Characterizing Biological Structure and Ecological Function of Playas and Upgrading the Existing Kansas Wetland Program Plan (WPP)

Kansas Biological Survey Report No. 204

June 2021

By

Debra S. Baker, Jude H. Kastens, Christopher R. Bishop, and Donald G. Huggins

Kansas Biological Survey

University of Kansas

For the Kansas Water Office

Prepared in fulfillment of

USEPA CD – 97763601 and KUCR 1000135

Wetland Program Development Grant (WPDG) FFY 2017

Characterizing Biological Structure and Ecological Function of Playas and Upgrading the existing Kansas Wetland Program Plan (WPP)

Report Date:	June 30, 2021
Report Period:	FINAL REPORT
Grant Recipient:	Kansas Water Office
Grant Title:	Characterizing Biological Structure and Ecological Function of Playas and Upgrading the existing Kansas Wetland Program Plan (WPP)
Grant Number:	CD – 97763601

Submitted to USEPA by: Kirk Tjelmeland, Kansas Water Office

Project 1 Description

Debra S. Baker, Jude H. Kastens, Christopher R. Bishop, and Donald G. Huggins
Kansas Biological Survey
University of Kansas

Playas may originate wherever water can periodically collect in a surficial depression and then expand by hydrologic and geomorphic processes. Thus, playas often occur where the topography is flat, climate is semi-arid, and evaporation rates are high, all of which contribute to the playa hydro period. Much of western Kansas meets this description and is home to thousands of playas, an appreciable fraction of which have not been mapped based on findings from our previous project, CD 97743401 (Kastens et al. 2016). Western Kansas is also intensively cultivated, and consequently playas within this region are embedded in a highly altered landscape, resulting in ecological and hydrological impairment of many playas. Healthy playas are biological "hot spots" within the Plains region that support a high diversity of plants, birds, mammals, and invertebrates upon which many vertebrate species feed. Additionally, ongoing research examines the role of playas as focal points for recharge of the High Plains Aquifer, a function that potentially is compromised due to cultivation and sedimentation that impacts playa structure and function (i.e. CD 97770301).

Outcomes from CD 97743401 established a methodology using TWIP tools and carefully prepared LiDAR data to significantly expand the state's potential playa inventory beyond features contained in the PLJV-PP dataset (www.pljv.org/). The PLJV-PP dataset for Kansas consists of approximately 22,000 features. The study area from the previous project contained about 8,900 of these features. The LiDAR-based evaluation from that project identified more than 3,100 additional potential wetland features that occurred in the broadly mapped playa-supporting region, which was defined using the loess soils class from the Kansas Surface geology map produced by the Kansas Geological Survey. Subsequent visual inspection of the 3,100 features resulted in the elimination of about 1,100 non-playa features (e.g. terrace retentions, feedlot ponds, etc.), leaving approximately 2,000 new potential playas identified through LiDAR analysis in the original study area. With this substantial increase to the state's playa inventory, the utility of the modified TWIP process to identify potential playas not included in the PLJV-PP dataset was firmly established, as was the need to apply the process to the rest of the playa-supporting regions of western Kansas to complete the dataset. LiDAR data are now available covering the entire region.

This proposal builds from and expands on the results from our previous project to develop LiDAR-based techniques to remotely identify and delineate potential playas along with their drainage catchments and landscape characteristics. This work included field-based efforts to assess identification accuracy and potential misclassification problems. Additionally, biological sampling was done on a subset of potential playas to identify the presence or absence of known playa community elements including wetland plants, invertebrates, and birds. As described in the project final report, the LiDAR-based approach was effective for identification of relatively large numbers of potential playas beyond those already included with the PLJV probable playa dataset that was developed primarily using aerial imagery. Further, the fieldwork revealed some notable difference in the plant communities (and lesser so with invertebrates) associated with playas occurring entirely within cultivated crop fields as opposed to those occurring in pastureland, which has implications for ecosystem services and functions associated with these sub-populations.

We proposed to expand upon our initial research within the large west-central Kansas playa complex by applying information and methodologies acquired in our initial project to a different large playa complex located in northwestern Kansas where there are some distinct physiographic differences. Within this new study area, we applied our developed methologies to locate and map potential playas and their catchments using recently acquired LiDAR elevation data not available at the time of our initial study. As these tasks were being accomplished, we performed fieldwork to collect biolgical and ecological data from a subset of playas from both regional groups. We then analyzed these data in a geospatial framework in an effort to identify potential physical and physiological similarities and differences between the two populations, as well as to assess various spatial indicators (localized and catchment-scale) for their abilty to predict biological structure, ecological function, and condition. In addition to expanding and enhancing the state's digital playa inventory, we expect the outputs from this project to be used in support of playa identification and prioritization efforts directed toward restoration or preservation, or for basic estimation of essential playa characteristics.

With LiDAR data now available covering all of western Kansas, with this project we applied the developed methodology to the rest of the area. In addition, during the previous project we discovered PLJV-PP features that corresponded with knob-like projections (which had the appearance of playas in imagery) rather than playa-like depressions. Using LiDAR, we examined the entire Kansas PLJV-PP dataset to identify and flag these non-playa anomalies for potential removal from the dataset.

The morphologic and ecologic functions of playas are directly influenced by land use within the playa drainage area (catchment). Wetlands located in cropland-dominated areas receive more surface runoff and sedimentation than wetlands within grassland areas. It has been found that playa catchments dominated by cropland in the Southern High Plains have lost their hydric soil-defined volume due to increased sedimentation, and that sedimentation reduced the original playa volume, increased surface water area and evapotranspiration rates, and as a result caused a shortened hydro period. Alterations to hydro period affect the ecological aspects of wetlands including nutrient cycling and the composition of flora and fauna species.

ACCOMPLISHMENTS MET FOR THE GOALS, OBJECTIVES AND TASKS OF THE PROJECT 1 WORKPLAN

PROJECT #1. GOALS AND OBJECTIVES:

Action: LiDAR & GIS data preparation

Accomplishments:

2-m resolution LiDAR digital elevation model (DEM) data covering the large western and central Kansas study area, all of which were from collections less than 10 years old, were mosaicked and pre-processed using the same methods described in the final report for our 2013 WPDG (CD97743401). Following mosaic, a 3-by-3 median smoothing filter was passed over the LiDAR data to reduce very high frequency noise. Next, TIGER 2014 roads and KDOT railroad GIS vector line data were downloaded from DASC (https://www.kansasgis.org/) in June 2018, buffered on both sides by 30 meters, and removed from the DEM. Voids were filled by interpolating across the gaps. Early in the project, at the request of one of our stakeholders (Ducks Unlimited), we expanded the study area to the east to include the Rattlesnake Creek basin leading in Quivira National Wildlife Refuge. This area, which falls outside the Kansas Surface Geology (KSG) playa area mask developed during WPDG13, is a highly sensitive agricultural and wildlife area for the state, with much irrigation and many isolated wetlands (Fig. 1).

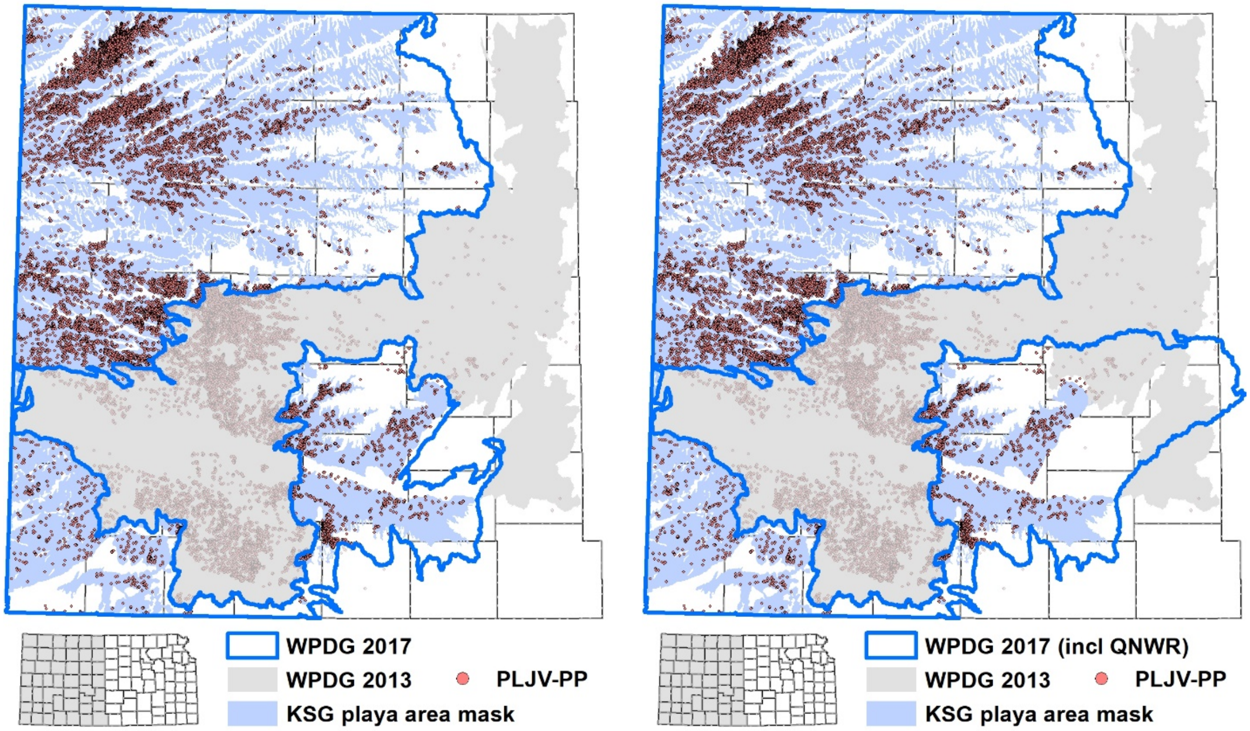


Figure 1. ***Left:*** Original study area. ***Right:*** Expanded study area to including Rattlesnake Creek basin.

We downloaded a copy of Version 4 (and later, Version 5) of the Playa Lakes Joint Venture Probable Playas (PLJV-PP) dataset in June 2018. At that same time, we also downloaded a copy of the high resolution USGS National Hydrography Dataset (NHD) for Kansas. We use the waterbodies from the NHD to help with closed-basin (endorheic) playa watershed mapping. As described in the final report for WPDG13, playas sit at the bottom of closed basins, and it is critical to identify as many non-playa closed basins as possible so that watersheds for these features can be excluded from playa watersheds.

We use features from the USFWS National Wetland Inventory dataset for the same purpose as NHD waterbodies. However, the version of the NWI that we downloaded in June 2018 had additions that made it very difficult to work with in semi-arid western Kansas, where true wetlands can be few and far between. Specifically, we found that version of the NWI to be loaded with bogus wetland features that would have required intense screening. For example, it appears that some set of streamlines (some of which, but not all, coincided with NHD flow line features) was buffered out 10 feet and the resulting polygons indiscriminately included among the NWI features. Among these riverine features are also included a large number of inexact duplicates of unknown origin, exacerbating the situation by causing overlapping feature geometries and sliver polygons. The 2014 version of the NWI used in WPDG13 had none of these problems, so we scrapped the new dataset and reverted to using the older one.

Action: Map potential playa areas (PPAs) using LiDAR

Accomplishments:

Capacity limitations in ESRI ArcGIS prohibited pre-processing of the entire study area at once or in large-region groups. After much trial-and-error, we settled on a buffered HUC-12 group-based partition for the study area by which to process the data for potential wetland area (PWA) mapping. Following WPDG13, for the first step of this process we applied the 0.5-m sinkhole identification, puncturing, and standpipe installation procedure to each analysis subgroup. Next, we applied the playa-adapted Topographic Wetland Identification Process (TWIP) model developed for WPDG13 to the conditioned LiDAR data to map the PWAs.

To clean up the overlaps and mismatched edges among PWA features, we merged all of the PWA polygons together (including those from WPDG13), dissolved them, and then split the resulting multi-part polygon features into single-part features. Next, we shape-screened the single-part polygons to eliminate exceptionally elongated features (which primarily corresponded with agricultural terrace water storage areas) using the statistical procedure developed for WPDG13. Specifically, the unitless ratio (shape index) of {perimeter}/{sqrt(area)} was computed, and all polygons with a shape index value greater than 6.5 (greater than 7 if the polygon intersected a PLJV-PP feature) were eliminated. For perspective regarding the choice of 6.5 for the cutoff, 99.9% of PLJV-PP features (22,024 out of 22,046) have a shape index value below this value. Next, PWA records from the processing subgroups were joined to the single-part polygons, allowing for one-to-many assignments (i.e. multiple PWAs possibly joining to a single-part polygon). Finally, we assigned all single-part polygon records that joined with more than one PWA record to the PWA record with the largest area. At the end of this process, 69,086 PWAs remained for the study area (Table 1, Fig. 2).

Table 1. Important TOTAL AREA numbers (includes WPDG13 coverage as well). Entries with highlighted letters are shown in the subsequent Figure 2.

Value	Description
22,046	PLJV-PP (v5) features [a]
21,150	PLJV-PP that intersect the PPA mask
96%	Percent of PLJV that intersect the PPA mask
99,615	Single part polygons (possible PWA)
69,086	PWA that remain following shape index screening [b]
8,059	PWA that intersect PLJV-PP
17,143	PWA that intersect the PPA mask (possible PPA) [c]
9,360	Possible PPA that do not intersect PLJV-PP (PPA\PLJV) [d]
5,817	PPA\PLJV remaining following visual screening [e]

Through our objective mapping procedures, we identified 9,360 possible PPA which do not coincide with PLJV-PP features. To further improve the quality of the PPA dataset, we visually inspected all of the possible PPA against a backdrop of high-resolution aerial imagery and LiDAR terrain information. This exercise resulted in the attribution of 3,543 of the 9,360 (38%) of the possible PPA as non-playas, thereby raising the likelihood that an arbitrary member from the remaining 5,817 possible PPA features will indeed possess playa-like qualities and will be complementary to the PLJV-PP dataset.

Associated File: ***KBS_PWA_possible_playas_westernKS.shp***

Download location:
https://kars.ku.edu/media/downloads/Kastens/EPA_WPDG_2017_final_materials/
(all deliverable files are contained in the single ZIP file accessible from this site)

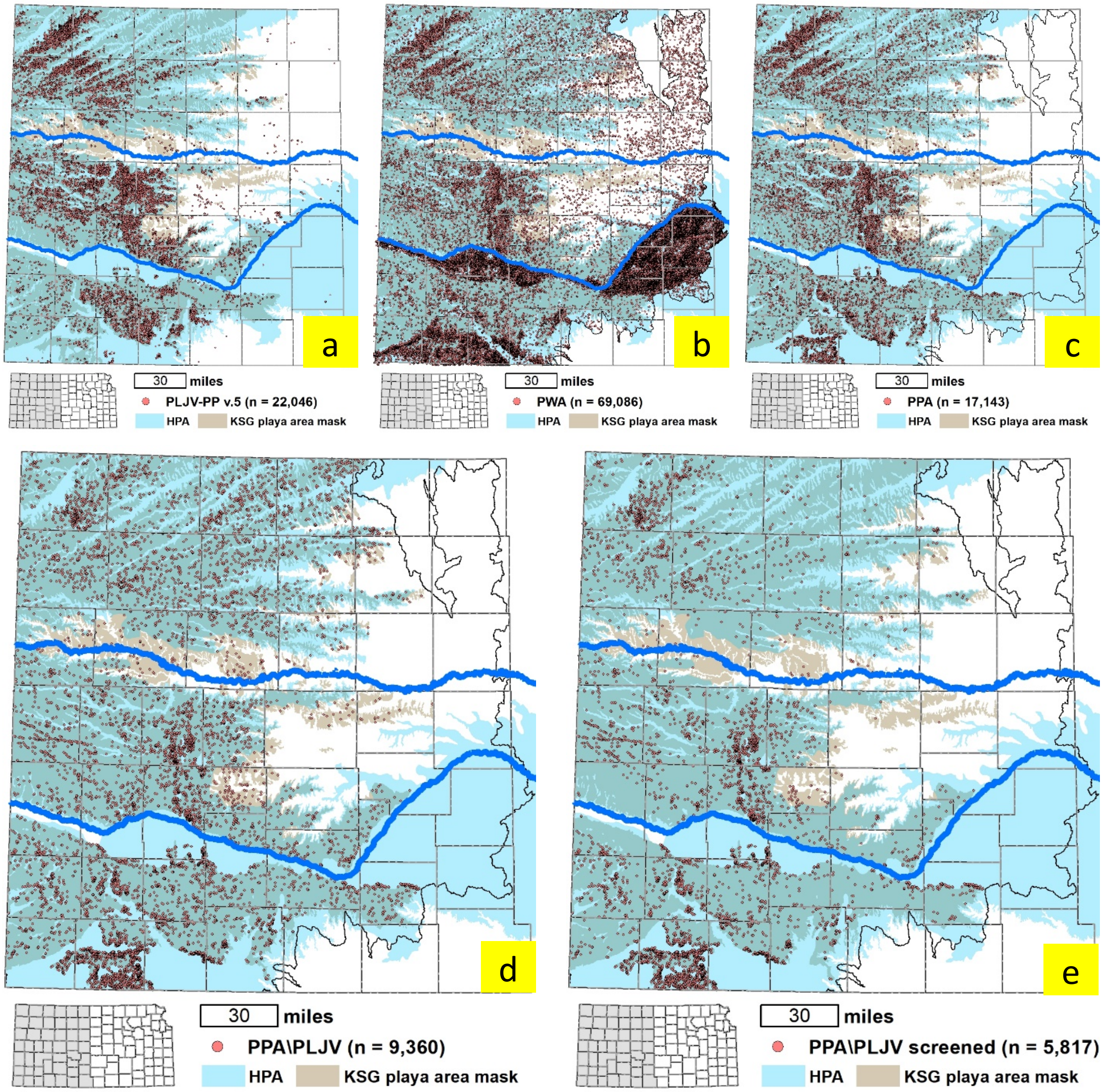


Figure 2. PLJV,-PP, PWA, and PPA features described in Table 1.

Action: Identify protrusion anomalies in the PLJV-PP dataset

Accomplishments:

Compared to their LiDAR footprints buffered outward by two meters, PLJV features had a propensity to exhibit extremely shallow or no depth, or had variable boundary elevation (i.e., were not contour-like). Consequently, we developed a statistical index to use for sorting PLJV features that helps to identify the most clear-cut PLJV protrusion anomalies (Fig. 3). Reasoning that net PLJV-PP volume is an important indicator of protrusion, where net {PLJV-PP volume =

depression volume – protrusion (inverted sink) volume}, we divided this value by PLJV-PP feature area to obtain the mean net PLJV-PP depth. Sorting the PLJV-PP using the index, the top 1% (221 features) were visually inspected, and ~90% of these were found to be protrusion features (not playas), illustrating the effectiveness of this statistic for protrusion anomaly detection (Table 2).

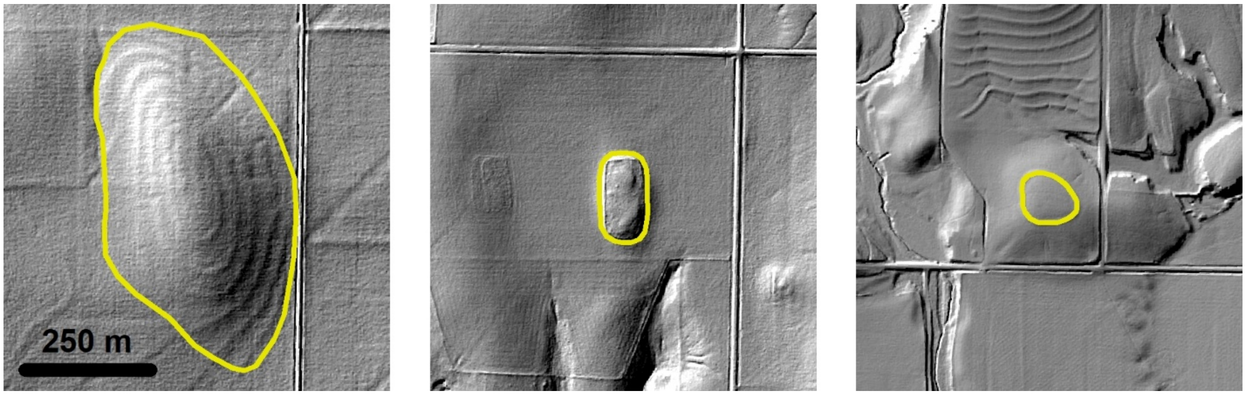


Figure 3. Protrusion anomaly examples from PLJV-PP (v5).

Associated Files: ***Prob_Playas_v4_KS_protrusion_anomaly_assessment.shp***
Prob_Playas_v4_KS_depression_protrusion_analysis.xlsx

Table 2. PLJV-PP (v4) depth-distribution table.

Maximum LiDAR depth (m)	Fraction of 22046 PLJV-PP features in the depth class (%)
0 - 0.1	31.2
≥ 0.1	68.8
≥ 0.15	46.2
≥ 0.2	29.8
≥ 0.25	19.1
≥ 0.3	12.8
≥ 0.35	9.2
≥ 0.4	7.0
≥ 0.45	5.6
≥ 0.5	4.7
≥ 1	2.2

Action: Map catchments for PLJV-PP and PWA features

Accomplishments:

Below is the DEM preparation and watershed mapping procedure that we developed and implemented for this project. Motivated by eliminating edge-matching and feature overlap problems, which likely would be even greater when mapping watersheds compared to PWA, we applied the procedure to the entire region (including the study area from WPDG13) in one massive hydro-processing exercise.

Procedure for mapping watersheds

Definitions

NHD = NHD waterbodies
NWI = NWI wetlands (c.2014)
HOL5 = 0.5-m sinkholes (created using the sinkhole identification tool; applied in pieces then mosaicked)
SNK25 = max-depth pixel-polygons from all depressions at least 0.25m deep

1) Create SNK25
    a. Create FIL = depressionless DEM
    b. Compute FIL_DEM_diff (fill depth map) = FIL-DEM
    c. Remove depth values < 0.25 m
    d. Convert to extents, then to polygons
    e. Perform zonal max fill
    f. Identify pixels where depth >= zonal max fill – 0.0001 [pixels near max depth]
    g. Convert to polygon
    h. Buffer 0.5 m, then scene-wide dissolve (to unify diagonally connected pixels)
    i. Multi-part to single part → SNK25 polygons
2) Compute PWAx = PWA\PLJV [polygon]
3) Compute PLJV-PWA = merge(PLJV,PWAx) [polygon]
4) Compute NHDx = NHD\(PWA-PLJV) [polygon]
5) Compute NWIx = NWI\(NHD\(PWA-PLJV)) [polygon]
6) Compute NHD-NWI = merge(NHDx,NWIx) [polygon]
7) Compute SNK25x = SNK25 intersect (NHD-NWI) [polygon; then clip to NHD-NWI]
8) Compute SNK25xx = SNK25x no intersect HOL5 [polygon]
9) Compute SNK25pt = inside_point(SNK25xx) [point]
10) Compute HOL5pt = inside_point(HOL5) [point]
11) Compute HOL-SNK = merge(HOL5pt,SNK25pt) [point]
12) Compute PUNC = HOL-SNK no intersect PLJV-PWA [point]
13) Create field PID = sequential ID for PLJV-PWA

14) Create field XID = sequential ID for PUNC (use range that is beyond PID range)
15) Create PUNC1 = convert PLJV-PWA to raster using PID [raster, from polygon]
16) Create PUNC2 = convert PUNC to raster using XID [raster, from point]
17) Create ALL_PUNC = mosaic(PUNC1,PUNC2) [raster]
18) Create pDEM = punctured DEM = Con(~IsNull(DEM),Con(IsNull(ALL_PUNC),DEM))
19) Create pFDR = D8 flow direction for pDEM
20) Create pWSHD = watersheds for pFDR using PLJV-PWA and PUNC as pour points
21) Create pWSHDv = raster_to_polygon(pWSHD) (don't generalize lines)

Considering that drainage area questions arise frequently with regard to NHD waterbody, NWI wetland or other bottom features in addition to playas, we decided to create an area-wide micro-watershed (microsheds) coverage. More than 415,000 microsheds were delineated, corresponding to all of the pour points outlined in the above procedure (Fig. 4).

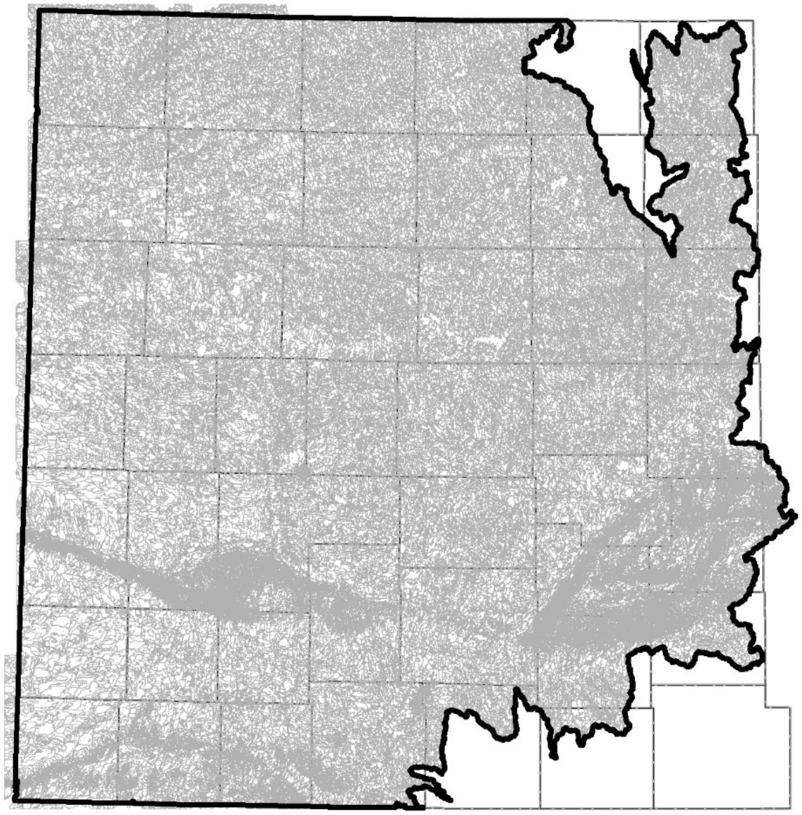


Figure 4. More than 415,000 micro-watersheds (microsheds) cover the western Kansas study region.

Associated Files: ***microsheds_westernKS.shp***
playas_v5_public_ks_watersheds.shp
KBS_PWA_possible_playas_westernKS_watersheds.xlsx

Goal 1 Action 3. Playa field assessment, Year 1. May-Aug 2018.
Goal 2 Action 2. Playa field assessment, Year 2. May 2019-Aug 2019.
Goal 2 Action 3. Geospatial analysis of field assessment data from northwest and west-central playa cluster. Jul 2019-Mar 2020.

Accomplishments:

Selection of playas for 2018 sampling

Selection criteria for playas to sample in 2018 reflected the sizes and ecoregion of the playas sampled in 2015. Playas were selected from the four northwestern counties of Kansas (Cheyenne, Rawlins, Sherman, and Thomas) and restricted to the Western High Plains ecoregion, Level 4 Flat to Rolling Cropland. The PLJV shapefile “pljv_Prob_playas_v4” was used to select playas within the same size range of playas we sampled in 2015 (n = 15, range 0.07 – 52.41 ha, mean 5.98 ha). Playa polygons within these parameters were highlighted on a map for reconnaissance by vehicle. Routes driven were chosen to encounter the densest area of polygons within 0.5 miles of the roads.

During the 4-7 June 2018 reconnaissance trip, we encountered 283 polygons and noted whether they were actually playas, possible playas, not playas (including artifacts such as ditches), or not visible (not able to see the indicated polygon due to crops, obstructions, etc.). Landuse category was noted: dry crop farming (no pivots), irrigated crop farming, grassy field, or other. Standing water, mud, or cracked soil was noted. The presence or absence of macrophytes and wetland plants (including barnyard grass *Echinochloa crus-galli*, *Persecaria*, and cottonwood trees) was also noted.

Of the 283 evaluated polygons:

- 252 were playas or possibly playas.
- 48 were not playas (commission): 8 polygons were artifacts (ditches, slope of the land). The other 40 polygons were just not anything or so obstructed by crop we could not see it and doubted that a playa existed.
- 17 playas we encountered were not included in the PLJV polygons (omission).

We ranked the playas according to suitability for sampling, then determined landowners from on-line county accessor data. Letters requesting permission were mailed, and a representative from the Kansas Alliance for Wetland and Streams (KAWS) followed up with landowners that did not respond. From 91 letters sent to obtain permission to sample 80 playas, we received permission to sample 35 playas. We were denied permission by 17 landowners and did not hear back from the remainder.

During 13-15 Aug. 2018 we sampled 15 playas of size range 0.55 – 26.45 ha (mean 8.87 ha).

Selection of playas for 2019 sampling

To select sites to sample in 2019, we compiled the data from the west-central 2015 and northwest 2018 sites and explored the data for gaps in sizes, trends among parameters, etc. To standardize volume, depth, and area we used prepped LiDAR 2-m DEM (i.e. 3-by-3 median filtered and roads removed/smoothed over). To help facilitate 'sinkness,' DEM data were buffered 4 or 10 m from the 2013 boundaries for the sites sampled in 2015, from the 2017 boundaries for sites sampled in 2018 and 2019, and from the PLJV boundaries. Sinks were filled and the DEM subtracted from the filled DEM, with stats then extracted from the resulting sink depth grid. Six playas were in neither the PLJV nor PWA and therefore not delineated for size statistics.

We ultimately choose to use size data derived from the PLJV 4 m buffer. For the five 2015 sites not mapped by PLJV, we instead used size data derived from the 4m buffer around the 2013 boundaries. Graphing and mapping these sites revealed lack of large grass playas in the west-central area of Kansas (Fig. 5). We therefore targeted playas in the west-central region that were 8 - 40 acres, in grassland (which included CRP) according to the klcp2018l1 GIS layer, not in sandy soils, and located in Finney, Scott, Gray, Lane, and Haskell Counties.

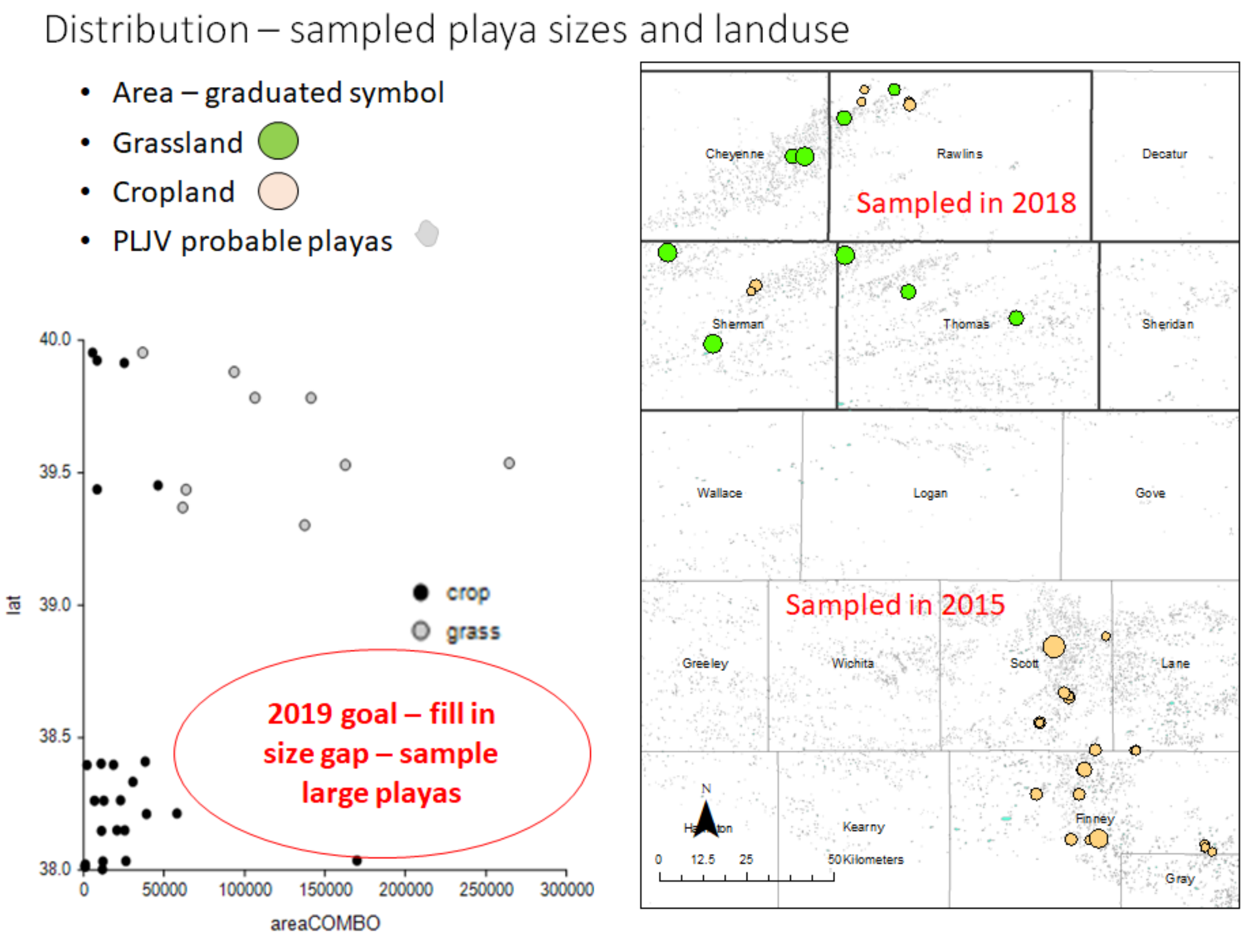


Figure 5. Graph of latitude vs. area of playas sampled in 2015 and 2018, and map of relative playa sizes coded by landuse, to determine where to sample in 2019.

During 25-27 June 2019 two crew members attempted to visit 86 of the PLJV possible playa polygons in Gray, Finney, Lane, Scott, and Haskell counties and noted landuse (crop or grass as pasture or CRP), soil condition (water, wet, mud, cracks), and plants (terrestrial, macrophytes).

Of these 86 evaluated polygons:

- 67 were playas
- 1 did not seem to be a playa
- 7 had very faint playa signatures so may or may not have been playas
- 11 we could not get close enough to for evaluation.

Of the playas marked in GIS as being in grassland, 23 were actually in non-irrigated crop land, and the playa itself may have been entirely cropped, or left uncropped (in some cases the LULC may have indicated that just the playa footprint itself was grass, while surrounding land was crop).

With the help of KAWS we contacted landowners of 41 playas to ask for permission to sample, obtained permission for 33 playas, and 7-9 Oct. 2019 sampled 15 playas.

Field methods

Field methods are detailed in the QAPP, and summarized here. See Appendix A for field forms.

Land use – We recorded land use within and surrounding each playa. Photos were taken at each playa.

Topography – Using a GPS unit, we obtained the latitude and longitude of the approximate center of each playa. We used a survey rod and rangefinder to determine depressional depth and length of the long and short axes.

Water – In situ water chemistry (water temperature, pH, DO, turbidity, specific conductance, salinity, and ORP) was measured with a Horiba U-52 at one site in the playa deep enough to properly submerse the probe.

Soil – From each playa, we collected a 20-inch sediment core for hydric determination by the University of Kansas soils lab in 2018, and by Kansas Geological Survey in 2019. Hydric soil evaluation followed the Natural Resources Conservation Service guidelines (USDA/NRCS 2018).

Macroinvertebrates – From each dry playa, a composited soil sample consisting of four subsamples was collected and cultured in the lab to check for macroinvertebrates in diapause (dormancy). From each wet playa, four one-meter D-frame kick net (500 um net) sweeps in representative habitat (vegetation or open water) were collected and composited. Samples were preserved in 10% formalin with rose Bengal stain, and transferred to alcohol in the lab. Specimens were identified to lowest practical level.

Vegetation – Vegetation was identified within ten 25-by-50 cm plots positioned along each playa axis, with the longer side of the sampling frame parallel to the axis. Plots were placed on alternating sides of the transect line to improve the probability of adequately sampling. Within each quadrat we estimated cover by plant species (or genus) as well as four other cover types: bare ground, water, litter, or duff. Percent canopy cover was recorded as one of six cover classes: 1=0–5%, 2=5–25%, 3=25–50%, 4=50–75%, 5=75–95%, 6=95–100% (Daubenmire 1959). Plant height was recorded using a meter stick. The plant that has the greatest height within each quadrant was measured to the nearest 1 cm. After completing 20 plot measurements, we surveyed the entire playa area in search of plant species that could have been missed within the quadrats. This additional survey allowed for a more complete plant list for each playa. A voucher collection made of each taxon encountered was verified by personnel from the R.L. McGregor Herbarium, University of Kansas, 2045 Constant Ave, Lawrence, KS 66047.

Wildlife – Birds associated with wetlands or water (red-winged blackbird, ducks, waders, etc.) were noted both during reconnaissance and during sampling, then tallied as present or absent. Sampling visits in 2019 were very windy and thus no birds were seen. Other wildlife seen was noted but not tallied.

Results

All data was compiled with the 2015 data in an MSAccess relational database. Statistical analyses were performed in NCSS (2013). The site list and raw data tables are presented in Appendix B. Geographic distribution and landuse are summarized in Table 3 and Fig. 6.

Table 3. Number of playas sampled in each region of Kansas (WC west-central, NW northwest), showing number that had water during the reconnaissance and sampling trips, and landuse within the playa.

		reconnaissance		sampled		within playa	
region	n	date	water	date	water	cropped	grass
WC	26	Aug. 2014	9	Jun. 2015	17	22	4
NW	15	Jun. 2018	6	Aug. 2018	3	6	9
WC	15	Jun. 2019	4	Oct. 2019	0	0	15

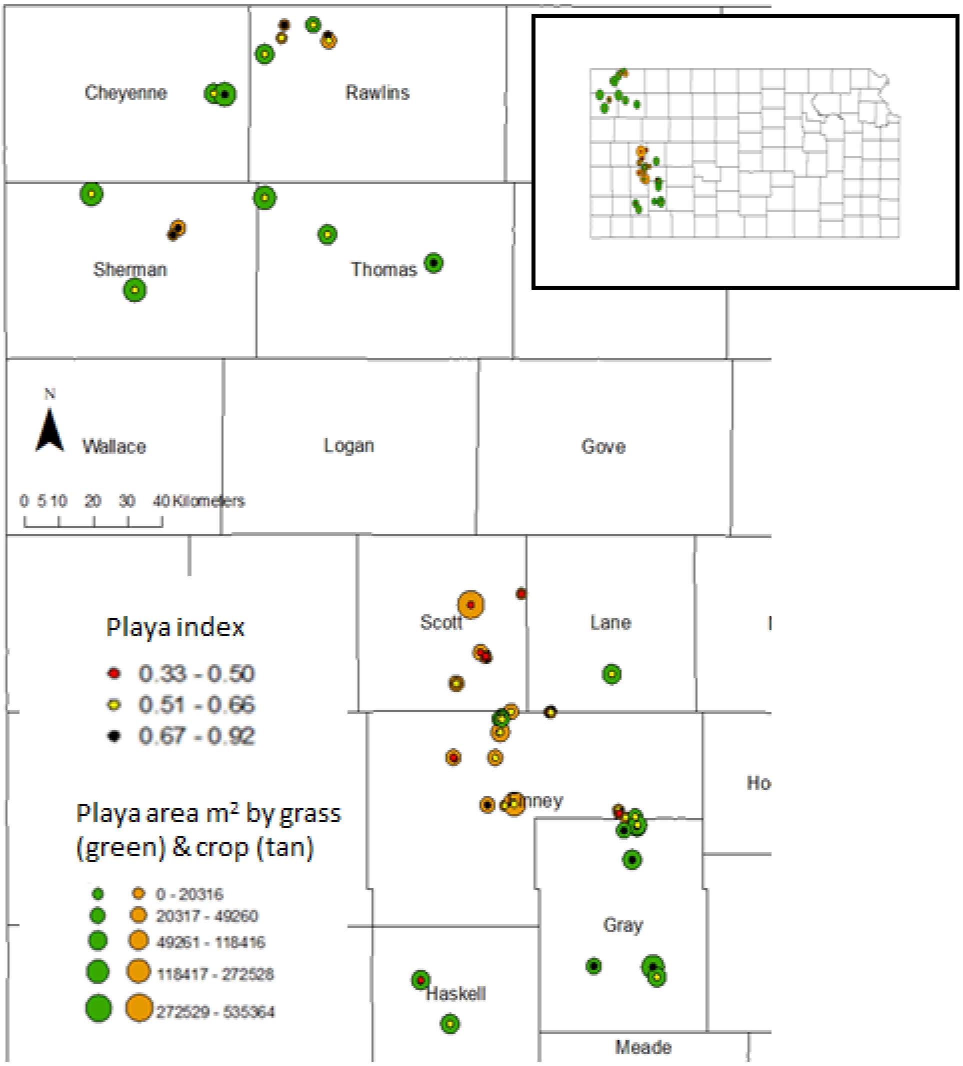


Figure 6. Distribution of sampled playas in western Kansas, by playa index interposed on size (area m^2), by landuse (grass/pasture or plowed/cropped) found within the playa.

Field parameters

Field parameters are briefly discussed here along with summary statistics. Raw data is presented in Appendix B. In 2019 all playas were dry at the time of our visit in October. Of the 20 playas in 2015 and 2018 that had water, one was too shallow to measure in situ water chemistry. Playas varied considerably in chemistry (Table 4). Macroinvertebrates sweep samples were collected only from these playas with water (Table 4). Since we could not collect samples from dry playas, we instead collected soil samples to hatch Branchiopods whose eggs survive desiccation. Branchiopods hatched from 25 of the 36 dry playas, and were found in 13 of the 20 wet playas. Since Branchiopods were the only taxa comparable between wet and dry playas, we considered only their presence or absence in the playa index.

Table 4. Descriptive statistics of in situ water chemistry in playas that had water, sampled in 2015, 2018, and 2019 in western Kansas.

	Count	**Mean**	**Median**	**Std Dev.**	**Std. Error**	**Minimum**	**Maximum**
water temperature C	19	27.25	28.86	4.87	1.12	20.47	36.23
dissolved oxygen mg/l	19	8.77	7.51	6.97	1.60	1.48	28.99
pH	19	8.37	8.29	0.69	0.16	7.50	10.39
conductivity mS/cm	19	0.197	0.183	0.124	0.029	0.044	0.445
salinity percent	19	0.01	0.01	0.01	0.00	0.00	0.02
turbidity NTU	18	453	350	416	98	20	999
oxidation reduction potential	19	80	96	100	23	-94	242
total dissolved solids g/l	19	0.129	0.117	0.084	0.019	0.028	0.296
macroinvertebrate taxa richness	20	16	16	6	1	5	27

Soil cores were collected to determine presence of hydric soils. Determination was uncertain for seven of the playas, while the remainder were split almost evenly between presence (24) of hydric soil and absence (23).

Wildlife use, especially aquatic and shorebird species, were noted at each site during both reconnaissance and the sampling visit. Amphibians or water-associated birds were heard or seen only at playas that had water, so that the majority were seen in the 2014/2015 visits, and primarily during the reconnaissance trips when the playas had water. Of the 56 playas ultimately sampled, 24 had birds commonly associated with water or wetlands: 19 playas in the 2014/2015 effort, two in 2018, and three in 2019. Notable was the conservation easement playa 3411 that had water depth of 33 cm in the center, with ten mallards, 30 blue-winged teal, one great blue heron, and 20 black-crowned night herons at the time of sampling in Aug. 2018. Additional birds seen were unknown ducks, American avocets (*Recurvirostra americana*), phalaropes (*Phararopus*), and also red-winged blackbirds (*Agelaius phoeniceus*) that were seen at most of the wet playas.

Approximately 120 plant taxa were noted in the playas (Appendix D). USFWS wetland indicator and coefficient of conservatism values for the region were assigned. Percent obligate (OBL) and facultative (FACW) wetland taxa were determined for each playa and incorporated into the playa index (Table 5). In 39 of the 56 playas we found at least one OBL or FACW taxon. The most commonly occurring OBL or FACW taxa (and number of sites) were *Eleocharis sp.* (17), *Marsilea vestita* (14), and *Persicaria bicornis* (9).

Table 5. Descriptive statistics of taxa richness of all plants, and taxa richness and percentage of just obligate (OBL) and facultative wetland (FACW) plants in playas sampled in 2015, 2018, and 2019 in western Kansas.

	Count	**Mean**	**Median**	**Std Dev.**	**Std. Error**	**Minimum**	**Maximum**
plant taxa richness	56	7	7	6	1	1	27
OBL FACW richness	56	1	1	2	0	0	8
OBL FACW percent	56	21	14	24	3	0	100

Playa index

One goal of this study was to identify potential physical and physiological similarities and differences between the two geographical (NW and WC) populations of playas. A second was to assess various spatial indicators (localized and catchment-scale) for their abilty to predict biological structure, ecological function, and condition. Thus to characterize the ecological condition of the playas, we used the playa index developed for the previous study. This index quantifies the degree of 'playa-ness' of each playa, in order to rank their health and give a score to explore statiscal correlations with spatial indicators of local and catchment sizes.

The playa index takes into account the presence of hydric soil and branchiopods, plant wetland indicator status, and land use. Each item was scored 1 (least playa-like condition) to 3 (most playa-like condition). Scores were summed and divided by a total possible score of 16 for all but those sites for which hydric soil was not examined (Table 6, raw data in Appendix B.).

- Cultivation within the playa was noted during the field assessment and scored as 1 if the site is cultivated (even if fallow) and 3 if not cultivated (no sign of planting, tracks, etc.). Further examination of sites in Google Earth satellite imagery through time (since 1991) revealed that some playas had occasionally been plowed, but for at least half the years examined had grass or pasture cover, with some grazed. A score of 2 was assigned to these playas.
- Percent obligate and facultative wetland plant taxa was divided into thirds, such that
    - 0 – 33.0% scores 1
    - 33 – 66.0% scores 2
    - >66% scores 3
- Hydric soil was scored as 1 not hydric or 3 hydric, with 2 assigned to possibly hydric.
- Branchiopod presence was scored as 1 not present or 3 present.

Table 6. Playa index ranges for each region in Kansas.

		landuse		index range		
region	sampled	crop	grass	0.33-0.50	0.51-0.66	0.67-0.92
NW	15	6	9	0	9	6
WC	41	26	15	16	19	6
total	56	32	24	16	28	12

The playa index serves as an assessment method to determine to what degree a shallow depressional waterbody shows characteristics of a playa. The lowest scoring playas are cropped through, highlighting a circular reasoning since the score depends on whether the depression is cropped or not. However, soil and biological condition also inform the index, and these low scoring playas, such as playa 5745, also did not have hydric soil, nor branchiopods or obligate wetland plant species (Fig. 1 and 2 in App. C). The highest scoring depressions were not plowed, and had hydric soils, branchiopods, and obligate wetland plant species. Playa 16598, which serves as a visual example of these depressions, also had bison which reflects the historic natural use of the playas (Fig. 3 and 4 in App. C).

Spatial indicators

We examined the area, depth, and volume calculated from the 4m buffer. These data were not normally distributed, not even within landuse type (crop or grass), so correlations were examined using Spearman Rank. Figure 7 shows distribution of sizes by region. Depth, area, and volume significantly correlated among each other (p = 0.00): volume and depth R = 0.87, volume and area R = 0.77, depth and area R = 0.47. One very large cropped playa (1435) skewed the data. To get a better visualization of playa sizes, we removed this and the next three largest playas (1435, 3923, 17275, 21251) from scatter plots of sizes (Fig. 8). In general grass playas were larger than crop playas, while the cropped ones had a tighter range of sizes. This makes sense given that farmers will more likely crop the small playas.

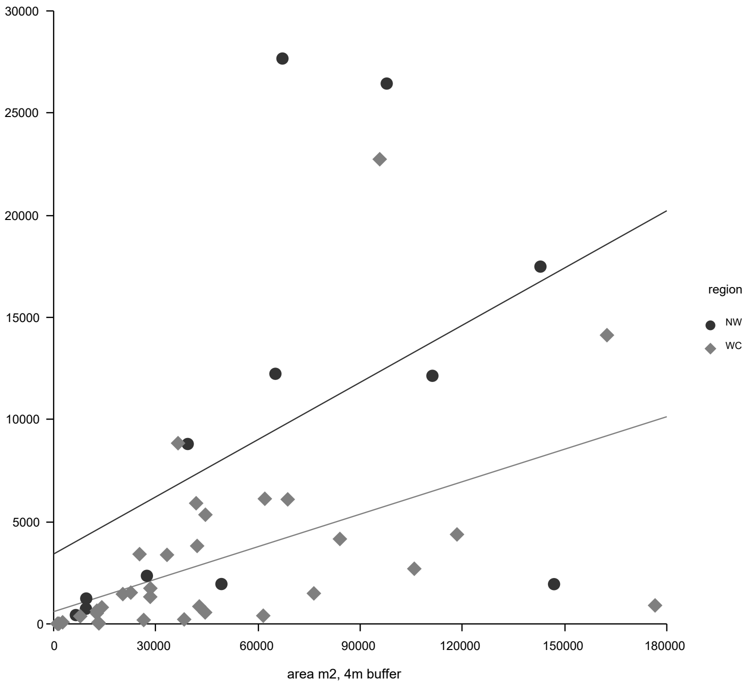


Figure 7. Volume m^3 and area m^2 by region northwest (NW, black) or west central (WC, gray) Kansas. Linear regression lines by region. Large playas 1435, 3923, 17275, 21251 were excluded.

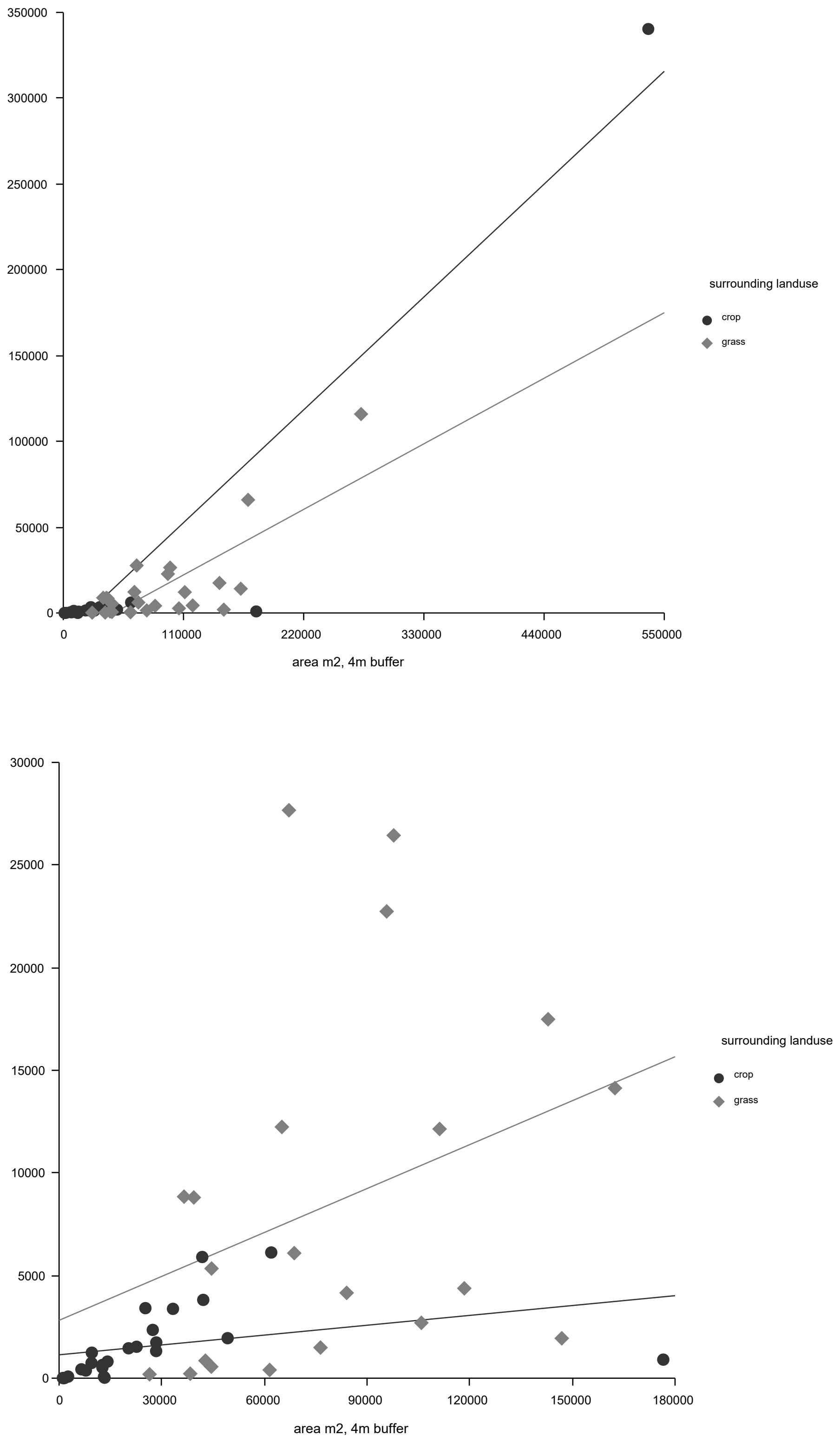


Figure 8. Volume m^3 and area m^2, by landuse, showing the large cropped playa 1435 as an outlier in the top plot. In the bottom plot, large playas 1435, 3923, 17275, 21251 were excluded. Linear regression lines are by surrounding landuse (black crop, gray grass).

Geographic and landuse differences

Descriptive statistics for playa size and index, by region and landuse, are presented in Appendix B Table 3. Playa size (area, depth, and volume) did not differ significantly between region (p>0.33) or landuse (p>0.08) alone, unless the four largest playas (1435, 3923, 17275, 21251) were removed from analyses, in which case depth and volume differed between regions (p = 0.00), and all three spatial statistics differed by landuse (p <0.01).

Next, notched box plots were generated to show the differences in playa size by landuse within each region (Fig. 9-11). Within the NW region, grass playas had significantly larger area and depth (p<0.04), but volume did not differ (p = 0.09). Within the WC region, none of these spatial indicators differed by landuse (p>0.34). However, since site selection was not random but was specifically targeted in 2019 for grassland playas in the west central region, it is difficult to extrapolate generalizations by region and landuse from the playas sampled for this study.

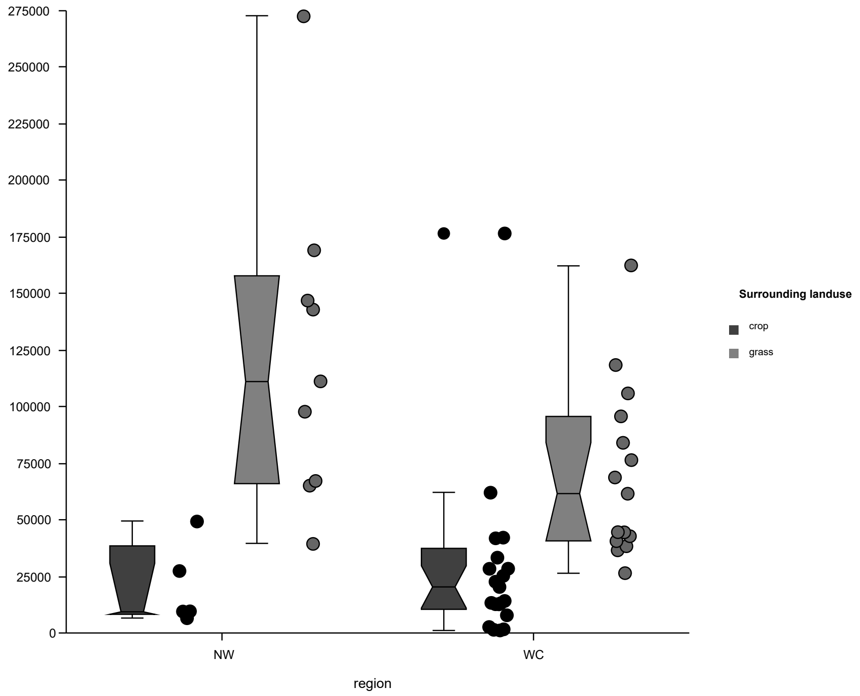


Figure 9. Notched box plots of playa area m^2, with sample points, for landuse (crop = black, grass = gray) within each study region in Kansas (NW northwest or WC west central). No sites were filtered from analyses, however severe outliers were cut off. Each pair of boxes for which the notched portions do not overlap has "statistically" different medians.

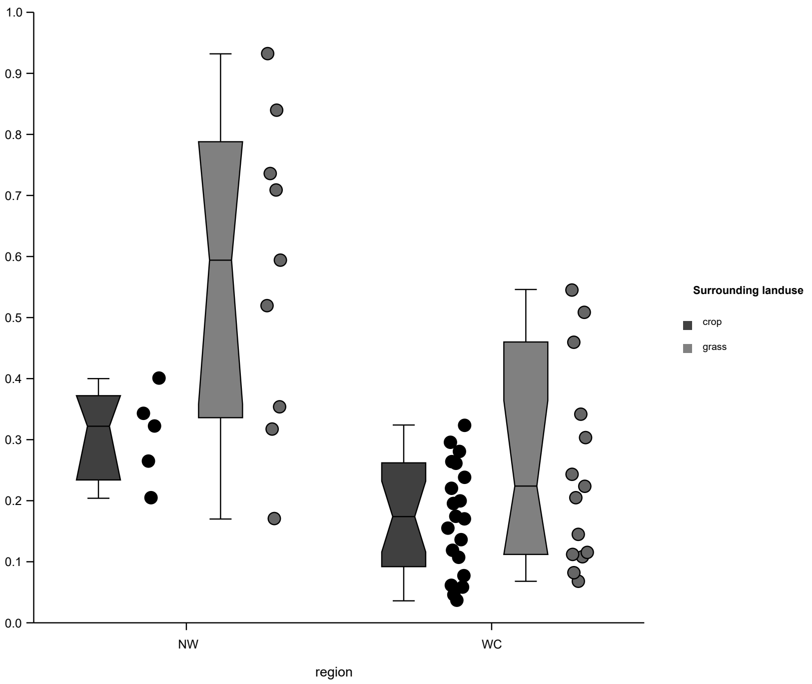


Figure 10. Notched box plots of playa depth m, with sample points, for landuse (crop = black, grass = gray) within each study region in Kansas (NW northwest or WC west central). No sites were filtered from analyses, however severe outliers were cut off. Each pair of boxes for which the notched portions do not overlap has "statistically" different medians.

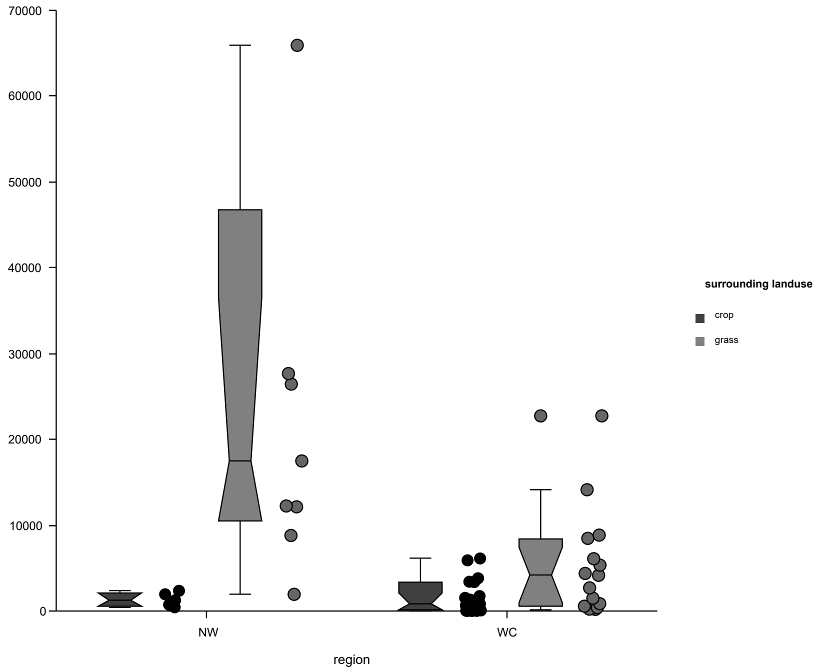


Figure 11. Notched box plots of playa volume m^3, with sample points, for landuse (crop = black, grass = gray) within each study region in Kansas (NW northwest or WC west central). No sites

were filtered from analyses, however severe outliers and all NW outliers were cut off. Each pair of boxes for which the notched portions do not overlap has "statistically" different medians.

Overall, playas in grass have a higher average playa index than playas in crop (mean 0.69 vs 0.58, p=0.00, Fig. 12). This relationship was stronger in the WC region, where the difference remained statistically significant (mean grass 0.69 vs 0.54 crop, p=0.00, Fig. 13). Within the NW region, the avereage index for playas in crop (0.76) was higher than for those in grass (0.68), though this was not statiscally significant (p=0.07). Surprisingly, all cropped playas in the NW had obligate wetland plants and branchiopods, while not all of the grass ones had these qualifiers.

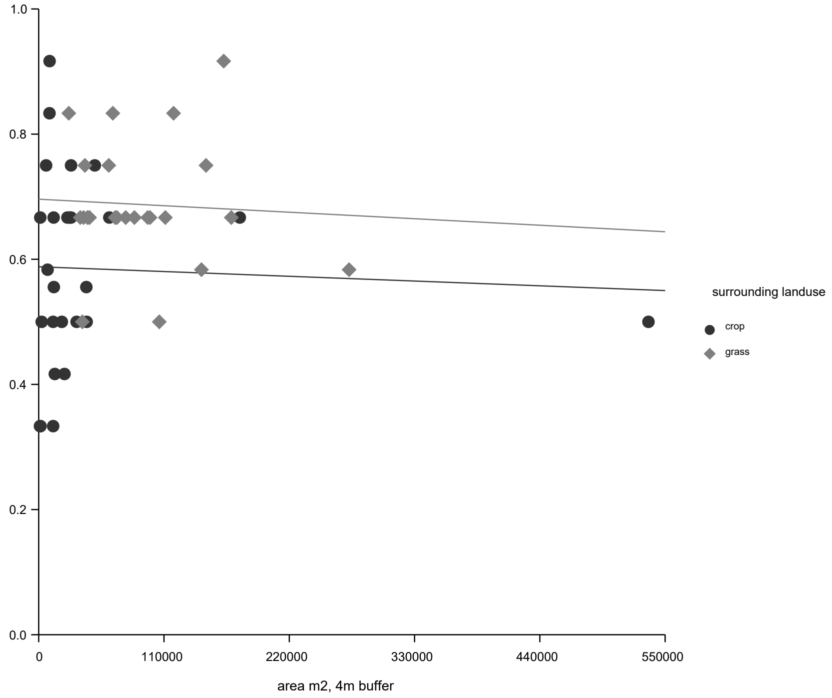


Figure 12. Scatter graph of playa index versus playa size m^2. Linear regression lines are by surrounding landuse (black crop, gray grass).

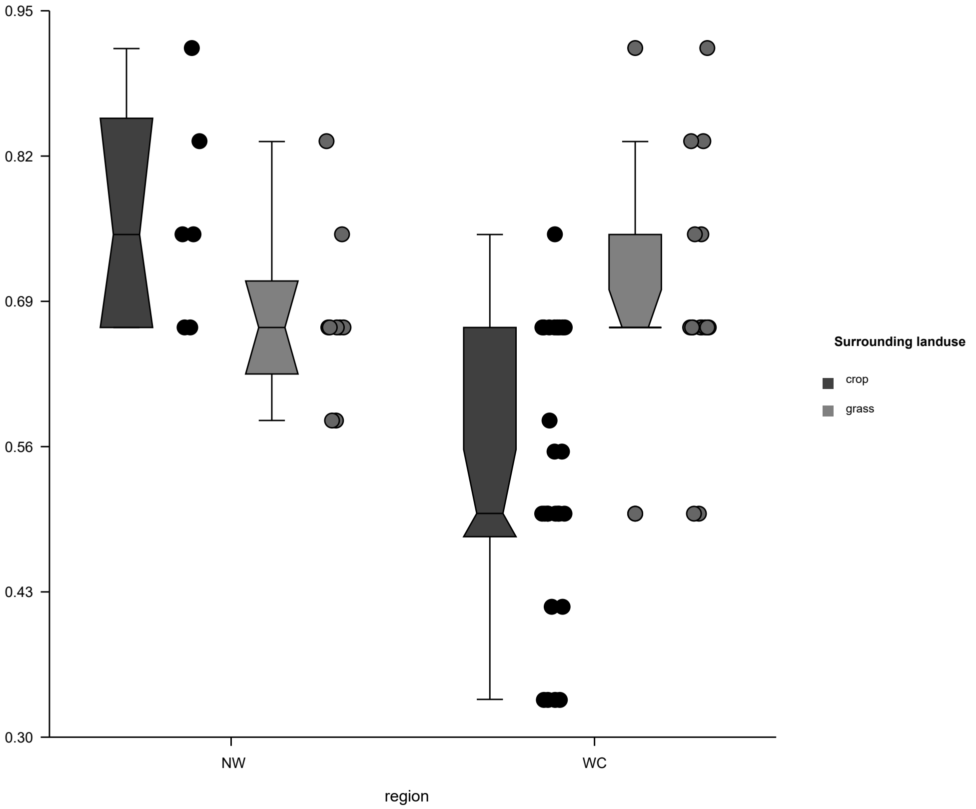


Figure 13. Notched box plots of playa index, with sample points, for landuse (crop = black, grass = gray) within each study region in Kansas (NW northwest or WC west central). Each pair of boxes for which the notched portions do not overlap has "statistically" different medians.

Discussion and conclusions

In addition to refining the inventory of potential playas and their catchments in Kansas, this study contrasts general ecological integrity of playas across sizes and regions of western Kansas. The playa index aids in assessment of playa ecological condition by examining the four factors of soil, macroinvertebrates, plants, and landuse. Follow up studies on the same sites (every 5 or 10 years) could indicate the persistence of this integrity, especially when contrasting disturbed versus undisturbed playas. Some short-comings in the application of these factors that could be improved with refinement of how the factors are applied, and with more consideration of past landuse.

One constraint of the playa index is that it uses *percent* obligate and facultative wetland (OBL & FACW) plants. However, five cropped (disturbed) playas had an OBL or FACW species as the only vegetation, either alone or in addition to Triticum (wheat). These species were *Marsilea vestita*, *Cyperus acuminatus*, or *Echinochloa muricata*. This resulted in a calculation of 50 to 100% of the vegetation as OBL or FACW which is misleading about the quality of this vegetation as wetland habitat. While *C. acuminatus* is an obligate wetland plant, and *Echinochloa muricata* is FACW, both tolerate disturbance. Using taxa richness of OBL and FACW instead of percent would strengthen the playa index, as the non-cropped playas had the most number of OBL and FACW species.

Five grassland playas surprisingly did not have OBL or FACW vegetation. We would like to explore if the use of glyphosate, or other disturbance mechanisms, is a factor in this. The herbicide glyphosate is commonly applied to rid fields of herbs (forbs), both for crop management and in ecological restoration, and if repeatedly applied will deplete the field of the seedbank (Rodriguez and Jacobo 2013, Gendron and Wilson 2007, Strehlow et al. 2017). Exploring if and when these OBL and FACW depauperate grassland fields were converted from cropland could indicate if past glyphosate applications or other disturbance mechanisms contributed to lack of OBL and FACW. From GoogleEarth coverage we determined that seven of the currently uncultivated playas had been cultivated in the recent past (since 1991). Only one of these (playa 3106) had OBL and FACW plants.

Also, branchiopods were found not only in 20 of the 29 currently uncultivated playas, but also 18 of the 27 currently cultivated playas, so perhaps are not a strong indicator of ecological health if they are also able to readily colonize any standing water. For example, O'Neill (2014) found no statistical difference in invertebrate metrics between natural playas and artificial waterbodies such as diches and stock ponds. This does not discount branchiopod importance as sources of food for migrating shorebirds in these ephemerally wet areas, but without additional habitat components (reviewed by Iglecia and Winn 2021) birds are less likely to access this food source.

Another constraint is the circular reasoning of using a disturbance factor, cultivation, as a defining factor of playa ecological health. Refining the index to include only biological responses such as wetland vegetation and aquatic macroinvertebrates may allow better characterization across a gradient of disturbance. Thus, in future characterization of playa health we would remove cultivation and adjust the biological response components. Disturbance could instead be an independent variable described by presence and absence of cultivation, livestock, and hydro connectivity such as road crossings, irrigation, or diversions within the playa boundary. We are currently involved in ecological characterization of an additional 15 playas for CD 97770301 which will add to this database and make for a more robust study to explore this.

This identification, determination, and characterization of Kansas playas and their watersheds provides information for managers to integrate into the Kansas WPP to aid in protection and enhancement of the State's wetland resources. Playas are less well understood than the state's other wetland types, and this increased knowledge of their ecological function, with respect to their location and *in situ* environment, will help the State and others to better educate the landowners responsible for their maintenance. Even playas that are cropped have elements of a wetland when standing water is present. These elements include aquatic macroinvertebrates and obligate or facultative wetland plants that aquatic and shorebirds and other wildlife use.

Goal 3. Prepare Final Report Action 1. Develop final report and datasets for dissemination. Jan-Jun 2020.

Outputs, outcomes, results

All of the action items established in the project workplan have been completed, as described in this final report. The following datasets are provided in the indicated links as outputs from this project.

1. A LiDAR-based potential playa inventory for western Kansas, in addition to estimated catchment delineations for playa-like features found in both the PLJV-PP dataset and in the LiDAR-based PPA dataset, and
2. A refined PLJV-PP dataset with anomalous, non-playa protrusion features eliminated.

Available at https://kars.ku.edu/media/downloads/Kastens/EPA_WPDG_2017_final_materials/.

3. A biological database that will help to inform the potential development of wetland water quality standards and will help to establish baseline conditions for Kansas playas. Available at http://biosurvey.ku.edu/characterizing-biological-structure-and-ecological-function-kansas-playas-year-1 and submitted as an MSAccess database.

The outcomes of this identification, determination, and characterization of Kansas playas and their watersheds and will allow the state to integrate this information into the WPP for the protection and enhancement of the State's wetland resources (See Project 2). Playas are less well understood than eastern wetlands and increased knowledge of their ecological function, with respect to their location and *in situ* environment, will help to better educate the landowners responsible for their maintenance.

Project management Action 0. Develop and secure EPA approval for QAPP before sampling begins. Jan.–Jun. 2018.

In June 2018 the USEPA approved the project QAPP.

Project management Action 1. Prepare quarterly reports. Jan 2018, April 2018, Jul 2018, Oct 2018, Jan 2019, Apr 2019, Oct 2019, Jan 2020, Apr 2020.

These were submitted to USEPA for each quarter.

Project management Action 2. Keep partners informed of progress. Jan 2018-2020.

We coordinated property access through the Kansas Alliance for Wetlands and Streams (KAWS) who contacted landowners in 2018 and 2019. At the invitation of NRCS and KAWS, PI Jude Kastens gave a presentation at the KAWS 3rd Annual Playa Tour and Workshop in Dodge City on January 10, 2019 and toured several impaired and restored wetlands upstream from Quivira National Wildlife Refuge, which has headwaters that extend into the KSG playa mask. KAWS, Ducks Unlimited, and other groups attended our annual meeting with USEPA on June 17, 2019 and were briefed on our progress and upcoming work. In Nov. 2019 Kastens and Debbie Baker (KBS) attended the Governor's Water Conference in Wichita, during which they were able to engage with a number of project stakeholders. During a session devoted to playas, Kastens gave a playa overview presentation that featured some of our work for this project and provided a progress update. Kastens attended and presented at the KAWS 4th Annual Playa Tour & Workshop in Garden City on January 15, 2020. Kastens also presented facets of this work at the Kansas Natural Resources Conference in Manhattan on January 30, 2020. We were able to engage with multiple stakeholders at these two events, including landowners, KAWS, PLJV, DU, and NRCS. In April 2020 KBS postcards were sent to landowners to thank them for access to their land. Also, a new user-group was identified for the PLJV and PPA catchment maps once they are completed. Kastens participated in a meeting with the Kansas Department of Agriculture – Division of Water Resources (KDA-DWR) to discuss hydrologic modeling problems that were being encountered during flood map updates for semi-arid northwest Kansas. Final field locations and datasets are available for partners and the public to download from the KBS website http://biosurvey.ku.edu/characterizing-biological-structure-and-ecological-function-kansas-playas-year-1.

Project management Action 3. Meet at least annually with EPA to review results.

An in-person meeting among KBS, KWO, and USEPA took place 17 June 2019. Other updates took place by email or phone call.

Project management Action 4. Write final report. Mar-Jun 2020.

Due to COVID-19 related country-wide shutdowns, a report deadline extension was granted until June 30, 2021.

Action 5. Submit final report. Jun 2020.

This is the final report.
Field data are submitted as a MSAccess database.
Zipped GIS files are available at
https://kars.ku.edu/media/downloads/Kastens/EPA_WPDG_2017_final_materials/

Action 6. Attend National Conference either 2019 or 2020.

We did not attend a national conference in 2019, and then COVID interrupted any chance of attending one in 2020.

Literature cited

Daubenmire, R.F. 1959. Canopy coverage method of vegetation analysis. Northwest Scientist. 33:43–64.

Gendron, F. and S.D. Wilson 2007. Responses to fertility and disturbance in a low-diversity grassland. Plant Ecol. 191:199–207.

Iglecia, M. and B. Winn. 2021. A shorebird management manual. Manomet. Mass., USA. 202pp.

Kastens, J.H, D.S. Baker, D.L. Peterson, and D.G. Huggins. 2016. Wetland Program Development Grant (WPDG) FFY 2013 – Playa Mapping and Assessment. KS Bio. Survey Report 186. 29pp.

NCSS 9 Statistical Software. 2013. NCSS, LLC. Kaysville, Utah, USA. ncss.com/software/ncss.

O'Neill, B. Community dynamics of ephemeral systems: food web drivers, community assembly, and anthropogenic impacts of playa wetlands. Master's Thesis, Univ. KS. 141pp.

Rodriguez, A.M. and E.J. Jacobo. 2013. Glyphosate effects on seed bank and vegetation composition of temperate grasslands. Appl. Vegetation Science. 16:51–62.

Strehlow, T., S. DeKeyser, and B. Kobiela. 2017. Managing Seedbank Composition to Enhance Wetland Restoration. Ecol. Restoration 35(1):12-16. https://www.muse.jhu.edu/article/648872

USDA/NRCS United States Department of Agriculture, Natural Resources Conservation Service. 2018. Field Indicators of Hydric Soils in the United States, Version 8.2. L.M. Vasilas, G.W. Hurt, and J.F. Berkowitz (eds.). USDA, NRCS, in cooperation with the National Technical Committee for Hydric Soils.

Appendix A. Field forms for playa assessment and vegetation survey.

Playa project KAN______ - QUANTITATIVE EVALUATION FORM

Site ID

County

Date

Crew

Hydrology notes, wet or dry

Crop notes (type and extent)

Water quality ____dry - none

Horiba model

Time (24hr)

Air temp C

Water temp C

DO mg/L

pH

Cond. mS/cm

Salinity %

Turbidity NTU

ORP

TDS

center latitude:

center longitude:

Photos

Macroinvertebrates

4 from water - composite ___*none*

1 m sweep in each of 3 dominant plant comm.

Plant communities sampled:

1

2

3

plus 4 open water

_____ # composited jars

OR 4 soil samples from dry playas

1 each from N, S, E, W

2cm deep x 15cm diam circle.

_____ # subsamples

_____ # composited bags

Location notes

Map of playa (landmarks, veg, water line, etc.)

Indicate actual dimensions for on-site eval.

Long axis: _______ m Short axis: _______ m Depressional depth: _______cm

Soil cores - single 20-in core from center of wet and dry playas.

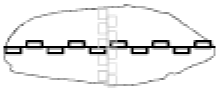
Notes:

Playa vegetation - axis LONG SHORT
Evaluator name ____________________

*Tallest plant in quadrant, to nearest cm.

Estimated % cover

1	0-5%	4	50-75%
2	5-25%	5	75-95%
3	25-50%	6	>95%



Site ID ____________
Date ____________

Long axis transect				
Plot	**Species**	**%cover**	**height***	**Press #**
1	Bare ground			
1	Water			
1	Litter			
1	Duff			
1				
1				
1				
1				
1				
1				
1				
1				
1				
2	Bare ground			
2	Water			
2	Litter			
2	Duff			
2				
2				
2				
2				
2				
2				
2				
2				
2				
3	Bare ground			
3	Water			
3	Litter			
3	Duff			
3				
3				
3				
3				
3				
3				
3				
3				
3				
4	Bare ground			
4	Water			
4	Litter			
4	Duff			
4				
4				
4				
4				
4				
4				
4				
4				
4				
5	Bare ground			
5	Water			
5	Litter			
5	Duff			
5				
5				
5				
5				
5				
5				
5				
5				
5				

Long axis transect				
Plot	**Species**	**%cover**	**height***	**Press #**
6	Bare ground			
6	Water			
6	Litter			
6	Duff			
6				
6				
6				
6				
6				
6				
6				
6				
6				
7	Bare ground			
7	Water			
7	Litter			
7	Duff			
7				
7				
7				
7				
7				
7				
7				
7				
7				
8	Bare ground			
8	Water			
8	Litter			
8	Duff			
8				
8				
8				
8				
8				
8				
8				
8				
8				
9	Bare ground			
9	Water			
9	Litter			
9	Duff			
9				
9				
9				
9				
9				
9				
9				
9				
9				
10	Bare ground			
10	Water			
10	Litter			
10	Duff			
10				
10				
10				
10				
10				
10				
10				
10				
10				

Appendix B. Data tables.

Table 1. Location and physical descriptors of all playas sampled. Northwestern Kansas playas were sampled in 2018, the remainder were in the west central region sampled in 2015 and 2019. Signs of plowing within (in) and surrounding (out) the playa indicated by y = yes, n = no. Index indicates playa condition described in the report, with hydric soils, cultivation (cult) within the playa, presence of branchiopods (branch.), obligate and facultative wetland plants (obl/facw) scored from 1 (not present or low amount) to 3 (present or high amount). Index is calculated from sum of scores divided by possible score.

					plowed		4 m buffer			playa index						
playa ID	date	latitude	longitude	wet/dry	in	out	area m2	depth m	vol. m3	hydric	cult	branch.	obl/facw	sum	possible	index
19	09-Jun-15	38.39629	-100.79013	dry	y	y	2640	0.14	78.59	1	1	3	1	6	12	0.50
37	11-Jun-15	38.02104	-100.44469	dry	y	y	1396	0.04	4.47	3	1	1	3	8	12	0.67
38	11-Jun-15	38.02146	-100.44617	dry	y	y				3	1	3	1	8	12	0.67
39	11-Jun-15	38.01253	-100.44472	dry	y	y	1116	0.06	9.14	1	1	1	1	4	12	0.33
40	11-Jun-15	38.01333	-100.44390	dry	y	y	1608	0.08	12.79		1	1	1	3	9	0.33
46	11-Jun-15	38.00279	-100.42699	wet	y	y	13120	0.05	66.95	3	1	3	1	8	12	0.67
60	11-Jun-15	38.26354	-100.62141	wet	y	y				1	1	1	1	4	12	0.33
61	11-Jun-15	38.26161	-100.62618	wet	y	y	14148	0.20	809.68	1	1	1	2	5	12	0.42
574	08-Jun-15	38.55405	-100.69873	wet	y	y				1	1	3	1	6	12	0.50
780	14-Aug-18	39.78488	-101.50287	wet	n	n	111196	0.32	12142.13	3	3	1	1	8	12	0.67
792	14-Aug-18	39.78268	-101.47409	dry	n	n	146904	0.17	1944.49	1	3	3	2	9	12	0.75
1019	09-Jun-15	38.39724	-100.79552	wet	n	y	20316	0.20	1458.19	1	1	3	1	6	12	0.50
1023	09-Jun-15	38.40280	-100.79254	wet	y	y				1	1	3	1	6	12	0.50
1026	09-Jun-15	38.40076	-100.79255	dry	y	y	12704	0.17	647.36	1	1	1	1	4	12	0.33
1253	09-Jun-15	38.40926	-100.80597	dry	y	y	42128	0.26	3815.60	1	1	3	1	6	12	0.50
1435	09-Jun-15	38.52660	-100.83093	wet	y	y	535364	1.91	340361.69	1	1	3	1	6	12	0.50
1604	15-Aug-18	39.95370	-101.31837	dry	y	y	6520	0.26	432.26	3	1	3	2	9	12	0.75
1611	15-Aug-18	39.95395	-101.24282	dry	n	n	39368	0.52	8805.11	1	3	3	1	8	12	0.67
1729	15-Aug-18	39.92452	-101.20428	dry	y	y	9480	0.40	740.06	3	1	3	3	10	12	0.83
1942	15-Aug-18	39.88200	-101.36986	dry	n	n	97784	0.59	26445.06	1	3	3	1	8	12	0.67
2005	10-Jun-15	38.14980	-100.76725	wet	n	y	28364	0.17	1323.48	3	1	3	1	8	12	0.67
2291	11-Jun-15	38.26140	-100.62183	wet	y	y	7816	0.12	373.93	3	1	1	2	7	12	0.58
2528	10-Jun-15	38.21125	-100.75817	wet	y	y	41836	0.32	5905.38		1	3	1	5	9	0.56
2529	10-Jun-15	38.21287	-100.75388	wet	y	y	62000	0.30	6123.85	3	1	3	1	8	12	0.67
2660	10-Jun-15	38.26311	-100.72600	wet	y	y	25224	0.28	3413.02	3	1	3	1	8	12	0.67
2792	10-Jun-15	38.33279	-100.86869	dry	y	y	33284	0.26	3378.94	3	1	1	1	6	12	0.50
2982	16-Jun-15	38.03166	-100.74194	wet	n	y	13296	0.06	24.87		1	3	1	5	9	0.56

					plowed		4 m buffer			playa index						
playa ID	date	latitude	longitude	wet/dry	in	out	area m2	depth m	vol. m3	hydric	cult	branch.	obl/facw	sum	possible	index
2983	17-Jun-15	38.03568	-100.71731	wet	y	y	176564	0.11	904.74	3	1	3	1	8	12	0.67
2989	13-Aug-18	39.45404	-101.59611	dry	y	y	49260	0.20	1950.60	3	2	3	1	9	12	0.75
3106	13-Aug-18	39.43732	-101.60883	dry	n	y	9572	0.34	1243.12	3	2	3	3	11	12	0.92
3411	14-Aug-18	39.30158	-101.70911	wet	y	y	142908	0.74	17486.20	3	2	1	1	7	12	0.58
3923	14-Aug-18	39.52797	-101.36971	wet	n	n	169116	0.71	65924.96	3	3	1	1	8	12	0.67
4519	13-Aug-18	39.43815	-101.20596	dry	n	y	67172	0.84	27670.00	1	3	3	1	8	12	0.67
4719	11-Jun-15	38.03359	-100.78745	wet	n	y	28400	0.22	1741.06	3	2	3	1	9	12	0.75
5186	13-Aug-18	39.36786	-100.92811	dry	n	y	65104	0.35	12240.60	3	3	3	1	10	12	0.83
5742	16-Jun-15	38.14780	-100.87424	wet	y	y	12660	0.16	519.67	3	1	1	1	6	12	0.50
5745	17-Jun-15	38.15037	-100.87709	dry	y	y	22652	0.24	1531.63	1	2	1	1	5	12	0.42
6104	10-Jun-15	38.33268	-100.86861	wet	y	y				3	1	3	1	8	12	0.67
10907	07-Oct-19	38.35542	-100.46280	dry	n	n	76396	0.11	1493.07	1	3	3	1	8	12	0.67
13016	07-Oct-19	38.25041	-100.75047	dry	n	n	36524	0.51	8844.11	1	3	3	1	8	12	0.67
13116	07-Oct-19	38.24625	-100.75606	dry	n	n	44560	0.34	5342.77	1	3	3	1	8	12	0.67
13122	07-Oct-19	38.24476	-100.74928	dry	n	n	42764	0.14	853.77	1	3	3	1	8	12	0.67
14369	08-Oct-19	38.00435	-100.40165	dry	n	n	44484	0.11	560.43	3	3	1	1	8	12	0.67
15675	08-Oct-19	37.60084	-100.96185	dry	n	n	38328	0.12	219.32	1	3	1	1	6	12	0.50
15677	08-Oct-19	37.60253	-100.96170	dry	n	n	105876	0.20	2698.81	1	3	1	1	6	12	0.50
16070	08-Oct-19	37.49435	-100.88535	dry	n	n	95732	0.46	22741.78	3	3	1	1	8	12	0.67
16598	08-Oct-19	37.98035	-100.39697	dry	n	n	118416	0.22	4378.35	2	3	3	2	10	12	0.83
16599	08-Oct-19	37.98465	-100.39583	dry	n	n	68720	0.24	6093.63	1	3	3	1	8	12	0.67
16669	08-Oct-19	37.97064	-100.43122	dry	n	n	26444	0.07	191.12	2	3	3	2	10	12	0.83
16943	08-Oct-19	37.89851	-100.40984	dry	n	n	61540	0.08	401.54	2	3	3	1	9	12	0.75
17275	09-Oct-19	37.63658	-100.50968	dry	n	n	40584	3.16	8464.33	2	3	3	1	9	12	0.75
17297	09-Oct-19	37.63498	-100.35521	dry	n	n	162440	0.30	14131.13	3	3	3	2	11	12	0.92
17376	09-Oct-19	37.60962	-100.34525	dry	n	n	84036	0.55	4156.93	2	3	1	2	8	12	0.67
21200	15-Aug-18	39.91559	-101.20239	dry	y	y	27380	0.32	2353.15	3	1	3	1	8	12	0.67
21251	14-Aug-18	39.53778	-101.82181	dry	n	n	272528	0.93	115930.20	1	2	3	1	7	12	0.58
100016	15-Aug-18	39.92242	-101.32555	dry	y	y				2	2	3	1	8	12	0.67

Table 2. Flora, fauna, and water chemistry. Birds n = no, y = presence of water-associated birds (red-winged blackbird, ducks, waders, etc.). Obligate and facultative wetland plants shown as taxa richness and percent of all plant richness.

	macroinv.		all plant	obl & facw		in situ water chemistry							
playa ID	richness	birds	richness	richness	percent	water temp C	DO mg/l	pH	cond. mS/cm	salinity	turb NTU	ORP	TDS
19		n	3	0	0								
37		n	1	1	100								
38		n	3	0	0								
39		n	1	0	0								
40		n	1	0	0								
46	14	y	9	0	0	29.88	6.44	8.29	0.128	0.01	990	-48	0.08
60	22	y	1	0	0	20.47	2.33	7.66	0.398	0.02	51	-30	0.26
61	16	y	2	1	50	20.95	4.03	8.07	0.309	0.01	19.5	96	0.2
574	8	y	12	1	8	36.23	6.94	8.52	0.094	0	131	190	0.06
780	23	y	7	2	29	28.86	28.99	8.76	0.445	0.02	38.6	140	0.29
792		n	17	8	47								
1019	5	y	5	1	20	27.7	8.24	8.39	0.052	0	999	190	0.03
1023	19	y	5	0	0	33.43	9.38	8.19	0.133	0.01	155	242	0.09
1026		y	12	1	8								
1253		y	9	1	11								
1435	13	y	1	0	0	20.93	6.17	7.99	0.133	0.01	999	204	0.09
1604		n	2	1	50								
1611		n	10	2	20								
1729		n	1	1	100								
1942		n	18	2	11								
2005	14	y	6	1	17	29.68	7.8	8.49	0.197	0.01	999	56	0.12
2291	17	y	2	1	50	21.9	1.64	7.81	0.322	0.02	45	-15	0.21
2528	27	y	7	1	14	29.7	8.74	8.39	0.133	0.01	999	110	0.09
2529	19	y	1	0	0	29.33	3.34	7.91	0.183	0.01	350	85	0.12
2660	14	y	3	1	33	25.26	7.16	7.91	0.076	0	150	82	0.05
2792		n	1	0	0								
2982	18	y	7	2	29	31.08	11.72	9.11	0.083	0	463	117	0.05
2983	23	y	1	0	0	22.2	7.51	7.85	0.415	0.02		-94	0.3
2989		n	8	1	13								
3106		n	6	4	67								
3411	13	y	8	2	25	24.98	23.92	10.4	0.187	0.01	367	1	0.12

	macroinv.		all plant	obl & facw		in situ water chemistry							
playa ID	richness	birds	richness	richness	percent	water temp C	DO mg/l	pH	cond. mS/cm	salinity	turb NTU	ORP	TDS
3923	8	n	19	1	5								
4519		n	8	2	25								
4719	16	y	8	0	0	32.26	11.68	9.45	0.044	0	999	107	0.03
5186		n	21	2	10								
5742	26	y	18	2	11	31.54	9.11	8.42	0.21	0.01	42	169	0.14
5745		n	7	1	14								
6104	9	y	7	1	14	21.3	1.48	7.5	0.198	0.01	350	-80	0.13
10907		n	6	2	33								
13016		n	6	1	17								
13116		n	6	0	0								
13122		n	4	0	0								
14369		n	9	3	33								
15675		n	4	0	0								
15677		y	6	1	17								
16070		n	11	3	27								
16598		n	5	2	40								
16599		y	10	3	30								
16669		n	9	5	56								
16943		n	9	1	11								
17275		n	10	3	30								
17297		n	10	5	50								
17376		y	14	6	43								
21200		n	3	0	0								
21251		n	27	1	4								
100016		n	2	0	0								

Table 3. Descriptive statistics for area, depth, and volume based on a 4m buffer of the playa polygon, and playa index, by region in Kansas (NW or WC) and by surrounding landuse (crop or grass). (No sites were filtered out).

	Count	Mean	Median	Std Dev.	Std. Error	Minimum	Maximum
	landuse_srd=crop						
4m_area_m2	26	46110	17232	105547	20700	1116	535364
4m_depth_m	26	0.26	0.20	0.35	0.07	0.04	1.91
4m_volume_m3	26	14586	1074	66467	13035	4	340362
playa index	32	0.58	0.57	0.15	0.03	0.33	0.92
	landuse_srd=grass						
4m_area_m2	24	89955	72558	57495	11736	26444	272528
4m_depth_m	24	0.49	0.33	0.62	0.13	0.07	3.16
4m_volume_m3	24	15382	7279	25738	5254	191	115930
playa index	24	0.69	0.67	0.10	0.02	0.50	0.92
	region=NW						
4m_area_m2	14	86735	66138	76047	20324	6520	272528
4m_depth_m	14	0.48	0.38	0.24	0.07	0.17	0.93
4m_volume_m3	14	21093	10474	32484	8682	432	115930
playa index	15	0.71	0.67	0.09	0.02	0.58	0.92
	region=NW, landuse_srd=crop						
4m_area_m2	5	20442	9572	18102	8096	6520	49260
4m_depth_m	5	0.31	0.32	0.08	0.03	0.20	0.40
4m_volume_m3	5	1344	1243	805	360	432	2353
playa index	6	0.76	0.75	0.10	0.04	0.67	0.92
	region=NW, landuse_srd=grass						
4m_area_m2	9	123564	111196	70435	23478	39368	272528
4m_depth_m	9	0.57	0.59	0.26	0.09	0.17	0.93
4m_volume_m3	9	32065	17486	36540	12180	1944	115930
playa index	9	0.68	0.67	0.08	0.03	0.58	0.83
	region=WC						
4m_area_m2	36	59541	37426	91946	15324	1116	535364
4m_depth_m	36	0.33	0.20	0.58	0.10	0.04	3.16
4m_volume_m3	36	12585	1476	56378	9396	4	340362
playa index	41	0.59	0.67	0.14	0.02	0.33	0.92
	region=WC, landuse_srd=crop						
4m_area_m2	21	52221	20316	116858	25501	1116	535364
4m_depth_m	21	0.25	0.17	0.39	0.08	0.04	1.91
4m_volume_m3	21	17738	905	73946	16136	4	340362
playa index	26	0.54	0.50	0.12	0.02	0.33	0.75
	region=WC, landuse_srd=grass						
4m_area_m2	15	69790	61540	37867	9777	26444	162440
4m_depth_m	15	0.44	0.22	0.77	0.20	0.07	3.16
4m_volume_m3	15	5371	4157	6250	1614	191	22742
playa index	15	0.69	0.67	0.11	0.03	0.50	0.92

Appendix C. Photo essay of low vs. high playa index sites 5745 (PI = 0.42) and site 16598 (PI = 0.83).

Figure 1. Playa site 5745 on 29 August 2014 during reconn (left, with wheat surrounding) and on 22 June 2015 (right) during sampling.

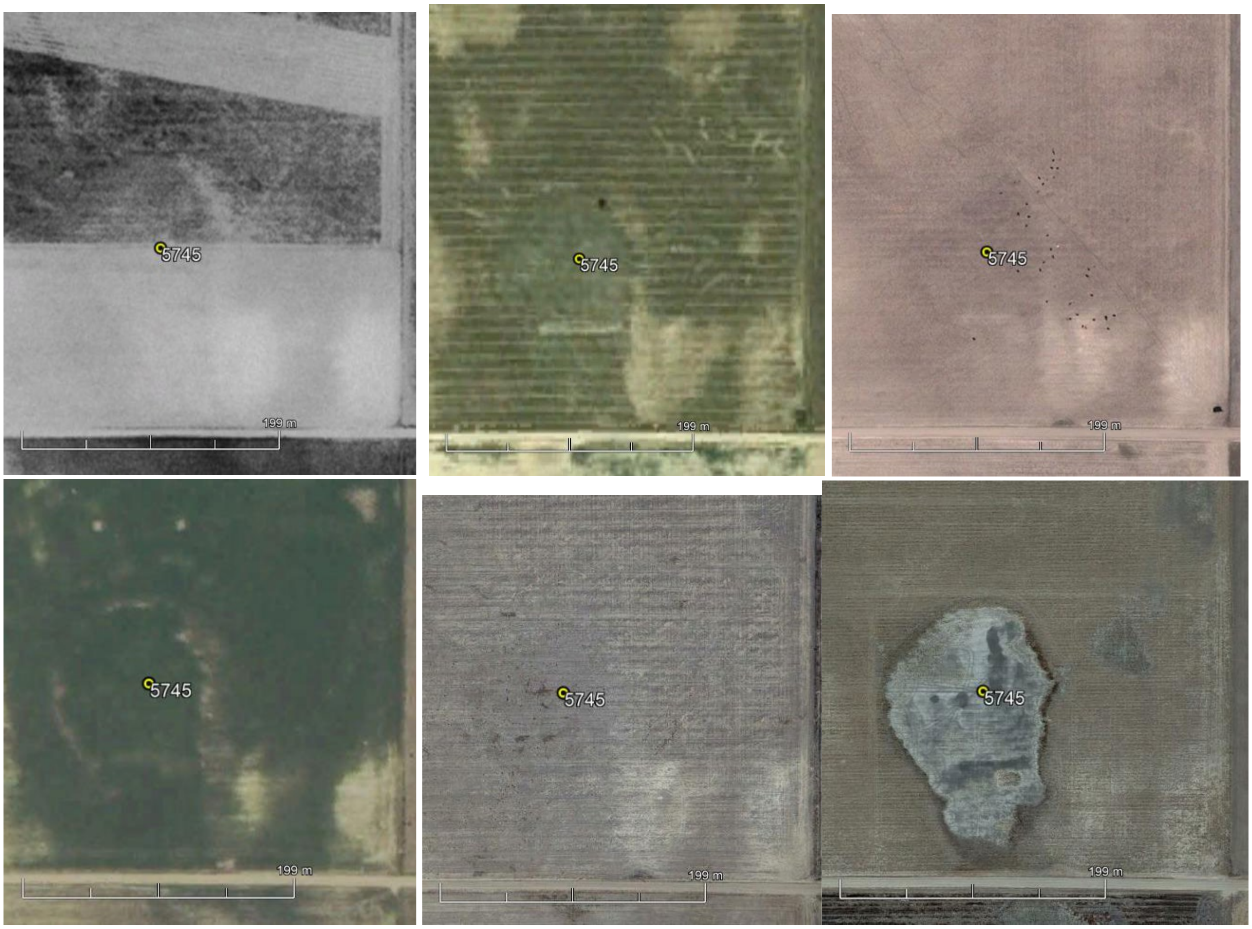


Figure 2. Historic imagery from GoogleEarth. Top row left to right: July 1991, Aug. 2003, July 2006. Bottom row left to right: July 2008, Sep. 2012, Oct. 2019. Photo width approximately 300m.

Figure 3. Playa site 1 on 26 June 2019 during reconn (left, bison in it) and on 8 Oct. 2019 (right) during sampling.

Figure 4. Historic imagery from GoogleEarth. Top row left to right July 1991, Aug. 2003, Aug 2006. Bottom row left to right Mar. 2012, July 2014, July 2017. Photo width approximately 750m.

Appendix D.

Table 1. Plant taxa presence (1) within each playa boundary. CoC is the coefficient of conservatism for Kansas. USFWS wetland indicator codes (Ind): FAC = facultative, FACU = facultative upland, FACW = facultative wetland, NS = no status, OBL = obligate wetland, UPL = upland.

Species	CoC	Ind	19	37	38	39	40	46	60	61	574	780	792	1019	1023	1026	1253	1435	1604	1611	1729	1942	2005	2291	2528	2529	2660	2792	2982	2983	2989	3106	3411	3923
Amaranthus								1								1													1		1			
Amaranthus albus	0	FACU																													1			1
Amaranthus palmeri	0	FACU																													1			1
Amaranthus retroflexus	1	FACU															1						1		1									
Ambrosia grayi	0	FAC						1			1	1	1		1			1		1		1			1	1		1			1		1	1
Ammannia auriculata	4	OBL																																
Ammannia coccinea	2	OBL																																
Apocynum																																		
Aristida purpurea		UPL																																
Asclepias latifolia	4	NS																																
Asclepias pumila	2	NS																																
Asclepias subverticillata	1	FACU																																
Bouteloua curtipendula		UPL																																
Bouteloua gracilis	5	NS																																
Bromus inermis	*	FACU																				1												
Bromus japonicus	*	FACU										1	1									1												
Bromus tectorum																																		
Buchloe dactyloides	3	FACU																		1														1
Carduus nutans	*	FACU																																
Carex											1	1																						
Carex accumulatus		UPL																																
Carex brevior	5	FAC																				1												
Carex gravida	4	NS																																
Chamaesyce glyptosperma		UPL																																
Chamaesyce nutans		FACU																		1														
Chamaesyce serpens		FACU																																1
Chenopodium berlandieri		UPL																																
Chenopodium pratericola	3	NS						1								1																		1
Cirsium vulgare	*	UPL																																
Convolvulus arvensis	*	NS																					1		1									
Convolvulus sp.																																		
Conyza canadensis	0	NS						1					1			1						1	1										1	
Coptochloa															1																			
'crabgrass'											1																							
Cyperus acuminatus	0	OBL																			1											1		
Cyperus lupulinus			1																															

Species	CoC	Ind	19	37	38	39	40	46	60	61	574	780	792	1019	1023	1026	1253	1435	1604	1611	1729	1942	2005	2291	2528	2529	2660	2792	2982	2983	2989	3106	3411	3923
Dalea purpurea		UPL																																
Descuraina sophia								1																										
Descurainia pinnata		UPL																																
Echinochloa																																		
Echinochloa crus-galli	*	FACW																																
Echinochloa muricata		FACW											1						1												1	1	1	
Echinochloa oleraceae		UPL											1																					
Echinochloa or Loptochloar or Setaaria											1						1																	
Echinocloa								1			1			1		1																		
Echinocloa muricata								1																					1					
Eleocharis		OBL											1							1		1												
Eleocharis acicularis	5	OBL											1							1		1												
Eleocharis macrostachya	3	OBL										1	1														1		1					1
Elymus canadensis																																		
Eragrostis cilianensis	*	FACU																																1
Euphorbia corollata	5	NS																																
Euphorbia davidii	0	NS																				1												
Euphorbia marginata	0	FACU																		1		1												1
Euphorbia sp.																																		
Grindelia squarrosa		UPL																																
Helianthus annuus	0	FACU										1	1									1											1	
Hordeum jubatum	1	FACW											1																					
Hordeum pursillum																																		
Juniperus virginiana	1	UPL																																
Kochia scoparia	*	FACU														1	1					1					1							
Lactuca serriola	*	FAC			1																	1											1	
Leptochloa													1																					
Longifolia physilus		UPL																																
Lythrum californicum																	1																	
Marsilea vestita		OBL		1						1	1		1			1	1						1	1					1			1		
Melilotus																																		
Oenothera canescens	3	FAC			1								1										1											1
Panicum capillare		FAC																																
Panicum dichotomiflorum	0	FAC																		1														1
Panicum virgatum	4	FAC																																
parsley leaf thing (not milfoil)											1																							
Pascopyrum smithii	2	FACU											1							1		1											1	1
Persicaria								1				1		1	1	1											1					1		1
Persicaria bicornis	1	FACW											1																1					
Persicaria lapathifolia	2	OBL																															1	
Persicaria pensylvanica	2	FACW												1																		1		
Phyla cuneifolia	3	FAC																		1		1												1
Physalis longifolia		UPL																																

Species	CoC	Ind	19	37	38	39	40	46	60	61	574	780	792	1019	1023	1026	1253	1435	1604	1611	1729	1942	2005	2291	2528	2529	2660	2792	2982	2983	2989	3106	3411	3923
Poa sp.																																		
Polygonum aristratum		UPL																																1
Polygonum aviculare	*	FACU																																1
Polygonum ramosissimum	2	FACW											1																					
Polygonum sp.																																		
Populus deltoides	0	FAC																															1	
Portulaca oleracea	1	FAC													1	1																		1
Portulaca pilosa																																		
Proboscidea louisianica	0	FACU															1												1		1			
Ranunculus											1																							
Rorippa sinuata																									1				1					
Rumex crispus	*	FAC											1																					
Salsola																1						1												
Salsola tragus																																		
Setaria			1																															
Setaria viridis		UPL																				1												
Solanum elaeagnifolium	3	NS																																
Solanum rostratum	0	NS															1			1														1
Sorghum																															1			
Sporobolus cryptandrus	0	FACU-	1																															
Symphyotrichum subulatum		OBL																																
Taraxacum																																		
Tragopogon dubius	*	NS																				1												
Tribulus terrestris	*	NS																													1			
Triticum						1	1	1	1	1	1			1	1	1			1					1	1					1		1		
Trogopogon dubius																							1		1									
Typha																																		
Typha angustifolia	0	OBL										1																						
unknown grass																									1									
unknown prostrate herb														1																				
unknown sedge											1																							
unknown seedling					1						1						1																	
unknown stumpyplant											1																							
Verbena bracteata	0	FACU																				1												1
Veronica peregrina																1																		
Zea mays																1	1																	

Species	4519	4719	5186	5742	5745	6104	10907	13016	13116	13122	14369	15675	15677	16070	16598	16599	16669	16943	17275	17297	17376	21200	21251	100016
Amaranthus		1		1	1																	1	1	
Amaranthus albus													1								1			
Amaranthus palmeri	1		1									1												
Amaranthus retroflexus																1								
Ambrosia grayi		1		1	1	1	1	1	1		1				1	1		1	1	1	1	1	1	
Ammannia auriculata											1													
Ammannia coccinea				1																	1			
Apocynum																		1						
Aristida purpurea																							1	
Asclepias latifolia																			1					
Asclepias pumila											1													
Asclepias subverticillata														1		1							1	
Bouteloua curtipendula																							1	
Bouteloua gracilis																							1	
Bromus inermis																								
Bromus japonicus																							1	
Bromus tectorum				1																				
Buchloe dactyloides							1	1	1	1	1			1		1		1	1		1			
Carduus nutans																							1	
Carex																								
Carex accumulatus																	1							
Carex brevior																								
Carex gravida			1																					
Chamaesyce glyptosperma																							1	
Chamaesyce nutans																								
Chamaesyce serpens																								
Chenopodium berlandieri	1		1																	1				
Chenopodium pratericola				1																				
Cirsium vulgare			1																					
Convolvulus arvensis			1			1										1							1	
Convolvulus sp.																	1							
Conyza canadensis			1	1					1			1	1					1					1	
Coptochloa																								
'crabgrass'																								
Cyperus acuminatus																								
Cyperus lupulinus																								
Dalea purpurea																							1	
Descuraina sophia				1																				
Descurainia pinnata									1	1														
Echinochloa														1										
Echinochloa crus-galli																				1	1			

Species	4519	4719	5186	5742	5745	6104	10907	13016	13116	13122	14369	15675	15677	16070	16598	16599	16669	16943	17275	17297	17376	21200	21251	100016
Echinochloa muricata	1																		1					
Echinochloa oleraceae	1																							
Echinochloa or Loptochloar or Setaaria																								
Echinocloa																								
Echinocloa muricata																								
Eleocharis														1	1	1	1	1	1	1	1			
Eleocharis acicularis																								
Eleocharis macrostachya			1				1																	
Elymus canadensis						1																		
Eragrostis cilianensis																								
Euphorbia corollata																		1						
Euphorbia davidii																							1	
Euphorbia marginata																								
Euphorbia sp.															1									
Grindelia squarrosa																			1					
Helianthus annuus	1		1											1										
Hordeum jubatum			1								1						1						1	
Hordeum pursillum				1																				
Juniperus virginiana			1																					
Kochia scoparia			1			1																	1	1
Lactuca serriola			1																				1	
Leptochloa			1																				1	
Longifolia physilus																1								
Lythrum californicum																								
Marsilea vestita											1					1			1		1			
Melilotus																							1	
Oenothera canescens			1	1	1		1	1	1	1				1			1	1	1	1	1		1	
Panicum capillare		1		1								1	1											
Panicum dichotomiflorum			1												1									
Panicum virgatum	1		1								1													
parsley leaf thing (not milfoil)																								
Pascopyrum smithii	1		1				1	1	1	1	1	1	1			1	1	1	1	1	1		1	
Persicaria		1		1																1	1			
Persicaria bicornis	1			1										1	1		1			1	1			
Persicaria lapathifolia																								
Persicaria pensylvanica																								
Phyla cuneifolia								1																
Physalis longifolia																							1	
Poa sp.											1													
Polygonum aristratum																								
Polygonum aviculare														1										
Polygonum ramosissimum							1	1								1	1			1				
Polygonum sp.													1	1										

Species	4519	4719	5186	5742	5745	6104	10907	13016	13116	13122	14369	15675	15677	16070	16598	16599	16669	16943	17275	17297	17376	21200	21251	100016
Populus deltoides																								
Portulaca oleracea			1																					
Portulaca pilosa				1																				
Proboscidea louisianica		1			1																			
Ranunculus																								
Rorippa sinuata				1	1	1																		
Rumex crispus																								
Salsola																							1	
Salsola tragus				1																				
Setaria																								
Setaria viridis			1																		1		1	
Solanum elaeagnifolium																							1	
Solanum rostratum		1	1	1																				
Sorghum																								
Sporobolus cryptandrus						1																	1	
Symphyotrichum subulatum													1	1			1			1	1			
Taraxacum			1																				1	
Tragopogon dubius																							1	
Tribulus terrestris																								
Triticum				1		1																1		1
Trogopogon dubius																								
Typha														1					1		1			
Typha angustifolia																								
unknown grass		1																						
unknown prostrate herb																								
unknown sedge																								
unknown seedling		1			1																			
unknown stumpyplant																								
Verbena bracteata				1														1						
Veronica peregrina																								
Zea mays																								