Technical Report

Managing risk and maximizing return; decision support for conservation of dynamic wetland landscapes in southern Oregon and northeast California

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Introduction

Managing risks associated with conservation investments has become an essential component of contemporary resource planning. Successful investments now demand outcome-based evaluations and properly managed portfolios to justify public expenditures necessary to communicate advances in natural resource conservation. These expectations pose new challenges to landscape conservation goals that often depend on maintenance of ecological processes that are inherently dynamic and difficult to predict. Across the western United States enormous sums of money have been spent on the protection and restoration of wildlife habitats, yet few conservation groups link past expenditures to beneficial outcomes. Sustaining future conservation funding will depend on resource managers' ability to minimize investment risk and demonstrate outcomes by incorporating ecological uncertainties into the planning process (Adams et al. 2014).

The seasonal dynamics of water resources poses specific challenges to conservation strategies that assume static returns on investments made in wetland systems. Climatic variability in the West drives annual precipitation and snowpack that falls below 75% of normal one of five years (Rajagopalan and Lall 1998). Snowpack is the driver of natural and working wetlands (i.e. flood irrigated hay meadows) that rely on melt water from mountain snows to flood productive valley bottoms during spring and early summer. The stochastic nature of climate underlying wetland flooding in the West leads to unpredictability in timing and duration of seasonal inundation that influences trends in range productivity and wildlife habitats. Complex irrigation infrastructure (i.e. canals, head gates, small dams) and water rights governing irrigation practices can further compound predictability of private working wetlands that encompass the majority of wetland resources in the West (Donnelly et al. 2018).

Waterfowl migrating through the semi-arid the West utilize rare wetland/riparian (herein 'wetland') landscapes located between breeding and wintering grounds. Birds spend days to weeks in these areas in spring and fall accumulating resources needed to carry them into wintering and breeding cycles. Climate-driven variation underlying these landscapes create unpredictable wetland conditions around which migratory birds have evolved their life history. Birds annually seek out favorable habitat conditions that influence migration pattern and habitat use. Birds unable to obtain adequate resources during migration may reach wintering or breeding grounds in poor body condition impacting their overwinter survival and breeding success (Sedinger and Alisauskas 2014).

Until recently, broad scale efforts to conserve waterfowl migration habitats have been unable to account for patterns of seasonal wetland dynamics that link the timing of wetland availability (i.e. flooding) to the chronology of bird migration through landscapes. Under these scenarios investment risk is assumed when potential misalignment of conservation actions and bird needs occur due to the lack of information needed to predict when and how often individual wetlands are flooded or dry. Emerging conservation science supported by the Natural Resources Conservation Service (NRCS) and the Intermountain West Joint Venture (IWJV) are overcoming these challenges by providing new and efficient approaches to landscape monitoring of dynamic seasonal wetland systems. In this report we outline development and application of spatiotemporal models that for the first time examine long-term patterns of seasonal flooding in natural and working wetland systems in the West. We link these patterns to waterfowl migration chronology as decision support to optimize conservation investment strategies by identifying wetland targets with the greatest potential benefit to migrating birds (Donnelly et al. in press). In addition, we use General Land Office plats to reconstruct ca. 1870 wetland footprints as a conservation guide that links historic and contemporary wetland values that are mutually beneficial to wildlife and ranching.

Project Area

The project area consists of southern Oregon, northeast California and northwest Nevada, (hereafter ‘SONEC’, Fig. 1). The SONEC region is an important area to migratory birds in North America supporting ~70% of the Pacific Flyway’s population of migratory waterfowl (>6 million birds). Regional wetlands act as an important migratory hub for waterbirds, connecting western North American wintering and breeding grounds The area is characterized by Mediterranean type climate patterns with cold winter precipitation and hot dry summers. Wetland flooding is driven by accumulating high elevation snowpack and spring runoff. Most wetlands are flooded seasonally, late winter through early summer, after which evaporative drying reduces their availability. Wetland resources are concentrated in productive valley bottoms across ownership boundaries including large, publicly managed wildlife refuges. Private wetlands were made up primarily of flood irrigated hay meadows managed for livestock forage and cattle ranching. Patterns of wetland flooding can be influenced by variability in annual precipitation trends that average three quarters of normal 20% of years (Miller et al. 1991).

Modeling wetland dynamics

Spatiotemporal dynamics of wetland flooding was modeled from 1984 to 2015 using remote sensing Landsat Thematic Mapper satellite imagery. Surface water extent was measured using constrained spectral mixture models (Adams and Gillespie 2006) that allowed a proportional estimation of water contained within a 30x30 meter pixel grid (Jin et al. 2017). This approach provided a more accurate account of flood extent when only a proportion of surface water was visible due to interspersion of emergent vegetation; a characteristic common to shallow seasonal wetlands of the West. Grid cells were considered flooded if surface water proportion were ≥ 20%. This was done to overcome reduced accuracy rates in grid cells with proportionately low surface water occurrence that resulted in false positives and over estimations of wetted footprints (Donnelly et al. in press).

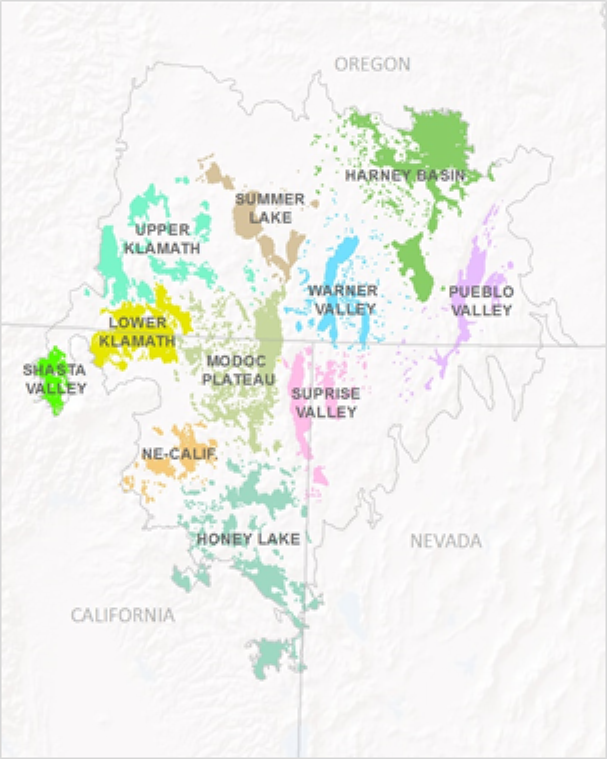


Figure 1. SONEC project area. Polygons represent a conglomerate of wetland and riparian features associated with seasonal wetland habitats. Colors identify regions used to summarize wetland and waterfowl data as defined by (Fleskes and Gregory 2010).

Spectral mixture models were partitioned by multi-year oscillations in above and below average precipitation trends (Fig. 2). Trends were derived from SNOTEL data collected from 14 local sites. Wetland response was averaged within these periods and divided into approximately 30 day intervals correlated to calendar months (January to November - December omitted). Applying this approach made it possible to isolate climate driven ecological means influencing wetland response (i.e. drought) and simultaneously reduced the potential of monitoring gaps resulting from poor quality Landsat data. Final analyses resulted in monthly wetland monitoring within six distinct climatic periods over a continuous 32 year span.

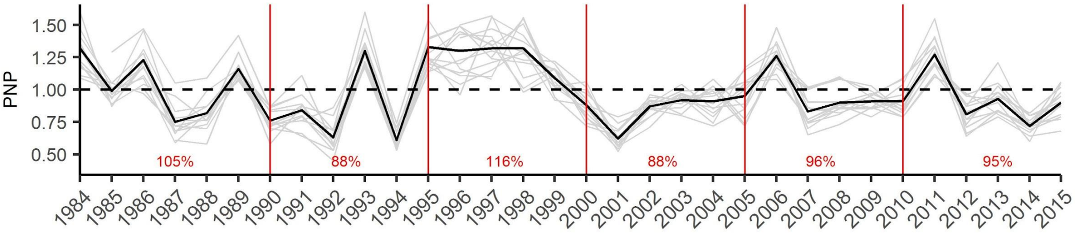


Figure 2. Mean percent normal precipitation (PNP) trend within study area - solid black line. Red lines mark beginning of climate periods used to average wetland response. Gray lines represent precipitation variance from individual SNOTEL sites used in trend estimation. Mean PNP for individual periods shown in red text.

Gridded estimations of wetland flooding were filtered spatially by clipping their extent to digitized wetland, riparian, and agricultural boundaries; hereafter '*wetland polygons*'. This process eliminated the potential of false water positives in the model by removing anthropogenic features (e.g. buildings, and asphalt) and topographic shadow known to be misclassified as water (DeVries et al. 2017). Surface water acres were then summarized within wetland polygons. This process was repeated for all months and climate periods to link long-term hydrologic patterns to potential wetland sites identified. Wetland polygons were produced as a derivative of National Wetlands Inventory (NWI) data and digitized agricultural field boundaries. Agricultural field boundaries were representative of irrigated rangelands (e.g. wet meadows/hay meadows) and other agricultural practices known to provide seasonal wetland habitats. The aggregation of agricultural and NWI boundaries provided an exhaustive representation of wetland features occurring within the project footprint. All polygons were labeled by ownership (public or private) with public lands identified by administrative agency.

Accuracy was assessed by visually inspecting 500 randomly distributed points within the study area to determine rates of omission and commission in surface water detection. Points were stratified first by month to evaluate potential seasonal differences in detection rates and second by surface water proportions estimated by the model. For example pixels estimating 20-40% water were stratified from those estimating 80-100% surface water. This was done to determine if detection rates differed among proportion of surface water estimated. Landsat imagery was used to evaluate presence and absence of water because higher resolution imagery was not available at the same temporal interval needed to complete the assessment.

Habitat objectives

Long-term timing and distribution patterns of seasonal wetland flooding were used to restructure existing habitat objectives developed by the IWJV for spring migrating dabbling ducks: American wigeon (*Anas americana*), gadwall (*Anas strepera*), green winged teal (*Anas carolinensis*), mallard (*Anas platyrhynchos*), and northern pintail (*Anas acuta*; (Petrie 2013). Prior to this analysis conservation outcomes had been evaluated through assessment of bioenergetic carrying capacity and did not consider timing of wetland resource availability (i.e. flooding). To account for variation in seasonal flooding and its synchrony with spring waterfowl migration chronology, existing habitat objectives were proportionately redistributed within the months of February, March, and April (Table 1). Distributions were allocated in proportions equal to the monthly dabbling duck abundance in SONEC derived from biweekly aerial surveys acquired in 2002 and 2003 (Fleskes and Yee 2007). Restructured habitat objectives were then combined with seasonal wetland flooding patterns to target sites that best aligned timing of resource availability and species need.

Table 1. SONEC habitat objectives for spring migrating dabbling ducks. Total need is proportioned by month (February-30%, March-50%, April-20%) and distributed within regions (*see* Fig. 1). Omitted are Honey Lake, Lower Klamath, Pueblo Valley, Shasta Valley, and Surprise Valley that currently lack habitat objects.

	FEB	MAR	APR	TOTAL
Modoc Plateau	4,050	6,750	2,700	13,500
Harney Basin	1,590	2,650	1,060	5,300
NE California	2,940	4,900	1,960	9,800
Upper Klamath	5,190	8,650	3,460	17,300
Summer Lake	2,490	4,150	1,660	8,300
Warner Valley	3,150	5,250	2,100	10,500
TOTAL	19,410	32,350	12,940	64,700

Reconstructing historic wetland landscapes

Reconstruction of historic wetland sites was completed by assembling ca.1870 General Land Office (GLO) survey plats in a GIS. Individual plat maps were geo-rectified covering wetland regions in SONEC (Fig. 3). Wetland features were extracted through on screen digitizing of plats and interpretation of accompanying surveyor field notes. Individual features were labeled in accordance to the original surveyor's description of the site (e.g. wet sagebrush flat, alkali flat, tule swamp, etc...). Final products were intended to inform private lands conservation that link historic and contemporary wetland values that are today mutually beneficial to wildlife and ranching.

Outcomes

Wetland flooding varied dramatically by season with average peak occurrence in May (563,509 acres) 7.4 times greater than the average low in October (75,897 acres; Fig. 3). Flooding trends exhibited stable long-term patterns over the study period (Appendix A, B) with the exception of drought from 1990-94. Wetland flooding trends were stable on state and federal wildlife refuges with the exception of Lower Klamath that showed a significant decrease in flooded area beginning in 2010 (see Appendix C and D; Klamath-Lower, public wetlands).

Model accuracy ranged from 93% to 98%. Accuracies were lowest in areas of lower surface water proportions (20-30%). Overall accuracy was estimated at 95%. High accuracy was attributed model confinement within known wetland sites that eliminated the potential of false positives correlated to non-wetland features (e.g. buildings, and asphalt) and topographic shadow known to be misclassified as water (DeVries et al. 2017).

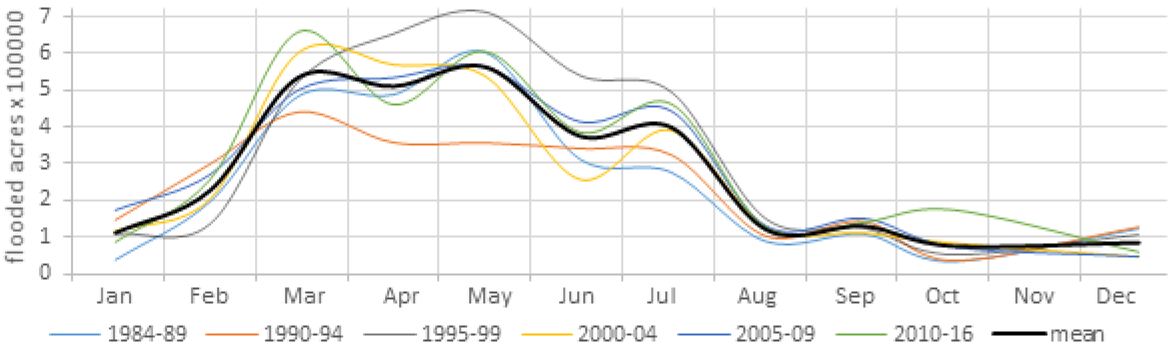


Figure 3. Flooded seasonal wetland acres by period (see Fig. 2) and long-term mean (1984-2016).

Private lands associated with flood irrigated hay meadows made up over half the flooded seasonal wetland resources during spring (51%) and fall (58%) waterfowl migration periods (Table 2). Managed and unmanaged seasonal wetlands on public lands made up 14% and 35% of flooded acres during spring and 13% and 29% during fall periods respectfully. Little evidence was identified supporting loss of flooded seasonal wetlands on private lands due to land use practices shifting from flood to sprinkler irrigation. A post-hoc analysis was conducted that examined patterns of annual flooding (from 1984-2015) on all center pivots existing prior to 2015. Approximately 500 acres of spring flooded wetlands were identified as lost. Sites attributed to conversion using wheel walker sprinkler systems were not included in the analysis and may also have contributed to potential loss. Observations suggest minimal impact of sprinkler conversion on seasonal wetlands linked to private flood irrigated hay meadows.

Table 2. Average flooded acres; seasonal wetlands in SONEC 1984-2016.

	Feb	Mar	Apr	mean	∝ acres	Sep	Oct	Nov	mean	∝ acres
public - mgd	50,299	76,552	82,965	69,932	14%	19,431	14,654	48,793	27,617	13%
public - unmgd	100,776	210,477	197,015	169,413	35%	64,556	49,276	66,262	60,024	29%
private	295,740	196,467	255,859	249,279	51%	78,196	41,334	246,400	121,944	58%

Over 2 million acres of ca.1870s wetland features were reconstructed form GLO plat data within SONEC (Fig. 4). Flood irrigated hay meadows made up the largest proportion (~60%) of sites (Table 3). This spatial correlation affirms long held beliefs that irrigated rangelands occur within the footprint of historic wetland resources of the West. Seasonal wetlands occurring in historic sites accounted for 56% and 53% of all flooded wetland acres in spring and fall respectively. GLO surveys provided important insight to past landscape condition, but cannot be considered exhaustive in there delineation of wetland features. Seasonal wetland systems occurring outside historic footprints should not be interpreted as artificial. Contemporary wetland features not identified are likely to have existed historically, but were undocumented by 1870’s surveyors.

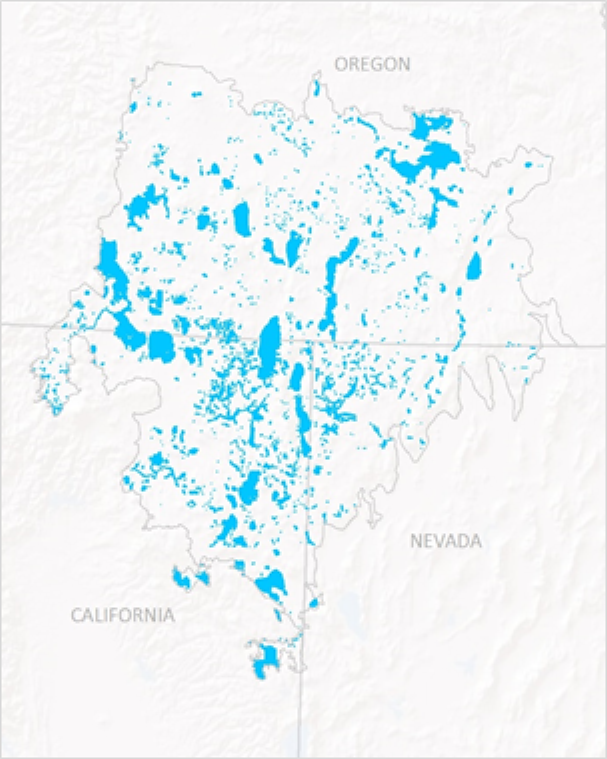


Figure 4. Historic ca. 1870 wetland extent (blue polygons) in SONEC.

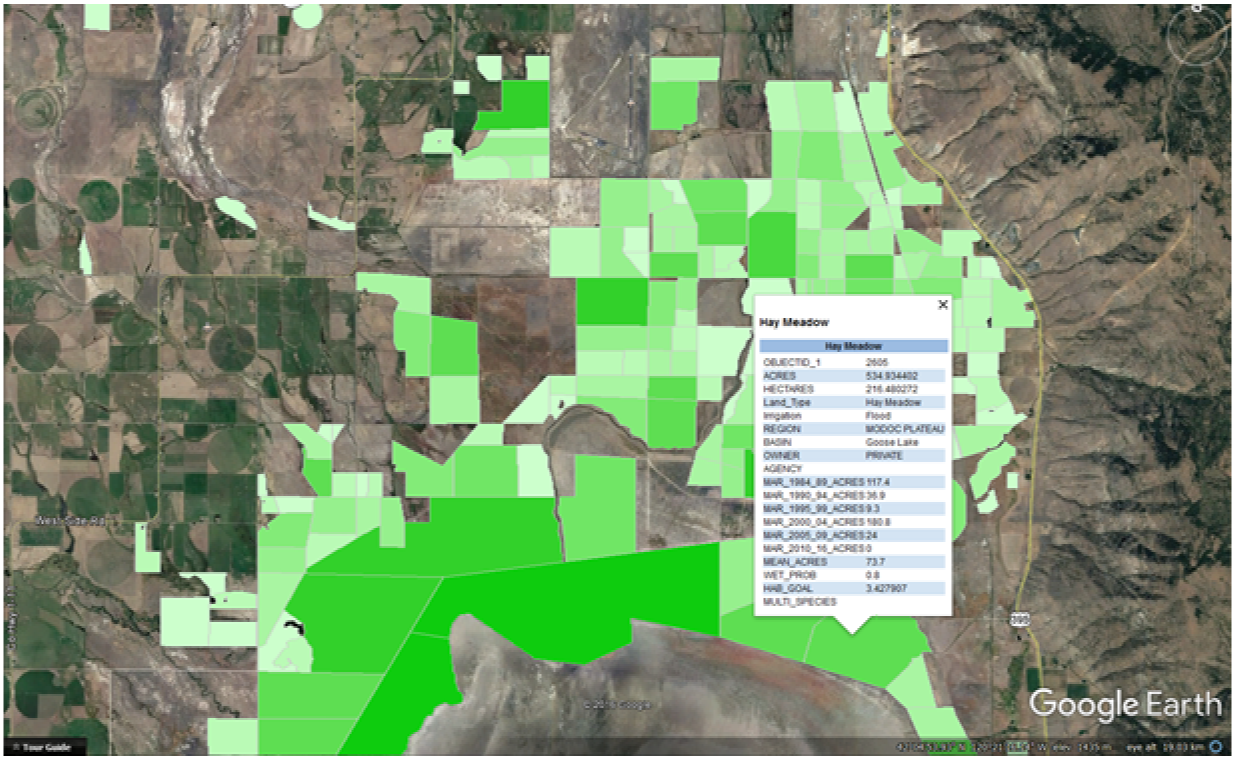
Conservation decision support

The decision support tool (DST) provided with this report incorporates trends in long-term wetland dynamics that reduces ecological uncertainty in conservation investment by identifying wetlands with the greatest potential benefit to migrating waterfowl. For the first time conservation actions may be considered from a perspective of timing in resource availability that can be linked to species life cycle needs. Tool users are able to view an interactive map to examine monthly availability of flooded wetland features during spring migration periods. DST attributes include; mean flooded acres for each time period examined (e.g. 1984-89), mean flooded acres for entire study period (1984-2016), and the annual probability of flood occurrence. This information provides user flexibility in conservation planning that may be applied to support specific species needs. For example; targeting of February flooding may be emphasized to ensure benefits of landscape resiliency are maintained to support depressed northern pintail populations (Fig. 5). Maps may be used as a guide to private landowner outreach or evaluation tool to support conservation program delivery.

Table 3. Contemporary land use within historic ca. 1870 wetland footprints. Summaries do not include alkali lake beds that exhibit ecological characteristics similar to those documented in the 1870's.

Contemporary land use	acres	∝ acres
Crop	154,618	10%
Wetland /managed wetland	484,431	30%
Hay meadow	952,120	60%

Understanding long-term patterns of wetland flooding allows the DST to estimate conservation potential of individual wetland features (Fig 6). The estimate determines proportion of the regional habitat objective (*see* Table 1) provided by a wetland if conserved. Calculations consider long-term ecological uncertainty of the site and scale outcomes to the probability of seasonal flooding. For example; a site estimated to provide 400 acres of flooded seasonal wetlands would be valued at 200 acres if the probability of wetland flooding was 50%. Providing this information removes speculation and improves investment efficiencies that may act as a guide to select wetlands of high conservation value. DSTs are provided as .kmz files to be used with the freely available Google Earth app. run on computer, tablet, or smartphone. On screen navigation may be implemented to guide site based evaluation while traveling in the field if used with GPS enabled devices.



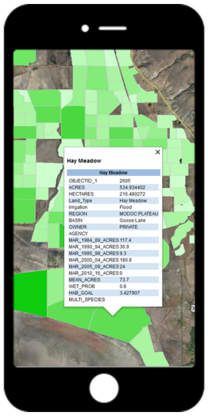
Hay Meadow

Hay Meadow	
OBJECTID_1	2605
ACRES	534.934402
HECTARES	216.480272
Land_Type	Hay Meadow
Irrigation	Flood
REGION	MODOC PLATEAU
BASIN	Goose Lake
OWNER	PRIVATE
AGENCY	
MAR_1984_89_ACRES	117.4
MAR_1990_94_ACRES	36.9
MAR_1995_99_ACRES	9.3
MAR_2000_04_ACRES	180.8
MAR_2005_09_ACRES	24
MAR_2010_16_ACRES	0
MEAN_ACRES	73.7
WET_PROB	0.8
HAB_GOAL	3.427907
MULTI_SPECIES	

Figure 6. Decision support tool displaying March flooded acres within agricultural field boundaries, Goose Lake Basin, OR. The darker green the color, the more wetland acres occurring within the polygon. Selecting individual polygons opens a data sheet (blue and white table) depicting associated patterns of wetland flooding (1984-2016), probability of flooding annually in March, and an estimate of contribution to existing habitat objectives.

KMZ metadata summary

Included are five KMZ files of SONEC wetland and historic wetland summaries for use in Google Earth desktop and mobile app. Software may be downloaded to computers or mobile devices for free. General instructions on how to download software and use KMZ files are available on the web. Viewing KMZ files in the field on a mobile device with Google Earth may require use of Google Drive and installation of the Google Drive app on your Android or iPhone in order to access data.



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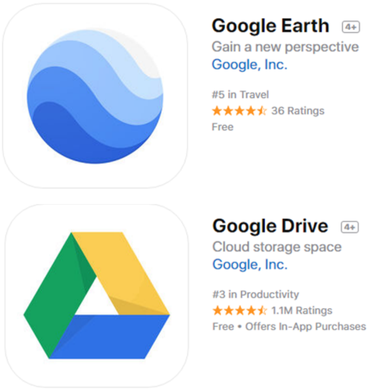
MAR_2005_09_ACRES	24
MAR_2010_16_ACRES	0
MEAN_ACRES	73.7
WET_PROB	0.8
HAB_GOAL	3.427907
MULTI_SPECIES	



KMZ - Google Earth files

wetFEB-DST.kmz[1] - February wetland dynamics (1984-2016) and waterfowl habitat objectives
wetMAR-DST.kmz - March wetland dynamics (1984-2016) and waterfowl habitat objectives
wetAPR-DST.kmz - April wetland dynamics (1984-2016) and waterfowl habitat objectives

- **STATE** - state containing polygon feature
- **REGION** - region containing polygon feature (e.g. MODOC PLATEAU see Fig. 1)
- **BASIN** - sub-region within region containing polygon feature (e.g. Goose Lake)
- **OWNER** - binary ownership, ‘Public’ or ‘Private’
- **AGENCY** - land management agency linked to polygon (e.g. BLM)
- **ACRES** - polygon area calculated as acres
- **FEB_1984_89_ACRES** - mean flooded acres in polygon from Feb 1984 to 1989
- **FEB_1990_94_ACRES** - mean flooded acres in polygon from Feb 1990 to 1994
- **FEB_1995_99_ACRES** - mean flooded acres in polygon from Feb 1995 to 1999
- **FEB_2000_04_ACRES** - mean flooded acres in polygon from Feb 2000 to 2004
- **FEB_2005_09_ACRES** - mean flooded acres in polygon from Feb 2005 to 2009
- **FEB_2010_16_ACRES** - mean flooded acres in polygon from Feb 2010 to 2016
- **MEAN_ACRES** - mean flooded acres in polygon from Feb from 1984 to 2016
- **WET_PROB** - Probability of wetland flooding occurring in FEB from 1984 to 2016
- **HAB_GOAL** - Proportion of spring waterfowl goal linked to polygon feature
- **MULTI_SPECIES** - Potential for multi wildlife conservation benefits (e.g. sage-grouse)

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[1] Data structure similar for wetFEB-DST, wetMAR-DST, and wetAPR-DST. Symbology set by MEAN_ACRES with darker greens correlated to higher values. Zero values are not visible.

wetSONEC_DST - SONEC monthly (Feb-Nov) wetland flooding and irrigation history
STATE - state containing polygon feature
REGION - region containing polygon feature (e.g. MODOC PLATEAU see Fig. 1)
BASIN - sub-region within region containing polygon feature (e.g. Goose Lake)
OWNER - binary ownership, ‘Public’ or ‘Private’
AGENCY - land management agency linked to polygon (e.g. BLM)
ACRES - polygon area calculated as acres
FEB_1984 - mean flooded acres in polygon from Feb 1984 to 1989
FEB_1990 - mean flooded acres in polygon from Feb 1990 to 1994
FEB_1995 - mean flooded acres in polygon from Feb 1995 to 1999
FEB_2000 - mean flooded acres in polygon from Feb 2000 to 2004
FEB_2005 - mean flooded acres in polygon from Feb 2005 to 2009
FEB_2010 - mean flooded acres in polygon from Feb 2010 to 2016
FEB_MEAN - mean flooded acres in polygon from Feb from 1984 to 2016
…
NOV_2010 - mean flooded acres in Nov 2010 to 2016
FEB_MEAN - mean flooded acres in Nov from 1984 to 2016

wetHISTORIC_DST - ca. 1870 wetland delineations cataloged from general land office (GLO) surveys.
ACRES - polygon area calculated as acres
DESCRIPTION - Term used in GLO survey notes to identify feature characteristic (e.g. swamp, slough, river, wet meadow, Warner Lake, etc...)

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For additional detail and discussion pertaining to research provided in this technical report please refer to associated peer reviewed publication:

Donnelly, J. P., D. E. Naugle, D. P. Collins, B. D. Dugger, B. W. Allred, and Tack Jason D Dreitz Victoria. in press. Synchronizing conservation to seasonal wetland hydrology and waterbird migration in semi-arid landscapes. Ecosphere.

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