conducted in accordance with approved plans, and that operations not obstruct natural flow or cause damage to adjacent structures. No excavation, stockpiling, or obstruction of the floodway would be permitted during flood-prone months. Excavation should be located far enough downstream of a structure so that a grade of one percent, beginning at the midpoint of the pit depth, would intercept the channel bed at least 200 feet downstream of a structure. Excavation would be set back 100 feet from the riverbank or below a plane at a slope of ten percent from the toe of the streambank, whichever is greater. Excavation would not be permitted below the existing low flow line unless channel stability could be demonstrated. Excavation would be conducted in a continuous manner, not as "leapfrogged" pits. The applicant would be required to assess potential hydraulic effects that might cause loss of property or environmental degradation, using a qualified engineer at the owners expense. Significant impacts would have to be addressed with appropriate mitigation measures.

The guidelines would require approved reclamation plans involving repair of damaged streambanks, removal of waste piles and equipment, stabilization of pit slopes, stabilization of streambanks to prevent erosion, and measures to limit access to abandoned pits. The guidelines would provide administrative procedures for monitoring of gravel operations, and measures to assure

compliance with reclamation plans (i.e., performance bonds, liens). The regulating agency would also have the authority to suspend gravel-mining operations.

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VII. SUMMARY OF GRAVEL MINING AND SEDIMENT TRANSPORT STUDIES ON MAJOR ARIZONA RIVERS

It is anticipated that previous studies on Arizona river systems will provide a valuable source of data for the river-basin classification work (Tasks 3 & 4) that will be undertaken in the subsequent phases of this research project. Such studies would also be useful in identifying and evaluating different engineering methodologies that have previously been used to conduct analyses of in-stream gravel mining operations.

In order to locate such studies, the questionnaires that were sent to regulatory agencies, consulting engineers, and gravel mining companies (see Chapter V) included a request for data or reports that the questionnaire recipients thought would be pertinent to this research project. Unfortunately the response to this category of requested information was minimal. Accordingly, SLA had to rely heavily on previous sediment transport, hydraulic, and gravel mining studies prepared by SLA. This accounts for the large number of SLA reports referenced in this section.

Studies selected for inclusion in this chapter were based on their relation to major Arizona river systems that have a high potential for in-stream sand and gravel mining. The data that has been collected relative to previous studies is summarized according to two categories:

° In-Stream Sand and Gravel Mining Studies

° Hydraulic/Sediment Transport Studies

Each of the following studies is described by: 1) name; 2) location; 3) date; 4) consultant preparing study; 5) name of client; 6) synopsis of results; and 7) list of computer models used in the study.

SUMMARY

In-Stream Sand & Gravel Mining Studies

1. Analysis of Effects of Sand & Gravel Mining Activities on the Stability of The Oracle Highway Bridge

   Location : Rillito River, Tucson, Az.

   Date : January 1981

Consultant : Simons, Li & Associates, Inc.
Client : Pima County Department of Transportation & Flood Control District
Synopsis : Study identified and examined causes of past, present, and future degradation and/or aggradation at the Oracle Highway Bridge and, in particular, examined the effects of gravel mining activities on the stability of the bridge.
Computer Models: HEC-2, PIT

2. Impact of Gravel Mining on the Proposd Salt River Channelization Project
Location : Salt River, Phoenix, Az.
Date : November 1980
Consultant : Anderson-Nichols & Colorado State University
Client : U.S. Army Corps of Engineers, Sacramento District
Synopsis : A physical model was constructed to simulate the impact of in-stream gravel pits on the stability of a proposed channelization scheme for the Salt River from I-10 to Sky Harbor Airport. The model results were used to develop guidelines to implement proper control of these mining operations to avoid adverse impacts.
Computer Models: None.

3. Sand and Gravel Mining Guidelines
Location : Salt and Gila Rivers, Maricopa County
Date : July 1980
Consultant : Boyle Engineering Corporation
Client : U.S. Army Corps of Engineers, Los Angeles District
Synopsis : Develops guidelines for sand and gravel extraction from the Salt and Gila Rivers in order that such guidelines might be used to reduce flood damages associated with in-stream mining. The report discusses hydraulic and erosion processes associated with such operations and outlines mitigation measures to minimize adverse impacts on the river system.

Computer Models: None.

4. An Evaluation of Effects of Excavations in the Vicinity of the I-10 Salt River Bridge on the Flow Regime and Local Scour at the Bridge

Location : Salt River, Phoenix, Az.
Date : December 1980
Consultant : W.R. Bruesch, Arizona Department of Transportation
Client : Arizona Department of Transportation
Synopsis : Presents an extensive photo-documentary on the changes in river regime near the I-10 bridge. These photos illustrate changes in flow patterns resulting from man's activities in and adjacent to the river channel. A subjective evaluation of the effects of changes in the flow regime on local scour at the bridge is also presented.
Computer Models: None.

5. Hydraulic and Geomorphic Analysis and Mine Plan Study for the Blue Circle Arizona, Inc. Pantano Wash Lease Site

Location : Pantano Wash, Pima County, Az.
Date : January 1986
Consultant : Simons, Li & Associates, Inc.
Client : Blue Circle Arizona, Inc.
Synopsis : This study was a hydraulic and geomorphic analysis to assess the feasibility of developing a 200-acre sand and gravel mining operation along Pantano Wash. The study resulted in a mining plan that included measures to mitigate adverse impacts to the river system.
Computer Models: HEC-2, QUASED

6. Engineering Analysis of In-Stream Gravel Extraction From the Agua Fria River, Vicinity of Indian School Road & Camelback Road

Location : Agua Fria River, Phoenix, Az.
Date : September 1985
Consultant : Simons, Li & Associates, Inc.

Client : Flood Control District of Maricopa County

Synopsis : This study presents a detailed analysis of river system impacts that would be expected to accompany the proposed excavation of two large gravel pits on either side of the Indian School Road Bridge. The analysis addresses both short- and long-term impacts that would be expected upstream and downstream of the proposed pits. The report is based on a head-cut and trap efficiency analysis of the two pits as well as a sediment routing model which was used to predict a downstream degradation profile of the riverbed.

Computer Models: HEC-2, QUASED, SETTLE

7. Development of Qualitative Guidelines for Sand and Gravel Mining in Salt, Gila and Agua Fria Rivers

Location : Salt, Gila and Agua Fria Rivers, Maricopa County, Az.

Date : June 1980

Consultant : Simons, Li & Associates, Inc.

Client : Boyle Engineering Corporation

Synopsis : This study focuses on the following objectives: (1) explain physical processes governing mechanics of the gravel pit during low, medium and high flows, considering both headcutting upstream and degradation downstream of the pit, along with the significance of the depth, size and volume of the pit; (2) provide a typical example of a simulation run of real-time response for an assumed storm hydrograph and a hypothetical gravel pit; (3) suggest a qualitative guide for sand and gravel extraction in the Salt, Gila and Agua Fria Rivers; and (4) recommend a study plan for developing a quantitative guide for sand and gravel extraction in the Salt River as a function of sediment supply and transporting capacity of the river.

Computer Models: None.

8. Preliminary Engineering Analysis of In-Stream Sand and Gravel Extraction From Three Sites on the Salt River

Location : 67th Avenue, 48th Street, and Indian Bend Wash Confluence, Salt River, Maricopa County, Az.

Date : November 1985

Consultant : Simons, Li & Associates, Inc.

Client : The Tanner Companies

Synopsis : An engineering investigation was made of three potential in-stream gravel pit locations on the Salt River in order to identify any utility conflicts and river mechanics problems that might restrict the excavation limits at each site. The report utilizes data from a physical-model study on the Salt River to: 1) establish recommended excavation limits (vertically and horizontally); and 2) to determine the maximum permissible yield from each pit.

Computer Models: None.

9. Sand and Gravel Mining Feasibility Study for The Tanner Companies - Los Reales/Pantano Wash Site

Location : Pantano Wash, Pima County, Az.

Date : February 1986

Consultant : Simons, Li & Associates, Inc.

Client : The Tanner Companies

Synopsis : This report presents the results of a hydraulic and geomorphic analysis to assess the feasibility of realigning a one-mile section of Pantano Wash to allow for expansion of an existing gravel pit. Bank protection and erosion buffer zones were recommended as mitigation measures to prevent adverse river system impacts that might result from the proposed pit expansion.

Computer Models: HEC-2, QUASED

10. Erosion and Sedimentation Analysis of Columbia Pit and San Xavier Pit in The Santa Cruz River, Tucson, Arizona

Location : Santa Cruz River, Tucson, Az.
Date : 1980
Consultant : Simons, Li & Associates, Inc.
Client : Cella, Barr, Evans and Associates
Synopsis : This report presents an analysis of the hydrologic, long-term geomorphic, hydraulic, and erosion and sedimentation processes for the river system. Aerial photographs and hydrologic records were used to determine gradual changes in the channel alignment and configuration that were occurring in the Santa Cruz River through the study areas. The response of both the river and the gravel pits during a 100-year flood was analyzed for a variety of possible gravel pit configurations and management schemes by using a water and sediment routing procedure developed by Simons and Li (1979). The long-term changes in the system and the changes resulting from a severe event (a 100-year flood) were used to make recommendations for engineering control measures for preventing any harmful interaction between the gravel pits and the Santa Cruz River.
Computer Models: HEC-2, PIT

11. Study of Gravel Mining Impacts, Verde River at Cottonwood, Arizona

Location : Verde River at Cottonwood, Az.
Date : May 1985
Consultant : Simons, Li & Associates, Inc.
Client : Yavapai County Flood Control District
Synopsis : This study presents an engineering analysis of river system impacts associated with in-stream gravel mining on the Verde River at Cottonwood. The analysis was specifically structured to address headcutting upstream of the gravel pit, bank erosion, shifting of the channel alignment, and downstream channel degradation. Extensive use was made of historical aerial and ground

photographs, historical bed profiles and hydrologic data.

Computer Models: HEC-2, MPM

12. Engineering Analysis to Establish Excavation Limits for In-Stream Extraction of Sand and Gravel Between 51st Avenue and 59th Avenue on the Salt River

Location : Salt River, Maricopa County, Az.

Date : January 1986

Consultant : Simons, Li & Associates, Inc.

Client : Arizona Crushing Company

Synopsis : This report presents the development of an excavation plan for extracting sand and gravel from a specific reach of the Salt River floodplain. Excavation limits, both vertical and horizontal, were developed to reduce the potential for creating a river system response which would have a high probability of causing damage to nearby utility lines and a major bridge structure.

Specifically, the study addressed potential damage that might result from pit-induced headcutting, downstream scour, and lateral erosion. Using physical model study data developed by the principals of SLA, excavation limits for pit depths of 20 feet, 40 feet, and 60 feet were established for the site. The excavation limits were offset a sufficient distance inside the property boundaries so as to minimize offsite erosion and scour damage. Approximate excavation volumes were then computed in order that a determination could be made of the feasibility for commercial sand and gravel extraction at the site.

Computer Models: None.

13. (Exact title unknown, information provided by the Pima County Department of Transportation and Flood Control District)

Location : Santa Cruz River, Pima County, Az.

Date : 1975
Consultant : Cella, Barr, Evans & Associates, Inc.
Client : Granite Construction Company
Synopsis : This study examined a proposal to modify the river channel near the approach to an existing bridge. The excavation was to be done by Granite Construction Company.
Computer Models: HEC-2

14. (Exact title unknown, information provided by the Pima County Department of Transportation and Flood Control District)
Location : Santa Cruz River, Pima County, Az.
Date : 1981
Consultant : Dooley-Jones & Associates, Inc.
Client : San Xavier Rock and Materials
Synopsis : This study presented a mining plan for sand and gravel extraction from the overbank of the river. Forms of bank protection were investigated.
Computer Models: HEC-2

15. (Exact title unknown, information provided by the Pima County Department of Transportation and Flood Control District)
Location : Rillito River, Pima County, Az.
Date : 1978
Consultant : Cella, Barr, Evans & Associates, Inc.
Client : Pueblo Pebbles
Synopsis : This report was prepared to determine safe setback limits for a sand and gravel mining operation in the overbank of the Rillito River.
Computer Models: HEC-2

16. (Exact title unknown, information provided by the Pima County Department of Transportation and Flood Control District)
Location : Rillito River, Pima County, Az.
Date : 1984

Consultant : Cella, Barr, Evans & Associates, Inc.
Client : Pueblo Pebbles
Synopsis : The gravel mining limits recommended in the 1978 study were exceeded. This new study presents additional engineering analyses required to justify further excavation.
Computer Models: HEC-2

17. (Exact title unknown, information provided by the Pima County Department of Transportation and Flood Control District)
Location : Pima County, Az.
Date : 1986
Consultant : CMG Drainage
Client : Blue Circle
Synopsis : This study presents the results of a seepage analysis, river cross-sections, and historical photos that were used to determine a safe setback limit for an overbank sand and gravel operation.
Computer Models: None.

18. (Toby Allen - Pantano Wash - exact title unknown, information provided by the Pima County Department of Transportation and Flood Control District)
Location : Pantano Wash, Pima County, Az.
Date : 1986
Consultant : Dooley-Jones Associates
Client : Toby Allen
Synopsis : Analysis of in-stream sand and gravel extraction. Details are unknown.
Computer Models: HEC-2, HEC-6, FLUVIAL 2

Hydraulic/Sediment Transport Studies

1. Santa Cruz River Mechanics Study - Rillito Creek to Cortaro Road

Location : Santa Cruz River, Pima County, Az.

Date : September 1985

Consultant : Simons, Li & Associates, Inc.

Client : Tucson Sand and Soil, Inc.

Synopsis : This study was a hydraulic and geomorphic analysis conducted to assess the impact of channelization and realignment of the Santa Cruz River between the Rillito River confluence and Cortaro road. Also contained within the plan was a proposal to widen the Santa Cruz River at the confluence with the Canada del Oro Wash to a width of approximately 1250 feet for the purpose of inducing sediment deposition in order to provide a source of mineable sand and gravel material. The objectives of this plan were to advance the economical development of the property as a sand and gravel mining operation, and to prevent future floods from causing additional bank erosion and lateral migration of the channel which has historically resulted in significant damage to private and public properties within the project area.

Computer Models: HEC-2, QUASED

2. Hydraulic, Erosion and Sedimentation Analysis of Indian School Road Bridge Over the Agua Fria River

Location : Agua Fria River, Maricopa County, Az.

Date : 1982

Consultant : Simons, Li & Associates, Inc.

Client : Flood Control District of Maricopa County

Synopsis : This study addresses the failure of the Indian School Road Bridge during the February 20, 1980 flood on the Agua Fria River and investigates stability measures to prevent a recurrence of the failure.

The three-level analysis applied to the ISRB failure

included: (1) a qualitative geomorphic analysis; (2) a quantitative engineering geomorphic analysis; and (3) and application of a mathematical model to evaluate the potential local scour, general regional scour, and potential aggradation/degradation at the ISRB and the RID flume crossing. The results of the three-level analysis were used in a litigation suit involving nearby gravel mining companies and were also used to develop mitigation measures to prevent future damage.

Computer Models: HEC-2, QUASED

3. Hydraulic and Scour Analysis of Salt River Bridge at Phoenix-Casa Grande Highway for Long-Term Protection Against Scour

Location : Salt River, Phoenix, Az.

Date : 1980

Consultant : Simons, Li & Associates, Inc.

Client : Dames and Moore

Synopsis : Excessive scour caused settlement of the I-10 bridge piers during the February 1980 flood. This report analyzes the susceptibility of the pier foundations to scouring during future floods in order to evaluate alternative structural and/or nonstructural methods that could be used to protect the piers from such scouring. Structural alternatives that were analyzed include: (1) channelization using guide banks; (2) a downstream grade control structure; and (3) control of side drainage flows. Nonstructural measures include: (1) control of gravel mining; and (2) operation of upstream reservoirs to regulate flow.

Computer Models: QUASED

4. Analysis and Design Study of the Agua Fria River

Location : Agua Fria River, Maricopa County, Az.
Date : November 1983
Consultant : Simons, Li & Associates, Inc.
Client : Flood Control District of Maricopa County
Synopsis : A hydrologic, hydraulic, erosion, and sedimentation study was completed for a nine-mile reach of the Agua Fria River from the confluence with the Gila River to the confluence with the New River. This investigation utilized a three-level approach which included: 1) a qualitative geomorphic analysis; 2) a quantitative engineering geomorphic analysis; and 3) a mathematical model simulation. The results of this analysis were used to design a channelization project for the Agua Fria River.
Computer Models: HEC-2, QUASED

5. Sediment Transport Analysis of Rillito River and Tributaries for The Tucson Urban Study

Location : Rillito River, Pantano Wash, Tanque Verde Creek, Sabino Creek, and Agua Caliente Wash, Tucson, Az.
Date : February 1982
Consultant : Simons, Li & Associates, Inc.
Client : Pima County Department of Transportation and Flood Control District
Snyopsis : A sediment transport analysis was conducted for approxmately 45 miles of various river systems in the Tucson area in order to determine the potential for aggradation and degradation associated with the 10-year and 100-year floods. This information was used to help manage the watersheds and river systems in order to minimize the potential for adverse impacts resulting from development activity.
Computer Models: HEC-2, QUASED

6. Hydraulic and Geomorphic Analysis of the Proposed New Tanque Verde Road Bridge Over the Tanque Verde Creek

Location : Tanque Verde Creek, Tucson, Az.
Date : 1981
Consultant : Simons, Li & Associates, Inc.
Client : Pima County Department of Transportation and Flood Control District
Synopsis : This report presents an engineering-geomorphic assessment (erosion/sedimentation) of the long-term bridge and river stability for a bridge that would pass a 100-year flood, versus a bridge that would pass a lesser flood. Hydraulic modeling investigated various bridge lengths and corresponding channel improvements. Environmental concerns for long-term river stability were also addressed.
Computer Models: HEC-2, QUASED

7. Sediment and Debris Transport Analysis at Eight Bridge Locations, Tucson, Arizona

Location : Magee Road, Thornydale Road, Ina Road, Craycroft Road, Sabino Canyon Road, Swan Road, Tanque Verde Road, and La Canada Drive - Tucson, Az.
Date : 1981
Consultant : Simons, Li & Associates, Inc.
Client : Pima County Department of Transportation and Flood Control Division
Synopsis : This debris and sediment transport analysis developed information to: (1) evaluate the stability of the bridge structures; (2) determine the lateral-migration tendencies of the channel; (3) estimate the extent of expected general downstream channel scour; (4) determine the potential local scour around bridge piers and abutments; and (5) estimate the long-term effects of sediment degradation and aggradation on the water-

surface profile. The potential problems associated with vegetative debris were also studied, particularly in relation to possible partial blockage of the channel and increased local scour at the bridge sites.

Computer Models: HEC-2, QUASED

8. Scour/Migration Analysis of the Rillito River at Pontatoc Road

Location : Rillito River, Tucson, Az.
Date : 1984
Consultant : Simons, Li & Associates, Inc.
Client : Brown and Caldwell Consulting Engineers
Synopsis : This study presents the results of a hydraulic and geomorphic analysis that was performed to determine the river response to a 10-, 25-, 50-, and 100-year flood. The analysis considered responses during previous floods for comparison with the quantitative responses which were estimated using locally accepted procedures.
Computer Models: HEC-2, QUASED

9. Hydraulic and Sedimentation Analysis of the 7th Street Bridge over the Salt River

Location : Salt River, Phoenix, Az.
Date : April 1981
Consultant : Simons, Li & Associates, Inc.
Client : RGA Consulting Engineers
Synopsis : This report presents the results of a sediment transport and scour analysis that was used to determine hydraulic bridge design parameters as a function of existing river conditions and a proposed channelization scheme. A three-level approach was used which included: 1) a qualitative geomorphic analysis; 2) a quantitative engineering geomorphic analysis; and 3) a physical process model.
Computer Models: HEC-2, QUASED

10. Scour and Sedimentation Analysis of the Proposed Channelization of the Salt River for Protecting the Sky Harbor International Airport

Location : Salt River, Phoenix, Az.
Date : 1980
Consultant : Simons, Li & Associates, Inc.
Client : Howard Needles Tammen and Bergendoff
Synopsis : Past floods caused significant damage to the Sky Harbor International Airport. The main runway was so severely damaged that 2400 feet of its length was unusable. As a result, a $10 million channelization project to protect the airport from a 100-year flood was formulated. Simons, Li & Associates, Inc. performed an analysis of the scour and sedimentation processes associated with the selected channelization alternative. The study considered the 100-year design event.

The investigation was carried out utilizing three levels: (1) a qualitative geomorphic analysis; (2) a quantitative engineering geomorphic analysis; and (3) a physical process model. The results of the analysis were used to provide recommendations to modify the proposed channelization scheme to prevent failure due to scour and sedimentation problems.

Computer Models: HEC-2, QUASED

11. River Response Analysis Associated With Rio Nuevo-Santa Cruz River Flood Control and Channelization Project

Location : Santa Cruz River, Tucson, Az.
Date : 1981
Consultant : Simons, Li & Associates, Inc.
Client : Cella Barr Associates
Synopsis : Using a HEC-2 model prepared by Cella Barr Associates, SLA performed a three-level analysis to assess erosion and sedimentation problems which included qualitative geomorphic, engineering geomorphic and physical process model analyses. This information was used to answer

questions regarding short-term and long-term responses to different flood events. The study concluded with an analysis of several design alternatives for bank protection.

Computer Models: HEC-2, QUASED

12. Canada del Oro Flood Control Project (Oro Valley), Arizona

Location : Canada del Oro Wash, Oro Valley, Az.
Date : 1981
Consultant : Simons, Li & Associates, Inc.
Client : Arizona Department of Water Resources
Synopsis : This reconnaissance-level report addressed the flooding problems along a two-mile reach of the Canada del Oro Wash in the vicinity of the town of Oro Valley in Pima County, Arizona. The study involved: (1) review of existing hydrologic, hydraulic, erosion and sedimentation information; (2) determination of existing and potential flooding problems in the study reach; (3) evaluation of potential erosion and sedimentation problems using a sediment routing model; (4) formulation of flood control alternative plans; and (5) evaluation of alternative plans considering operation and maintenance, environmental factors, and economics.
Computer Models: HEC-2, QUASED

13. Sediment Transport Report for the New River and Skunk Creek

Location : New River and Skunk Creek, Maricopa County, Az.
Date : January 1985
Consultant : Simons, Li & Associates, Inc.
Client : U.S. Army Corps of Engineers, Los Angeles District
Synopsis : In order to evaluate the impact of rapid urbanization and commercial/industrial development within the New River/Skunk Creek watersheds, the Corps of Engineers retained Simons, Li & Associates, Inc. (SLA) to prepare a comprehensive hydraulic/sediment transport/flood

control study for nine miles of the New River (upstream of the confluence with the Aqua Fria River) and three miles of Skunk Creek (upstream of its confluence with New River).

The study involved three levels of analysis: 1) qualitative geomorphic; 2) quantitative geomorphic; and 3) sediment routing. Existing conditions were first investigated in order to determine specific problem areas within the river systems. A flood control solution, prescribed by the Corps of Engineers, was then evaluated using a sediment routing model developed by SLA.

Computer Models: HEC-2, QUASED

14. Excavation Plan/Salt River Southbank Project

Location : Salt River, Phoenix, Az.
Date : January 1986
Consultant : Born, Barrett & Associates
Client : DENRO LTD. DEVELOPERS
Synopsis : The information provided on this project by the City of Phoenix consisted of plan/profile sheets and river cross-sections which depict a river excavation and levee plan extending from the I-10 bridge to about 36th Street. The analysis consists of HEC-2 runs showing "before" and "after" hydraulic conditions in the river.
Computer Models: HEC-2

15. Hydraulic Analysis for Salt River Between 19th Avenue and 35th Avenue

Location : Salt River, Phoenix, Az.
Date : October 1986
Consultant : Water Resources Associates
Client : Harding Greene, Ltd.
Synopsis : This report presents a hydraulic analysis of a river channelization scheme that was investigated as part of a plan to install a conveyor bridge across the Salt

River. A scour analysis was also performed to determine the scour depth for the piers supporting the conveyor bridge.

Computer Models: HEC-2

16. River Mechanics and Floodplain Analysis, Phase 1, East Papago Extension - SR217, Hohokam Expressway Extension - SR143

Location : Salt River, Phoenix/Tempe, Az.

Date : June 1986

Consultant : Simons, Li & Associates, Inc.

Client : John Carollo Engineers

Synopsis : This is the first of a three-phase study which will determine design parameters for the East Papago/Hohokam Freeway alignments that encroach into the Salt River floodplain. The Phase 1 report presents a preliminary examination of river system impacts associated with these alignments and investigates mitigation measures (including major river channelization) that would protect the freeway system from flood damage. Increased scour effects around existing bridge piers are also examined. Subsequent phases of this study will provide a historical geomorphic analysis of the river and will include the development of a sediment routing model for this reach of the Salt River.

Computer Models: HEC-2, QUASED

VIII. ECONOMIC INFORMATION

Literature and data on the economic aspects of the sand and gravel industry was gathered and reviewed. Information was available from private and governmental sources. Basic data on resource areas in Arizona, annual production and value of rock products, and transportation costs were compiled from the literature. Sources of economic information included the Arizona Rock Products Association (1), the Arizona Bureau of Geology and Mineral Technology (formerly the Arizona Bureau of Mines) (2,3), the U.S. Geological Survey (4), and the U.S. Army Corps of Engineers (5).

8.1 Resource Areas

Keith (2) provides a general description of where sand and gravel deposits occur in the three physiographic regions of Arizona: the northern plateau region, the central mountain region, and the southern basin and range region. For the plateau region, the best commercial deposits occur along the streams and washes in local bars and terraces but they are rather thin and limited in area. The mountain region has good quality, but generally small, alluvial deposits of sand and gravel along both the stream channels and the terraces along the valley sides. In the basin and range region the best deposits of sand and gravel occur in alluvial fans along mountain ranges where intermittent streams constantly supply new deposits. Stream channels and dry washes yield a large part of the sand and gravel production.

Moore, et al (4) compiled a map showing aggregate deposits in the Phoenix area. The map scale is 1:250,000 and shows construction material exposed at the ground surface. The map also shows the approximate location of sand and gravel pits, and rock quarries. The COE (5) estimates in-stream aggregate resources in the Phoenix area to be 368 million cubic yards (490 million tons) over a 33 mile-long reach of the Salt River from Granite Reef dam to 67th Avenue. Through the main urban area of Phoenix and Tempe, in-stream aggregate resources are estimated at 120 million cubic yards (160 million tons) for this eleven mile reach.

8.2 Annual Production

Keith (2) notes that variations in the production of sand and gravel in Arizona are related to changing levels in construction activity and is influ-

nced by the installation of major dams, highways, irrigation ditches, airfields, defense establishments, and the building of commercial and residential structures. Important projects that have stimulated sand and gravel production since World War II include the Federal Aid Highways Act of 1956, the Central Arizona Project, and Proposition 300 for freeway expansion in Maricopa County.

The Arizona Bureau of Geology and Mineral Technology in cooperation with the U.S. Bureau of Mines, compiles aggregate production data by county on an annual basis. The information is published in the Minerals Yearbook. The accounting of aggregate production by county began in 1952. Keith (2) summarizes state-wide production from 1900 through 1966 and provides information on commercial and governmental production. Williams (3) summarizes production data from the Tucson area from 1952 to 1966 and compares this data to population growth in the area. Based on this comparison he estimates future sand and gravel production using forecasted population growth. The COE (5) estimated the demand for aggregate resources in the Phoenix area as a function of the following parameters

$$D = 10.3 + 0.59M + 3.11C + 0.38E$$

where D is the estimated annual demand (tons), M is the annual miles of roads constructed, C is the annual number of commercial-building permits issued, and E is the annual number of workers employed in construction.

The Arizona Rock Products Association (1) has estimated demand for sand and gravel to the year 2000, Figure 8.1. This estimate anticipates that demand for rock products will outpace Arizona population growth through the end of the century. Production of sand and gravel is expected to reach 58 million tons per year by the year 2000, compared to 1985 production of 38 million tons. They also estimate that construction of planned freeways in the Phoenix metropolitan area will require 14.5 million tons of sand and gravel, and 8.8 million cubic yards of concrete.

8.3 Market Value

Williams (3) notes the following about sand and gravel unit prices, and their relation to supply and demand. "When production of sand and gravel is

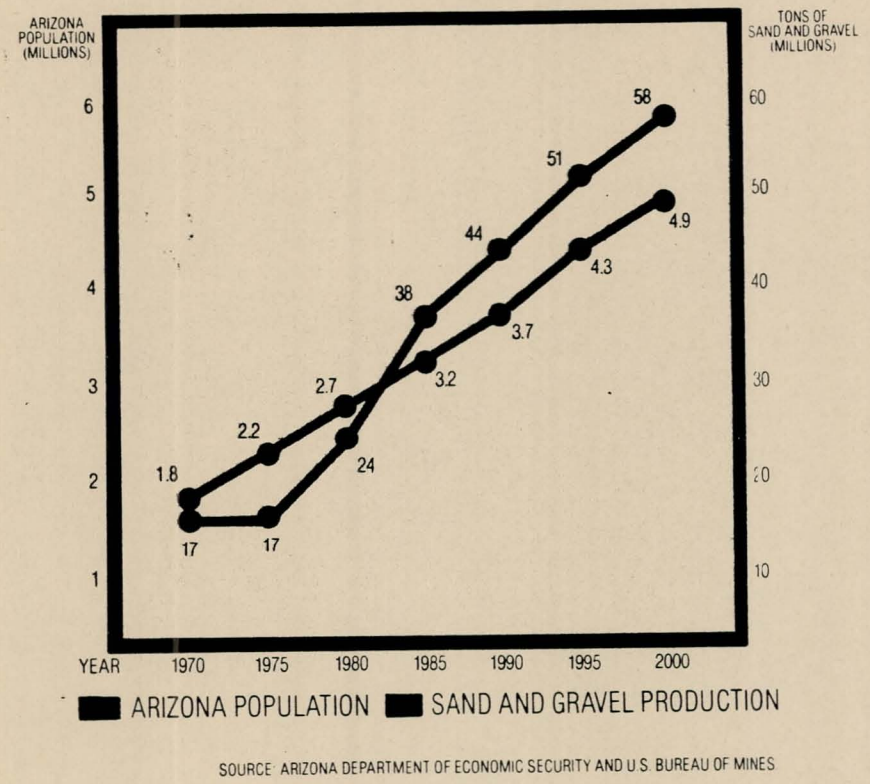

Figure 8.1
Arizona population and sand and gravel production: 1970-2000 (1).

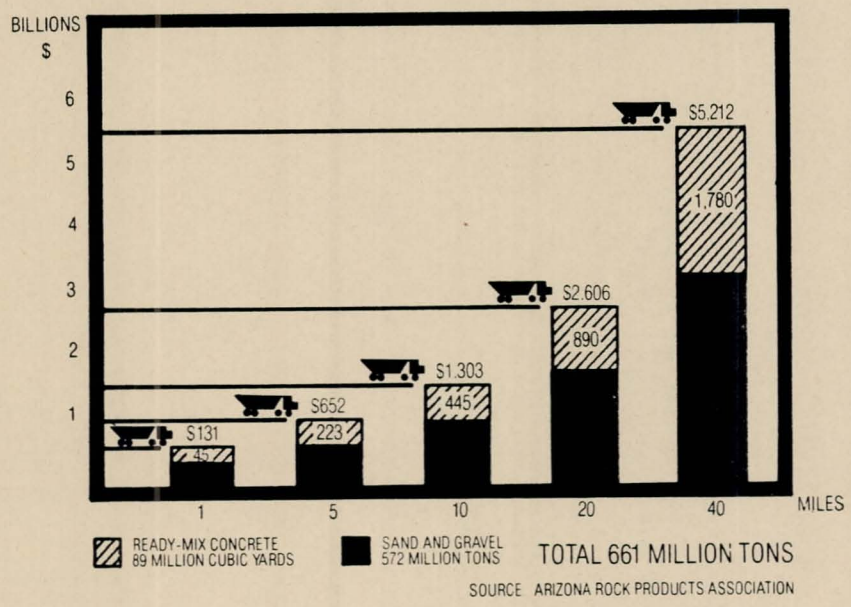

Figure 8.2
Transportation costs (1).

high because of demand, competition among operators is keen and sale prices are usually lower. In addition, higher volume lowers unit production costs and permits profitable operation at a smaller unit profit. Fixed costs can be spread out and charged to more tons at a lower rate."

The COE (5) performed a price trend analysis for sand and gravel in the Phoenix area, which gave the following equation:

$$P_t = 1.03 + 0.065t - 0.027t^2 + 0.0029t^3$$

where P_t is the estimated price ($/ton), and t is the cummulative time in years since 1965. The price trend analysis was based on sand and gravel prices from 1965 to 1981. The corps study reported a 1981 sand and gravel price of $6.80/ton.

The Arizona Rock Products Association (1) reports a 1985 market value of state-wide sand and gravel production of $122.9 million. The value of Arizona production is also reported by the Arizona Bureau of Geology and Mineral Technology in the Mineral Yearbook. The value of output per sand and gravel worker in 1985 was $80,900. This compares to an output of $80,500 per worker in the Arizona electronics industry (1).

8.4 Transportation Costs

Because of the weight of sand and gravel products, and the perishability of concrete, transportation is a major portion of the cost (1). Research sited by the Arizona Rock Products Association shows that the additional cost paid for sand and gravel products and ready-mix concrete increases rapidly with transportation distance (Figure 8.2).

8.5 Employment

Employment statistics compiled by the Arizona Rock Products Association (1) indicates the very fundamental role that sand and gravel production plays in the construction economy of Arizona. Figure 8.3 shows the relationship between workers in the sand and gravel industry and other workers in the construction industry. The 1,519 sand and gravel workers create essential materials that support an additional 79 jobs (per sand and gravel worker) in the construction sector of the Arizona economy. The construction industry as

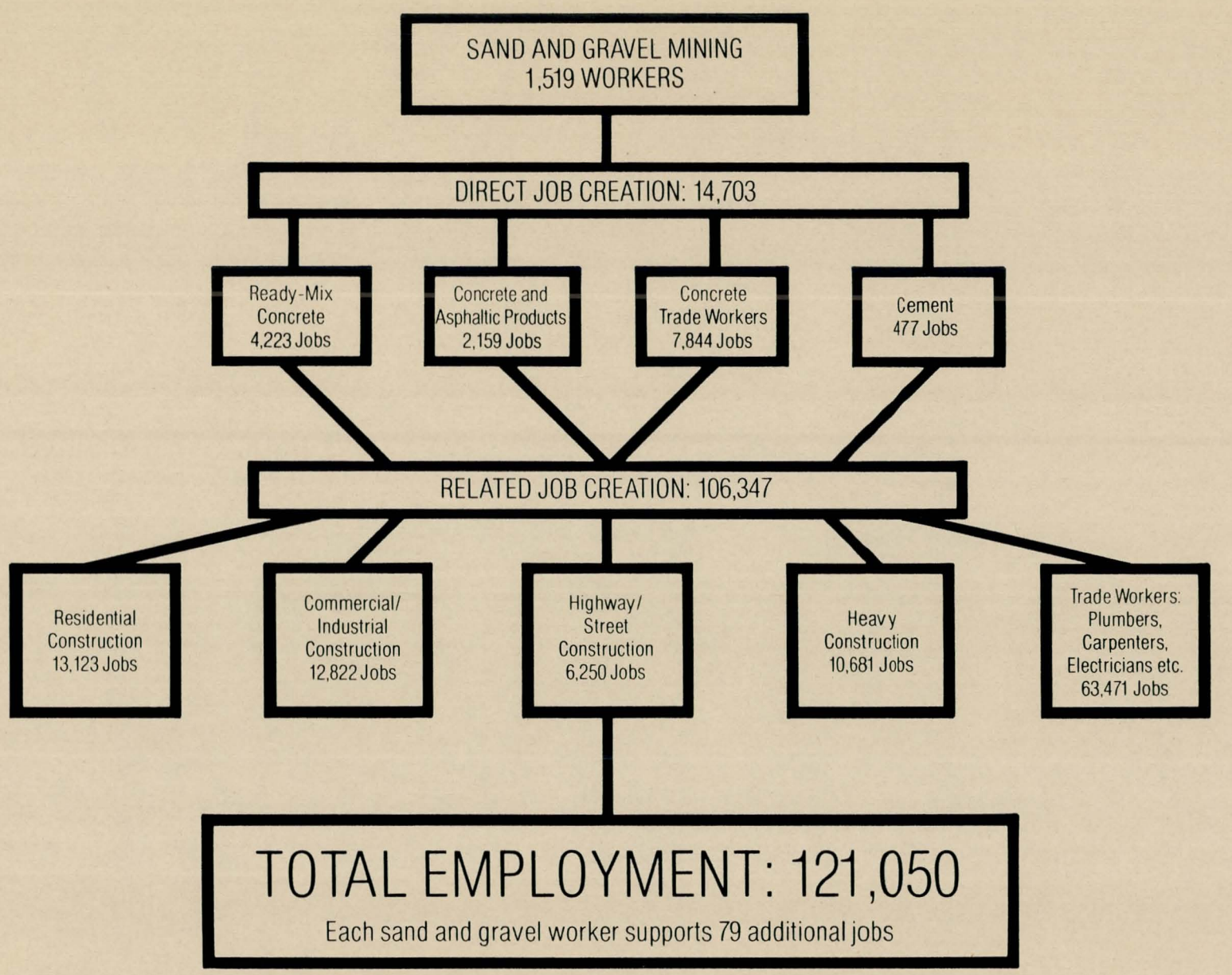

Figure 8.3
Sand and gravel employment and related construction industry jobs (1).

a whole results in the creation of other jobs in the service, finance and trade sectors of the economy.

The total 1985 payroll for the sand and gravel industry and various affiliated and related industries approached $2.4 billion. Table 8.1 summaries the 1985 payrolls for these industries.

8.6 Taxes and Fees Paid

The sand and gravel producers are taxed on their investments in land, machinery, and transportation equipment. Property taxes and vehicle fees for 1985 totalled nearly $9 million (1). In addition, income, corporation, unemployment and sales taxes amounted to $36.5 million.

TABLE 8.1

Payroll in sand and gravel and related industries (1).

Sand and Gravel Mining	$ 28,600,000
Ready-Mix Concrete	98,400,000
Concrete and Asphaltic Products	44,500,000
Concrete Trade Workers	172,600,000
Cement	14,000,000
Residential Construction	231,200,000
Commercial/Industrial Construction	276,000,000
Highway/Street Construction	153,600,000
Heavy Construction	308,200,000
Building Trade Workers	1,063,000,000
TOTAL PAYROLL	$ 2,390,100,000

REFERENCES

(1) Arizona Rock Products Association, 1986, "The Bedrock for Arizona's Growth".

(2) Keith, S.B., 1969, "Mineral and Water Resources of Arizona," The Arizona Bureau of Mines, Bulletin 180, p. 424-441.

(3) Williams, F.E., 1967, "Urbanization and the mineral aggregate industry, Tucson, Arizona area", U.S. Bureau of Mines, Inf. Cir. IC8318.

(4) Moore, R.T. and R.J. Varga, 1976, "Maps showing nonmetallic mineral deposits in the Phoenix area, Arizona", U.S. Geological Survey, Misc Invest. Series, Map I-845-J.

(5) Los Angeles District, 1981, "Stage III Non-Structural Appendix, Central Arizona Water Control Study", U.S. Army Corps of Engineers.

IX. SUMMARY OF FINDINGS

The purpose of this section is to: 1) highlight preliminary conclusions relative to this initial acquisition of data; and 2) to present recommendations for the remaining tasks outlined in the original Scope of Work prepared for this research project.

9.1 Conclusions

Highlights of information from each section of the report are presented.

Economics

1. Sand and gravel products are a fundamental resource for the construction industry.

2. The sand and gravel mining industry in Arizona is a very competitive, productive industry that is an efficient supplier of sand and gravel products.

3. The cost of sand and gravel products to the consumer is a function of both production costs and transportation costs. Production costs are a function of the quality of the sand and gravel resource available to the operator, and demand for sand and gravel products. Transportation costs are a function of the distance from the mining operation to the consumer.

4. The value of sand and gravel production for the ten-year period from 1975 to 1984 was $646,951,000 (Mineral Yearbook). The value of sand and gravel production for 1985 was $122,900,000 (Arizona Rock Products Association).

Flood Damages

1. The reported flood damages to roads/bridges and to the sand and gravel industry in Arizona for the period from 1965 to 1983 was estimated at $103,981,586 (Flood Damage Reports).

Regulatory Practice

1. The Federal flood insurance program has significant influence on instream and flood plain sand and gravel operations. Federal water quality regulations on dredged and fill material (Section 404) must be complied with

by sand and gravel operators, but do not restrict such operations.

2. Regulations implemented in the State of California for management of sand and gravel resources address issues and conditions similar to those in Arizona. A resource management approach toward sand and gravel regulation balances resource requirements and costs, against costs to assure other in-stream uses.

3. Floodplain management regulations are the predominant method of regulating sand and gravel operations in Arizona at the present time.

Litigation

1. Information on fourteen cases is presented.

Questionnaire responses

1. The feasibility of uniform guidelines implemented at the State government level is questioned.

2. Regulation should be administered at the local level backed by a state enabling law.

3. At the present time, in-stream sand and gravel operations are regulated through local zoning and flood plain ordinances.

4. Enforcement of ordinances is carried out through contact with operators and, if necessary, then through litigation in civil court.

5. The primary benefit of in-stream sand and gravel operations is an economical, convenient source of quality construction materials. Other benefits include: a) increased channel capacity; b) reduced potential for overbank flooding; c) partial runoff storage; d) minor, local groundwater recharge; and e) job creation and increased tax base.

6. Sand and gravel mining was sited as a contributing factor in damage to river crossings, primarily transportation structures.

7. It was suggested that environmental concerns and long-term consequences be considered when considering the benefits of a particular mining site.

8. It was suggested that technical analysis should evaluate long-term stability of the overall river system and then the local effects resulting from in-stream mining within that system.

Methodologies for analysis of sand and gravel mining impacts

1. There is no standard methodology presently being used in Arizona to analyze the impacts of in-stream sand and gravel mining.

2. Methods of analysis include field measurements, physical models, and analytical techniques.

3. Field measurements are best suited to monitoring existing sand and gravel mining operations.

4. Physical models provide a relative assessment of river conditions, but have limited application because of their cost and accuracy.

5. A wide range of analytical methods are available, including at least eight models for simulating general river response, and two models for simulating in-stream mining.

6. A multi-level approach for evaluating response of river systems is available.

7. Procedures are available for assessing the large scale effect of sand and gravel mining in a river basin, and for evaluating local effects. The "red-line" procedure sets mining limits for entire river reaches. The Corps of Engineers sand and gravel mining guidelines pertain to specific sand and gravel mining sites.

Gravel mining and sediment transport studies

1. Eighteen studies related to in-stream sand and gravel mining on major Arizona rivers were summarized. Sixteen studies related to sediment transport

on major Arizona rivers were summarized.

9.2 Recommendations

The following recommendations are made regarding the direction of the next phase of work for this study.

1. River segments for the case studies should be developed such that individual study segments combine to form a long reach of river. This would allow the cummulative effect of sand and gravel operations to be addressed as well as site specific conditions.

2. Develop a three-tier analysis approach.

   The first tier would use envelope curves to assess in-stream mining. This would be the basic level of analysis for all rivers in the State of Arizona.

   The second tier would develop "red-line" boundaries for major river reaches that have significant mining activity. The "red-line" boundaries would then define the lateral and vertical limits for mining excavation. "Red-line" studies would be conducted by county or local agencies with state overview.

   The third tier would allow individual mining operations to refine or modify the "red-line" boundaries on a site specific basis by conducting their own engineering analysis, and obtaining the approval of the regulatory authority.

3. The regulatory program should take into account the resource requirements for various sections of the state to assure that an adequate supply of sand and gravel is available at a reasonable cost to consumers. To the extent possible the incremental cost of any regulation to the sand and gravel industry should be compared to the benefits derived.

4. The research study should be continued in accordance with the original Scope of Work and incorporate the recommendations stated herein.

APPENDIX A

SAND AND GRAVEL MINING QUESTIONNAIRES

QUESTIONNAIRE

Effects of In-Stream Mining on Channel Stability

Arizona Department of Transportation

Project Number HPR-PL-1-31(250)

Name of Agency: _____

Name of Respondent: _____

Area of Jurisdiction: _____

A. GENERAL	YES	NO
1. Do you have in-stream sand and gravel mining operations within your jurisdiction?	___	___
2. Do you regulate in-stream sand and gravel mining operations?	___	___

3. If the answer to Question No. A.2 is yes, please answer the following questions.

   a. What year did the regulatory program start? _____

   b. How many permits have been issued....

      - since the program started? _____

      - in the last five years? _____

      - in the last year? _____

   c. How many gravel mining operations are currently active within your jurisdiction? _____

4. If you regulate in-stream sand and gravel mining, do you have written guidelines/policies?	___	___

   If yes, please attach a copy of these guidelines/policies.

5. If you regulate in-stream sand and gravel mining, what kind of enforcement program do you have? _____

_____

_____

_____

6. If you do not regulate in-stream sand and gravel mining, does any other agency have this responsibility in your jurisdiction? ___ ___

   If yes, please identify this agency and give the name of the person in charge. _____

7. If there is no regulation of in-stream sand and gravel mining in your jurisdiction, do you feel there should be regulation? ___ ___

8. If a state-wide program were to be adopted to regulate in-stream sand and gravel mining, upon what criteria or factors should such a program be based? _____

9. Do you perceive that damage to public or private property has occurred due to, or in part from, in-stream sand and gravel mining operations? ___ ___

   If yes, please list cases and note when and where the damage took place. _____

10. What benefits to public or private property has accrued due to, or in part from, in-stream sand and gravel operations? _____

11. Has your agency been involved in litigation attributed

to any damage listed under Question A.9? ___ ___

Was your agency the plaintiff or defendent? _____

Please state the status or outcome of the litigation and the name and date of the case. _____

_____

_____

_____

B. DESIGN PRACTICE	YES	NO
1. Does your agency design, regulate, and/or maintain any in-stream (or floodplain) structures (e.g., bridges, utility crossings or alignments, flood control structures, etc.)? (Please circle which function(s) your agency performs.)	___	___
If yes, do you...		
a. consider the effects of erosion/sedimentation (e.g., scour, lateral movement of the channel banks, sediment deposition, etc.) on the design/regulation/maintenance of these structures?	___	___
b. consider the effect of in-stream sand and gravel mining on the design/regulation/maintenance of these structures?	___	___
2. If the answer to Question B.1.b. is yes, please answer the following questions. Do you base structure design requirements on the following gravel pit characteristics:		
a. Pit depth?	___	___
b. Distance from gravel pit to structure?	___	___
c. Pit side-slopes?	___	___
d. Other? _____		

3. If the answer to any part of Question B.2. is yes, please state or include the design methods used. Please list and name the source of information from which these methods were developed (e.g., computer programs, design manuals, agency reports, research reports, collected data,

in-house analysis, etc.) _____

_____

_____

_____

C. INFORMATION YES NO

1. Do you know of any data or reports that would be helpful to this research project? ___ ___

   If yes, please provide a copy of the data or a citation for the reports. _____

   _____

   _____

   _____

2. Would you recommend any Arizona river segments in your area of jurisdiction be included in a detailed study of in-stream sand and gravel mining operations? ___ ___

   If yes, please list recommended river segements. Note segment location (approximate starting and ending points) and provide a brief description of river features and gravel mining effects that prompt you to recommend this river. _____

   _____

   _____

   _____

D. ADDITIONAL COMMENTS. Please note below any additional comments which you feel are relevant to this study. (Please feel free to use attachments, if necessary). _____

_____

_____

_____

QUESTIONNAIRE (Revised 9/24/86)

Effects of In-Stream Mining on Channel Stability

Arizona Department of Transportation

Project Number HPR-PL-1-31(250)

Name of Company: _____

Name of Respondent: _____

A. RESOURCE INFORMATION

1. Please complete Table 1 (attached) for sand and gravel mining operations that you have conducted from pits located within a floodplain[1] in the State of Arizona during the past five years.

2. Considering product demand and resource areas available to your company, please complete Table 2 and estimate your company's future annual production from pits within a floodplain[1] for the next five years.

TABLE 2. ESTIMATED FUTURE ANNUAL PRODUCTION

Facility Number	Years From Present				
	1	2	3	4	5

[1] This refers to areas within the designated flood hazard boundary area as defined on a flood hazard boundary map issued by the Federal Emergency Management Agency.

TABLE 1. FACILITY RESOURCE INFORMATION
(Revised 9/24/86)

Facility Number	Location (County and Nearest Town)	River Name	Opening Date (mo/yr)	Closing Date (mo/yr)	Material Reserves (cu yd)		Extraction Rate (cu yd/yr)
					Initial	Current	

B. REGULATORY COMPLIANCE

1. List the local, state and/or federal agencies to which your company has submitted permit applications for in-stream sand and gravel mining as related to floodplain locations in Arizona.

2. Please indicate (without reference to specific permit submittals) the average length of time (in months) required for the regulatory agency to process a permit application submitted by your company. (That is, the time from the date the permit was submitted to the date the permit was either granted or denied.) Also, indicate the minimum and maximum length of time that was required to process a permit application.

3. Based on your companies experience, please estimate the average total cost (survey, engineering, testing, etc.) required to complete a permit application. Also, estimate the maximum and minimum cost for submitting permit applications.

4. What are the major factors that lead to different costs for submitting permits? (circle applicable factors)

   a. Operation location to in-stream structures (e.g., bridges)
   b. Operation size (pit volume, depth, etc.)
   c. River characteristics
   d. Varying requirements of different regulatory agencies
   e. Public comment
   d. Other factors (please list)

   _____

   _____

   _____

5. How many permit applications have you submitted? _____

   a. How many were approved? _____

      How many were denied? _____

   b. To the best of your knowledge, state the reasons for permit denial. _____

      _____

      _____

6. Has your firm been involved in litigation attributed to effects of sand and gravel mining on in-stream or floodplain structures? YES ___ NO ___

   Was your firm the plaintiff or the defendent? _____

   Please state the status or outcome of the litigation, and the name and date of the case. _____

   _____

   _____

   _____

7. If a state-wide program were to be adopted to regulate in-stream sand and gravel mining, upon what criteria or factors should such a program be based? _____

   _____

8. Based on your experience, what benefits do in-stream gravel mining operations offer? _____

C. DESIGN PRACTICE

	YES	NO
1. Does your company design/analyze in-stream sand and gravel mining facilities using your own engineering staff?	___	___

If your own engineering staff is used, please answer the following questions.

a. What are the design criteria you use to assess effects of mining on channel stability (e.g., sediment supply, pit volume, pit shape, trap efficiency, location with respect to bridges or utilities, etc.)? _____

b. Do you use specific design procedures in the analysis of a sand and gravel pit operation to assess channel stability? ___ ___

If yes, please cite the source of these procedures (e.g., computer programs, design manuals, reports, articles, etc.). _____

c. Based on your experience, what factors or parameters related to channel stability are the most difficult

to evaluate in the analysis of sand and gravel mining facilities? _____

_____

_____

_____

D. GENERAL INFORMATION	YES	NO
1. Do you know of any data or reports that would be helpful to this research project?	___	___
2. Would you recommend any Arizona river segments that should be included as a detailed study of in-stream sand and gravel mining operations?	___	___

If yes, please provide references to where this information could be obtained. _____

_____

_____

_____

If yes, please list recommended river segments. Note segment location (approximate starting and ending points) and provide a brief description of river features and gravel mining effects that prompt you to recommend this river segment. _____

_____

_____

_____

_____

_____

_____

D. **ADDITIONAL COMMENTS.** Please note below any additional comments which you feel are relevant to this study. (Please feel free to use attachments, if necessary.) _____

_____

QUESTIONNAIRE

Effects of In-Stream Mining on Channel Stability

Arizona Department of Transportation

Project Number HPR-PL-1-31(250)

Name of Firm: _____

Name of Respondent: _____

A. DESIGN PRACTICE	YES	NO
1. Has your firm designed and/or analyzed in-stream sand and gravel mining facilities?	___	___

If yes, please answer the following questions.

a. What are the design criteria you use to assess effects of mining on channel stability (e.g., sediment supply, pit volume, pit shape, trap efficiency, location with respect to bridges or utilities, etc.)? _____

_____

_____

_____

b. Do you use specific design procedures in the analysis of a sand and gravel pit operation to assess channel stability? ___ ___

If yes, please list and name the source of these procedures (e.g., computer programs, design manuals, reports, articles, etc.). _____

_____

_____

_____

2. Do you consider the effect of in-stream sand and gravel mining during the design of in-stream structures (e.g., bridges, utility crossings or alignments, channel stabilization works, etc.)?	___	___

If yes, please answer the following questions.

a. What are the design criteria you use to assess

potential effects of mining on the structure (e.g., distance of the pit from the structure)? _____

_____

_____

_____

b. Do you use specific analysis procedures in the design of a structure to assess potential problems related to in-stream mining? ___ ___

If yes, please list and name the source of these procedures (e.g., computer programs, design manuals, reports, articles, etc.). _____

_____

_____

_____

c. Based on your experience, what are the major hazards to in-stream structures caused by the presence of sand and gravel operations? Please note which of these hazards are the most difficult to accurately assess during design. _____

_____

_____

_____

d. Based on your experience, what are the major benefits from in-stream sand and gravel mining operations. _____

_____

_____

_____

3. Has your firm been involved in litigation attributed to effects of sand and gravel mining on in-stream structures? ___ ___

Was your firm representing the plaintiff or the defendent? _____

Please state the status or outcome of the litigation, and the name and date of the case. _____

_____

_____

_____

B. REGULATORY COMPLIANCE **YES** **NO**

1. Has your firm prepared permit application information for in-stream sand and gravel mining operations? ___ ___

If yes, please answer the following questions.

a. Please list the agency(s) to which the permit submittal(s) was(were) made and the approximate date of the submittal(s). _____

_____

_____

_____

b. Based on your experience, please estimate the total cost (your fee, subcontracted services, testing, etc.) required to complete permit application preparation for the following size sand and gravel mining operations in Arizona.

100,000 cu yd or less _____

500,000 cu yd or less _____

1,000,000 cu yd or less _____

5,000,000 cu yd or less _____

Greater than 5,000,000 cu yd _____

c. Please indicate (without naming specific cases) the length of time (in months) from the date the permit was submitted to the date the permit was either granted or denied. _____

_____

_____

d. Please indicate (approximately) the percentage of permit applications approved and the percent denied. _____

e. Please list the reasons why permits were denied. _____

2. Has your firm provided permit application review services of in-stream sand and gravel mining operations to a local, state, or federal agency? ___ ___

If yes, please answer the following questions.

a. Please list agencies for which you have provided review services and give the total number of reviews that your firm has conducted. _____

b. In what percent of the cases, as a part of the review process, did you conduct a separate analysis of the potential impacts on in-stream mining on channel stability in addition to the analysis submitted by the applicant? _____

c. What was the average length of time required to conduct your review? _____

What was the longest and shortest period of time required?

C. **GENERAL INFORMATION** YES NO

1. Do you know of any data or reports that would be helpful to this research project? ___ ___

   If yes, please provide references as to where this information could be obtained. _____

2. Would you recommend any Arizona river segments that should be included as a detailed study of in-stream sand and gravel mining operations? ___ ___

   If yes, please list recommended river segments. Note segment location (approximate starting and ending points) and provide a brief description of river features and gravel mining effects that prompt you to recommend this river segment. _____

D. **ADDITIONAL COMMENTS.** Please note below any additional comments which you feel are relevant to this study. (Please feel free to use attachments, if necessary). _____