Deflation Troughs, Water, and Prehistoric Occupation on the Margins of the South Texas Sand Sheet

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ABSTRACT

Within the South Texas Plains, the area broadly defined by the Rio Grande to the south and the Nueces River to the north, a distance of ca. 175 km, evidence of open human occupation is remarkably abundant. Because it is predominantly a region of loose, sandy soils and active and relict sand dunes where wind processes dominate, the area is known as the South Texas Sand Sheet (STSS). There is no running water within the STSS and all streams are ephemeral. Existing drainage systems are small, localized, and not integrated, carrying water for a few days and up to two weeks after the passage of a storm. The lack of running water makes human occupation on this semi-arid area even more remarkable. The STSS and the adjacent wind deflated areas have hundreds of small and shallow elongated deflation troughs. Most of these poorly drained swales retain seasonal fresh water that sustain high moisture plants and are ephemeral wetlands; a small percentage of them hold water year round. As a result, the long history of human occupation of the STSS was possible due to the presence of the deflation troughs. This study explores the connection between human occupation of the STSS and deflation troughs at four previously unreported archeological sites in northern Hidalgo County using a combination of intensive archeological and geological survey, oral history, GIS technology, and existing soil maps.

INTRODUCTION

Located in the central part of the general area defined by the Rio Grande to the south and the Nueces River to the north is the South Texas Sand Sheet (STSS) occupying an area of approximately 4,200 km^2 of predominantly loose, sandy soils, and active and relict sand dunes where wind processes are dominant. The STSS includes most of Kenedy and Brooks counties, and parts of northern Hidalgo and northwestern Willacy counties (Figure 1). There is no running water within the STSS or the areas adjacent to it; all streams are ephemeral, carrying water only for a few days to a few weeks after the passage of a storm (Brown et al. 1980). The area is considered a subtropical desert with limited precipitation and high summer temperatures. In the interior away from the gallery forests that line the two bounding rivers and their adjacent resacas, vegetation cover consists mostly of sparse grasses and brush; stands of live oak trees cover most of the relict dunes and provide the only shade in the sand sheet. Deflation (wind erosion) is evident on the land surface in the form of hundreds of small, shallow, deflation troughs across the STSS and adjacent areas, and these serve as temporary water reservoirs following occasional heavy rains. Areas north and south of the STSS lack

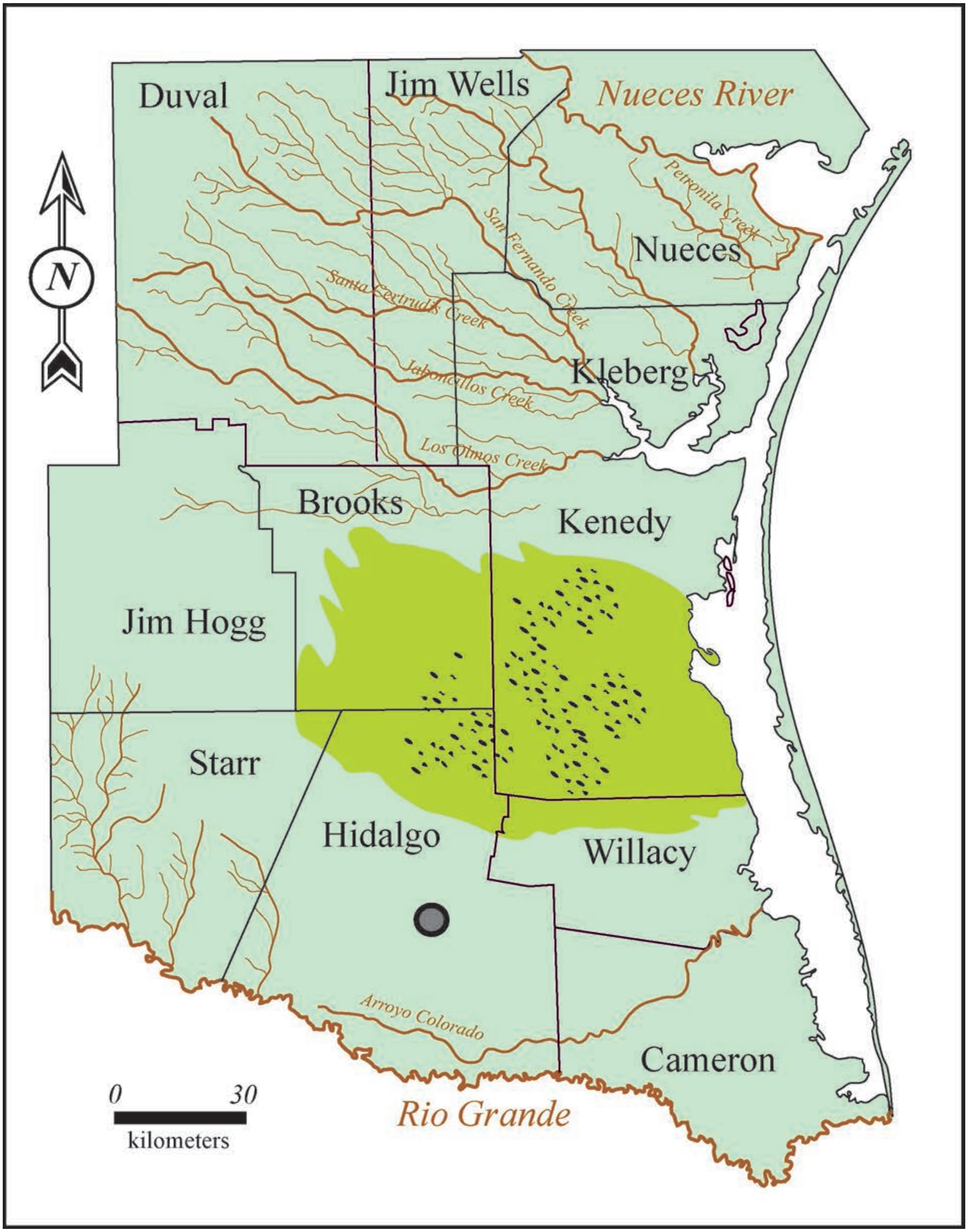

Figure 1. Map of South Texas between the Nueces River to the north and the Rio Grande to the south. Area in yellow shows the location of the STSS; deflation troughs are shown schematically. The black circle denotes the study area. Note that there is no running water between the two river systems, a distance of ca. 175 km. Los Olmos, Jaboncillos, Santa Gertrudis, San Fernando, and Petronilla streams are ephemeral and carry water only for a short time following heavy rain.

loose sediments but are also subject to wind erosion. In the study area, located outside the STSS in central Hidalgo County, the surface geology is a deeply deflated bedrock surface of the Pleistocene Beaumont Formation. North of the STSS, in the vicinity of Baffin Bay, deflation troughs are abundant on the surface of the Pliocene Goliad Formation.

Despite the lack of running water and high temperatures for much of the year, evidence of human use and occupation of the STSS and deflated areas that border it is remarkably abundant and extends back to ca. 3500-6000 B.C. This research study from an area outside the STSS, where running water is absent and deflation is the dominant geologic process, can be used to explain the long history of human occupation of this harsh environment. We contend that human occupation was made possible by natural water storage in deflation troughs following heavy rains.

CLIMATIC CHARACTER OF THE STSS

There is a climatological gradient along the STSS with a reduction in rainfall from north to south and east to west (Figure 2) (Norwine et al. 1978; Le Houerone and Norwine 1988). Average annual rainfall for Kleberg and Kenedy counties in the northeast is 67.6 cm and 67.3 cm, respectively, while Willacy and Hidalgo counties in the south receive 65.5 and 50.5 cm (Brown and Macon 1977; Brown et al. 1980). Over 55 percent of the precipitation occurs between May and September when ca. 65 percent of the days have temperatures greater than 32 degrees C, enhancing evaporative losses (Southern Regional Climate Center 2014). Precipitation is often bimodal with peak amounts in May-June and September-October, the later period associated with tropical storms (Norwine et al. 1978; Le Houerone and Norwine 1988). Across the STSS annual evaporation values range from 50 to 70 cm, matching and sometimes exceeding precipitation values; thus there is a water deficit throughout the STSS (Brown et al. 1980).

WIND EROSION AND DEFLATION TROUGHS

The landscape of the STSS is shaped by both wind deposition and deflation; much of the sheet is covered with active dune complexes that migrate under the influence of the prevailing southeasterly winds. According to Brown and Macon (1977), in areas underlain by a shallow water table the amount of deflation is controlled by soil moisture derived from the intersected water table. Where this occurs, the land surface is marked with hundreds of small, 50 to 500 m diameter, circular, oval, or irregularly-shaped deflation troughs that average 1.0 m in depth (Figure 3). Such is the case in parts of southern Brooks County and in western Kenedy County, where deflation troughs are the most conspicuous geomorphic element of the landscape, reaching densities of 10 troughs per km^2.

Observations from exploratory boreholes drilled in central Hidalgo County indicate that the water table is often deeper than 3.5 m and thus we favor the idea that eolian erosive forces are stymied when underlying clay and clay/loam substrate soil layers are encountered (Hernandez-Salinas et al. 2012; Garcia et al. 2014). Most of these poorly drained swales hold water only after the passage of a storm. A small percentage of them retain some water year-round and become ephemeral wetlands that sustain high-moisture plants like California bulrush, common three-square bulrush, spikerushes, flatsedges, cattails, white-topped sedge,

Figure 2. Annual precipitation for South Texas showing the location of the STSS (in gray shade). Isohyets are the average for the period 1961-1990. Data from NOAA Cooperative and USDA-NRCS.

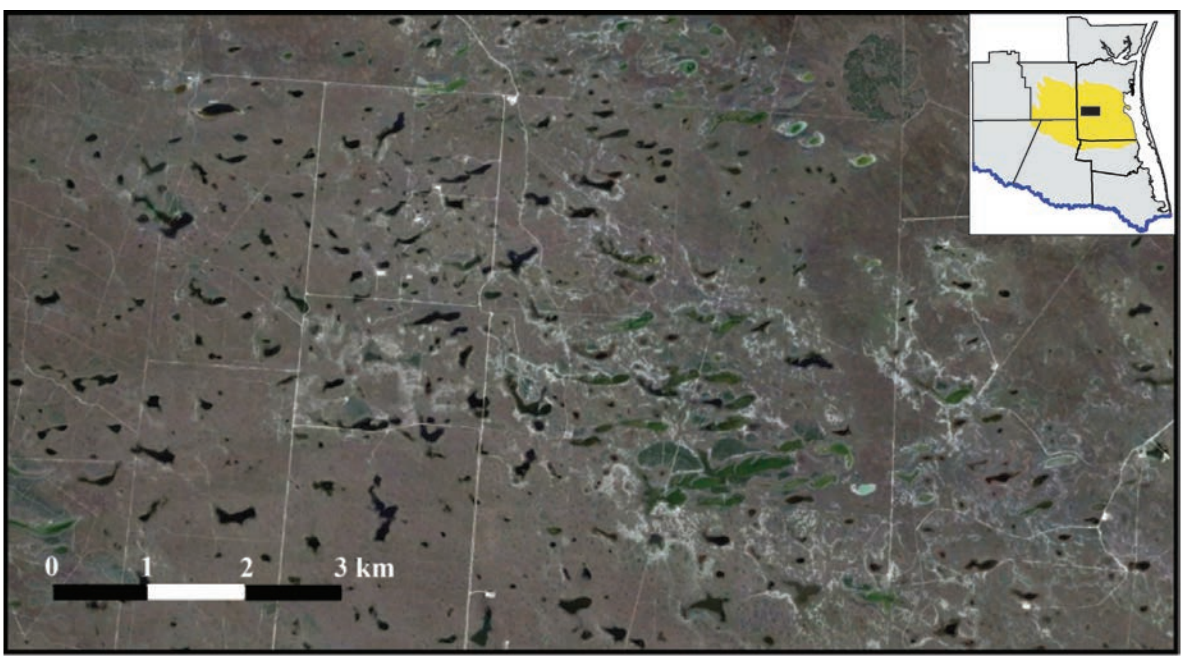

Figure 3. Google Earth image of a portion of western Kenedy County where deflation troughs are the most conspicuous landscape feature. The area encompasses 105 km^2. The image date is March 11, 2011.

paspalums, and gulf cordgrass (Texas Coastal Sand Sheet Wetlands 2014). Water levels fluctuate during the course of the year depending on seasonal rains and tropical storms: a graphic example is shown in Figure 4 for a small area in central Hidalgo County

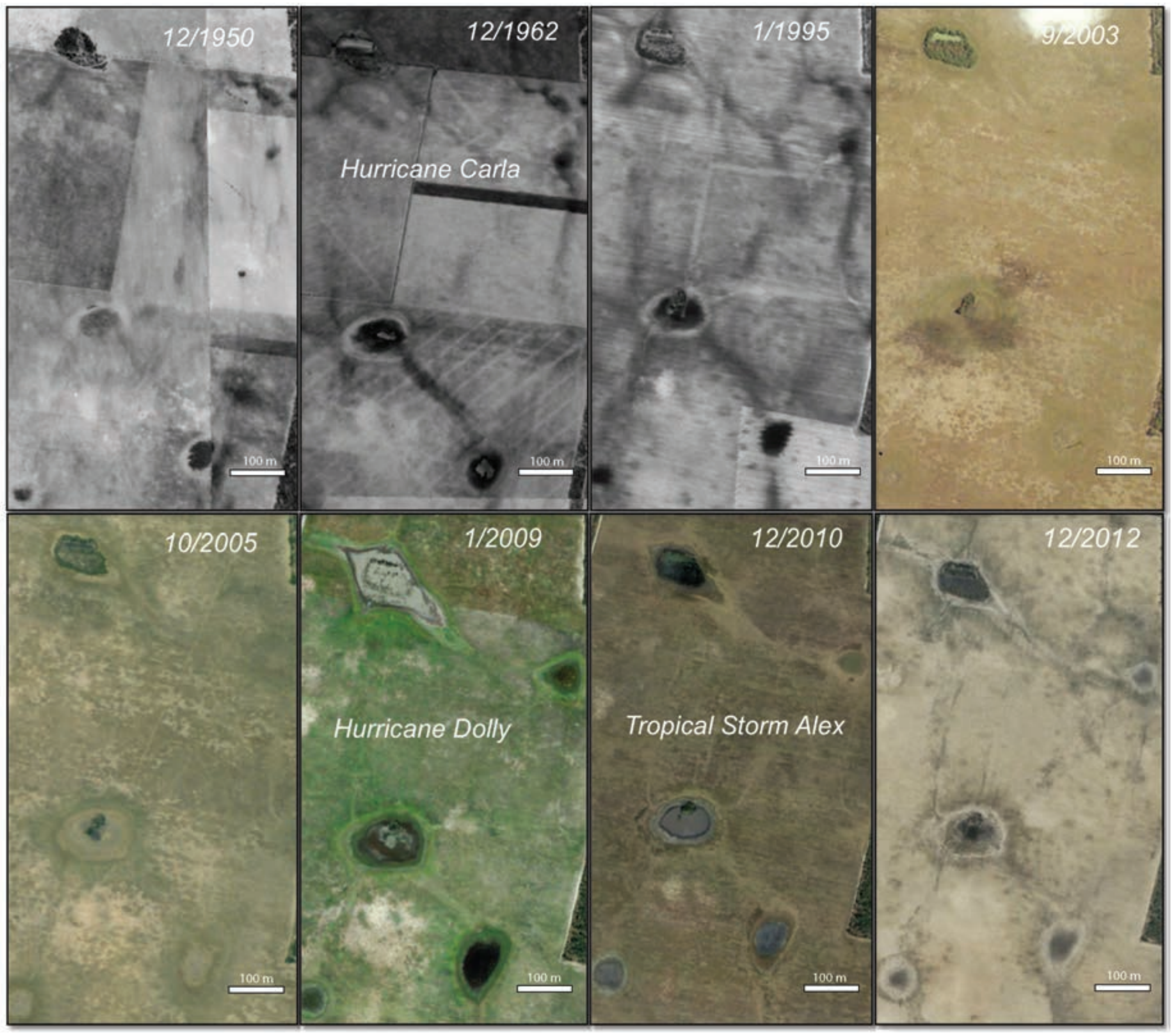

Figure 4. Google Earth time series imagery encompassing the period 1950-2012 for an area in central Hidalgo County (centered around Lat. 26°32'27.37''N. Long. 97°57'27.32''W). The four deflation troughs in the images retain water during wet years (1962, 2009, and 2010), and shrink during drought years (1950, 1995, 2003, 2005, and 2012).

It is unclear when deflation started in the STSS and adjacent areas. In South Texas the Holocene climate became increasingly arid as glaciations ended and sea level rose. Assessments of climate stability using isotopic studies (Ricklis and Cox 1998) and geologic mapping (Price 1958; Fisk 1959; Brown and Macon 1977, Brown et al. 1980; Russell 1981) have concluded that little variability in climate occurred in the Holocene. More recently other studies have presented evidence suggesting climatic instability. Forman et al. (2009) used luminescence dating to recognize two episodes of dune formation at 2700-2000 years B.P., most likely occurring with decreased ground cover caused by climatic fluctuations, and 200 years B.P., likely associated with historic land use grazing practices. Collins et al. (2011) used the distribution of time diagnostic projectile points to infer several climatic intervals characterized by different moisture regimes. Furthermore, Hall et al. (1987) and Collins et al. (1989) have suggested that Early to Middle Holocene erosion may have been fairly widespread. This observation is supported with geomorphic evidence from 41HG118, where a gully eroded into a Beaumont Formation knoll, the Pleistocene basement in the area, began to fill by 4500 ± 130 radiocarbon years B.P. (Beta-17434) (4835-5578 radiocarbon years B.P., calibrated at 2 sigma). On these grounds we assume that deflation started at least by 8000 years B.P., if not at the onset of the Holocene, and deflation troughs have been an important part of the landscape since then. Some evidence, however, seems to indicate that at least some of the troughs may have been formed in the Late Pleistocene, and may be inherently related to antecedent topography. Evidence for this include a radiocarbon date from a fragment of a molar identified as ***Bison latifrons*** found in organic-rich sediments from one trough north of Edinburg, Texas, excavated to increase water capacity (Armando Vela, personal communication, August 2013). It yielded an age of 18,670 ± 45 radiocarbon years B.P. (UGA-17416) (2 sigma calibrated age range of 22,670-22,930 radiocarbon years B.P.). In addition, excavations of La Paloma site (41KN18) in northern Kenedy County encountered Pleistocene fauna, including mammoth, ground sloth, horse, and extinct bison (Suhm 1980), in close proximity to large deflation troughs.

SOILS AND DEFLATION TROUGHS

The shape, dimensions, and general orientation of the deflation troughs are best observed on satellite images and aerial photographs of the land surface (see Figure 3). But to understand why the troughs can retain water and become temporary lakes, it is best to examine soil maps. The removal of the top sandy soils by wind action causes the formation of depressions. The ***Soil Survey for Hidalgo County*** (Jacobs 1981) describes a soil unit that is most common on deflation troughs throughout Hidalgo County in an area south of the STSS where deflation is intense: soil unit 60, Rio clay loam (Figure 5). Deflation troughs in neighboring Willacy County are characterized by soil unit 67, Tiocano clay. Both soil types are described as poorly drained, with very low permeability, and high water capacity. Areas of the land surface where these soils are exposed contain pond water from runoff and most of the year are saturated with water.

Deflation troughs as water reservoirs

In the STSS and peripheral deflated areas water collects in deflation troughs following rain events. Observations made in the field confirmed that water starts ponding quickly during moderate rain events, even after a prolonged drought (Figure 6a-b). In exceptional cases involving extreme rainfall, water depths can exceed 1 m in some troughs. This was well documented when, following Hurricane Beulah's landfall in South Texas in 1967, many troughs retained water for more than a year. Once filled with water the temporary ponds serve as haven for local fauna, offering not only a source for food and water, but also ground cover for wildlife habitats and protection from predators. Waterfowl, particularly ducks, gather at the larger depressions during the rainy season in September and October.

HUMAN OCCUPATION OF THE STSS

Evidence abounds of prehistoric human use and occupation of the STSS and adjacent areas where deflation occurs and water is limited. The Texas Archeological Site Atlas indicates that there are more than 300 recorded sites in Willacy, Kenedy, Brooks, and central Hidalgo counties (Table 1). This record is biased, however, and underestimates the extent of occupation since the majority of the reported sites

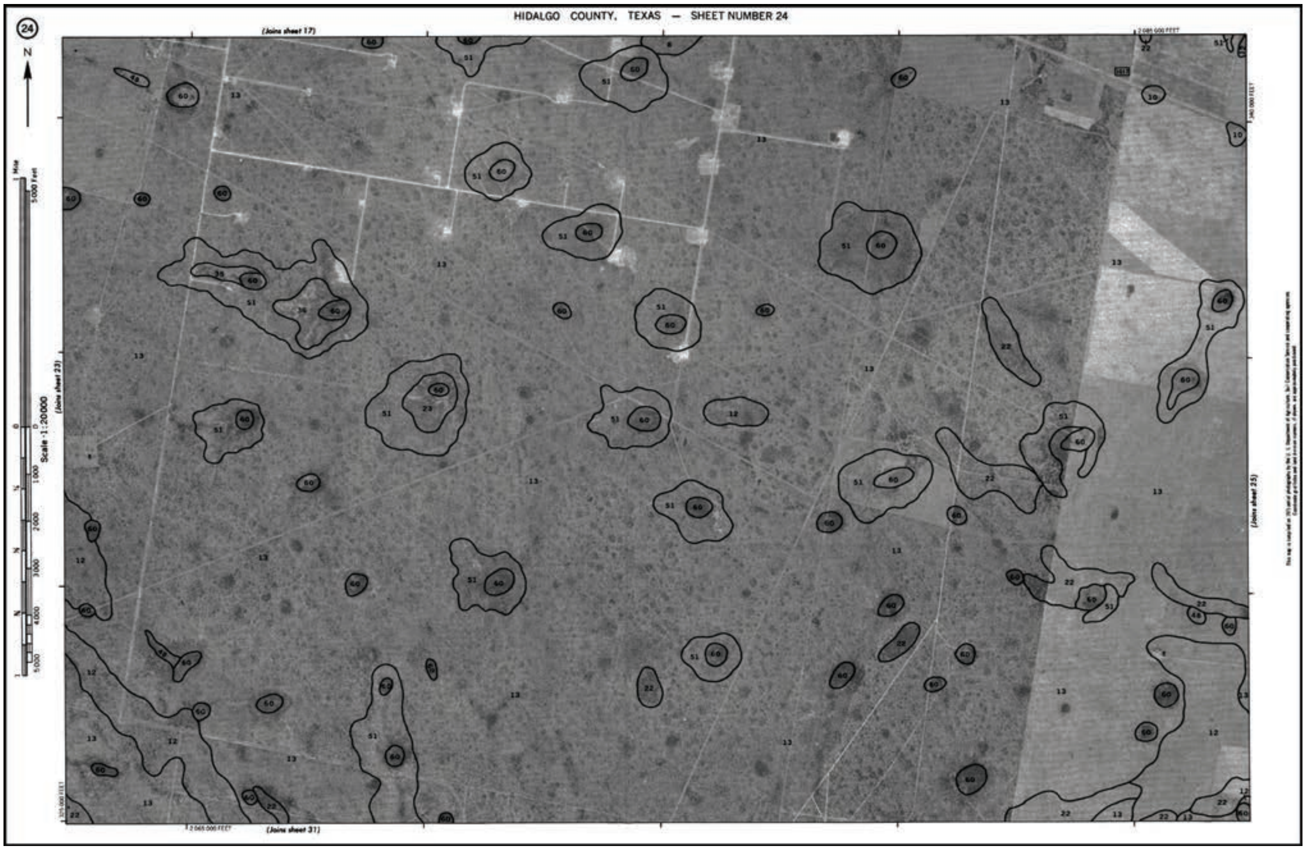

Figure 5. Sheet 24 of the Hidalgo County Soil Survey. Notice the soil unit 60, Rio clay loam, at the center of the circular or elongated deflation troughs. This soil type has low permeability and high water capacity.

occur along main highways, drainage canals, and transmission power lines, and they were recorded as part of cultural resource management surveys. Beyond these survey projects, only a handful of archeological sites have been excavated in the region (Mallouf et al. 1977:87; Day et al. 1981; Hall et al. 1987; Bousman et al. 1990; Kibler 1994; Hester 2004). These investigations have revealed the archeological record in the STSS and adjacent areas to be characterized by poorly stratified campsites, low preservation of non-lithic remains, and overall very sparse cultural remains (Hester 2004:129). As a result, cultural chronology, subsistence strategies, and settlement patterns for the sand sheet and adjacent water-limited areas remain poorly known. The lack of a reliable radiocarbon chronology further hinders an understanding of the region's prehistory. For these reasons Ricklis (2004:177) described the area as "virtually unknown archeologically."

There is limited environmental and cultural data suggesting a human presence in the STSS during the Paleoindian and Early Archaic periods. At a site in Kenedy County (41KN18), located in the northeastern part of the sand sheet, mammoth and bison bones were found close to several dart points and one fluted lanceolate specimen. Suhm (1980) radiocarbon-dated four samples of mammoth bone, only two of those yielded reliable ages: 9,560 ± 120 radiocarbon years B.P. (TX- 2195) (calibrated at 2 sigma to 10,575-11,202 radiocarbon years B.P.), and 9,830 ± 110 radiocarbon years B.P. (TX- 2196) (calibrated at 2 sigma to 10,794-11,709 radiocarbon years B.P.). An isolated Lerma projectile point, dating from the Early Archaic period

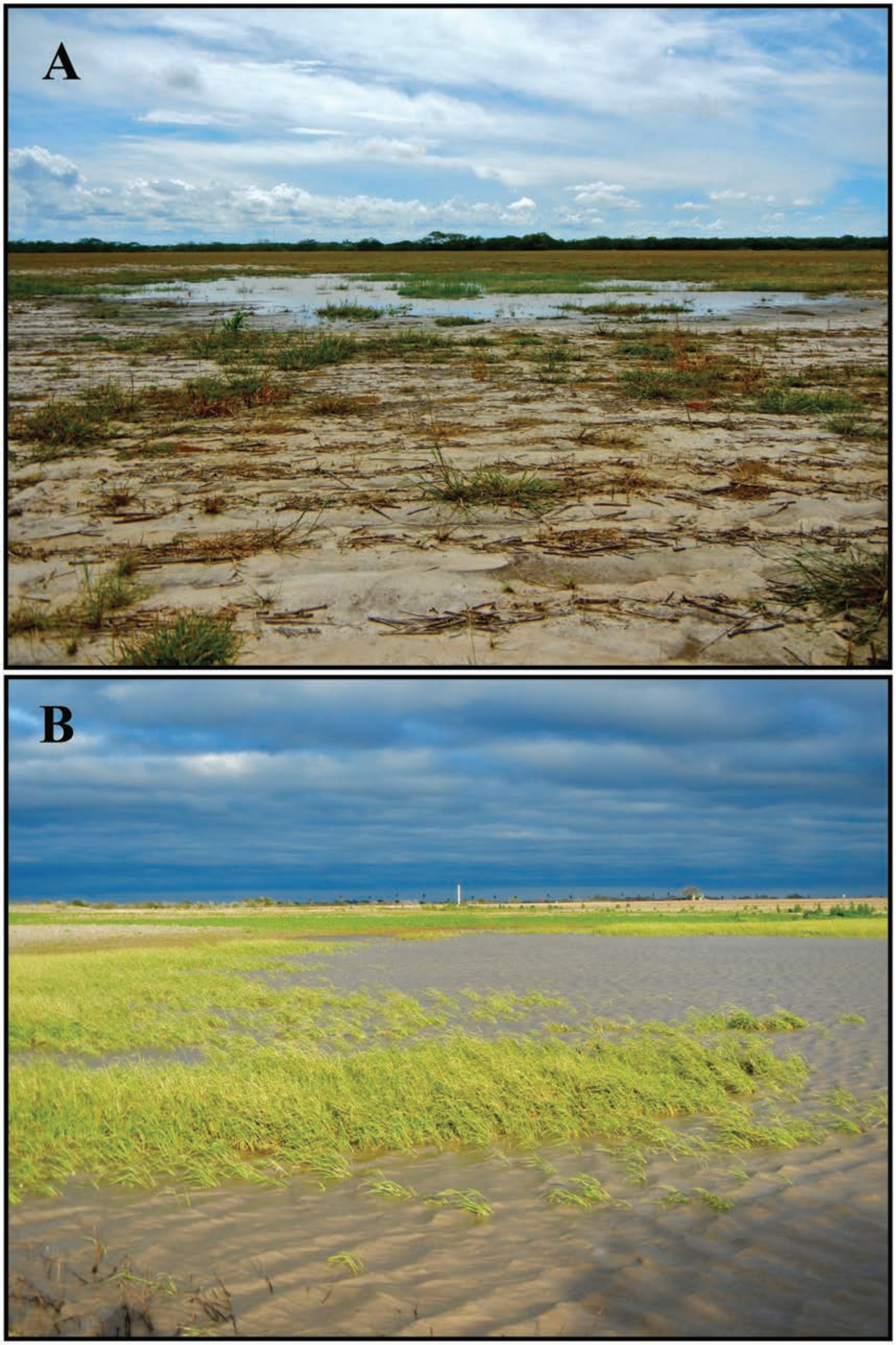

Figure 6. Deflation troughs with water near the town of McCook in central Hidalgo County: A, the water in this trough accumulated after an hour-long rain event; B, pool of water with wave ripples. Water depth in this trough reached a depth of 0.3 m and had accumulated two weeks before the picture was taken in the Fall of 2013.

Table 1. Archeological sites within and adjacent to the STSS (Texas Archeological Site Atlas).

County	Number of archeological sites
Kenedy	22
Brooks	28
Willacy	152
Central Hidalgo	104
Total	306

(3500-6000 B.C.), was reported by Mallouf et al. (1977:167) on a site in Willacy County to the east of the sand sheet. Both Mallouf et al. (1977) and Bousman et al. (1990) excavated a number of low-density sites in northern Hidalgo and Willacy counties and their findings suggest a human presence from as early as the Early Archaic.

The later part of the Archaic period is also poorly represented and understood (Kibler 1994). Early to Middle Archaic periods sites are rare, and Mallouf et al. (1977:118) suggest that the sparse distribution of sites could be related to migrating aeolian deposits that have effectively buried cultural deposits. Bousman et al. (1990) interpreted their rarity as being due to the onset of more xeric conditions and to aeolian deflation of occupational surfaces during the Early and Middle Archaic periods. Most evidence of prehistoric land use comes from surface-collected artifacts, primarily unstemmed triangular thin bifaces, gouges, and stemmed dart points (Hall et al. 1987).

Late Archaic period sites are not infrequent in the region but often their components are mixed with cultural materials from later Late Prehistoric assemblages. Hall et al. (1987) propose that it is probably no coincidence that the apparent increase in sites during the Late Archaic is contemporaneous with the beginning of landscape stability, in agreement with the chronologic data that constrained eolian activity of the STSS (Forman et al. 2009). Finally, evidence of occupation during the Late Prehistoric period is widespread. The Late Prehistoric period is defined by the presence of small triangular arrow points on sites (Hester 1981, 2004:143-147).

Water as the limiting factor for human occupation of the STSS and neighboring areas was first discussed by Mallouf et al. (1977) in a study prepared for the U.S. Army Corps of Engineers assessing the potential impact of drainage canal construction on cultural resources. In their predictive assessment of cultural resources in Hidalgo and Willacy counties, Mallouf et al. (1977:113) recognized that the distribution of archeological sites was closely associated with the location of deflation troughs as the only source of fresh water, remarking that "archeological sites are associated with intermittent water supplies provided by the eolian plain depressions."

The rapidly changing cultural environment that characterizes South Texas at the beginning of the twenty-first century is rapidly erasing millennia of human occupation. These changes are serving as an opportunity to reexamine Mallouf et al.'s (1977) observations regarding the juxtaposition of deflation troughs, ponded water, and prehistoric archeological sites in the STSS and its margins.

IDENTIFICATION OF ARCHEOLOGICAL SITES BY THE CHAPS PROGRAM

The Community Historical Archaeology Project with Schools (CHAPS) Program at The University of Texas-Pan American reaches out to farmers and ranchers in northern Hidalgo County to salvage the rapidly disappearing cultural heritage associated with this way of life. Collected information includes oral histories focusing on natural disasters (hurricanes, floods, and droughts), soil types, depth to the water table, and observed changes in flora and fauna. Archeological and biological surveys are conducted of each property, while title searches trace the land use history of each parcel to the era of Spanish colonial and more recent land grants. In the last three years, the CHAPS Program has worked with four families (the Atwood, Eubanks, Norquest, and Sekula families) around the city of Edinburg. These families have either a long farming tradition or work history in agriculture and have found prehistoric lithic artifacts that can be precisely located on their properties. Classifying these collections led to the identification of four previously undocumented archeological sites and has enabled us to test the hypothesis that prehistoric human occupation in an area adjacent to the STSS, where there is no running water, was possible because deflation troughs provided temporary storage for rainwater.

For this project an area of approximately 70 km^2 in central Hidalgo County (see Figure 1) was studied using Geographic Information Systems (GIS). The surface geology of this area, located just south of the STSS and north of the Rio Grande and its associated resacas, consists of deflated sandstones and siltstones of the Goliad Formation. It has a long history of human occupation and is dotted with hundreds of small deflation troughs.

On a base map of Hidalgo County all areas that are known to flood during episodes of heavy rain were plotted. Topographically, much of the pooled water coincides with circular, oval, or irregularly-shaped deflation troughs (Figure 7A). A plot of the distribution of the Rio clay loam soil for Hidalgo County (Figure 7B), which matches the locations prone to flooding, validates the notion that impermeable soils promote the ponding of rainwater in the wind-carved troughs. Next, each newly discovered archeological site was plotted on the flood map, and a 5 km diameter collection catchment circle was drawn around each site to indicate a one hour walk distance. Finally, a projectile point chronology, using Turner et al. (2011), was built to provide an estimate on the history of occupation for each site.

Results

Norquest Site

Following their emigration from Sweden in the 1860s the Norquests arrived, by way of Nebraska, in Edinburg in the 1920s. The Norquests have been engaged in commercial agriculture for the last 90 years. Evidence of a prehistoric human presence on what is today the Norquest's farm includes an assortment of projectile points, a whelk shell, and a stone pestle collected over years of farming. The projectile point types

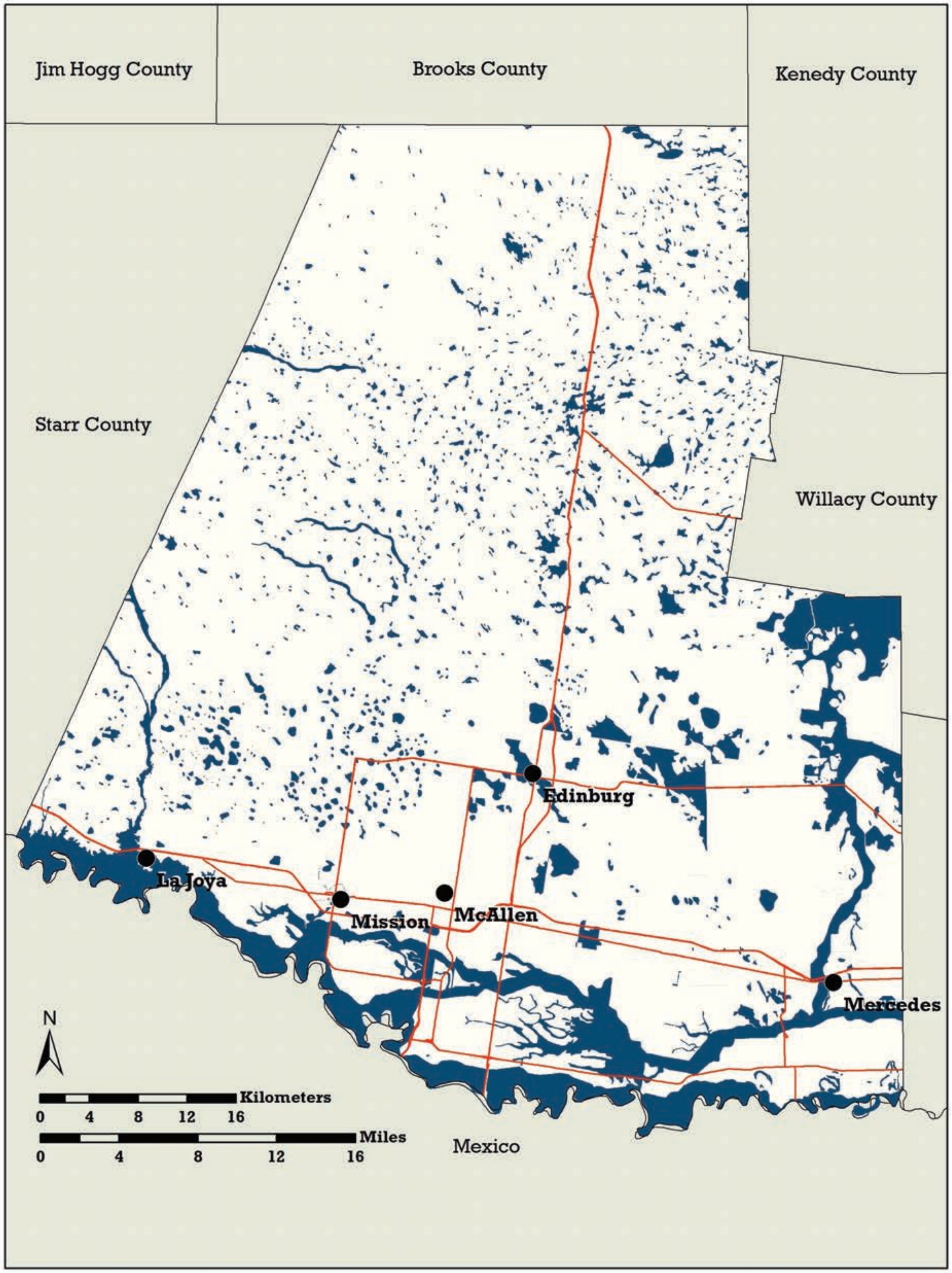

Figure 7. Hidalgo County base: A, GIS flood map based on data collected following Hurricane Beulah (1967). Notice the patchy flooding pattern coinciding with deflation troughs;

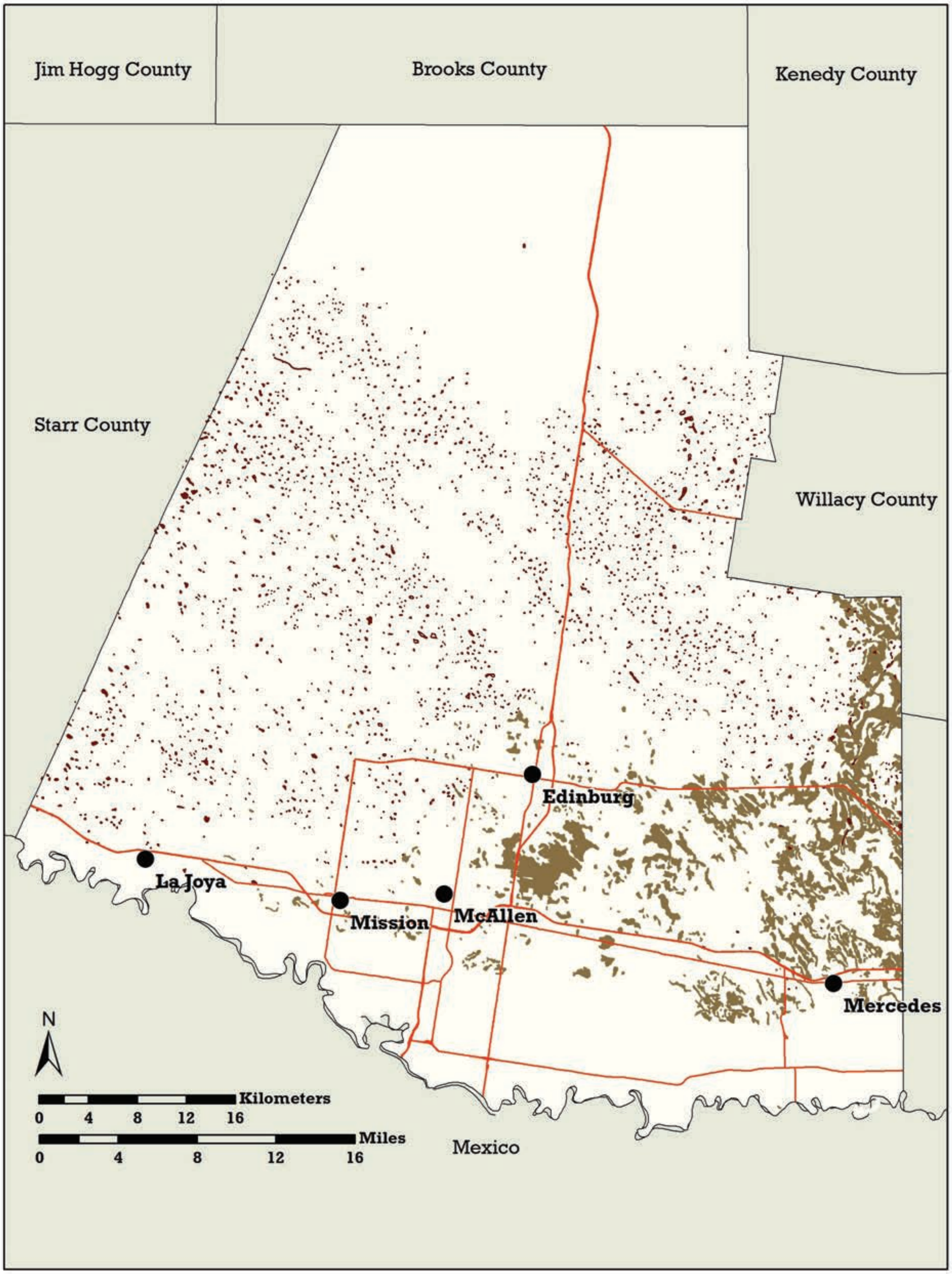

Figure 7. *Continued*. B, GIS map depicting the Rio clay loam soil. The distribution of this soil type matches the position of deflation troughs.

found on the farm indicates a continuous human presence from the Early Archaic to the Late Prehistoric (Figure 8) (Hernandez-Salinas et al. 2012:22-24). The closest point of the Rio Grande, the nearest source of running water, is 23 km away. There is a large northwest-southeast-oriented deflation trough within the defined collection catchment circle associated with this site (Figure 9). The flood map suggests that about 40 percent of the area contained within the collection catchment circle would have been under water following heavy rains.

Atwood Site

The Atwood family has farmed their land since the 1920s. Only one diagnostic Hidalgo point, dated to the Early Archaic period, has been found in their property (Figure 10) (Garcia et al. 2014). This point is made of the distinctive El Sauz chert, which outcrops 62 km west of the Atwood's farm in Starr County (Gonzalez et al. 2014). The Atwood property is located 4 km due west from the Norquest farm, so the collection catchment circles for the two sites overlap. This site is located 21 km from the Rio Grande. There are several large and small troughs that retain water within the 5 km diameter circle around the site (see Figure 9).

Eubanks Site

The Eubanks have been in the citrus growing business since 1979. A large collection of whole and broken points has been recovered from their orchard. Like the Norquest family collection, the projectile points from the Eubanks farm spans the periods from the Early Archaic to the Late Prehistoric (Figure 11) (Bacha-Garza 2014). The citrus grove is located 25 km north of the Rio Grande. The associated collection catchment circle circumscribes two small troughs, and several others are just outside it (see Figure 9). The circle intersects the Atwood and the Norquest sites, suggesting that perhaps this area north of Edinburg was a favorite seasonal camp by many prehistoric groups.

Sekula Site

Danielle Sekula worked for many years as the entomologist for the Rio Queen Citrus Groves. She gathered and cataloged an impressive collection of projectile points in the Rio Queen orchard. The projectile point types in this collection date from the Early Archaic to the Late Prehistoric period (Figure 12) (Leal 2013). The Rio Grande flows 18 km from the Rio Queen orchard. Many small troughs are within an hour's walk from the site (Figure 13).

DISCUSSION

We draw three conclusions from the archeological record discussed above. First, there is evidence for a human presence in northern Hidalgo County, dating to as early as the Early Archaic period. This is an area far from the nearest source of running water, the Rio Grande. Second, deflation troughs known to have held fresh rainwater are widely distributed in this area. And third, newly identified single and multi-component archeological sites lie adjacent to these potential water sources associated with deflation troughs. Mallouf et al. (1977) acknowledged the role of deflation troughs in human occupation in the STSS and neighboring water-poor areas. Our findings lend further support to the hypothesis that these aeolian features, which have

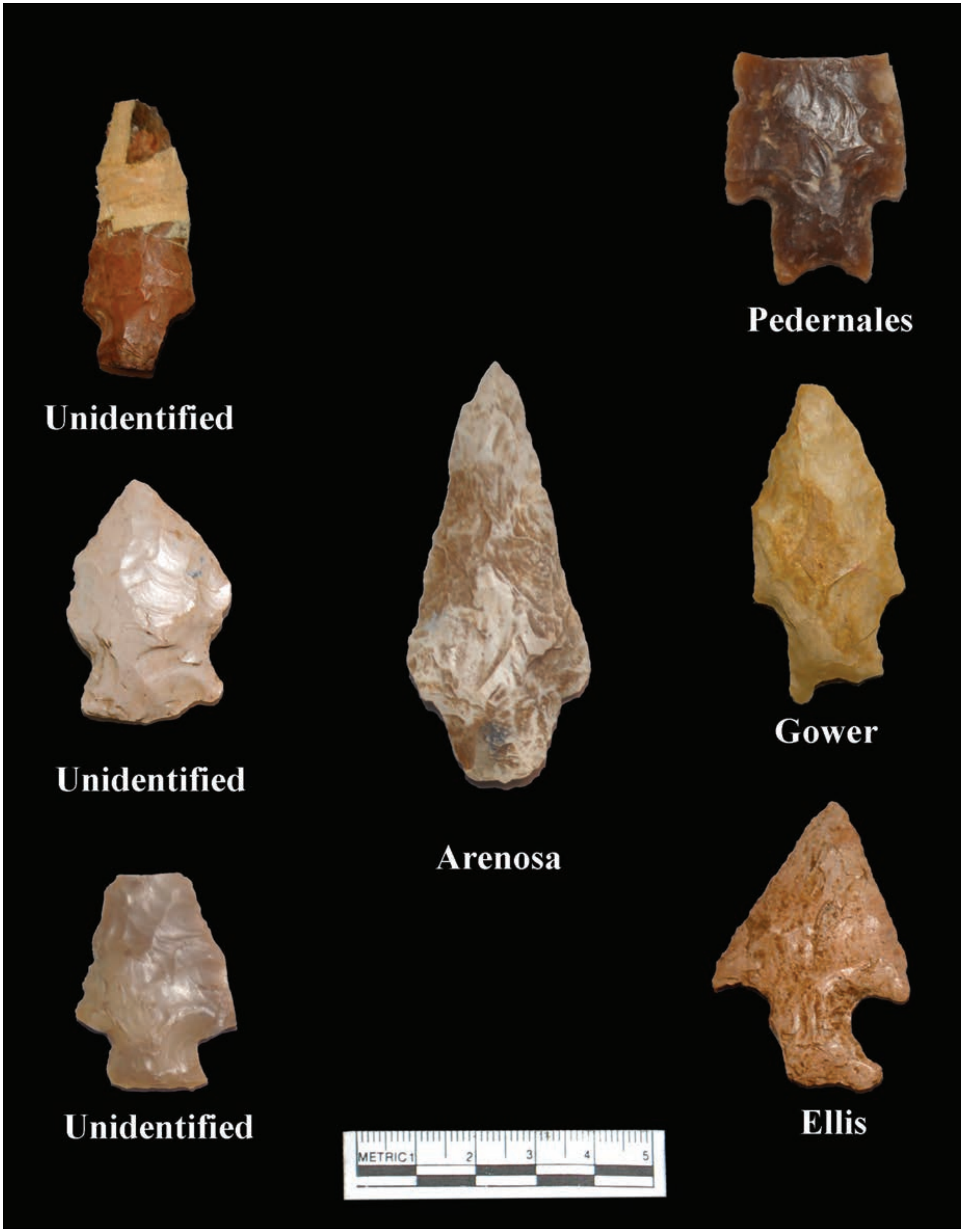

Figure 8. Selection of projectile points from the Norquest site spanning the Early Archaic to the Late Prehistoric. Early Archaic: Gower; Middle Archaic: Arenosa, Pedernales, and Ellis; Late Archaic: unidentified projectile points.

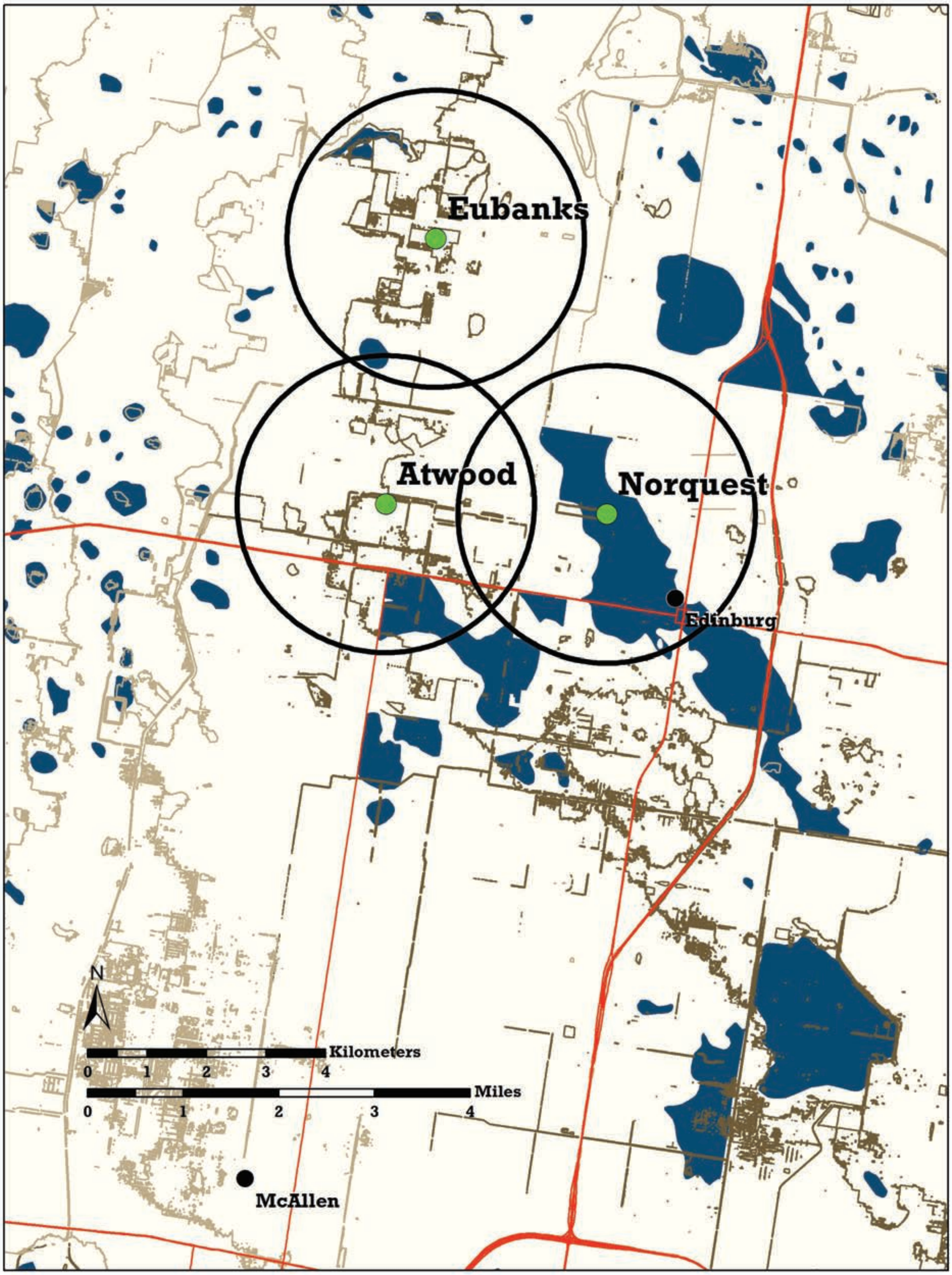

Figure 9. Collection catchment circles for the Norquest, Atwood, and Eubanks sites. All circles have a diameter of 5 km and represent a distance that can be easily covered in an hour's walk. Within the circles the flood map indicates that water can accumulate following heavy rain.

Figure 10. Hidalgo point from the Early Archaic period found by the Atwood family on their farm.

been a persistent element of the landscape on the STSS for most of the Holocene, were determinants of settlement and subsistence strategies, and thus, most of the evidence of widespread human occupation in the STSS and neighboring areas, even if it is in the form of sparse surface materials, owes it presence to deflation troughs.

Traversing the STSS in prehistoric times between the nearest sources of running water, the Rio Grande to the south and the Nueces River to the north, a distance of over 175 km, would have been possible only seasonally or after heavy rains. The only other prehistoric sources of water were seeps that originated from underground aquifers; Brune (2002) reported on a saline spring in Hidalgo County. Even today the unforgiving conditions of the STSS claim on average the lives of 100 immigrants who die of dehydration and exposure trying to cross it to enter the United States (*The Monitor*, May 18, 2014).

The lack of water, the high constant temperatures for eight months of the year, and the limited protection from sun exposure precluded year round use and occupation of the STSS. In our view the annual cycles of drought and high temperature that alternated with wetter periods and cooler temperatures favor the interpretation that prehistoric groups only made seasonal incursions into this harsh terrain and established temporary camps. This observation underlines Ricklis' (2004:180) interpretation of the

Figure 11. Selection of projectile points from the Eubanks site spanning the Early Archaic to the Late Prehistoric periods: Early Archaic: Hidalgo; Middle Archaic: Tortugas; Transitional Archaic: Ensor; Late Prehistoric: Fresno, Caracara, Starr, Catan, and Padre.

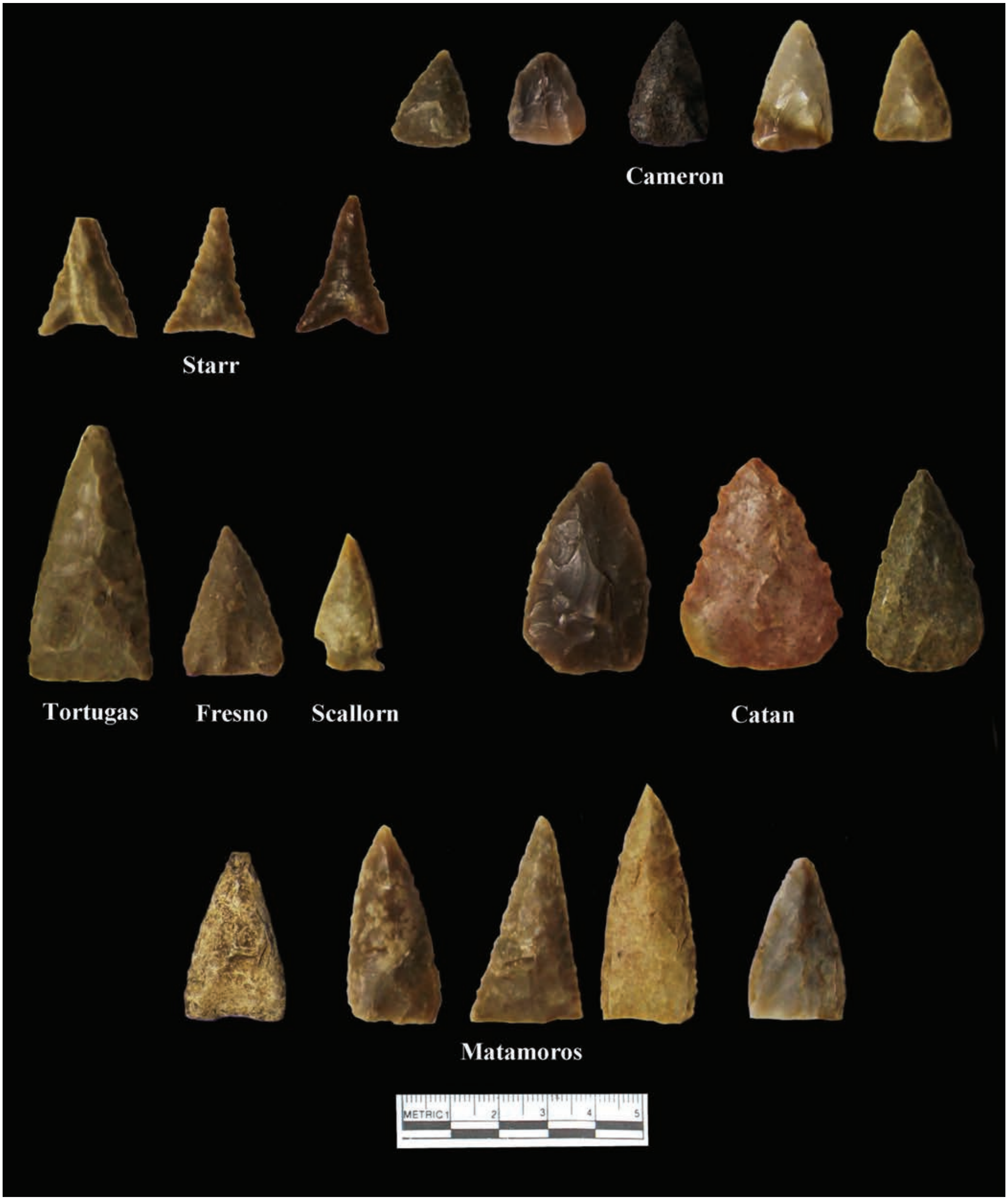

Figure 12. Selection of projectile points from the Sekula site spanning the Middle Archaic to the Late Prehistoric: Middle Archaic: Tortugas; Late Archaic: Catan and Matamoros; Late Prehistoric: Cameron, Fresno, Starr, and Scallorn.

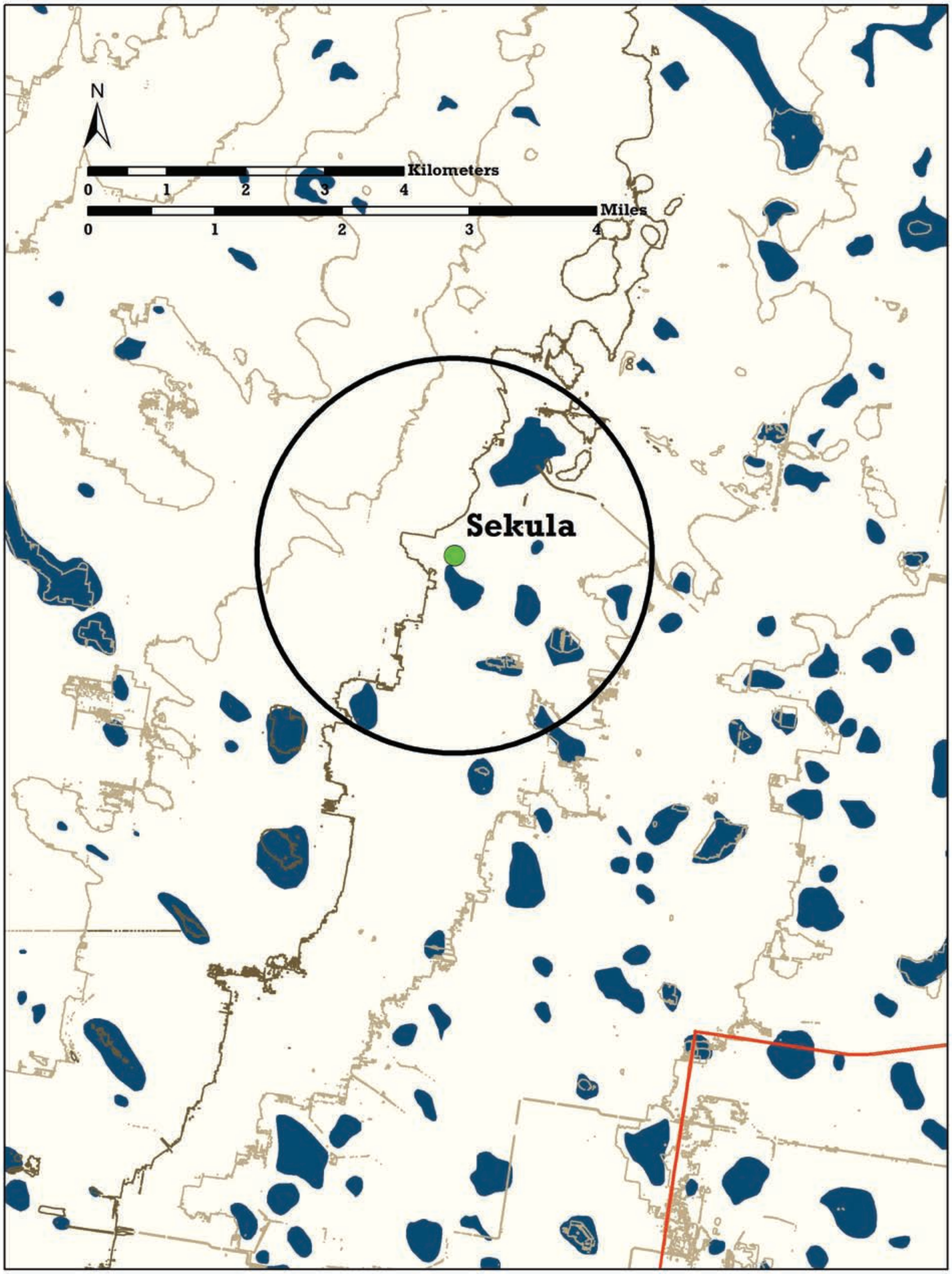

Figure 13. Sekula collection catchment circle. Many small troughs are found within the circle and at a short distance outside of it. Those fill with water following heavy rains.

fact that most investigations in the STSS show low densities of archeological material remains and thus suggest short-term occupations by highly mobile groups. The motivation to venture into the STSS and neighboring deflated areas for a stay, of few weeks to a few months, either from the Nueces River to the north or from the Rio Grande, would have been driven by the procurement of salt from one of the three salt lakes at the southern boundary of the STSS or for hunting and gathering forays. It is also possible that river flooding following episodes of heavy rain along the course of the Rio Grande encouraged prehistoric peoples to move temporarily into the STSS where they would find drier land as well as plant, animal, and water resources clustered at the deflation troughs.

If, as proposed by Forman et al. (2009), the onset of dune movement in the STSS most likely occurred between 2700 and 2000 B.P. with decreased ground cover probably caused by climatic fluctuations, then our findings of a number of Early and Middle Archaic points at or near the land surface in an area of deeply deflated bedrock but lacking moving sand, provides additional support to Mallouf et al. (1977) explanation regarding the sparse distribution of sites. Migrating aeolian deposits have effectively buried archeological sites of comparable ages in the STSS.

A century of commercial agriculture plowing and other surface altering activities has not completely obliterated the deflation troughs, which made feasible the prehistoric occupation of the STSS and areas peripheral to it. Building from the observations made by Mallouf et al. (1977) regarding the use of the STSS in prehistory and using a combination of intensive archeological and geological survey, oral history, GIS technology and existing soil maps, details of this occupation are being systematically salvaged and recorded before it is lost through development. Future research will focus on coring the organic-rich sediments that have been deposited in deflation troughs to obtain botanical macrofossils (seeds, pollen, or peat), and faunal remains that are dateable and can shed light on changing climatic conditions and plant and animal communities in the STSS and its margins.

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REFERENCES CITED

Bacha-Garza, R.

2014 *Tom Eubanks Collection: Arrow, Dart and Fragmented Projectile Points Found Within the Lower Rio Grande Valley Region*. CHAPS Special Report No. 5. CHAPS Program, the University of Texas-Pan American, Edinburg, Texas.

Bousman, C. B., S. A. Tomka, and G. L. Bailey

1990 *Prehistoric Archeology and Paleoenvironments in Hidalgo and Willacy Counties, South Texas: Results of the phase II test excavations*. Reports of investigations No. 76. Prewitt and Associates, Inc., Austin.

Brown, L. F. and J. W. Macon

1977 *Environmental geologic atlas of the Texas coastal zone: Kingsville area*. Bureau of Economic Geology, The University of Texas at Austin.

Brown, L. F., J. L. Brewton, T. J. Evans, J. H. McGowen, W. A. White, C. G. Groat, and W. L. Fisher

1980 *Environmental geologic atlas of the Texas coastal zone-Brownsville-Harlingen area*. Bureau of Economic Geology, The University of Texas at Austin.

Brune, G. M.

2002 *Springs of Texas, Volume 1*. Texas A&M University Press, College Station.

Collins, M. B., G. D. Hall, and C. B. Bousman

1989 Archeological applications of geochronological techniques in southern Texas. *La Tierra* 16:14-27.

Collins, M. B., D. M. Yelacic, and C. B. Bousman

2011 "Realms," A Look at Paleoclimate and Projectile Points in Texas. *Bulletin of the Texas Archeological Society* 82:3-30.

Day, D. W., J. L. Day, and E. R. Prewitt

1981 *Cultural Resources Survey and Assessments in portions of Hidalgo and Willacy Counties, Texas*. Reports of Investigations No. 15. Prewitt and Associates, Inc., Austin.

Fisk, H. N.

1959 Padre Island and the Laguna Madre flats, coastal south Texas. In *2nd Coastal Geography Conference*, pp. 103-151. Louisiana State University, Baton Rouge.

Forman, S. L., L. Nordt, J. Gomez, and J. Pierson

2009 Late Holocene dune migration on the south Texas sand sheet. *Geomorphology* 108:159-170

Garcia, J. D., J. N. Alaniz, R. Garza, S. L. Lopez, D. E. Neal, A. Casiano, A. L. Aparicio, J. A. Hernandez, B. A. Martinez, J. P. Meave, M. A. Allen, N. Perez, R. Pena, R. C. Fink, and C. J. Newton

2014 Atwood acres: A Porción of Edinburg. Report Prepared for the Atwood Family and for the University of Texas-Pan American, Community Historical Archaeology Project with Schools Program. University of Texas-Pan American, Edinburg, Texas.

Gonzalez, J. L., J. Hinthorne, R. Skowronek, T. Eubanks, and D. Kumpe

2014 Characteristics and genesis of El Sauz chert, an important prehistoric lithic resource in south Texas. *Lithic Technology* 39(3):1-10.

Hall, G. D., M. B. Collins, and E. R. Prewitt.

1987 *Cultural Resources Investigations along Drainage Improvements, Hidalgo and Willacy Counties, Texas: 1986 Investigations*. Reports of Investigations No. 59. Prewitt and Associates, Inc., Austin.

Hernandez-Salinas, S. Flores, S. l., D. Nicholson, R. Silva, M. Vallejo, M. Noell, G. Waters, A. De La Fuente, G. Shwartz, O. Ysasi, P. Rodriguez, M. Martinez, E. Robles, R. Galloso, and M. Gutierrez

2012 The Norquest Family: A Porción of Edinburg. Report Prepared for the Norquest Family and for the University of Texas-Pan American, Community Historical Archaeology Project with Schools Program. University of Texas-Pan American, Edinburg, Texas.

Hester, T. R.

1981 Tradition and diversity among the prehistoric hunters and gatherers of southern Texas. *Plains Anthropologist* 26(92):119-128.

2004 The Prehistory of South Texas. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 127-151. Texas A&M University Press, College Station.

Jacobs, J. L.

1981 *Soil Survey of Hidalgo County, Texas*. United States Department of Agriculture, Soil Conservation Service in cooperation with the Texas Agricultural Experiment Station, Washington D.C.

Kibler, K.W.

1994 *Archeological and Geomorphological Investigations at Prehistoric Sites 41WY50 and 41WY60, Willacy County, Texas*. Reports of Investigations No. 95. Prewitt and Associates, Inc., Austin.

Leal, A.

2013 *Danielle Sekula Collection: Arrow, Dart and Fragmented Projectile Points Found Within the Lower Rio Grande Valley Region*. CHAPS Special Report No. 2. CHAPS Program, the University of Texas-Pan American, Edinburg, Texas.

Le Houerone, H. and J. Norwine

1988 The ecoclimatology of south Texas. In *Arid lands: today and tomorrow*, edited by E. E. Whitehead, pp. 417-443. Westview Press, Boulder.

Mallouf, R. J., B. J. Baskin, and K. L. Killen

1977 *A Predictive Assessment of Cultural Resources in Hidalgo and Willacy Counties, Texas*. Archeological Survey Report 23. Texas Historical Commission, Austin.

Norwine, J., R. Bingham, and V. Zepeda

1978 Twentieth century semiarid climates and climatic fluctuation in Texas and Northeastern Mexico. *Journal of Arid Environments* 1:313-325.

Price, W. A.

1958 Sedimentology and Quaternary Geomorphology of South Texas Gulf Coast. *Association of Geological Society Transactions* 3:41-75.

Ricklis, R. A.

2004 Prehistoric occupation of the central and lower Texas coast. In *The Prehistory of Texas*, edited by T. K. Perttula, pp. 155-180. Texas A&M University Press, College Station.

Ricklis, R. A. and K. A. Cox

1998 Holocene climatic and environmental change in the Texas coastal zone: some geoarchaeological and ecofactual indicators. *Plains Anthropologist* 43(164):125-136.

Russell, J. L.

1981 The south Texas Eolian sand sheet. In *Modern depositional environments of sands in south Texas*, edited by J. L. Russell and C. E. Sterling, pp. 43-46. Gulf Coast Association of Geological Societies, Corpus Christi, Texas.

Southern Regional Climate Center

2014 Texas Normal Monthly Precipitation webpage, Texas. http://www.srcc.lsu/southernClimate/atlas/images/TXprcp.html

Suhm, R. W.

1980 The La Paloma mammoth site, Kenedy County, Texas. In *Papers on the Archaeology of the Texas Coast*, edited by L. Highley and T. R. Hester, pp. 79-103. Special Report No 11. Center for Archaeological Research, The University of Texas at San Antonio.

The Monitor

2014 Webpage, http://www.themonitor.com.

Texas Coastal Sand Sheet Wetlands

2014 Texas A&M Agrilife Extension. Webpage, http://texaswetlands.org/wetland-types/texas-coastal-sand-sheet-wetlands/.

Turner, E. S., T. R. Hester, and R. L. McReynolds

2011 *Stone Artifacts of Texas Indians*. Taylor Trade Publications, Lanham, Maryland.