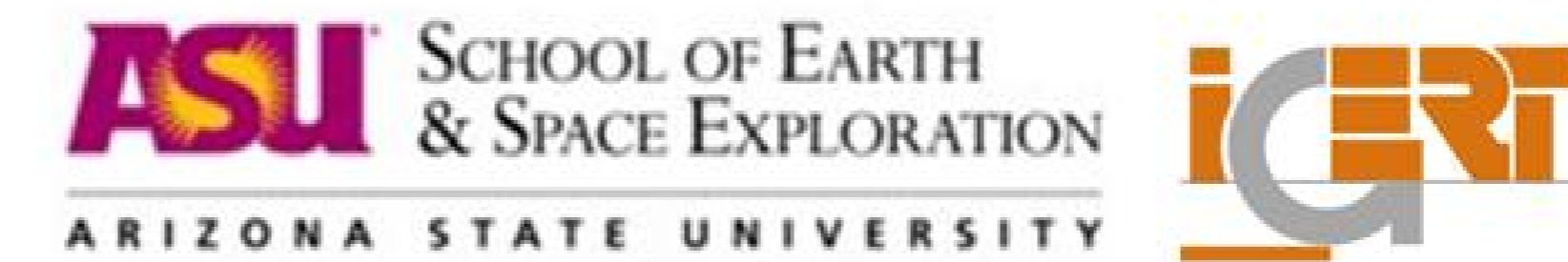


Geologic Investigations of Urban Sedimentation Using Retention Basins in Tempe, AZ

Laila El-Ashmawy¹, Nathan A. Toké², and J Ramón Arrowsmith²

1- Civil, Environmental, and Sustainable Engineering, 2- School of Earth and Space Exploration Arizona State University, Tempe, AZ 85287

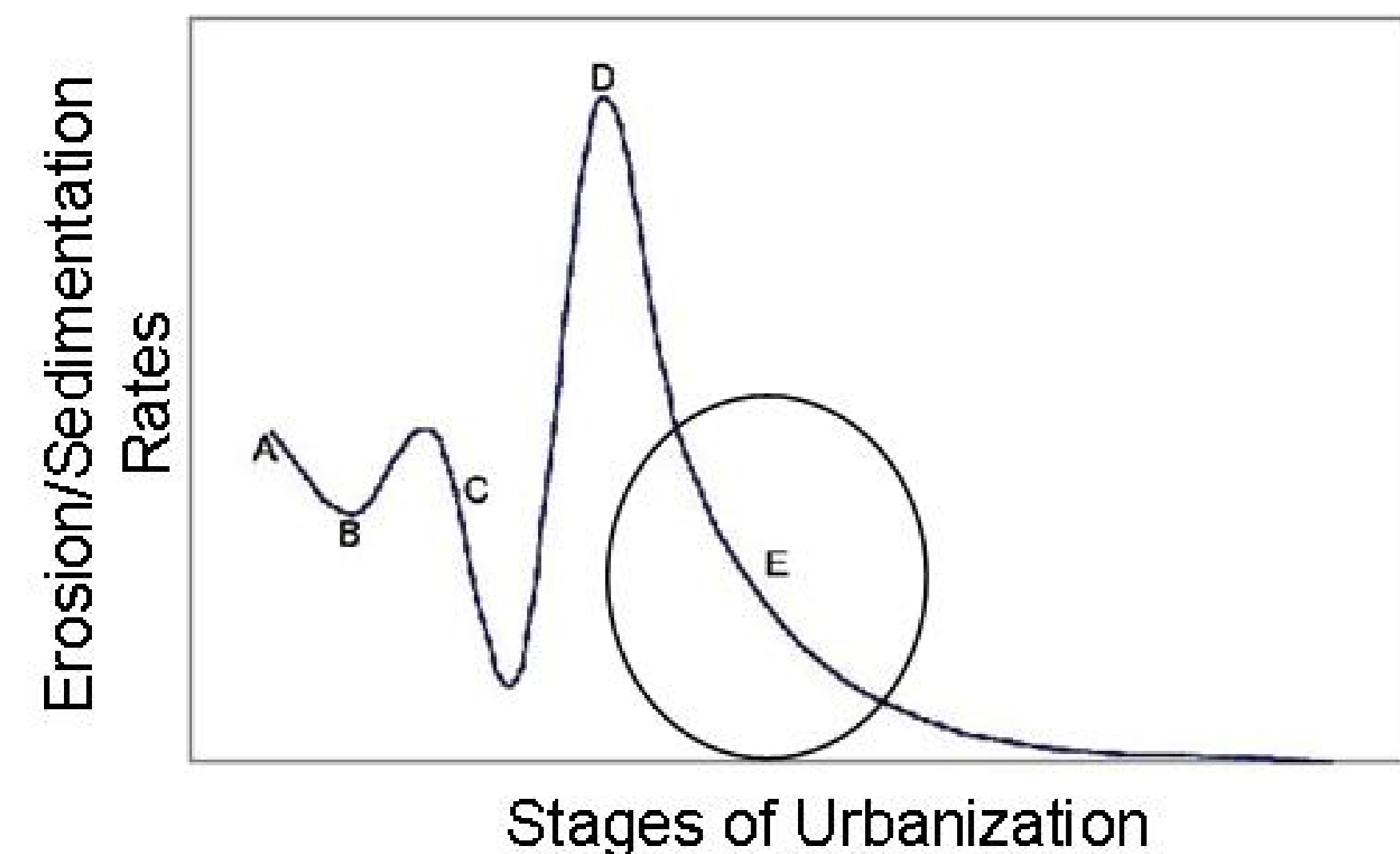


Acknowledgements: This research was supported by NSF award number: DGE0504248: Integrated Graduate Education and Research Training in Urban Ecology. We thank Mike Golden, Sherman McCutcheon and Tom Ankeny with the City of Tempe. Special thanks to Dr. Nelson and the COURs program at Arizona State University.

References:
 Wolman, M.G. 1967a. *A cycle of sedimentation and erosion in urban river channels*. Geografiska Annaler, vol. 49a, 385-395.
 Bierman, P.R. and J. Turner. 1995. "Ee-10 and Al-26 evidence for exceptionally low rates of Australian bedrock erosion and the likely existence of pre-Pleistocene landscapes". *Quaternary Research* 44, pp. 367-377.

Conceptual model for erosional response to human modification of the desert landscape

Sediment production is influenced by urban structure and drainage, which in turn alters hydrologic flow. We are testing a conceptual model of how changes in erosion relate to the urbanization of the Phoenix area. Our conceptual model is adapted from Wolman's, 1967 model, representing sedimentation through urbanization in Baltimore, Maryland. The conceptual model is modified to account for the arid environment of the Phoenix location.

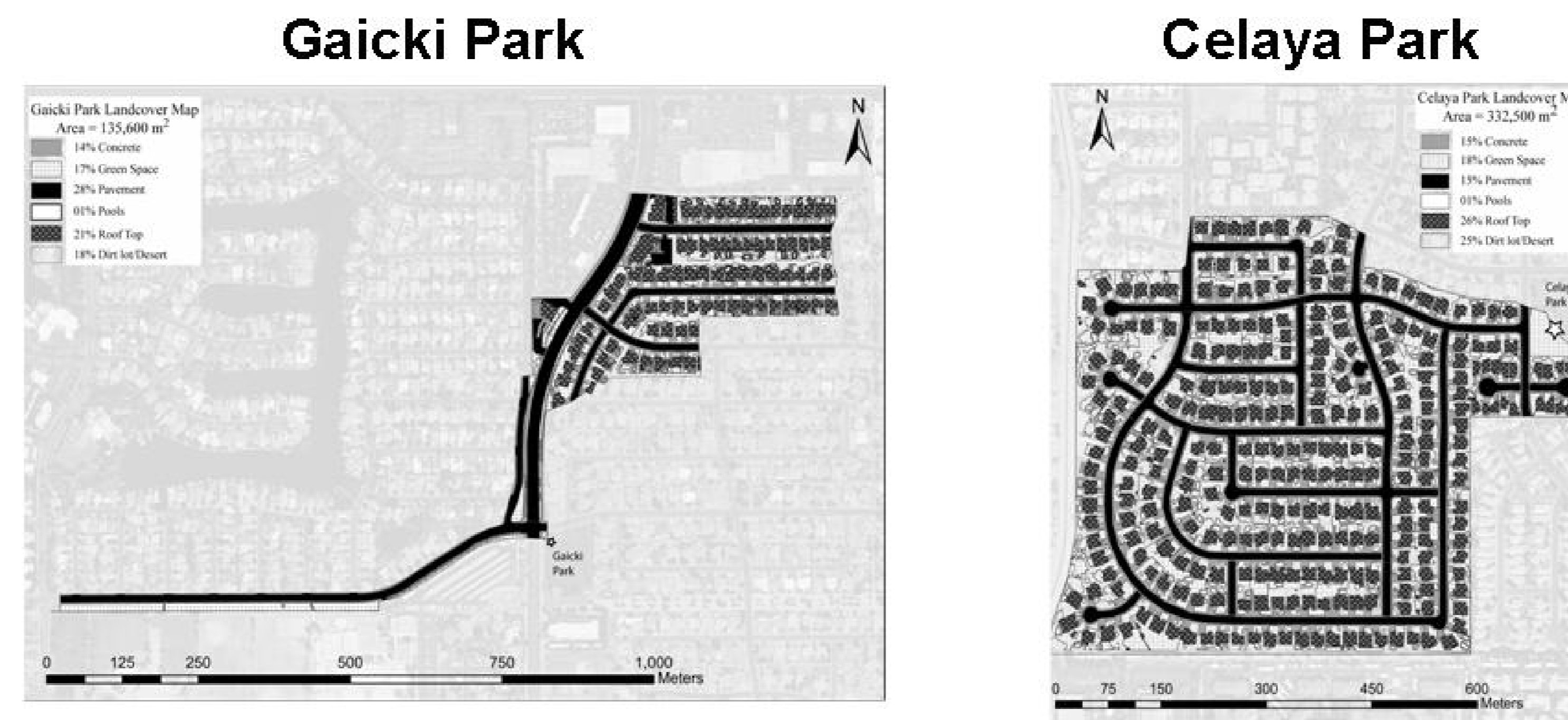


- A** The desert landscape is sparsely vegetated, so few roots are available to hold dirt in place.
- B** Low impact agriculture creates a more dense root system, decreasing erosion off the land.
- C** Land is cleared for industrial agriculture, causing an initial spike in sedimentation. Once the land is farmed, sediment and erosion decrease.
- D** Land is not only cleared, but moved around to begin construction in the urbanization phase. Erosion and sedimentation rises significantly during construction.
- E** After cities have been developed, the ground is paved, built on, and landscaped, allowing virtually no land to erode.

Figure 1. Our research focuses on stages D, construction, and E, post construction developments. We are evaluating different sites during these phases of urbanization and calculating erosion rates to test the shape and scale of the conceptual curve of urban sediment production.

Neighborhood watersheds in Tempe, AZ yield information to evaluate developed land (E) in the conceptual model.

Retention basins reduce stormwater volumes reaching channels and trap urban sediments. Through analysis of aerial photography and City of Tempe stormwater GIS data, we selected and mapped two internally-drained neighborhood retention structure watersheds and collected sediment stored in the retention structures to calculate yearly-scale sediment production rates (Table 2).



Landcover mapping



Sediments collected

TABLE 2. Calculations of area-normalized sediment production/erosion rate for Gaicki and Celaya Parks

	Landcover:	Watershed	Pervious Area ¹	Desert Landscaping ²
Gaicki Park				
Area (m ²) ¹		135,600	47,500	24,400
Sediment produced (Inorganic mass g/yr)		4,400	4,400	3,600 ³
Area-normalized sediment production (g/yr*cm ²) ⁴		0.32 x 10 ⁻⁵	0.93 x 10 ⁻⁵	1.5 x 10 ⁻⁵
Area-normalized sediment production rate (mm/yr) ⁵		0.16 x 10 ⁻⁴	0.46 x 10 ⁻⁴	0.74 x 10 ⁻⁴
Sediment production English units (ft ³ /yr per acre)		2.3 x 10 ⁻³	6.6 x 10 ⁻³	1.1 x 10 ⁻²
Implied erosion rate: Geologically-scaled and area-normalized (m/my) ⁶		0.016	0.046	0.074
Celaya Park				
Area (m ²) ¹		332,500	144,500	83,100
Annual sediment produced (g/yr) ⁷		545,000	545,000	501,400 ³
Area-normalized sediment production (g/yr*cm ²) ⁴		1.6 x 10 ⁻⁴	3.8 x 10 ⁻⁴	6.0 x 10 ⁻⁴
Area-normalized sediment production rate (mm/yr) ⁵		8.2 x 10 ⁻⁴	1.9 x 10 ⁻³	3.0 x 10 ⁻³
Sediment production English units (ft ³ /yr per acre)		0.12	0.27	0.43
Implied erosion rate: Geologically-scaled and area-normalized (m/my) ⁶		0.82	1.9	3.0

¹ Area was calculated from landcover mapping (figures 3 and 5). Pervious area includes greenspace and desert landscaping
² Desert landscaping includes areas covered with landscaping rocks/desert plants and unimproved dirt lots.
³ Total inorganic fraction of sediment produced over one year.
⁴ = sediment produced in one year/area
⁵ = area normalized sediment production/density; we assume that the density of the sediment mass is approximately 2 g/cm³
⁶ typically a geomorphologists might think of erosion in meters per million years.
⁷ Celaya Park sediments (figure 6) accumulated over 2 years this number represents the yearly average for that time period.

Compositional analyses of sediments



We used sieves to separate the sediments into size fractions (Table 1). For the pebble size fraction we separated the sediment into the rock, organic and trash fractions. Most of the material was rock: 92% at Celaya and 82% at Gaicki. The majority of material collected appears to be derived from imported landscaping and roadway products. In the future we plan to analyze the composition of the smaller size fractions.



TABLE 1. Analysis of sediment size fraction and composition collected from Gaicki and Celaya Parks.

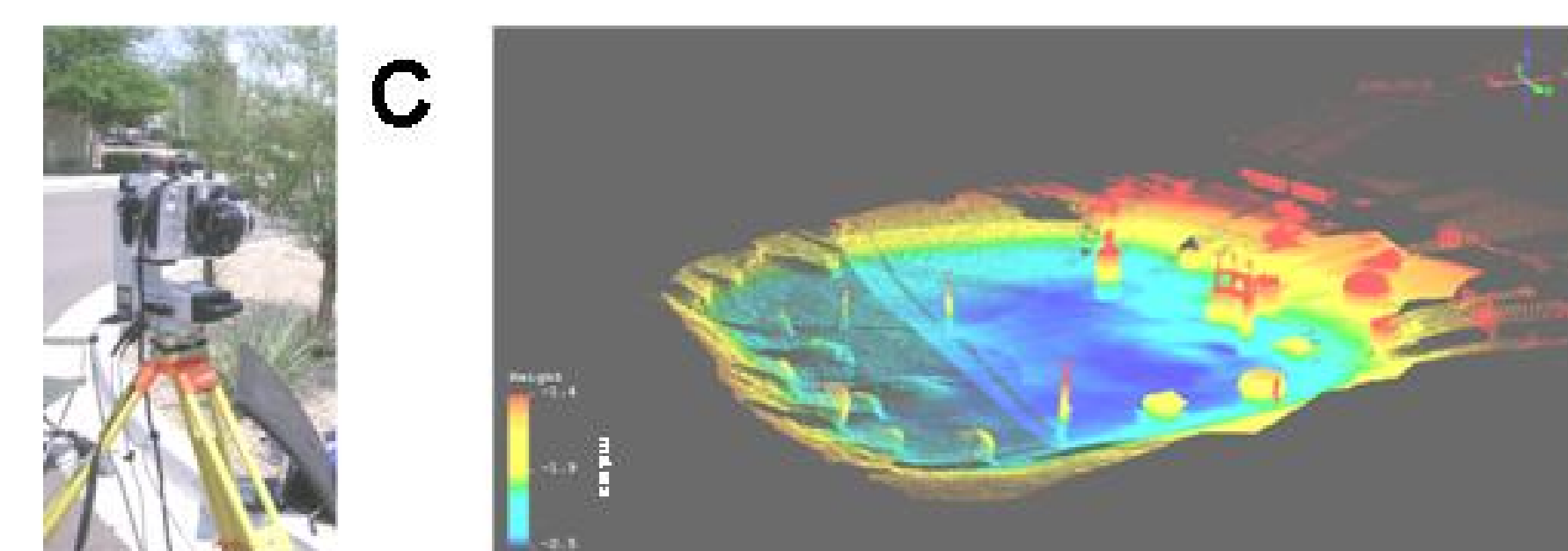
size (mm)	size (description)	sediment size ¹ analysis	
		Gaicki Park ²	Celaya Park ³
>4mm	Pebble and Greater	41 %	45 %
1-4mm	Coarse - Medium Sand	40 %	27 %
0.125-1mm	Medium - Fine Sand	18 %	23 %
<0.125mm	Silt and Clay	02 %	05 %
compositional analysis (pebble size fraction) ⁴			
material		Gaicki Park	Celaya Park
Organic Material ⁵		16 %	05 %
Granitic Grus		42 %	16 %
Other Rocks ⁶		40 %	76 %
Trash ⁷		02 %	03 %

¹ Sediment was separated by size fraction using geologic sieves.
² Percentage based upon a 2.2 kg sample, this was half of the sediment collected on the Gaicki Park apron over 1 year (figure 4 and table 2).
³ Percentage based upon a 8.33 kg sample, for total sediment see figure 6.
⁴ The compositional analysis was sorted by hand and only for the pebble size fraction (see table 2).
⁵ Organic materials consisted primarily of bark, twigs, leaves, and seeds.
⁶ Rounded metamorphic rocks are consistent with rock types observed in the gravels of the Salt River (figure 1).
⁷ Trash consisted of items such as glass, bubble gum, pieces of rubber.

Future and ongoing analyses



Figure 2. A) This small neighborhood was recently constructed (2007 aerial photography). Its watershed is constrained by brick walls and an onsite retention basin. Now construction is complete and there is a sediment pile developing (B) in the base of the retention pond. In August 2009, we surveyed the retention basin using tripod-mounted LIDAR (C). We plan to use this survey to construct elevation models and calculate the sediment produced in the 2+ years since construction. In addition to understanding the post construction phase of the urbanization process we are looking for sites to study longer records of sedimentation and sites outside of the urban area



Results

•The sediment production rates estimated here are extremely low because so much of the land area is concrete or otherwise built, which creates a stable surface and low sediment production rate. These rates **imply an erosion rate of ~1 m/My**. This rate is comparable to extremely stable surfaces such as bare bedrock arid landscapes (e.g., Bierman and Turner, 1995).

•Most of the eroded sediments are actually **material imported to the landscape by humans** for landscaping and other uses.

•Sedimentation rates and sediment composition are significantly different between Gaicki and Celaya Parks. This suggests there is a **strong relationship between landcover variations and sediment production**. We hope to explore this more by looking at watersheds with more variable landcover.