Introduction
A soil study was conducted at the Las Capas archaeological site in order to document and evaluate the soil productivity and hydraulic soil properties of this ancient agricultural irrigation complex in the northern Tucson Basin of southeast Arizona. This site presented an unprecedented opportunity to study the complete configuration and evolution of the oldest irrigation system documented in the United States to date, at more than three millennia old. The Las Capas site is significant archaeologically for a number of reasons, including: (1) the antiquity (~750–1225 B.C.) of the Early Agricultural period irrigation systems represented at the site, (2) the fact that irrigation systems dated to different times are separated stratigraphically within the site, and (3) the fact that extensive and well-preserved gridirrigation features were identified in the field by mechanical stripping and then sampled. The stratigraphic separation and abundant cultivated irrigation plots facilitated soil sampling so that field, border, and uncultivated control samples could be compared in order to measure the anthropogenic effects of agriculture on soil quality in the irrigated lands. Long-term indicators of agricultural soil quality, such as organic carbon, nutrient content, and hydraulic soil water properties, indicate that anthropogenic changes were favorable for agricultural production and that the Las Capas irrigation system was sustainable. Canals regularly supplied water to the fields, but they also supplied nutrient-rich sediments that continually renewed soil fertility, enough to counter nutrient losses resulting from crop uptake, volatilization, leaching, and oxidation. Fields have significantly elevated organic carbon, nitrogen and available phosphorus levels relative to the borders, at levels that are slightly below but comparable to the control soils. Sodium and sodium adsorption ratios, though elevated in the Las Capas fields, are far below levels that could have had a serious detrimental effect on crop production.

Small white circles mark the locations of conical-shaped planting holes within cultivated fields. The looser fill of these holes promoted water infiltration into the root zone of silty clay loam soils.

The complex alluvial history of Las Capas is documented by cycles of geomorphic stability, soil formation, erosion, and aggradation over seven centuries (see figures above). Below right is a map showing the layout of the irrigation canals and the field grids defined by earthen berms. Below left is an aerial photo showing part of Locus D-

Research Objectives
- Measure long-term anthropogenic effects of irrigation on agricultural soil quality
- Model hydraulic soil properties
- Determine if ancient agriculture degraded soil quality
- Assess agricultural sustainability of the Las Capas irrigation system

Methods
- A total of 238 soil samples were collected and analyzed: 116 soil samples from cultivated fields, 93 from field borders, and 29 from uncultivated controls.
- Samples were collected from all strata where evidence of Early Agricultural period irrigation was identified. These included: (1) Stratum 504 (~800–975 B.C.); (2) Stratum 505 (~650–925–800 B.C.); and (3) Stratum 506 (~1225–950–925 B.C.).
- pH, total and organic carbon (C), nitrogen (N), C:N ratio, calcium carbonate (CaCO₃), available and total phosphorus (P), calcium (Ca), potassium (K), sodium (Na), sodium adsorption ratio (SAR), bulk density, and particle-size analyses were completed.
- Tests were used to evaluate statistical differences between field, border, and uncultivated control soils of different strata and loci.

Conclusions
- Improved soil fertility in the Las Capas irrigrnic soils indicates that the ancient farming system was sustainable.
- Long-term indicators of agricultural soil quality indicate that anthropogenic changes were generally favorable for agricultural production, with fields having significantly elevated organic carbon, nitrogen, and available phosphorus levels relative to the borders, at levels comparable to uncultivated control soils.
- Canals supplied nutrient-rich silt and clay that renewed soil fertility, enough to counter losses caused by crop uptake, volatilization, leaching, and oxidation.
- SAR levels, though elevated in the fields, are far below levels detrimental to crop production. Properly managed irrigation water reduces salinity through leaching.
- Subterranean erosion (piping) was likely a factor in field abandonment. Natural floodplain sediments at the site are highly dispersive and are very prone to piping.

Most soils are moderately (pH: 7.9–8.4) or slightly (pH: 7.4–7.8) alkaline, levels suitable for maize cultivation. Soil pH differences between the field, border, and control soils are insignificant.

Concluding Thoughts
- It is important for future studies of ancient irrigation systems to search for the agricultural fields, not just the canals.
- The Las Capas study is an important milestone, but much more research is needed on ancient irrigic soils of the Southwest. Much less is known about the anthropogenic effects on irrigic soils than on runoff and rock mulch soils.

Acknowledgments
First and foremost, we thank Pima County for funding this study as part of the Las Capas data recovery. We appreciate the help of Jeanne South of Desert Archaeology, Inc. (DAI), for collecting soil samples in the field. The aerial photographs were supplied by Henry Wallace of DAI. Soil sample processing and pH and bulk density analyses were conducted by Victoria Stoia in the Statistical Research, Inc. (SRI) soil lab in Tucson. Total and available phosphorus (P) were analyzed in the Soil and Plant Testing Laboratory at Iowa State University under the direction of Brian Hill. C, N, Na, SAR, and pH analyses were completed by Desert Archaeology, Inc. (DAI). SAR levels, though elevated in the fields, are far below levels detrimental to crop production. Properly managed irrigation water reduces salinity through leaching.

Subterranean erosion (piping) was likely a factor in field abandonment. Natural floodplain sediments at the site are highly dispersive and are very prone to piping.