Arizona is Cracking Up

Ray Harris – *Arizona Geological Survey*

Earth fissures attracted a lot of media attention in Arizona in summer 2005. Heavy rain in early August in the San Tan Mountains in central Arizona produced flooding that affected broad areas of an unincorporated area known as Chandler Heights, south of the town of Queen Creek. Some of the floodwater found its way into an old fissure system, parts of which had been covered over for development. As water flowed through the fissure and under the capping of dirt, the surface collapsed into the underlying void and the old fissure was reborn. That particular fissure was first reported in *USGS Circular 466* in 1962, having formed a few years previously; it is perhaps the most mapped, photographed, and described earth fissure in Arizona. So although the opening of fissures in the Chandler Heights area was not news to geologists, residents who were unaware of their occurrence or what they actually look like were shocked by the appearance of the large feature that cut across yards, driveways, and roads.

Why and Where Do They Occur?

Earth fissures are caused by tension created by differential subsidence resulting from lowering of the groundwater table. As groundwater is lowered, aquifer sediments lose some of the buoyant support of the water and undergo compaction. If compaction is great enough, the ground surface subsides. Near the edge of the subsiding area, which is commonly but not always near the margin of a basin, earth fissures may develop.

For more than 40 years, geologists have warned people about the hazards of earth fissures, but until recently the warnings went unheeded. In the past, earth fissures were considered an interesting phenomenon, but because they were mostly in undeveloped areas around the edges of the basins where no one lived, they were not perceived as a problem. In recent years, with the population expanding into areas known to have fissures, the potential for damage to property has increased. The issue today is not earth fissures forming where people have built houses – it is people building houses on known fissures.

Chandler Heights is not the only place in Arizona experiencing earth fissures; they are present in four counties, with the vast majority in Pinal County. Maricopa and Cochise counties have perhaps one-tenth the fissures that Pinal County has, and Pima County has only half a dozen or so.

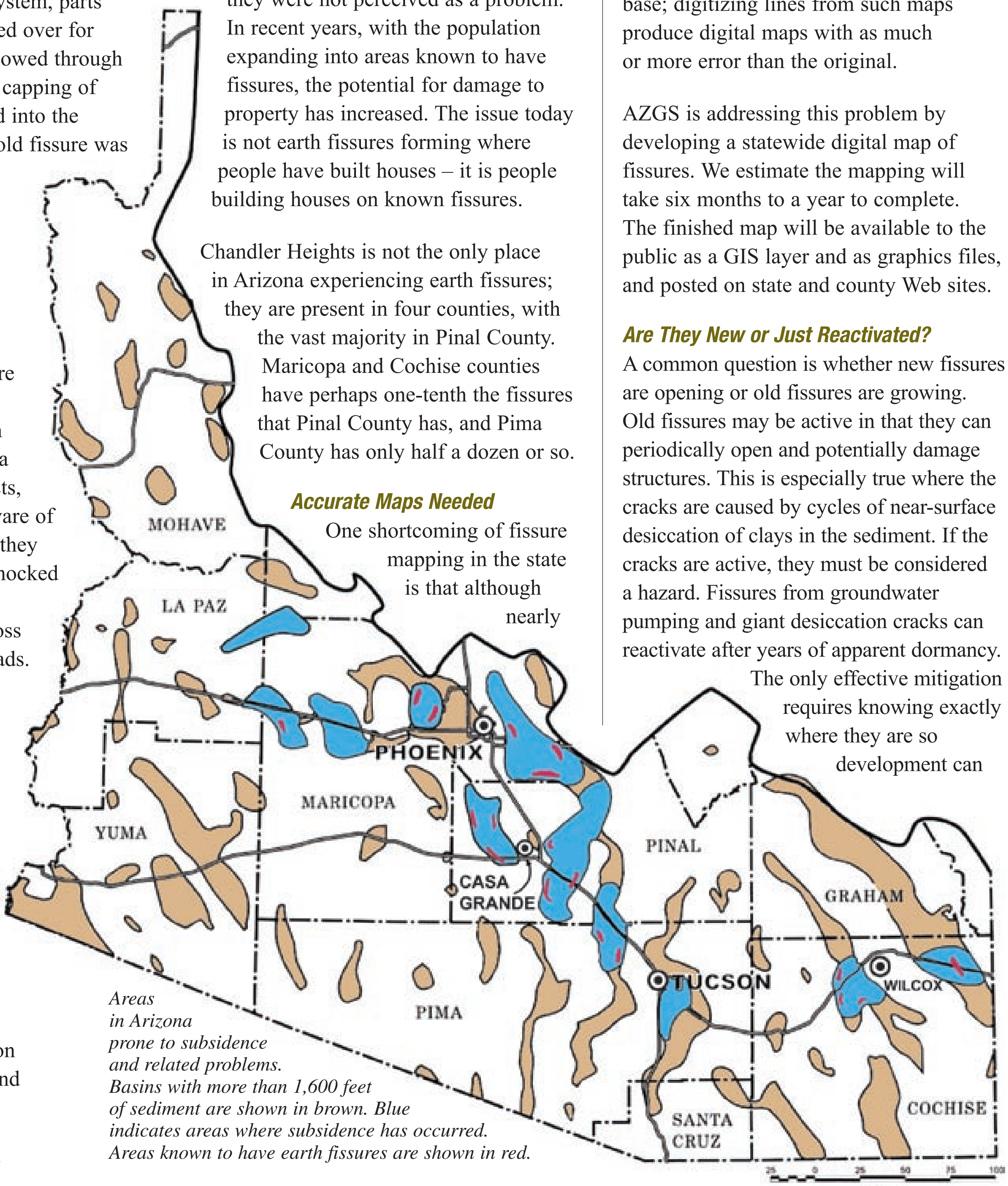
Accurate Maps Needed

One shortcoming of fissure mapping in the state is that although nearly every fissure has been mapped at some time, finding all the fissures would require reviewing dozens of reports, some of which are not readily accessible. The Arizona Geological Survey (AZGS) did not use GPS or GIS technology for fissure mapping until 1998. Earlier mapping was done on aerial photos. Lines on published maps were drawn with ink on mylar superimposed over a topographic map base; digitizing lines from such maps produce digital maps with as much or more error than the original.

AZGS is addressing this problem by developing a statewide digital map of fissures. We estimate the mapping will take six months to a year to complete. The finished map will be available to the public as a GIS layer and as graphics files, and posted on state and county Web sites.

Are They New or Just Reactivated?

A common question is whether new fissures are opening or old fissures are growing. Old fissures may be active in that they can periodically open and potentially damage structures. This is especially true where the cracks are caused by cycles of near-surface desiccation of clays in the sediment. If the cracks are active, they must be considered a hazard. Fissures from groundwater pumping and giant desiccation cracks can reactivate after years of apparent dormancy. The only effective mitigation requires knowing exactly where they are so development can



Areas in Arizona prone to subsidence and related problems. Basins with more than 1,600 feet of sediment are shown in brown. Blue indicates areas where subsidence has occurred. Areas known to have earth fissures are shown in red.

Photo: Ray Harris

The Rogers fissure in the Harquahala Plain, central Arizona, in 1997. The Chandler Heights fissure originally looked very similar to this.

be planned around them. The reopening of the Chandler Heights fissure this past summer did not necessarily reflect that the fissure was growing or changing, only that the fissure had not been filled completely to the bottom, creating a void that surface material could wash into.

For more information, or to report an earth fissure, contact Ray Harris at the Arizona Geological Survey at 520-770-3500 or ray.harris@azgs.az.gov.

The National River Restoration Science Synthesis Project in the Southwest

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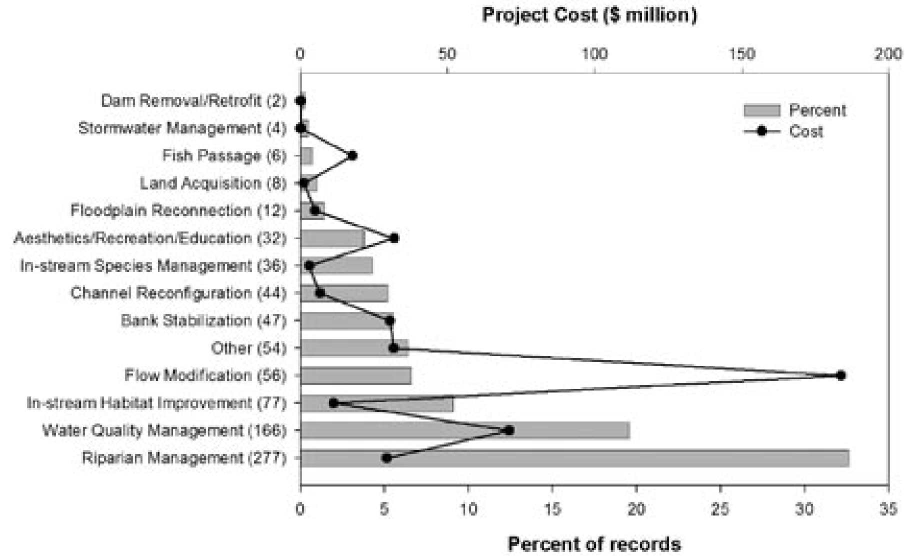
This article is the first of a 3-part series.

A dramatic increase in river and riparian restoration activity across the United States over the past 15 years has resulted in expenditures averaging $1 billion annually since 1990. Restoration efforts have garnered public attention, yet little is known about the number, foci, cost, and effectiveness of restoration projects across broad scales. The National River Restoration Science Synthesis (NRRSS) project is the first step toward synthesizing information on restoration projects nationwide. More than 37,000 project records have been consolidated into a single, Internet-accessible database.

Restoration activity in the Southwest (defined herein as Arizona, Colorado, New Mexico, and Utah) has surged as a result of efforts to mitigate detrimental effects to river ecosystems caused by flow regulation and water diversion, overgrazing, mining, and urbanization. Presently, 576 records on restoration in the Southwest are included in the NRRSS-SW database covering the four states. The datasets from which these records were collected include both national and regional sources. Review of



Distribution and cumulative costs of projects in the NRRSS-SW database by category. Numbers in parentheses are number of projects per category. Note: one-third of the projects cross more than one category, thus the sum exceeds the total of 576 projects.

project records by experts in each state confirmed the NRRSS-SW database includes at least 50 percent of completed or ongoing projects not associated with large-scale species recovery or ecosystem adaptive management programs.

In the Southwest, most projects have occurred in Arizona (193), followed by New Mexico (179), Colorado (112), and Utah (101). (Nine projects cross state boundaries.) The median channel length of these projects ranges by state from 1 to 3.5 miles, with 51 percent less than two miles long and eight percent longer than 20 miles. These statistics are consistent with those nationwide.

Projects in the NRRSS-SW database fall into 14 categories (see table and figure). The dominant project types are riparian management, water quality management, in-stream habitat improvement, and flow modification.

Records from 75 percent of the projects provide information on costs. Based on these data, the cost of restoration in the Southwest totals $311 million. The mean project cost is $721,000, while the median cost is $65,000. An additional $9.3 million to $104 million in total restoration costs can be assumed by applying mean and median project costs to records that lack cost information. These figures do not include costs associated with most of the following large-scale species recovery or ecosystem adaptive management programs in the Southwest: the Glen Canyon Dam Adaptive Management Program, Lower Colorado River Multi-Species Conservation Program, Middle Rio Grande Endangered Species Collaborative Program, San Juan River Basin Recovery and Implementation Program, Upper Animas Abandoned Mine Land Program, Upper Colorado River Endangered Fish Recovery Program, and Utah Reclamation, Mitigation, and Conservation Commission's Restoration of the Provo River. Since 1989, the total cost of these large-scale programs approaches $1 billion, 79 percent of which has been allocated to restoration activities. Thus, estimates of total reported restoration costs in the Southwest are $1.1 billion to $1.2 billion.

The most costly projects are associated with flow modification and water quality management. Flow modification projects typically require the use of heavy machinery or the purchase of water rights, and water quality projects often encompass numerous activities at the scale of an entire watershed. Riparian management projects are often relatively low-cost, typically involving the removal of livestock from streamside areas via fencing or planting native vegetation on stream banks. However, riparian management projects that are focused on large-scale control of non-native plants can be as costly as efforts to improve water quality at the watershed scale.

NRRSS-SW database records indicate some type of monitoring occurred in conjunction with 28 percent of the restoration projects. This proportion is double that of the nation as a whole, where only 14 percent of project records include monitoring activities. Monitoring and post-project evaluation prove to be the greatest challenge, as well as the greatest opportunity, for learning from restoration successes and failures. The NRRSS database is inadequate for summarizing trends in monitoring and evaluation because these activities are either simply not done or results are not reported. Accountability and efficacy of restoration projects – and ultimately the benefit to river ecosystems – can only be assessed if efforts are made to better track restoration activities, costs, and data, utilizing approaches that include both pre- and post-project evaluation.

In the next issue, we will describe differences in the projects performed among individual states in the Southwest.

Project category	Examples of common restoration activities	Mean cost ($ million)
Aesthetics/Recreation/Education	Educational kiosks	0.99
Bank Stabilization	Revegetation, bank grading	0.65
Channel Reconfiguration	Bank or channel reshaping	0.15
Dam Removal/Retrofit	Dam removal	no data
Fish Passage	Fish ladders installed	2.94
Floodplain Reconnection	Backwater canal dredging	0.42
Flow Modification	Purchase of water rights, irrigation efficiencies	3.34
In-stream Habitat Improvement	Boulders/woody debris added	0.15
In-stream Species Management	Non-native fish species eradication	0.08
Land Acquisition	Land acquisition	0.17
Riparian Management	Livestock exclusion, plantings	0.11
Stormwater Management	Wetland construction	no data
Water Quality Management	Riparian buffer creation, arroyo headcut prevention	0.43
Other	Endangered species recovery, fuels reduction	0.59

Restoration project categories used in the NRRSS database.

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A detailed description of this work is available in Bernhardt, E.S., M.A. Palmer, J.D. Allan, G. Alexander, K. Barnas, S. Brooks, J. Carr, C. Dahm, J. Follstad Shah, D. Galat, S. Gloss, P. Goodwin, D. Hart, B. Hassett, R. Jenkinson, S. Katz, G. M. Kondolf, P. S. Lake, R. Lave, J.L. Meyer, T.K. O'Donnell, L. Pagano, B. Powell, and E. Sudduth, 2005. Restoration of U.S. rivers: A national synthesis, Science, 308:636-637.

The above reference also contains limited information about projects in Nevada. Data on restoration projects in California are being analyzed by researchers at the University of California at Berkeley. A listing of datasets used to populate the NRRSS-SW database can be found at nrrss.umd.edu.