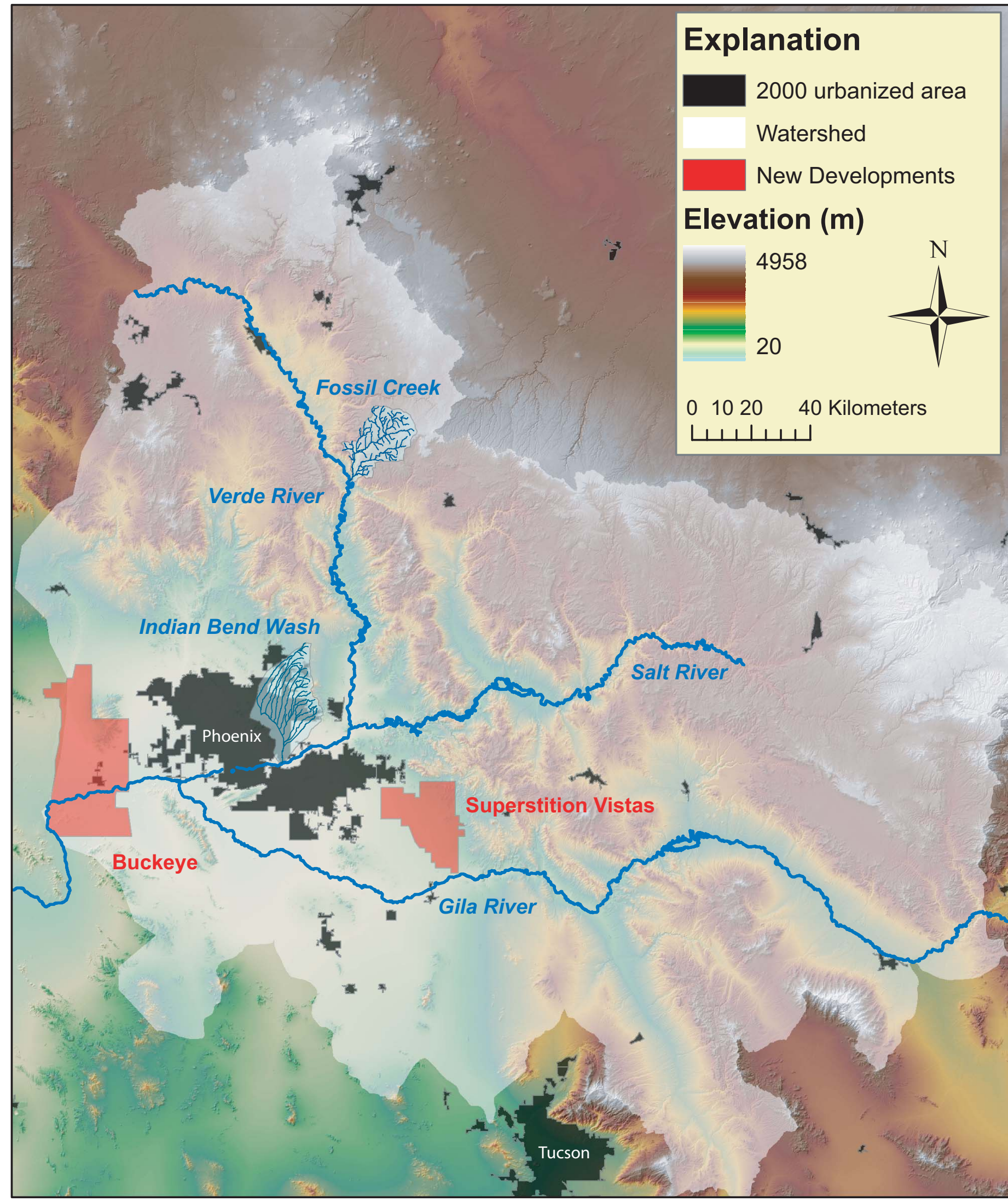


Fluvial Processes in Phoenix, Maricopa County, Arizona: A natural laboratory for studying urbanized dryland fluvial systems

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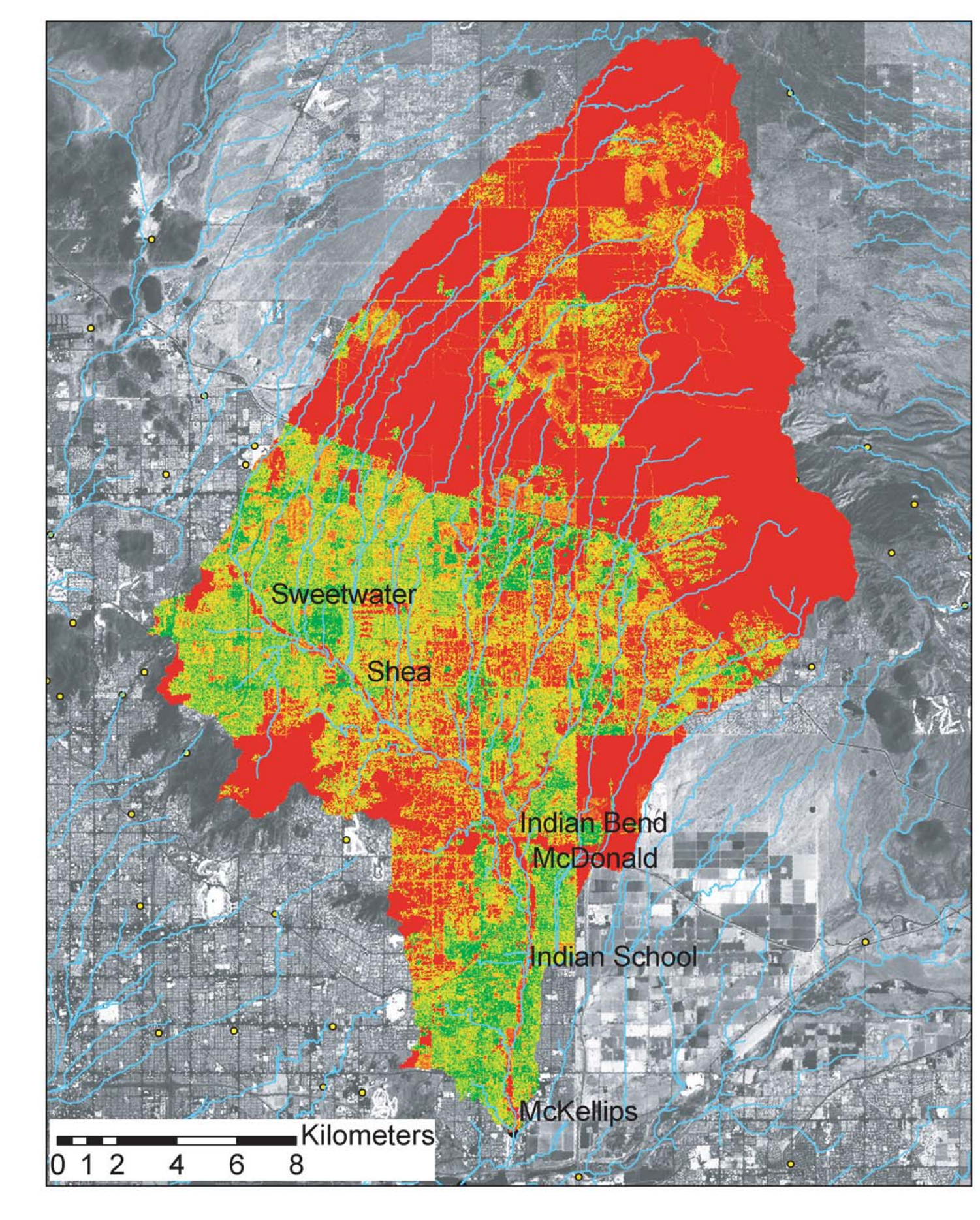
ABSTRACT:
 Maricopa County is characterized by low relief basins with intervening bedrock mountain ranges. Fluvial processes are driven by low frequency but high intensity rainfall events that convey runoff and sediment from adjacent uplands and urbanized desert piedmonts to tributaries of the lower Colorado River. Since the 1950's, the population of metropolitan Phoenix has increased tenfold. Now, approximately 3.5 million people live within 1500 square kilometers of developed land. With so much growth, the fluvial system has been significantly altered. Urbanization and attempts to control flooding have led to 1) an increase in impermeable land cover, 2) straightening and channelization of piedmont distributaries and washes, 3) alteration or removal of riparian vegetation, 4) diversion of runoff and sediment into localized retention basins, 5) development of artificial local wetlands and lakes as part of groundwater recharge projects and municipal amenities, and 6) damming of the previously non-ephemeral Salt, Verde, and Gila Rivers of the lower Colorado River system. The ongoing urbanization surrounding greater Phoenix represents a special opportunity to explore the responses of dryland fluvial processes to these types of changes. Existing urban catchments are monitored by the Maricopa County flood control district; therefore precipitation and hydrograph data mining in conjunction with historical land use mapping and drainage basin delineations reveal valuable information about the urban fluvial system. Phoenix's continued growth provides an opportunity to establish monitoring experiments to study fluvial responses during the initiation of new urban developments. Additionally, geomorphic mapping and stratigraphic analyses of urban sediments provides data to compare with geomorphic investigations of undeveloped piedmonts. Through these analyses and substituting space for time we will be able to better assess how urbanization transforms drainage basin architecture and thus how water, sediment, and chemicals move through and are stored within the urban landscape. This knowledge will also help us understand how fluvial processes within the urban landscape influence and feedback between biological and social parts of the urban ecosystem.



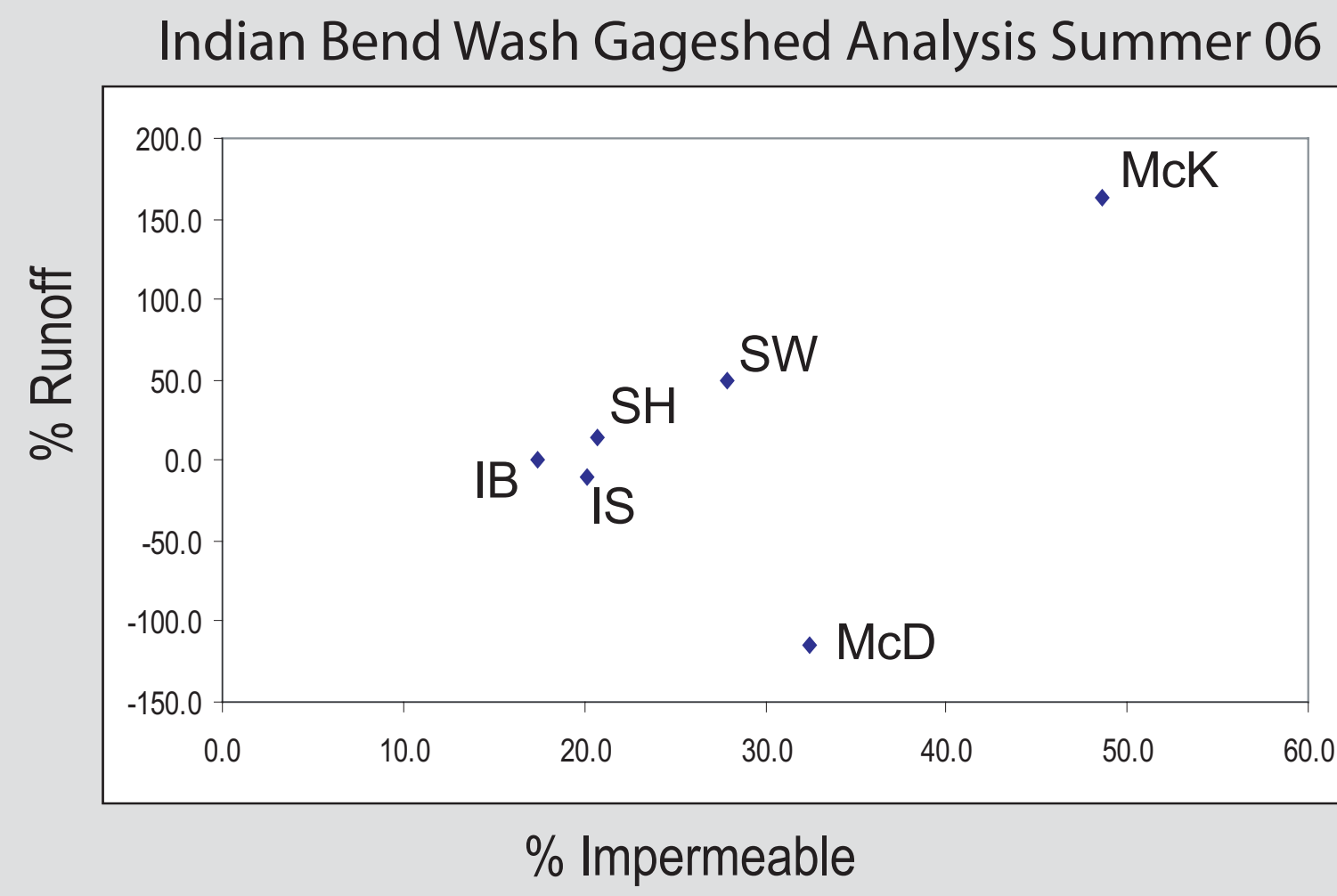
The Phoenix metropolitan area sits within the tributary watersheds of the Salt, Gila, and Verde Rivers of the Lower Colorado River. These rivers drain the Arizona Transition zone and runoff from agricultural and urbanized low desert. Two large areas of the desert are slated for development (red). Buckeye has annexed more land than the city of Phoenix currently occupies and development is underway on what will hold about 1 million residents. The Superstition Vistas is a plot of AZ State Trust Land that is being discussed for development in the next 50 years and would also support about 1 million new residents (<http://www.asu.edu/copp/morrison/SV.htm>). Many urbanized washes such as Indian Bend Wash flow through this desert landscape. Thus we are interested to know how are dryland fluvial and ecological processes affected by this urbanization? How does the morphology of these fluvial and alluvial systems feedback and shape urbanization decisions?

How do development patterns and engineering practices affect the movement of runoff? Indian Bend Wash (IBW) example.

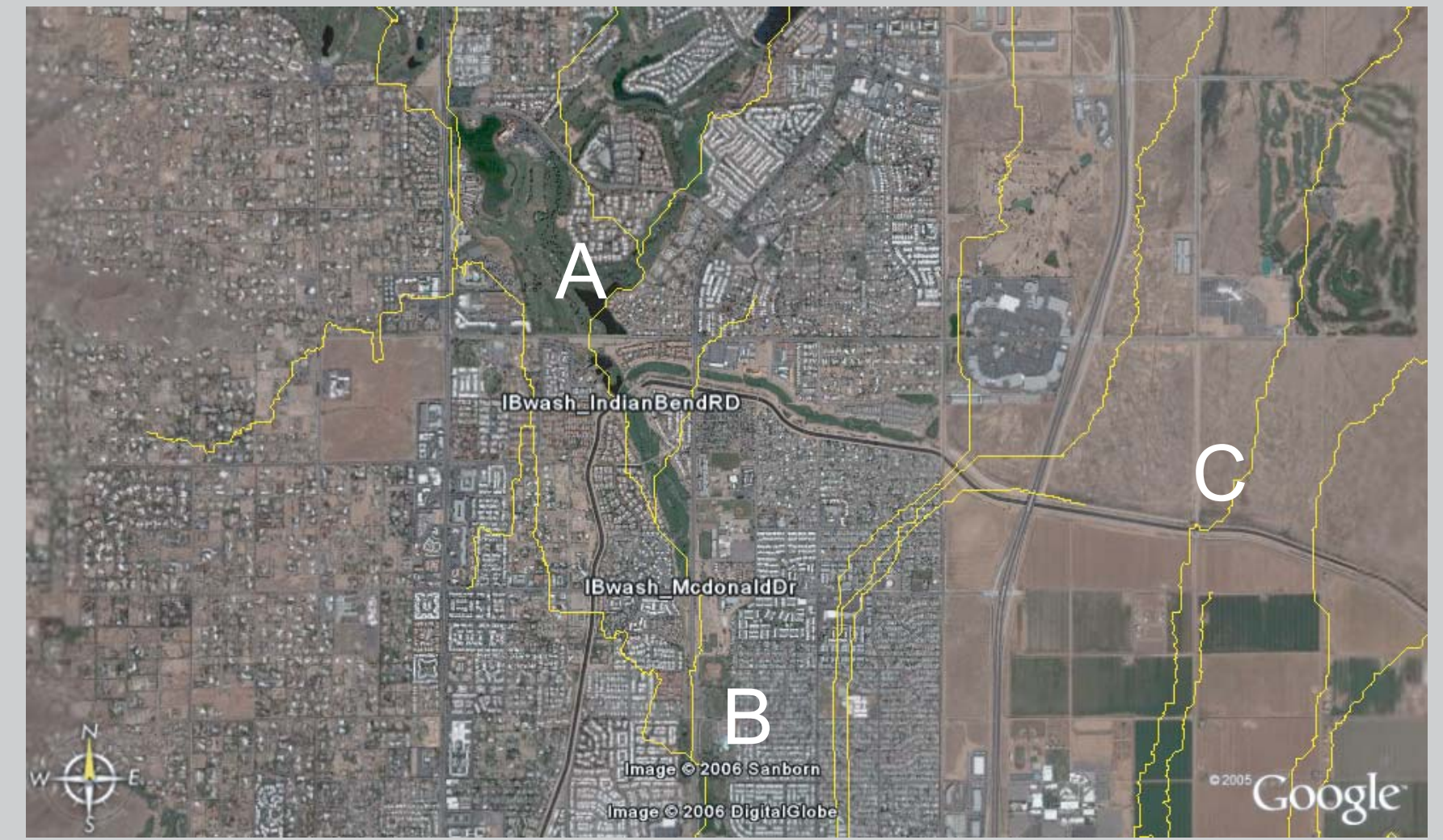
Precipitation and runoff observations from June 1st - October 8th, 2006 show that there is not an intuitive downstream accumulation of runoff despite the increased imperviousness downstream through the watershed. Indian Bend Wash is a greenbelt recreation area in Scottsdale and Tempe, AZ (photo middle). Previously it was an ephemeral channel, but now it serves as a flood water detention corridor. It is also a superfund site with a large plume of volatile organic compounds in the upper aquifer below the channel. Watershed was defined by a 10m USGS DEM and Archydro modeling. Precipitation data is from the Maricopa County Flood Control District: <http://www.fcd.maricopa.gov/Services/ALERT/>, and land cover imperviousness data is from the NLCD, 2001.



Land cover impermeability for IBW gagesheds.
 Gage locations for the Maricopa County Flood Control District. Gagesheds calculated in ArcHydro from the 10m USGS DEM. Impermeability data from the NLCD, 2001 (http://www.mrlc.gov/mrlc2k_nlcd.asp)



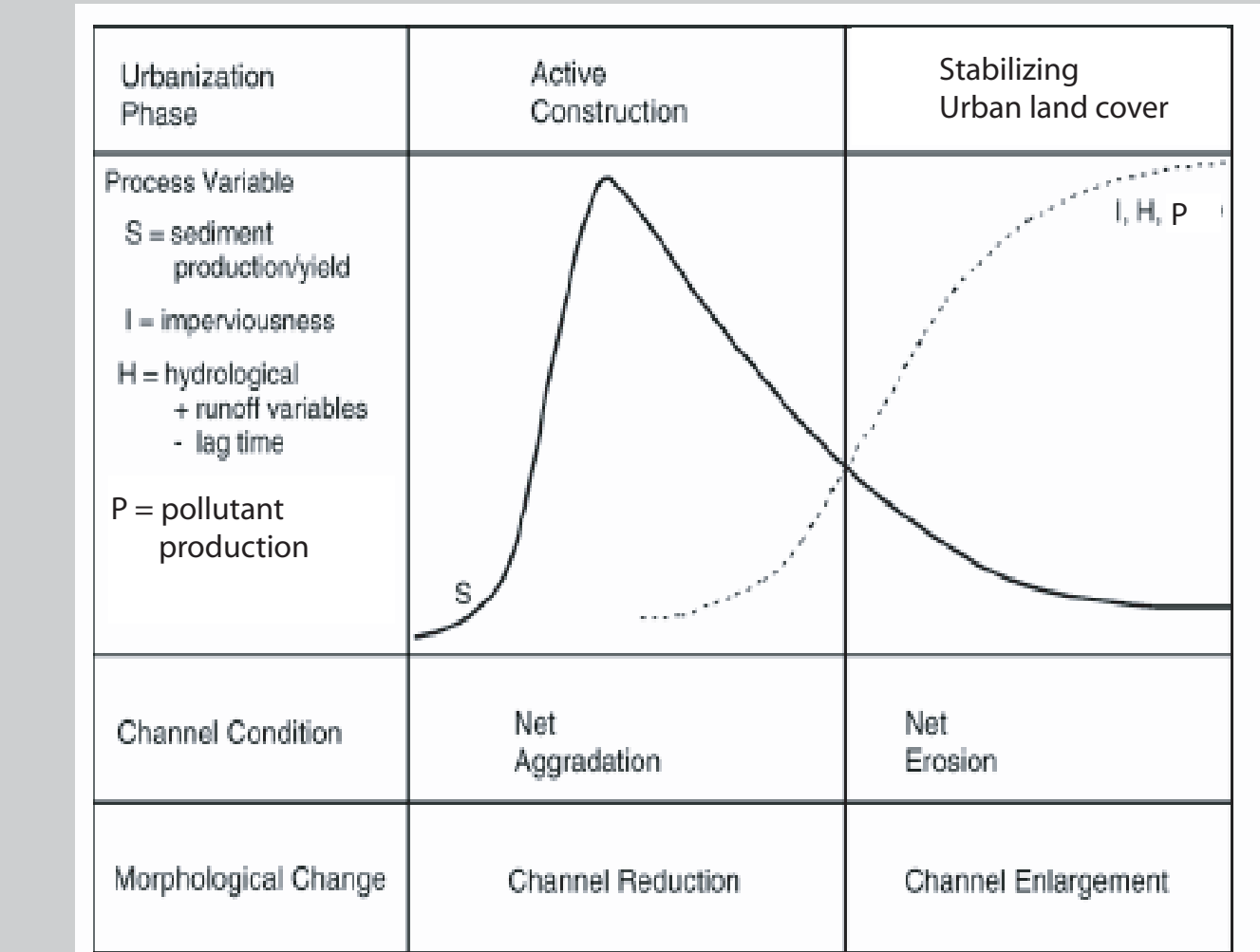
Imperviousness was not directly correlated with % runoff because runoff does not follow the natural flow paths calculated with the DEM. Some gages (Indian School and McDonald) suggested that these parts of the drainage basin were net sinks of runoff. This is possible because both of these gaging stations are associated with large retention ponds that store and evaporate runoff. However, we must also consider that McKellips had more runoff than it received in rainfall. This seems to imply that the drainage paths to IBW are not as suggested in the model. It is likely that stormwater from IB, IS, and McD flows down streets before entering the channel near McK.



Traditional DEMs are inadequate to model flow through the urban landscape without significant oversight and consideration of the urban drainage network. One clear error was the contributing area at Indian Bend and McDonald gages. According to the model, these gages receive runoff only from the eastern side of IBW, but in fact they are within IBW and the stream paths shown above merging at B, really merge at A. I have reconciled this in the data table below. Also of interest is the modeled flow through infrastructure such as canals (C). Obviously the flow is not through the canal, but either along the canal or the canal is acting as a barrier. Another example of infrastructure damming is along highways as seen by the vegetation fanning out where the stream meets the highway (D, below). Clearly better data are needed to represent the drainage network.

Drainage network alterations are common in temperate regions too, but in arid regions like Phoenix it is a common practice to simply let the runoff flow on the street rather than in subsurface drains (however, there are some). Undoubtedly these passive drainage alterations from the urban infrastructure will have impacts on the fluvial system. The crux of my research will be to quantify the impacts of these interactions on the fluvial system. What are the spatial scales that these dryland urban/fluvial changes occur on? What are the progression of these changes and the time scales over which the fluvial system responds to these urban interactions.

I am also interested in the sedimentation of these passive and artificial retention basins. How polluted are these, what types of material is included, what is the scale of the anthropogenic contribution?



Typical impacts of Urbanization (modified from Chin, 2006)
 The urbanization process consists of two main phases: 1) active construction and 2) a period of stabilizing urban cover. The following relationships have been observed. Sediment production is highest during peak construction and decreases once urban land cover begins to stabilize. This happens because imperviousness and other land covers stabilize the sediment. Imperviousness, Runoff volumes and velocities, and pollutant production all generally increase with time of urbanization. During active construction there is net aggradation and channel reduction and this is followed by net erosion and channel enlargement.

Urbanization usually results in channel enlargement that increases downstream within the urban landscape. Chin and Gregory, 2001 show that this stream (below) in Fountain Hills, AZ has instead become segmented by road crossings. Just downstream is a gravel mining operation. The ephemeral nature of aridland fluvial systems invites much more human interaction with the fluvial system. The lower left photo is an aerial view of the Salt River after a significant wet period that resulted in flow. The Salt is dammed upstream of Phoenix six times, is channelized over several reaches, has many gravel mining operations, waste water wetlands, artificial lakes, and other human interactions. Clearly the morphology of this river has been significantly altered. With historical aerial photography perhaps we can determine some sequential responses from the fluvial system to the urbanization practices.



Dryland urban channel is fed both by upstream flow and urban street flow. Increased flow and velocity results in channel scour downstream of the road crossing (Chin, 2006). Chin and Gregory show increased segmentation of this channel in Fountain Hills, AZ. But will channel change become integrated like temperate regions by future large runoff events?



Desert piedmont urbanization in Buckeye, AZ offers the opportunity to monitor geomorphic change from the start of urbanization. The Hassayampa River valley and piedmont of the White Tank Mountains (above) are beginning to be cleared for urban developments. With an anticipated population of more than a million people, a large fluvial channel, and numerous alluvial fans, Buckeye is an ideal place to follow the urbanization process in a dryland system. The effects of urbanization will depend heavily upon the development choices made. We are working to acquire repeat LiDAR surveys over this landscape which will allow us to quantify the geomorphic change. Other tools will include field mapping, total station surveys, and remote sensing of satellite and aerial photography.



Some hypotheses to test

- 1) Because urban street networks are an important hydrologic pathways and are often directly integrated with natural dryland channels, their interactions with those channels will significantly control changes in channel morphology. This may be especially true on piedmont channels and may result in significant channel enlargements and/or migrations.
- 2) Dryland channel geomorphology is controlled by the largest hydrologic events, therefore it will require longer time scales to integrate channel response to urbanization; unless of course a fortuitous large event occurs immediately after urbanization is stabilized.
- 3) During dryland construction, large volumes of highly erodible material (see photo of fan soil profile) is available for transport, this may lead to initial rapid aggradation of piedmont channels. However, this hypothesis assumes that it rains on the construction sites, if rain does not occur then dryland channels may not see an initial urban sediment pulse.
- 4) Retention and detention basins may starve some dryland channels of runoff and sediment, resulting in a geomorphology controlled more by bioturbation and direct human modification.
- 5) Urban impoundments and detention basins will become unique ecological niches in dryland systems and may rival traditional channels with biological productivity. However, they may also be sites of pollutant retention.

References:
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 Chin, A. and K.J. Gregory. 2001. Urbanization and Adjustment of Ephemeral Stream Channels. *Annals of the Association of American Geographers*, vol. 91, 595-608.
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Suggestions and comments:

What about dryland systems? Are the relationships the same?

Dryland relationships among urbanization, hydrology, and geomorphology are qualitatively similar because of the underlying physics, but the detailed interactions of these systems are different as a result of the ephemeral nature of these systems and the resulting use of these systems. Aridland urban-fluvial interactions seems to be ever evolving. What are the implications for reaching a steady geomorphic state? What are the implications for fluvial ecosystems?

