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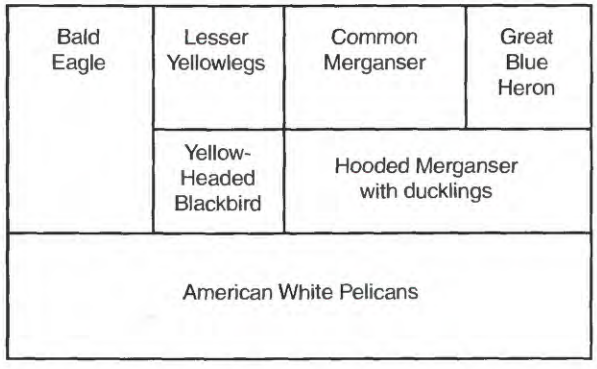
Topography and Sedimentation Characteristics of the Squaw Creek National Wildlife Refuge, Holt County, Missouri, 1937–2002

Water-Resources Investigations Report 03–4211

U.S. Department of the Interior
U.S. Geological Survey

Cover Photographs

Front cover: Sunset at Squaw Creek National Wildlife Refuge with collage of selected birds found at the wildlife refuge.
Back cover: Snow geese in flight above muskrat mounds in Eagle pool at the Squaw Creek National Wildlife Refuge.
All photographs by David C. Heimann, U.S. Geological Survey



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Rolla, Missouri
2003

U.S. DEPARTMENT OF THE INTERIOR

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U.S. GEOLOGICAL SURVEY

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VERTICAL DATUM

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88) unless otherwise specified. **Elevation,** as used in this report, refers to distance above or below NAVD 88. NAVD 88 can be converted to the National Geodetic Vertical Datum of 1929 (NGVD 29) by using the National Geodetic Survey conversion utility available at URL **http://www.ngs.noaa.gov/TOOLS/Vertcon/vertcon.html**.

Topography and Sedimentation Characteristics of the Squaw Creek National Wildlife Refuge, Holt County, Missouri, 1937–2002

By David C. Heimann *and* Joseph M. Richards

Abstract

The Squaw Creek National Wildlife Refuge (hereafter referred to as the Refuge), located on the Missouri River floodplain in northwest Missouri, was established in 1935 to provide habitat for migratory birds and wildlife. Results of 1937 and 1964 topographic surveys indicate that sedimentation, primarily from Squaw Creek and Davis Creek inflows, had substantially reduced Refuge pool volumes and depths. A study was undertaken by the U.S. Geological Survey, in cooperation with the U.S. Fish and Wildlife Service, to quantify and spatially analyze historic rates of sedimentation in the Refuge and determine the surface elevations, depths, and pool capacities for selected managed pools from a 2002 survey.

The 1937 to 1964 mean total sediment deposition, in the area corresponding to the 2002 surveyed pool area (about 4,900 acres), was 1.26 ft (feet), or 0.047 ft/yr (foot per year). Mean annual rates of deposition, by pool, from 1937 to 1964 varied from 0.016 to 0.083 ft/yr. From 1964 to 2002, the mean total sediment deposition in the 2002 surveyed pools was 0.753 ft, or 0.020 ft/yr. Therefore, the mean rate of sediment-depth accumulation from 1964 to 2002 was about 42 percent of the mean 1937 to 1964 rate, or a 58 percent reduction. Mean annual rates of deposition by pool from 1964 to 2002 varied from 0.010 to 0.049 ft/yr. Despite a substantial reduction in the average sediment accumulation rate for the Refuge, 5 of the 15 separate pools for which annual rates were calculated for both periods showed a small increase in the deposition rates of up to 0.008 ft/yr.

Sediment deposits have resulted in a substantial cumulative loss of volume in the Refuge pools since 1937. The 1937 to 2002 total sediment volume deposited in the 2002 surveyed pool area was about 9,900 acre-ft (acre-feet), or 152 acre-ft/yr (acre-feet per year). The volume of sediment deposited from 1937 to 1964 for these pools was about 6,200 acre-ft, or 230 acre-ft/yr. The volume deposited from 1964 to 2002 was about 3,700 acre-ft, or 97.3 acre-ft/yr.

Bulk density values were determined from sediment cores collected from 22 sites in the Refuge and the bulk densities, along with sediment volumes, allowed for the calculation of sediment mass contributions to the Refuge. From 1937 to 2002, about 10,300,000 tons of sediment were deposited in the 2002 surveyed area, or 32.4 tons/acre/yr (tons per acre per year). The total computed mass of sediment deposited between 1937 and 1964 was about 6,510,000 tons, or an average of 49.1 tons/acre/yr. The total mass deposited from 1964 to 2002 in surveyed pools was about 3,830,000 tons, or an average of 20.5 tons/acre/yr. As with sediment thickness comparisons, the rate of sediment mass deposition between 1964 to 2002 was about 42 percent of that from 1937 to 1964, or a 58 percent reduction.

The greatest amounts of sediment deposition in the Refuge for 1937 to 2002 have been near the

Squaw Creek and Davis Creek inflow spillway locations. Sediment depths in some areas near former inflow locations have exceeded 8 ft. Relocation of an inflow spillway effectively reduced additional sediment deposition at the original location, and caused increased sedimentation at the new inflow location. This is most clearly depicted in a pool located in the north section of the Refuge that directly received Squaw Creek inflows from 1937 to 1964 and had a mean deposition rate of 0.081 ft/yr reduced to 0.012 ft/yr, from 1964 to 2002, after inflows were redirected and erosion-management plans were implemented in the contributing basins.

INTRODUCTION

Squaw Creek National Wildlife Refuge (hereafter referred to as the Refuge) occupies 7,350 acres on the Missouri River floodplain and neighboring bluffs in Holt County, Missouri. Established in 1935 from acquired farmland, the Refuge is managed for the primary purpose of providing habitat for migratory birds and wildlife. Several constructed pools in the Refuge form and maintain critical marsh and wet-prairie habitat for hundreds of species of birds, reptiles, and mammals including the Bald Eagle (*Haliaeetus leucocephalus*) and the State endangered eastern Massasauga rattlesnake (*Sistrurus catenatus*). A nearly 1,000-acre wet prairie located on the Refuge represents one of the largest wet prairies remaining in the State. The Refuge also attracts some 128,000 visitors annually for viewing wildlife, hiking, and other forms of recreation.

Bordering the Refuge are highly erosive loessal (wind-deposited silt) bluffs through which Squaw Creek and Davis Creek flow before draining into the Missouri River. Water from these streams is used to flood Refuge pools for waterfowl. Historically, agricultural land use in the basins of these streams has resulted in the transport of high sediment loads into the Refuge. Sediment deposited from these streams has resulted in a reduction in Refuge pool volumes and depths, a loss of waterfowl habitat, and a reduced ability of managers to manipulate existing habitat conditions. A 1964 study comparing the then current topographic surface to a 1937 survey documented "alarming" rates of sedimentation in areas of the Refuge (U.S. Fish and Wildlife Service, 1964). The changes in topography, sedimentation rates, and sedimentation distribution in the Refuge since the 1964 survey were unknown.

A study was undertaken by the U.S. Geological Survey (USGS) in cooperation with the U.S. Fish and Wildlife Service (USFWS) to quantify the historic rates and spatial distribution of sedimentation on the Refuge and determine the 2002 surface elevations, depths, and capacities for selected managed pools. The results will aid the USFWS in the management of the Refuge pools and provide the USGS a better understanding of the rate and delivery mechanisms of sediment to the diminishing Missouri River wetlands.

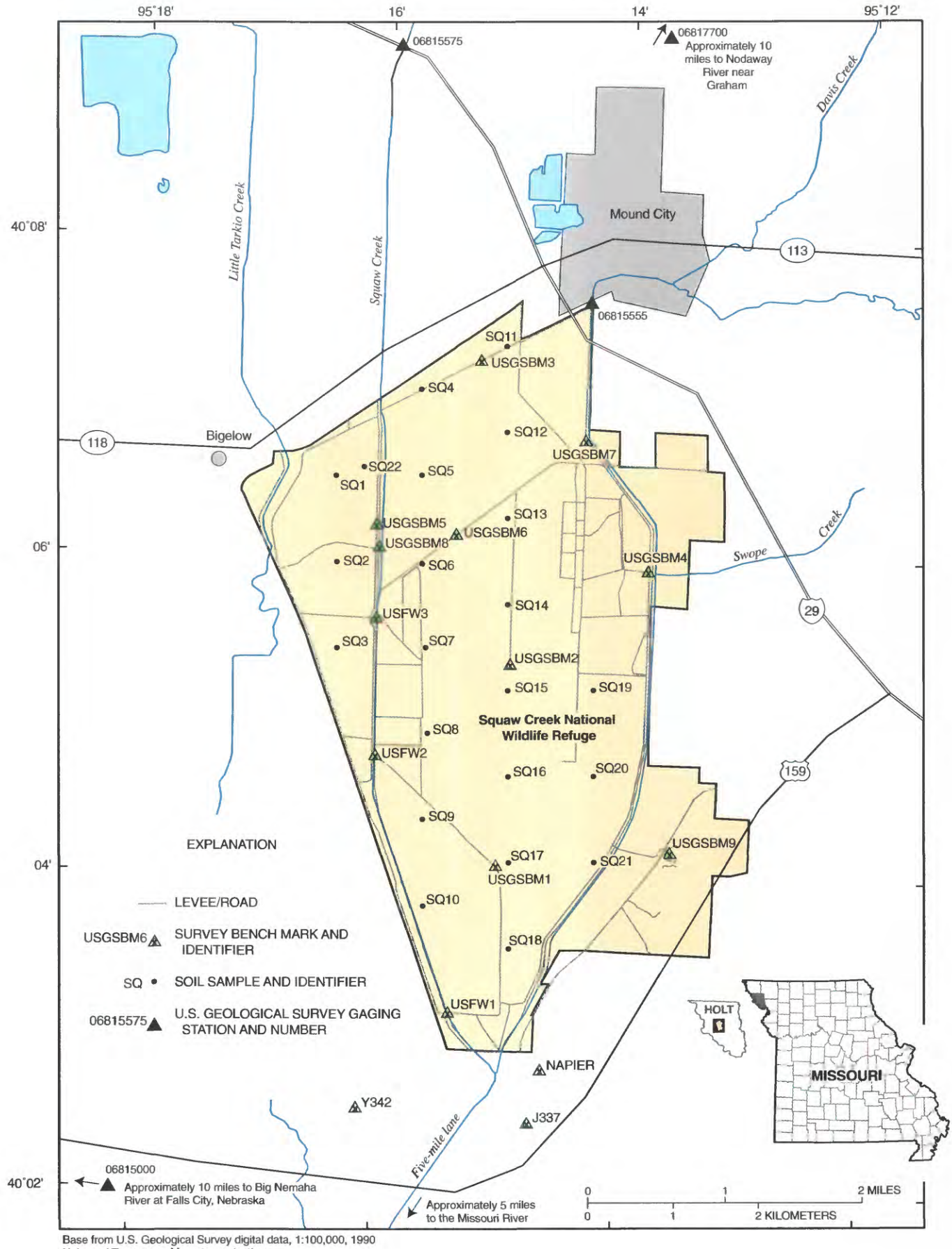
Purpose and Scope

This report describes topography and sedimentation characteristics of the Squaw Creek National Wildlife Refuge. The current volume and area of selected pools, as well as land-surface changes from 1937 and 1964 surveys, are presented along with graphical depictions of sedimentation in the Refuge. Average rates of sedimentation volume, thickness, and mass are computed for 1937 to 1964, 1964 to 2002, and 1937 to 2002.

Description of Study Area

The Refuge is located on 11.5 mi^2 (square miles; 7,350 acres) in Holt County near Mound City, Missouri (fig. 1). The primary sources of water to the Refuge are Squaw Creek and Davis Creek with drainage areas of 63 and 23 mi^2, respectively. Continuous streamflow and suspended-sediment data were collected for Davis Creek near the point it enters the Refuge (station number 06815555) from January 2000 to September 2002, and for Squaw Creek (station number 06815575) from October 2000 through the current (2003) year.

The Squaw and Davis Creek drainages consist of soils in the Marshal-Exira-Shelby soil series association, which are silt loam/silty clay loams (U.S. Department of Agriculture, 1997). Marshal, Exira, and Shelby soils are present on the slopes (greater than 7 percent) while minor soils in this association—Judson and Kenridge soil series—are present on the footslopes and floodplains. Soils in these associations are used for crops including corn, soybeans, and winter wheat. Erosion is the main management concern with all of these soils. Relief in the Squaw and Davis Creek Basins is about 232 ft (feet) from where the upper basin divides



Base from U.S. Geological Survey digital data, 1:100,000, 1990
Universal Transverse Mercator projection
Zone 15

Figure 1. Location of study area.

(1,096 ft) to the north Refuge boundary (about 864 ft). The 1971 to 2000 mean annual precipitation for Oregon, Missouri (located about 10 miles southeast of the Refuge) is 39.0 inches per year (National Oceanic and Atmospheric Administration, 2002).

There were no formal erosion-control programs in place in Holt County before the establishment of the Holt County Soil and Water Conservation District in 1974. The U.S. Department of Agriculture funded the construction of 21 floodwater retarding structures/sediment retention ponds in the Davis Creek Basin in the 1960's (Marilyn Roberts, Holt County Soil and Water Conservation District, oral commun., 2003). A Special Area Land Treatment (SALT) project was undertaken in the Davis Creek Basin in the 1990's to work with landowners to reduce soil erosion from cropland, pasture, and woodlands. Currently (2003), the Squaw Creek Basin is in the second year of a 5-year Agriculture Non-Point Source (AGNPS) pollution management project to provide assistance to landowners in enhancing Squaw Creek water quality, including reducing sediment and nutrient transport. Historically, agricultural land use in the Squaw and Davis Creek Basins was more pasture than cropland. Today (2003), agricultural land use in the basins is more cropland than pasture (Marilyn Roberts, oral commun., 2003). While there is a greater portion of cropland in the basins, which has the potential to be more erosive than pasture, most landowners in the basins employ no-till farming in an effort to reduce erosion; this was not commonly practiced in previous decades.

Acknowledgments

The authors acknowledge Ron Bell, Squaw Creek National Wildlife Refuge Manager, and Rick Spear, Assistant Refuge manager, for their assistance during the course of this study.

METHODS

Topographic data from 1937 and 1964 USFWS surveys were used with a 2002 USGS survey to determine changes in land-surface elevations in the Refuge. The topographic contour and point data were then used to build Geographic Information Systems (GIS) digital surfaces and used in the determination of sedimentation characteristics (depth, volume).

Topography

The 1937 and 1964 topographic information was obtained from historic USFWS surveys (U.S. Fish and Wildlife Service, 1964). There are no available data regarding the methodology of these surveys or the number of points used in the development of the maps, but it is likely that these maps were developed using a base line survey, a method described in Rausch and Heinemann (1968). With this method, point data would have been collected along selectively spaced survey cross sections perpendicular to an established base line oriented parallel to the Refuge. The contours would then have been developed by interpolating between the cross-sectional point data. For this report, the 1937 and 1964 maps were digitized, and digital surfaces created, to compare these data with a 2002 topographic survey. Elevations for the 2002 survey were collected between January and April 2002, along pre-determined 660-ft cross-hatched gridlines, developed and oriented for each pool, and point data were collected approximately every 100 ft along the gridlines. Bench marks were established within the Refuge at selected locations (fig. 1, table 1) and tied into established first-order horizontal and vertical survey markers near the Refuge. The vertical accuracy of the established USGS bench marks was plus or minus 0.06 ft, and the horizontal accuracy was plus or minus 0.02 ft.

Approximately 9,500 topographic points, consisting of a set of Universal Transverse Mercator (UTM) coordinates and an elevation, were collected between January and July 2002. The points were collected with a Global Positioning System (GPS), which consisted of a base unit established over a known bench mark and as many as two rover units that collected position information (coordinates and elevation) relative to the base unit. In this way, kinematic or "real time" survey points were collected without the need for post processing. The rovers were mounted on an all-terrain vehicle, a surveying rod (for hiking or boat work), or an automobile, and points were collected on a pre-set time interval of 20 to 30 seconds at a traveling speed of approximately 5 miles per hour. Comparisons were made at least once per day between established bench mark coordinates and the current daily corresponding bench mark reading to ensure proper operation of equipment and determine temporal errors in GPS elevation readings. The vertical errors, and, therefore, the topographic point data errors, were determined on average to be within plus or minus 0.06 ft. All 2002 survey data were collected in reference to the North Amer-

Table 1. Survey bench marks used in 2002 sedimentation survey at Squaw Creek National Wildlife Refuge

[All coordinates and elevations are referenced to the North American Vertical Datum 1988 (NAVD 88); UTM, Universal Transverse Mercator; USGS, U.S. Geological Survey; ", inch; USFW, U.S. Fish and Wildlife Service]

Site (fig. 1)	UTM coordinates		Latitude	Longitude	Elevation, in meters	Elevation, in U.S. Survey feet	Description
	Northing	Easting					
J337	308464.648	4434699.345	40 02'26.84322" N	95 14'42.35252" W	273.296	896.64	National Geodetic Survey—first order vertical bench mark
Y342	306457.502	4434883.673	40 02'31.16793" N	95 16'07.18522" W	258.487	848.05	National Geodetic Survey—first order vertical bench mark
NAPIER	308622.174	4435326.458	40 02'47.29675" N	95 14'36.37659" W	341.287	1,119.71	National Geodetic Survey—first order horizontal bench mark
USGSBM1	308102.919	4437705.353	40 04'03.97176" N	95 15'00.81070" W	261.507	857.96	USGS—temporary vertical and horizontal bench mark (3/8" rod in concrete)
USGSBM2	308280.114	4440040.195	40 05'19.78876" N	95 14'55.82619" W	260.963	856.18	USGS—temporary vertical and horizontal bench mark (3/8" rod in concrete)
USGSBM3	307955.753	4443577.967	40 07'14.18035" N	95 15'13.29766" W	262.222	860.31	USGS—temporary vertical and horizontal bench mark (3/8" rod in concrete)
USGSBM4	309896.263	4441111.138	40 05'55.81720" N	95 13'48.76298" W	263.147	863.34	USGS—temporary vertical and horizontal bench mark (3/8" rod in concrete)
USGSBM5	306715.767	4441677.766	40 06'11.57392" N	95 16'03.59812" W	263.97	866.04	USGS—temporary vertical and horizontal bench mark (3/8" rod in soil)
USGSBM6	307650.690	4441562.135	40 06'08.59742" N	95 15'24.01562" W	262.157	860.09	USGS—temporary vertical and horizontal bench mark (3/8" rod in soil)
USGSBM7	309176.856	4442639.603	40 06'44.76860" N	95 14'20.74901" W	265.928	872.47	USGS—temporary vertical and horizontal bench mark (3/8" rod in soil)
USGSBM8	306747.611	4441421.025	40 06'03.27945" N	95 16'01.97780" W	262.328	860.65	USGS—temporary vertical and horizontal bench mark (3/8" rod in soil)
USGSBM9	310145.037	4437842.026	40 04'10.06653" N	95 13'34.81009" W	289.049	948.32	USGS—temporary vertical and horizontal bench mark (center of compass layed in sidewalk at Refuge headquarters)
USFW1	307541.821	4435996.552	40 03'08.12932" N	95 15'22.65192" W	262.628	861.64	USFW—vertical bench mark (brass tab)
USFW2	306699.287	4438989.878	40 04'44.44766" N	95 16'01.40143" W	262.602	861.55	USFW—vertical bench mark (brass tab)
USFW3	306711.173	4440591.850	40 05'36.37636" N	95 16'02.62319" W	263.627	864.92	USFW—vertical bench mark (brass tab)

ican Datum of 1983 (NAD 83) horizontal datum, and the North American Vertical Datum of 1988 (NAVD 88) vertical datum.

The number of topographic points collected during the 2002 survey probably exceeded the number of points collected during the 1937 and 1964 surveys; therefore, the accuracy of the 2002 survey was greater. Comparisons between the 2002 and historic topographic surveys will be limited by the detail available from the historic maps.

The 2002 survey data were collected from the floodplain part of the Refuge corresponding with the 1937 and 1964 surveys, with the exception of the unsurveyed Moist soil unit pools, Cattail Complex, and Bluff pool (fig. 2). The 2002 surveyed area was about 4,900 acres compared to a total of about 6,200 acres surveyed in 1937 and 1964 (table 2). The specified lower management priority of the unsurveyed areas, the smaller pool size, tree cover, and flooding conditions of these pools resulted in these areas being the least efficient to survey with the available resources. While some data points were collected at these sites, there was insufficient information with which to draw revised elevation contours.

Sedimentation Characteristics

Topographic contour maps of the Refuge and estimates of sediment thickness and volume information were generated using digital surfaces created from the 2002 survey data and existing maps. GIS software were used in the creation and comparisons of the digital maps. A digital representation of the 2002 Refuge topographic surface was generated from the 2002 survey data. This surface was edited using a combination of field observations, survey sketches, and aerial photographs to accurately depict the land surface features. Digital surfaces also were generated from pre-existing (1937 and 1964) topographic maps of the area (U.S. Fish and Wildlife Service, 1964). All of the digital surfaces were projected and transformed into a common horizontal and vertical datum (NAD 83, NAVD 88) for calculations of differential sediment thickness, sediment volume, and pool elevation-area and elevation-capacity data. Separate differential sediment thickness maps were generated by subtracting the 1937 topographic surface from the 1964 surface, the 1937 topographic surface from the 2002 surface, and the 1964 topographic surface from the 2002 surface. The total sediment volume for a given pool was calculated by summing the volumes of the individual thickness intervals in the pool. Pool elevation-area and elevation-capacity relations were determined from the 2002 topographic digital surface using GIS techniques. The cumulative pool volumes were determined in 0.1 ft increments for each pool. The 1964 topographic surface was used to compute pool volumes where the 2002 surface was not surveyed.

Soil Bulk Density and Mass

The sediment masses for 1937 to 1964 and 1964 to 2002 were determined by multiplying the volume of deposition (from GIS calculations) by the bulk density of the soil. Soil samples were collected November 29, 2002, and December 2, 2002, at 22 locations, including 21 grid points regularly spaced at 3,281 ft [1,000 m (meter)], and one additional point (SQ22) located in an area of particularly high deposition (fig. 1). Samples were collected using a 2-inch diameter hand corer, and analyzed at the USGS laboratory in Lee's Summit, Missouri, for bulk density and soil texture. Bulk density was determined by dividing the oven dry weight of the soil by the volume of the soil sample (Blake and Hartge, 1986). Complete soil cores were used in the analyses and oven drying was conducted at 105 °C (degrees Celsius) for at least 24 hours. Soil texture was determined by the hydrometer method as described in Gee and Bauder (1986). One or more samples were collected at each of the 22 sampling points for the 1937 to 1964 and 1964 to 2002 deposition layers, with the exception of points 11, 16, 17, 20, and 21, in which only one deposition layer was identified to sample. The 1937 to 1964 deposition layer was determined from the difference between the 1937 to 2002 and 1964 to 2002 differential sediment thickness maps. Sediment mass was determined pool-by-pool using the calculated volume from the pool and bulk density sample values from the pool or selected bulk density values from the closest soil samples.

Sediment Loads

The sediment loads and yields from the Squaw and Davis Creek Basins were computed to determine the relative sediment contributions, and compare these contributions with deposition patterns in the Refuge. Streamflow and suspended-sediment concentration data collected at Squaw Creek (USGS streamflow gag-

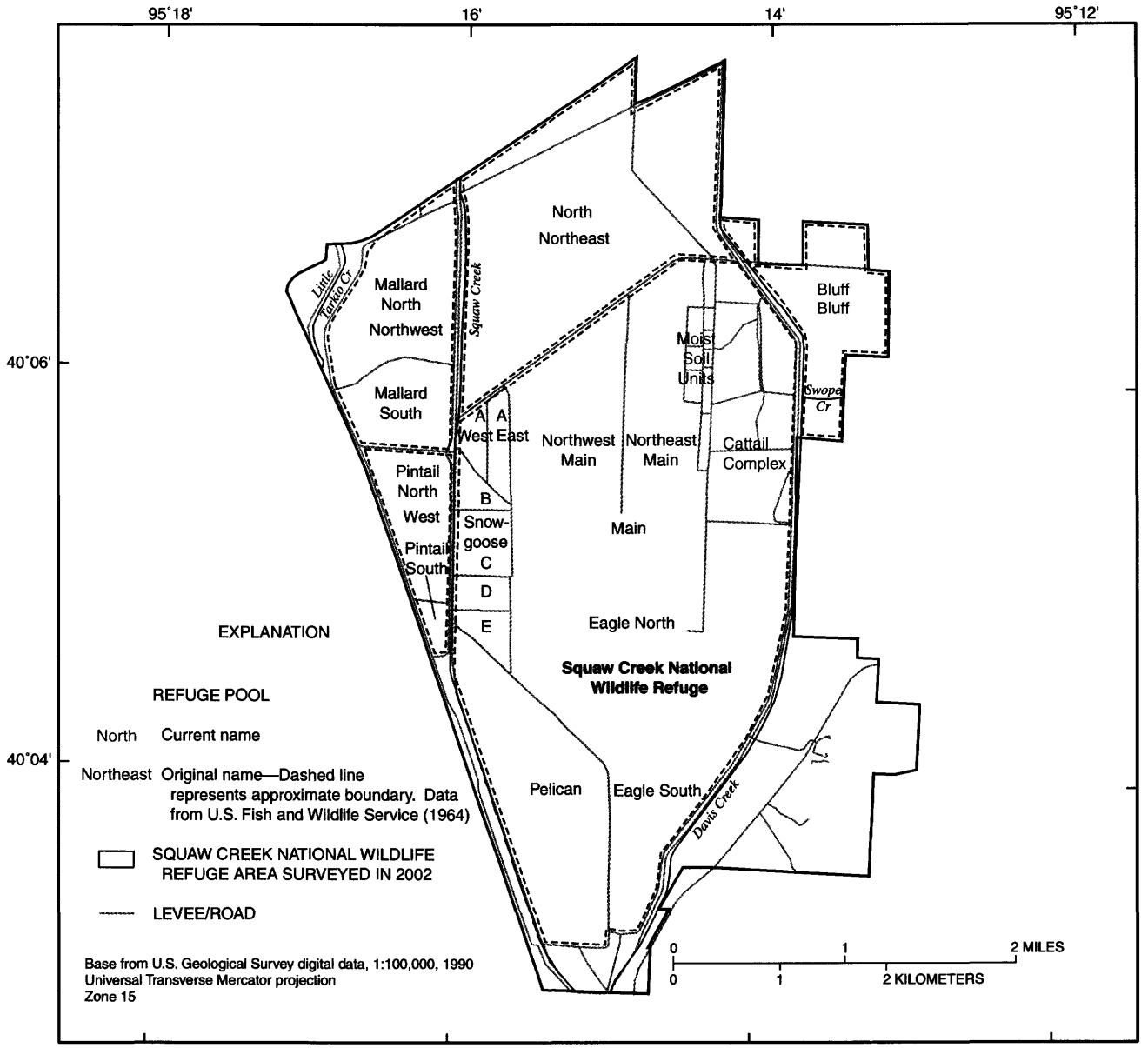


Figure 2. Comparison of current (2003) and original pool names in the Squaw Creek National Wildlife Refuge and the 2002 surveyed area.

ing station number 06815575) and Davis Creek (USGS streamflow gaging station number 06815555) streamflow gaging stations near Mound City, Missouri (fig. 1) were used to determine the relative sediment load and yield from these basins. Sediment samples were collected using an automatic point sampler, and manually sampled using a D-74 or DH-48 depth-integrated sampler at equal-width increments according to methods described in Edwards and Glysson (1999). Sediment samples were analyzed at the USGS sediment laboratory in Rolla, Missouri, according to methods described in Guy (1969). Periodic manual and automatic samples were collected concurrently to develop "box coefficients" or correction factors to adjust the point samples collected by automatic samplers to that of the more representative equal-width increment samples. Annual sediment loads and yields were computed for the 2001 and 2002 water year record using the USGS program Graphical Constituent Loading Analysis System (GCLAS) (McKallip and others, 2001).

Table 2. Summary of Squaw Creek National Wildlife Refuge pool volume, mass, area, and mean sediment deposition

[acre-ft, acre-foot; acre-ft/yr, acre-foot per year; lbs/ft^3, pounds per cubic foot; na, not available; tons/acre, tons per acre; tons/yr, tons per year; tons/acre/yr, tons per acre per year; ft, feet; ft/yr, feet per year]

Area and sediment deposition characteristics	Mallard North	Mallard South	North	Pintail	Snow-goose A West	Snow-goose A East	Snow-goose B	Snow-goose C	Snow-goose D	Snow-goose E	Eagle South	Eagle North	North-east Main	North-west Main	Pelican	Bluff	Cattail/ Moist soil complex	Total (all pools)	2002 Surveyed area (without Bluff and Cattail/ Moist soil complex)
Area, in acres	327	172	1,150	208	29.9	37.8	30.5	71.9	34.6	36.8	1,070	431	356	408	554	369	390	5,670	4,910
1937–1964 volume, in acre-ft	737	318	2,490	196	33.5	16.4	31.6	68.1	53.8	42.8	662	292	323	189	744	720	835	7,750	6,200
1937–1964 mean annual volume, in acre-ft/yr	27.3	11.8	92.3	7.2	1.2	.6	1.2	2.5	2.0	1.6	24.5	10.8	12.0	7.0	27.6	26.6	30.9	287	230
1937–1964 bulk density, in lbs/ft^3	58.1	58.1	45.6	58.1	58.1	58.1	58.1	58.1	58.1	58.1	30.0	49.3	49.3	49.3	52.4	45.6	49.3	na	na
1937–1964 mass, in thousands of tons	932	402	2,470	248	42.3	20.8	40.0	86.1	68.0	54.1	432	314	347	203	850	714	897	8,120	6,510
1937–1964 mass, in tons/acre	2,850	2,340	2,160	1,190	1,420	548	1,310	1,200	1,970	1,470	404	727	975	497	1,530	1,940	2,300	1,430	1,320
1937–1964 mean annual mass, in thousands of tons/yr	34.5	14.9	91.6	9.16	1.57	.77	1.48	3.19	2.52	2.00	16.0	11.6	12.9	7.52	31.5	26.4	33.2	301	241
1937–1964 mean annual mass, in tons/acre/yr	106	86.5	79.9	44.0	52.5	20.3	48.6	44.4	72.8	54.5	15.0	26.9	36.1	18.4	56.8	71.7	85.3	53.0	49.1
1937–1964 mean deposition, in ft	2.25	1.85	2.18	.941	1.12	.434	1.04	.948	1.56	1.16	.618	.677	.908	.463	1.34	1.95	2.14	1.37	1.26
1937–1964 mean annual deposition, in ft/yr	.083	.068	.081	.035	.041	.016	.038	.035	.058	.043	.023	.025	.034	.017	.050	.072	.079	.051	.047
1964–2002 volume, in acre-ft	556	270	543	301	55.3	28.6	45.4	56.2	61.6	53.5	688	477	137	210	217	na	na	na	3,700
1964–2002 mean annual volume, in acre-ft/yr	20.6	10.0	20.1	11.1	2.00	1.10	1.70	2.10	2.30	2.00	25.5	17.7	5.10	7.80	8.00	na	na	na	97.3
1964–2002 bulk density, in lbs/ft^3	51.8	51.8	60.5	51.8	51.8	51.8	51.8	51.8	51.8	51.8	29.3	49.9	49.9	49.9	36.2	na	na	na	na
1964–2002 mass, in thousands of tons	628	304	716	340	62.4	32.2	51.2	63.4	69.5	60.3	440	519	149	228	171	na	na	na	3,830
1964–2002 mass, in tons/acre	1,920	1,770	625	1,630	2,090	852	1,680	882	2,010	1,640	410	1,200	419	558	308	na	na	na	780
1964–2002 mean annual mass, in thousands of tons/yr	16.5	8.00	18.8	8.93	1.64	.85	1.35	1.67	1.83	1.59	11.6	13.6	3.93	6.00	4.50	na	na	na	101
1964–2002 mean annual mass, in tons/acre/yr	50.5	46.5	16.4	42.9	55.0	22.4	44.2	23.2	52.9	43.2	10.8	31.7	11.0	14.7	8.12	na	na	na	20.5
1964–2002 mean deposition, in ft	1.70	1.57	.474	1.45	1.85	.755	1.49	.782	1.78	1.45	.642	1.11	.385	.513	.391	na	na	na	.753
1964–2002 mean annual deposition, in ft/yr	.045	.041	.012	.038	.049	.020	.039	.021	.047	.038	.017	.029	.010	.014	.010	na	na	na	.020

Table 2. Summary of Squaw Creek National Wildlife Refuge pool volume, mass, area, and mean sediment deposition—Continued

[acre-ft, acre-foot; acre-ft/yr, acre-foot per year; lbs/ft^3, pounds per cubic foot; na, not available; tons/acre, tons per acre; tons/yr, tons per year; tons/acre/yr, tons per acre per year; ft, feet; ft/yr, feet per year]

Area and sediment deposition characteristics	Mallard North	Mallard South	North	Pintail	Snow-goose A West	Snow-goose A East	Snow-goose B	Snow-goose C	Snow-goose D	Snow-goose E	Eagle South	Eagle North	North-east Main	North-west Main	Pelican	Bluff	Cattail/ Moist soil complex	Total (all pools)	2002 Surveyed area (without Bluff and Cattail/ Moist soil complex)
1937–2002 volume, in acre-ft	1,290	587	3,040	497	88.8	45.0	77.0	124	115	96.3	1,350	769	460	398	961	na	na	na	9,900
1937–2002 mean annual volume, in acre-ft/yr	47.9	21.7	112	18.4	3.30	1.70	2.90	4.60	4.30	3.60	50.0	28.5	17.1	14.8	35.6	na	na	na	152
1937–2002 mass, in thousands of tons	1,560	706	3,190	587	105	53.0	91.2	150	138	114	872	832	496	431	1,020	na	na	na	10,300
1937–2002 mass, in tons/acre	4,770	4,100	2,780	2,820	3,510	1,400	2,990	2,080	3,980	3,110	814	1,930	1,400	1,060	1,840	na	na	na	2,100
1937–2002 mean annual mass, in thousands of tons/yr	24.0	10.9	49.1	9.03	1.61	.82	1.40	2.30	2.12	1.76	13.4	12.8	7.64	6.63	15.7	na	na	na	159
1937–2002 mean annual mass, in tons/acre/yr	73.4	63.1	42.8	43.4	53.9	21.5	46.0	32.0	61.2	47.9	12.5	29.7	21.5	16.2	28.3	na	na	na	32.4
1937–2002 mean deposition, in ft	3.96	3.41	2.65	2.39	2.97	1.19	2.53	1.73	3.34	2.62	1.26	1.78	1.29	.976	1.73	na	na	na	2.01
1937–2002 mean annual deposition, in ft/yr	.061	.053	.041	.037	.046	.018	.039	.027	.051	.040	.019	.027	.020	.015	.027	na	na	na	.031

TOPOGRAPHY AND SEDIMENTATION CHARACTERISTICS

Topography

The Refuge lies near the floodplain/upland edge of the Missouri River floodplain and has a topographic gradient running generally from the northeast corner of the Refuge toward the southwest corner. The elevation range over the Refuge pools in 1937 was 20 ft with a maximum of 865 ft at the northeast corner of North pool [fig. 3; Note current Refuge pool names will be used throughout this report. The original pool names identified in U.S. Fish and Wildlife Service (1964), along with current pool names, are shown in figure 2 for comparison.] and a minimum of 845 ft at the bottom of the former Squaw Creek channel through the southwest section of Pelican pool. In 1964, the elevation range in the Refuge pools was 15 ft, with a maximum of 865 ft (northeast corner of North pool, fig. 4) and a minimum elevation of 850 ft (south end of Eagle South pool). In 2002, the range was 16 ft, with a maximum of 866 ft (northeast corner of North pool, fig. 5) and a 850 ft minimum elevation (south end of Eagle South pool).

Sedimentation Characteristics

To understand the historic deposition and spatial distribution of sediment deposits in the Refuge, the historic locations of pool inflows from Squaw and Davis Creeks should be considered. The location of these inflows and delivery mechanisms have changed since the inception of the Refuge in response to high rates of deposition at inflow points.

The Refuge was established in 1935 from farms "plagued with excessive surface water and poor drainage" (U.S. Fish and Wildlife Service, 1964) and the location of inflows and management-unit boundaries have changed substantially since that time. At the time of the first survey in 1937, Squaw Creek was partially channelized within the Refuge and Davis Creek was channelized through the Refuge essentially at their present locations (fig. 1).

The inflow spillways from Squaw and Davis Creeks historically have been located in the north section of the Refuge as the topographic gradient is from north to south, and water is moved through the Refuge by gravity. Inflow to the Refuge was by means of uncontrolled spillways in the channelized streams (fig. 3). The Squaw Creek spillways were located in the northwest section of the Refuge and allowed flows into Mallard North and North pools. Inflow spillways were established on the Davis Creek channel near the northeast corner of the present Moist soil unit complex (fig. 3). A small Squaw Creek tributary, Porter Creek, also entered the Refuge uncontrolled at the north central part of the North pool through the Todd Ditch (fig. 3). Squaw Creek was the primary source of inflows, and spillways and ditches routed water in the Mallard North and North pools. The only water-level control in the Refuge was at the outflow gate (fig. 3). The natural Davis Creek channel originally coincided roughly with the R38W-R39W range line; when Davis Creek was channelized, the abandoned former channel became known as Long Slough (fig. 3).

By 1942, many of the inflow ditches were filled by sedimentation as "the frequency and magnitude of sedimentation after establishment of the Refuge exceeded expectation" (U.S. Fish and Wildlife Service, 1964) and this led to modifications in the Refuge that continued through the early 1990's. About 1942, Squaw Creek was fully channelized, and spillways with gated control structures were established to control flows into Mallard North and North pools. The Moist soil units and Cattail Complex were established in 1956. Pintail pool also was formed between 1942 and 1964. Since the second survey in 1964, Pelican pool was formed from the Main pool (fig. 2). In the early 1970's the Squaw Creek inflow spillways were relocated to their present location at the southeast corner of Mallard South pool (fig. 5). From 1989 to 1991, additional modifications were made in which Mallard pool was subdivided into a north and south unit, Snowgoose pool complex was formed, and Pintail pool also was subdivided into a north and south unit. The various levees dividing the pools are from 4 to 8 ft above the adjacent pool floor. The pools were identified by their present "waterfowl" names beginning in the 1970's (Ron Bell, U.S. Fish and Wildlife Service, Squaw Creek National Wildlife Refuge Manager, oral commun., 2003; fig. 2).

The historic spatial distribution of sediment in the Refuge is closely related to the location of Squaw and Davis Creek inflow spillways. The low gradient Squaw and Davis Creeks effectively carry fine-sized sediment particles (silt/clay) in suspension to the Refuge. Upon entering the Refuge pools, the streams deposit the larger silt particles near the discharge points forming deltaic features. The smaller clay particles

Figure 3. Squaw Creek National Wildlife Refuge topography, 1937.

Figure 4. Squaw Creek National Wildlife Refuge topography, 1964.

Figure 5. Squaw Creek National Wildlife Refuge topography, 2002.

remain in suspension for longer times, allowing a greater distribution as waters are transferred from pool to pool, and a more uniform depositional pattern. Because the inflow streams are low gradient and channelized over much of the flow there is little opportunity for redistribution of sediments once they are deposited. The only way to remove the sediment is by mechanical means. The Squaw and Davis Creek spillways (figs. 3 and 4) are cleaned of sediments nearly annually. The channelized stream ditches also require periodic cleaning albeit at a less frequent interval—approximately every decade (Ron Bell, oral commun., 2003). No data were available quantifying the amount of material removed from the ditches and control structures since the Refuge was established.

Sediment Deposition, 1937 to 1964

Between 1937 and 1964, the mean sediment deposition in all pool areas was about 1.37 ft, or 0.051 ft/yr (foot per year) (table 2). Mean annual rates of deposition by pool from 1937 to 1964 varied from 0.016 ft/yr in Snowgoose pool A East, to a maximum of 0.083 ft/yr in Mallard North pool (table 2) adjacent to Squaw Creek. The high sediment deposition rates in Bluff (0.072 ft/yr) and the Cattail Complex/Moist soil unit complex (0.079 ft/yr) are evidence of the substantial contributions that are possible from adjacent Davis Creek inflows. The 1937 to 1964 mean sediment deposition for areas corresponding to the 2002 surveyed area was 1.26 ft, or 0.047 ft/yr.

The spatial distribution of sediment deposits did not follow a homogenous pattern, and varied with proximity to inflow spillways. The North pool was the area of greatest initial sedimentation in the Refuge and already contained deposits exceeding 8 ft deep by 1964 (fig. 6). This pool area was originally planned as a settling basin, and much of the sedimentation had occurred by the early 1940's; however, the magnitude and extent of the sedimentation prompted further control and development projects of the Squaw and Davis Creek channels within the Refuge. The southwest corner of North pool had once been the area of greatest water depths in this pool, but by 1964 the southwest corner of the pool was used as an agricultural field (U.S. Fish and Wildlife Service, 1964). Depositional areas from 4 to more than 8 ft thick exist over the western one-third of the pool near the original inflow spillways, with about 2 ft of sediment covering the remaining western one-half of the pool. The remaining eastern one-half of the pool received less than 2 ft of deposition.

In 1964, the areas of greatest concern and most rapid deterioration with respect to sedimentation were Mallard North and Mallard South pools (U.S. Fish and Wildlife Service, 1964; fig. 6). The original spillway into the east central part of the pools (fig. 3) allowed larger Squaw Creek flows to enter freely and quickly develop a depositional delta. Gate structures were installed on the spillways from Squaw and Davis Creeks in the 1940's for better control of the inflows. With the newer gate structures it became possible to take water from the streams during low flows, which also have the least sediment transport, by ponding flows behind the gate until water levels reached inflow culvert levels. By 1964, most of Mallard North and Mallard South pools were covered with 2 ft of sediment deposits, with a maximum of about 7 ft closer to the Squaw Creek inflow spillway. Also of concern in the Refuge in 1964 were restrictions in the discharge of Squaw and Davis Creeks downstream from the Refuge. Woody debris accumulations and downstream bridge restrictions allowed Refuge outflows to form backwater, and reverse flow back into the Refuge over the top of the outflow control gate (U.S. Fish and Wildlife Service, 1964) potentially resulting in additional sedimentation in the Eagle South pool area.

Between 1937 and 1964 sedimentation in pools other than Mallard and North took place predominantly near the inflow spillways from Davis and Squaw Creeks (fig. 6). From 2 to 6 ft of sediment was deposited in the Cattail Complex/Moist soil unit areas, with more deposited towards the Davis Creek inflow spillway. The 5-ft deep drainage ditch in the middle section of Pelican pool was filled in with sediment between 1937 and 1964 by natural or mechanical means (fig. 6), and 4 to 5 ft of sediment was deposited at the present location of Pintail south pool, again by natural or mechanical means. Deposition in the Northeast and Northwest Main pools, most Snowgoose pools, Eagle North and South pools, and much of present Pelican pool generally was less than 1 ft. Excluding North pool and Mallard North and South pools, the mean deposition in the rest of the Refuge between 1937 and 1964 was 1.04 ft.

An oddity in the 1937 to 1964 differential sediment thickness maps were areas of 2 to 3 ft of apparent erosion in the central Eagle South pool and the northeast corner of the North pool (fig. 6). These isolated areas are not in the path of a water course or pool dis-

charge capable of causing erosion, and are located in an unlikely area of extensive mechanical sediment removal. It is likely that the apparent erosion in these areas may be the result of erroneous survey information in this area from either the 1937 or 1964 surveys.

Sediment Deposition, 1964 to 2002

From 1964 to 2002, the total average sediment deposition in the 2002 surveyed pool area (all pools except Bluff and the Cattail Complex/Moist soil units) was 0.753 ft, or 0.020 ft/yr (table 2) compared to 1.26 ft, or 0.047 ft/yr from 1937 to 1964 for the same area. The mean rate of sediment depth accumulation, therefore, from 1964 to 2002, was about 42 percent of the mean of the 1937 to 1964 rate, or a 58 percent reduction in the accumulation rate by depth.

Mean annual rates of deposition by pool from 1964 to 2002 varied from 0.010 ft/yr in the Northeast Main pool and Pelican pool to 0.049 ft/yr in Snowgoose pool A West (table 2). The two highest mean annual rates for the 1964 to 2002 period were detected in Snowgoose pools and four of the highest six rates were located in pools in the Snowgoose complex of pools. The change in rankings of mean pool deposition from 1937 to 1964 and 1964 to 2002 was not a result of substantial increases in the deposition rates in the Snowgoose pools, as the deposition rates in one-half of the Snowgoose pools actually decreased between measurement periods. The ranking changes were a result of the substantial decrease in the deposition rates for those pools with the highest rates of deposition between 1937 to 1964 (for example, 0.083 to 0.045 ft/yr for Mallard North, and 0.081 to 0.012 ft/yr for North pool). Despite a substantial reduction in the average rate of sediment accumulation for the Refuge, 5 of the 15 separate pools for which annual rates were calculated for 1937 to 1964 and 1964 to 2002 showed an average increase in the deposition rates between the two periods of 0.004 ft/yr, although the maximum increase was only 0.008 ft/yr in Snowgoose A West.

Changes in inflow spillway structures caused a change in the depositional patterns in the Refuge between 1937 to 1964 and 1964 to 2002. The Squaw Creek spillways were shifted from the original locations by the early 1970's (Ron Bell, written commun., 2003; figs. 3 and 4) and new gates were installed to allow better control of inflows. Porter Creek flows were routed into Squaw Creek upstream from the Refuge between 1964 and the early 1970's. Deposition from 1964 to 2002 was greatest in areas of Mallard North and Mallard South pools near inflow points with deposits up to 7.5-ft thick in some small areas, and 1- to 4-ft deposits in the remaining areas of these pools (fig. 7). The nearby Pintail pool also received 1 to 4 ft of deposits during this period. Most of Northeast and Northwest Main, Pelican, and Eagle North and Eagle South pools received 0 to 1 ft of additional sediment between 1964 to 2002. Parts of the original Davis Creek channel (Long Slough, fig. 3) received 2 to 3 ft of sediment during this period. The Snowgoose pool complex received 1 to 2 ft of sediment deposits, with up to 3 ft in some areas including pool D, which is located near a historic inflow point, and pool E. The backwater problem at the Refuge outlet control structure was remedied with the elimination of downstream restrictions and the construction of the "Five-mile lane" drainage ditch to the Missouri River that was completed in 1969 (Ron Bell, written commun., 2003; fig. 1).

The 2- to 3-ft mounded areas in the central part of Eagle pool and the northeast corner of North pool depicted in the 1937 survey map (fig. 3), shown to have eroded between the 1937 and 1964 surveys (fig. 6), are again suspicious as the mounded areas were apparently reformed between 1964 and 2002 (fig. 7). This supports the likely scenario that these mound features actually existed during the 1964 survey. However, because they likely did not fall along a survey transect line, these features were erroneously omitted. Other erosional areas shown in figure 7 may be the result of accuracy differences between the 1964 and 2002 surveys.

Approximately 75 topographic points were collected within Bluff pool in the 2002 survey; while these points were not distributed well enough to use in developing contours and differential sediment thickness maps, they can provide point-elevation comparisons. The data indicated that the northern one-third of the pool had bottom elevations similar to that of the 1964 map (fig. 4), the middle one-third had surface elevations generally a foot above those shown in the 1964 topographic map (and 2 ft above the central area depicted by the 854-ft contour in the 1964 map), and the southern one-third of the pool had surface elevations generally 2 ft higher than the 1964 contours. A small tributary, Swope Creek, enters Bluff pool from the east (fig. 1), in the southern one-third of the pool, and sediment loads from this stream may account for the greater deposition at the south end of this pool.

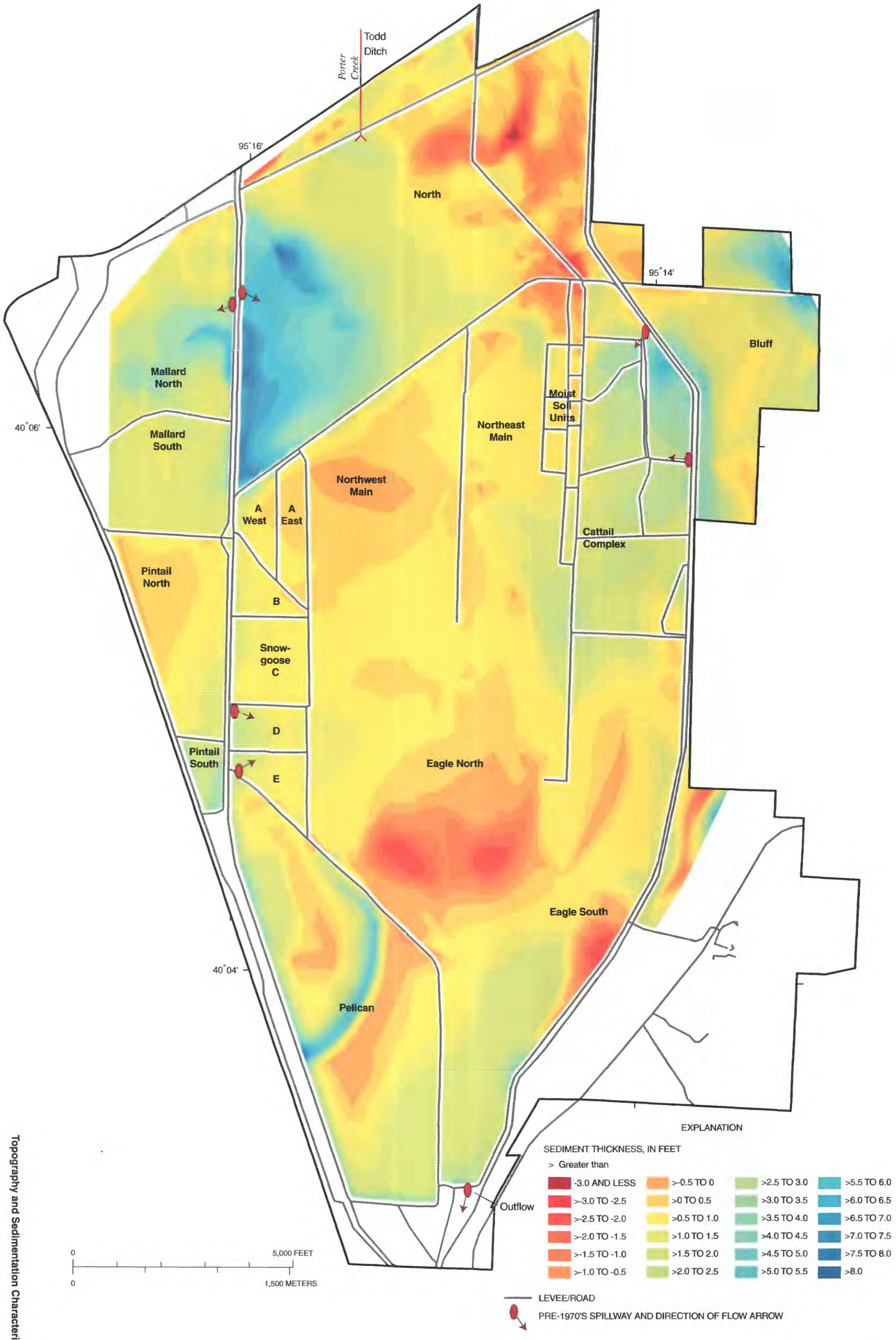


Figure 6. Squaw Creek National Wildlife Refuge differential sediment thickness, 1937 to 1964.

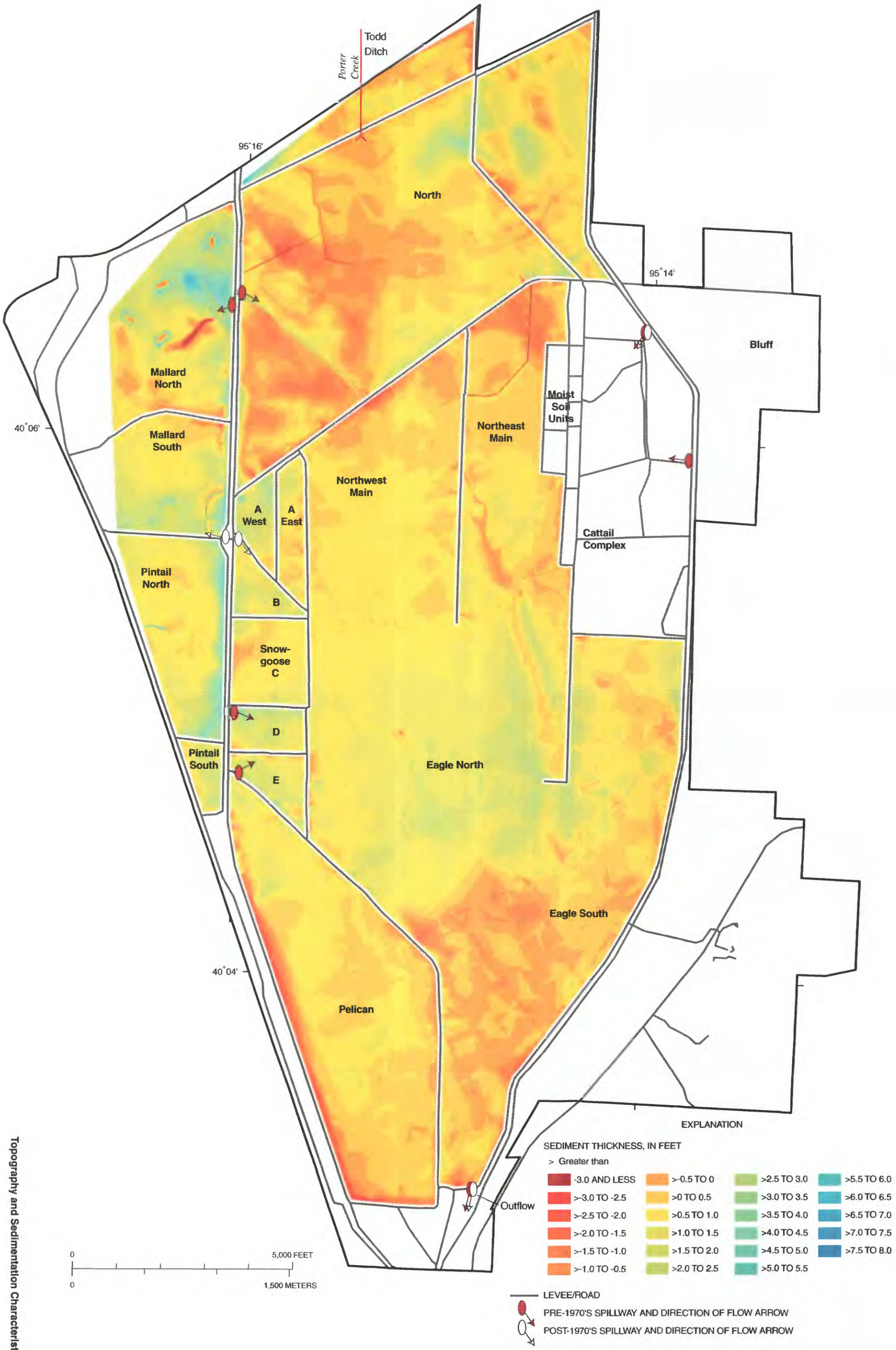


Figure 7. Squaw Creek National Wildlife Refuge differential sediment thickness, 1964 to 2002.

Sediment Deposition, 1937 to 2002

The greatest amounts of sediment deposition in the Refuge have been near the Squaw and Davis Creek inflow spillways, which have been located at various locations in the northwest and northeast sections of the Refuge (figs. 6 to 8). Maximum deposits near historic inflow spillways (fig. 3) have exceeded 8 ft in the Mallard pools and North pool, and more than 3 ft in the inflow areas corresponding with the current Snowgoose pools (fig. 8). When an inflow spillway is relocated, this can reduce additional sediment deposition at the original location, but cause increased sediment deposition at the new inflow location. Such reductions occurred in the North pool that directly received Squaw Creek inflows from 1937 to 1964, and had a deposition rate of 0.081 ft/yr reduced to 0.012 ft/yr from 1964 to 2002 (table 2), after inflows were redirected in the 1970's. The current inflows from Squaw Creek are closer to the Snowgoose and Pintail pools (fig. 8), and Pintail and the northernmost Snowgoose pools all received greater mean annual accumulations of sediment from 1964 to 2002 than from 1937 to 1964.

While the greatest deposition depths exist near present or historic inflow spillways, essentially the entire Refuge has received, on average, 2 ft of sediment deposition since 1937 (table 2). The individual pools that received the greatest amounts of mean sediment deposition include Mallard north (3.96 ft), Mallard south (3.41 ft), and Snowgoose pool D (3.34 ft), all located near current or historic Squaw Creek spillways. The pools receiving the least amount of average deposition between 1937 and 2002 include Northwest Main (0.98 ft), Snowgoose pool A East (1.19 ft), and Eagle South (1.26 ft). While pools received, on average, 1 to 3 ft of deposition, there were areas of the Refuge that remained relatively unchanged since 1937 including parts of the Northeast and Northwest Main pools, eastern sections of North pool, and the central part of Eagle South pool (fig. 8).

While the Squaw and Davis Creek Basins were the primary contributors of sediment to the Refuge between 1937 and 2002, sediment contributions also could have been made by other Refuge tributaries and flooding from the Missouri River. The peak stage in the Refuge during the July 1993 Missouri River flood was 858.20 ft [National Geodetic Vertical Datum of 1929 (NGVD 29)] and the refuge was inundated by floodwaters for weeks (Ron Bell, oral commun., 2003). A comparable event to the 1993 flood, in terms of streamflow, occurred in 1952 on the Missouri River in northwest Missouri. No mention was made of sediment contributions from the 1952 flood to the Refuge in the 1964 USFWS Refuge management plan (U.S. Fish and Wildlife Service, 1964), and there are no records or observations of possible sediment contributions to the Refuge from either of these floods. The strong association between Squaw and Davis Creek spillway locations and Refuge sediment deposits, the lack of measurable deposition over some areas in the Refuge that were inundated during the 1993 flood (areas of Northeast, Northwest Main pool, eastern section of North pool, and central Eagle pools that in 2002 were unchanged from 1937 topography), and the distance of the Refuge from the Missouri River (approximately 5 miles) indicate or suggest that sediment contributions from the Missouri River floods were not substantial. The sediment contributions from Porter Creek (fig. 3), Little Tarkio Creek (fig. 1), and Swope Creek (fig. 1) during the 1937 to 2002 period are likely insignificant in comparison with Squaw and Davis Creek but still unknown.

Sediment Volume and Mass

Sediment deposits have resulted in a substantial cumulative loss of pool volume in the Refuge pools since 1937. Total volume of sediment deposited in all pools between 1937 and 1964 was about 7,750 acre-ft (acre-feet) (table 2). A comparable volume for 1964 to 2002 is unavailable as the Cattail Complex/Moist soil units and Bluff pool data were lacking for the 2002 survey, but the 1937 to 1964 sediment volume for all pools excluding these areas was about 6,200 acre-ft, or 230 acre-ft/yr (acre-feet per year) and the 1964 to 2002 deposition value was about 3,700 acre-ft, or 97.3 acre-ft/yr (table 2). The 1937 to 2002 total sediment volume deposited in the 2002 surveyed pool area in the Refuge was about 9,900 acre-ft, or 152 acre-ft/yr.

Any errors associated with the 1937 and 1964 sediment surveys, and comparisons between the 2002 survey and the earlier surveys, would be reflected in the volume and mass calculations. However, the methods, data, and errors associated with these historic surveys are unknown. While it is unlikely that any areas of extensive erosion (figs. 6 to 8) actually occurred in the Refuge between 1937 and 2002, these erosion values were included in the total net volume values (table 2). Sediment erosion losses amounted to approximately 3 percent of the total deposition between 1937 and 1964, and 0.3 percent of the deposition between 1964 and 2002. These values (3 percent, 0.3 percent) can perhaps

provide an estimation of mean errors associated with comparisons between the 2002 survey and earlier surveys.

Analyses of sediment samples collected from the Refuge resulted in the determination of representative soil texture and bulk densities for the assumed 1937 to 1964 and 1964 to 2002 deposits. Soil texture and bulk density were heterogeneous between sites and within site profiles, indicating a complex spatial deposition pattern with time, reflecting changes in Refuge inflow spillways and source characteristics (table 3). Textural analyses indicate sand content in the samples was from 1 to 16 percent, silt content was 29 to 88 percent, and clay content was 9 to 69 percent, with resulting textural classes from silt to clay (table 3). Bulk densities ranged from 16.9 lb/ft^3 (pounds per cubic foot) [0.27 g/cm^3 (grams per cubic centimeter)] from a surface (1964 to 2002 layer) sample at site SQ21 (fig. 1) to 74.3 lb/ft^3 (1.19 g/cm^3) at a surface (1964 to 2002 layer) site sample at site SQ5. Despite the differences among and between sites, the soil types present at most Refuge sample locations were consistent with the silty clay loam and silt loams characteristic of the Squaw Creek and Davis Creek Basins. Measured soil bulk densities varied with texture and the amount of organic matter in the samples, and also were related to the vegetation distribution and water depth in the pools.

The total computed mass of sediment deposited between 1937 and 1964 in the 2002 surveyed Refuge pool area (excludes Cattail Complex/Moist soil unit and Bluff pool) was about 6,510,000 tons, or an average of 49.1 tons/acre/yr (tons per acre per year) (table 2). The total mass from 1964 to 2002 for the 2002 surveyed pool area was about 3,830,000 tons, or an average of 20.5 tons/acre/yr. Similar to the depth accumulation comparisons, the 1964 to 2002 rate of sediment mass deposition was about 42 percent of that from 1937 to 1964, or a 58 percent reduction. Overall, from 1937 to 2002, about 10,300,000 tons of sediment were deposited in the 2002 surveyed area, or 32.4 tons/acre/yr.

Pool Elevation-Area and Elevation-Capacity Data

Elevation-area and elevation-capacity data serve a useful purpose in the management of the Refuge pools for desired vegetation conditions and wildlife habitat in that it provides an estimate of the volume of water needed to meet a target pool depth or the maximum water-surface area at a specified water-surface elevation. Pool elevation-area and elevation-capacity data provide for a graphical means of comparing the historic status of deposition in the Refuge (figs. 9 to 11). The graphs clearly show the greater area and volume losses that occurred between 1937 and 1964 when compared with the 1964 to 2002 measurement interval for both the Mallard North and Mallard South (fig. 9) and North pool (fig. 10). The 1964 to 2002 pool capacity and area changes were not as substantial as the 1937 to 1964 changes in the area including Snowgoose, Northeast and Northwest Main, Cattail Complex/Moist soil units, Eagle North and South, and Pelican pool areas (fig. 11). Pool-specific elevation-area and elevation-capacity data, based on 2002 survey data, are provided for all 2002 surveyed pools to better define current (2003) storage and area conditions (table 4, at the back of this report). These data can aid in the current management of the Refuge pools and provide a basis for future pool-specific comparisons.

Squaw Creek and Davis Creek Sediment Loads

The differential sediment thickness maps indicate that Squaw Creek was the primary contributor of sediment to the Refuge during 1937 to 2002 (figs. 6 to 8) and suspended-sediment data from Squaw Creek and Davis Creek for the 2001 and 2002 water years (October 1 to September 30) supports the conclusion that Squaw Creek contributes greater total sediment loads than Davis Creek. The total annual sediment loads from the Squaw Creek Basin exceeded those from the Davis Creek Basin for the 2001 and 2002 water years; however, the 2001 basin-area adjusted sediment yield for the smaller Davis Creek Basin [2.33 tons/acre (tons per acre)] exceeded that of the Squaw Creek Basin (1.04 tons/acre). The 2001 total sediment load at the Squaw Creek near Mound City, Missouri, streamflow gaging station (station number 06815575, fig. 1) was about 42,000 tons, while the 2001 sediment load at the Davis Creek near Mound City, Missouri, streamflow gaging station (station number 06815555, fig. 1) was about 34,200 tons. Regional streamflow volume in the 2001 water year was near average based on long-term record from the nearby Nodaway River near Graham, Missouri streamflow gaging station (station number 06817700, fig. 1), where average flow for 2001

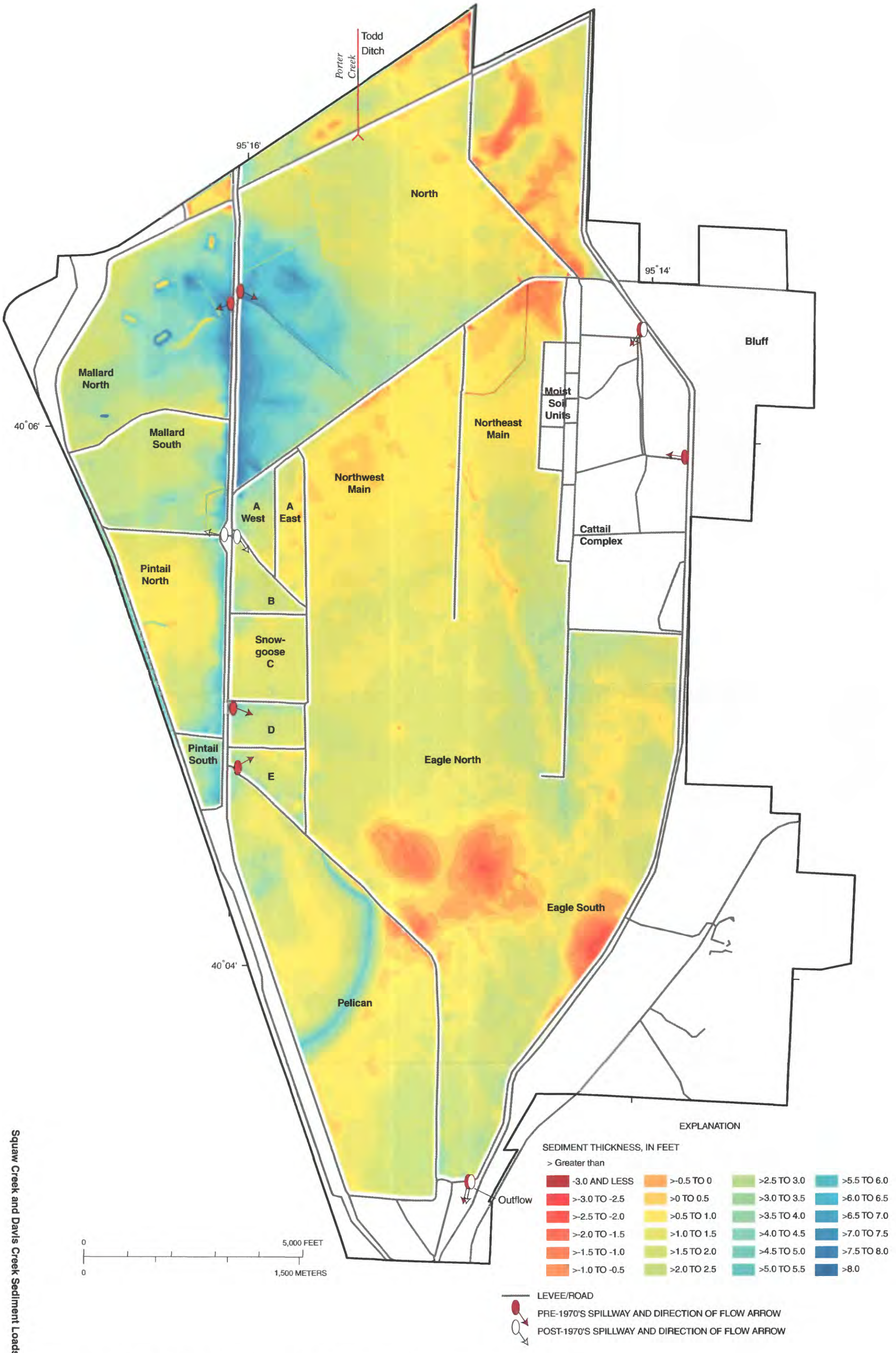


Figure 8. Squaw Creek National Wildlife Refuge differential sediment thickness, 1937 to 2002.

Table 3. Squaw Creek National Wildlife Refuge soil sample characteristics

[no., number; UTM, Universal Transverse Mercator; m, meters; ft, feet; lb/ft^3, pounds per cubic foot; >, greater than; mm, millimeters; <, less than; --, no data]

Site no. (fig. 1)	Sample date	Sample location UTM coordinates		1937–1964 depth, in ft	1964–2002 depth, in ft	Bulk density, lb/ft^3	Average 1937–1964 bulk density, lb/ft^3	Average 1964–2002 bulk density, lb/ft^3	Percent sand (>0.053 mm)	Percent silt (0.05–0.002 mm)	Percent clay (<0.002 mm)	Textural class
		Northing, in m	Easting, in m									
SQ1	11/29/2002	306250	4442250	--	0-1	45.6	--	--	1	61	38	Silty clay loam
				--	1-2	46.2	--	--	2	72	26	Silt loam
				--	2-3	59.9	--	50.6	1	79	20	Silt loam
				3-4	--	56.8	--	--	1	43	56	Silty clay
				4-5	--	67.4	62.1	--	2	42	56	Silty clay
SQ2	11/29/2002	306250	4441250	--	0-1	36.2	--	36.2	2	54	45	Silty clay
				1-2	--	35.6	--	--	2	49	49	Silty clay
				2-3	--	54.9	--	--	1	35	64	Clay
				3-4	--	56.2	--	--	1	35	64	Clay
				4-5	--	57.4	51.0	--	1	34	65	Clay
SQ3	11/29/2002	306250	4440250	--	0-0.8	30.0	--	30.0	3	33	64	Clay
				0.8-1.1	--	68.7	68.7	--	3	43	54	Silty clay
SQ4	11/29/2002	307250	4443250	--	0-1	61.2	--	--	2	64	34	Silty clay loam
				--	1-2	59.3	--	60.2	3	74	23	Silt loam
				2-3	--	51.8	51.8	--	3	83	14	Silt loam
SQ5	11/29/2002	307250	4442250	--	0-0.2	74.3	--	74.3	3	81	16	Silt loam
				0.2-1	--	52.4	--	--	5	83	12	Silt loam/silt
				1-2	--	39.0	45.7	--	3	88	9	Silt
SQ6	11/29/2002	307250	4441223	--	0-1	69.3	--	69.3	1	84	15	Silt loam
				1-2	--	50.6	50.6	--	1	46	53	Silty clay

Table 3. Squaw Creek National Wildlife Refuge soil sample characteristics—Continued

[no., number; UTM, Universal Transverse Mercator; m, meters; ft, feet; lb/ft^3, pounds per cubic foot; >, greater than; mm, millimeters; <, less than; --, no data]

Site no. (fig. 1)	Sample date	Sample location UTM coordinates		1937–1964 depth, in ft	1964–2002 depth, in ft	Bulk density, lb/ft^3	Average 1937–1964 bulk density, lb/ft^3	Average 1964–2002 bulk density, lb/ft^3	Percent sand (>0.053 mm)	Percent silt (0.05–0.002 mm)	Percent clay (<0.002 mm)	Textural class
		Northing, in m	Easting, in m									
SQ7	11/29/2002	307290	4440250	--	0-0.7	49.9	--	49.9	2	33	65	Clay
				0.7-1.1	--	--	--	--	1	39	60	Clay
SQ8	11/29/2002	307311	4439250	--	0-1.3	42.4	--	42.4	2	33	65	Clay
				1.3-2.4	--	63.0	63.0	--	2	36	62	Clay
SQ9	11/29/2002	307250	4438255	--	0-1.1	38.1	--	38.1	8	41	51	Silty clay
				1.1-1.5	--	61.2	61.2	--	1	59	40	Silty clay loam/silty clay
SQ10	11/29/2002	307250	4437250	--	0-0.6	35.0	--	35.0	6	66	28	Silty clay loam
				0.6-1.7	--	43.7	43.7	--	7	66	27	Silt loam/silty clay loam
SQ11	12/02/2002	308250	4443748	0-1	--	55.2	55.6	--	2	62	36	Silty clay loam
SQ12	12/02/2002	308250	4442750	--	0-0.6	50.6	--	50.6	3	45	52	Silty clay
				0.6-1.2	--	29.6	30.0	--	3	59	38	Silty clay loam
SQ13	12/02/2002	308250	4441750	--	0-0.1	44.9	--	44.9	4	45	51	Silty clay
				0.1-0.8	--	39.6	39.9	--	3	35	62	Clay
SQ14	12/02/2002	308250	4440750	--	0-0.8	43.7	--	43.7	2	29	69	Clay
				0.8-1.3	--	41.2	41.2	--	2	32	66	Clay
SQ15	12/02/2002	308250	4439750	--	0-1.3	49.0	--	49.3	2	33	65	Clay
				1.3-1.8	--	52.7	53.1	--	2	32	66	Clay

Table 3. Squaw Creek National Wildlife Refuge soil sample characteristics—Continued

[no., number; UTM, Universal Transverse Mercator; m, meters; ft, feet; lb/ft^3, pounds per cubic foot; >, greater than; mm, millimeters; <, less than; --, no data]

Site no. (fig. 1)	Sample date	Sample location UTM coordinates		1937–1964 depth, in ft	1964–2002 depth, in ft	Bulk density, lb/ft^3	Average 1937–1964 bulk density, lb/ft^3	Average 1964–2002 bulk density, lb/ft^3	Percent sand (>0.053 mm)	Percent silt (0.05–0.002 mm)	Percent clay (<0.002 mm)	Textural class
		Northing, in m	Easting, in m									
SQ16	12/02/2002	308250	4438750	--	0-1	37.5	--	--	5	44	51	Silty clay
				--	1-2	30.0	--	33.7	1	33	66	Clay
SQ17	12/02/2002	308250	4437750	0-0.7	--	33.7	33.7	--	9	51	40	Silty clay loam/silty clay
SQ18	12/02/2002	308250	4436750	--	0-0.4	29.3	--	29.3	2	44	54	Silty clay
				0.4-2.4	--	39.9	39.9	--	2	42	56	Silty clay
SQ19	12/02/2002	309250	4439750	--	0-1	33.1	--	33.1	6	32	62	Clay
				1-2	--	21.2	21.2	--	2	35	63	Clay
SQ20	12/02/2002	309250	4438750	0-1.2	--	23.7	23.7	--	1	67	32	Silty clay loam
SQ21	12/02/2002	309250	4437750	--	0-0.2	16.9	--	16.9	16	54	30	Silty clay loam
SQ22	11/29/2002	306575	4442350	--	0-1	53.7	--	--	3	72	25	Silt loam
				--	1-2	57.1	--	--	5	78	17	Silt loam
				--	2-3	62.7	--	--	3	75	22	Silt loam
				--	3-4	63.7	--	--	2	71	27	Silt loam/silty clay loam
				--	4-5	63.7	--	60.2	3	70	27	Silt loam/silty clay loam
				5-6	--	59.9	--	--	3	76	21	Silt loam
				6-7	--	66.8	63.4	--	2	66	32	Silty clay loam

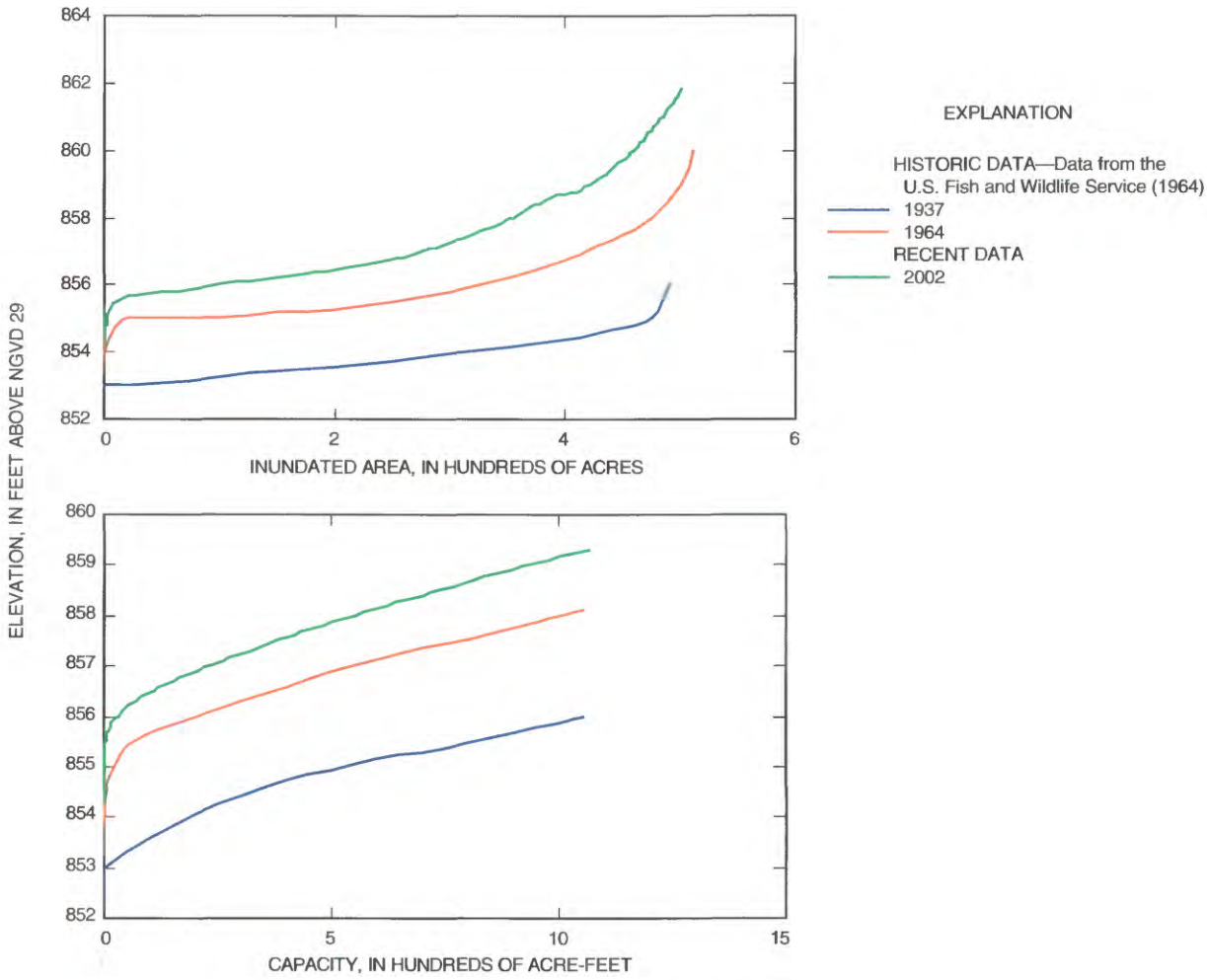


Figure 9. Elevation-area and elevation-capacity data for Mallard North and Mallard South at the Squaw Creek National Wildlife Refuge.

was 957 ft^3/s (cubic feet per second) compared with a 19-year mean of 971 ft^3/s (Hauck and Nagel, 2002). The 2002 total sediment load from the Squaw Creek Basin was about 11,000 tons, and the 2002 Davis Creek Basin total sediment load was about 690 tons. The 2002 yield from the Squaw Creek Basin (0.27 tons/acre) also exceeded that of the Davis Creek Basin (0.05 tons/acre). The 2002 water year streamflow in the region was substantially below average based on the 2002 Nodaway River near Graham, Missouri, mean annual flow of 192 ft^3/s (Hauck and Nagel, 2003).

Davis Creek had higher maximum suspended-sediment concentrations than Squaw Creek as a result of lower streamflows in combination with possibly higher erosion rates in the Davis Creek Basin. In comparison the greater streamflows in Squaw Creek resulted in greater sediment loads despite lower maximum concentrations. The measured suspended-sediment concentrations from Squaw Creek near Mound City, during the 2001 and 2002 water years, varied from 46 to about 26,000 mg/L (milligrams per liter). The range in concentrations from Davis Creek near Mound City for the same period varied from 46 to about 72,500 mg/L. The mean annual flows for Squaw and Davis Creeks in 2001 were 36.0 and 15.9 ft^3/s, respectively. The 2002 mean annual flows for Squaw and Davis Creeks were 13.1 and 4.5 ft^3/s, respectively (Hauck and Nagel, 2003).

The combined sediment load from Squaw and Davis Creeks during a water year of average flow (2001) was 76,200 tons, while the mean deposition mass in the Refuge (2002 surveyed area) from 1937 to 1964 was 241,000 tons/yr (tons per year) and 101,000 tons/yr from 1964 to 2002 (table 2). The higher deposition mass in 1937 to 1964 compared with 1964 to 2002 is likely the result of erosion-control management

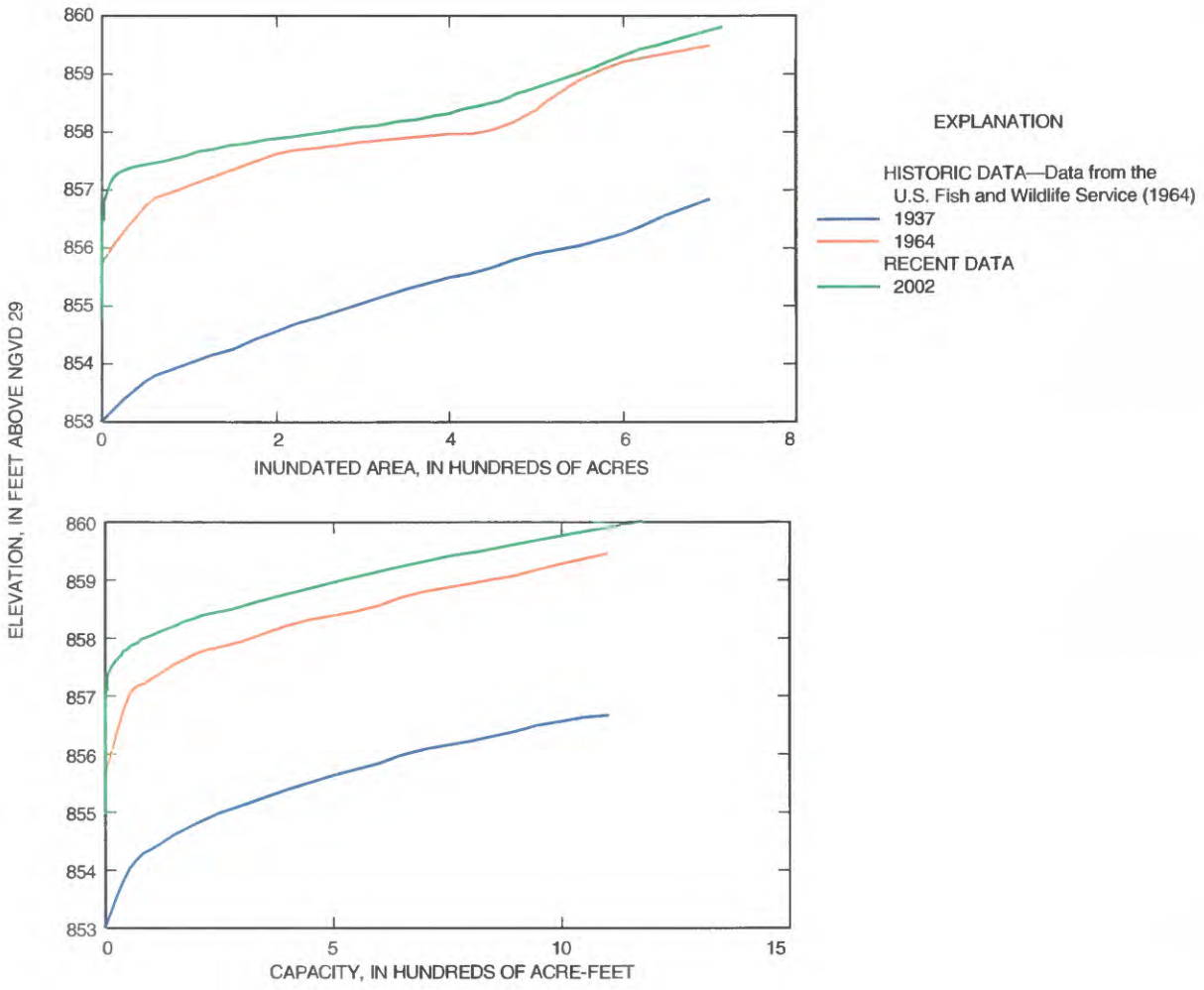


Figure 10. Elevation-area and elevation-capacity data for North pool at the Squaw Creek National Wildlife Refuge.

activities in the Squaw and Davis Creek Basins and Refuge spillway modifications made in the 1970's to regulate inflows and sediment contributions. Although a greater number of high magnitude floods from 1937 to 1964 than from 1964 to 2002 also could cause greater deposition during the earlier period, there was no statistically significant trend in the magnitude of historic peak flows with time from 1944 to 2002 (p= 0.70, significance level 0.05; fig. 12) at the nearby Big Nemaha River at Falls City, Nebraska, gaging station (fig. 1).

The difference in the 2001 suspended-sediment loads and the average annual sediment deposition between 1964 and 2002 is likely due, again, to a reduction in sediment inflows in the Refuge following the 1970's spillway modifications and a continuation of erosion control practices in the basins. These two sediment reduction mechanisms would not have been in place from 1964 to the 1970's, and would affect the overall 1964 to 2002 average deposition amounts. Other possible factors for the difference between the 2001 suspended-sediment loads and the 1937 to 1964 and 1964 to 2002 deposition values could be sediment deposition contributions from other basins [Missouri River, Little Tarkio Creek (fig. 1), and Porter Creek (fig. 3)] during flooding, and the variability in measurement and calculation of deposited sediment mass and sediment loads. The two largest Missouri River floods in recent history that affected the Refuge occurred in 1952 and 1993, and may have contributed sediment in some areas. Additional sediment load data collected during a range of flow conditions would be required to determine more conclusive relations between Squaw and Davis Creek suspended-sediment transport and Refuge deposition.

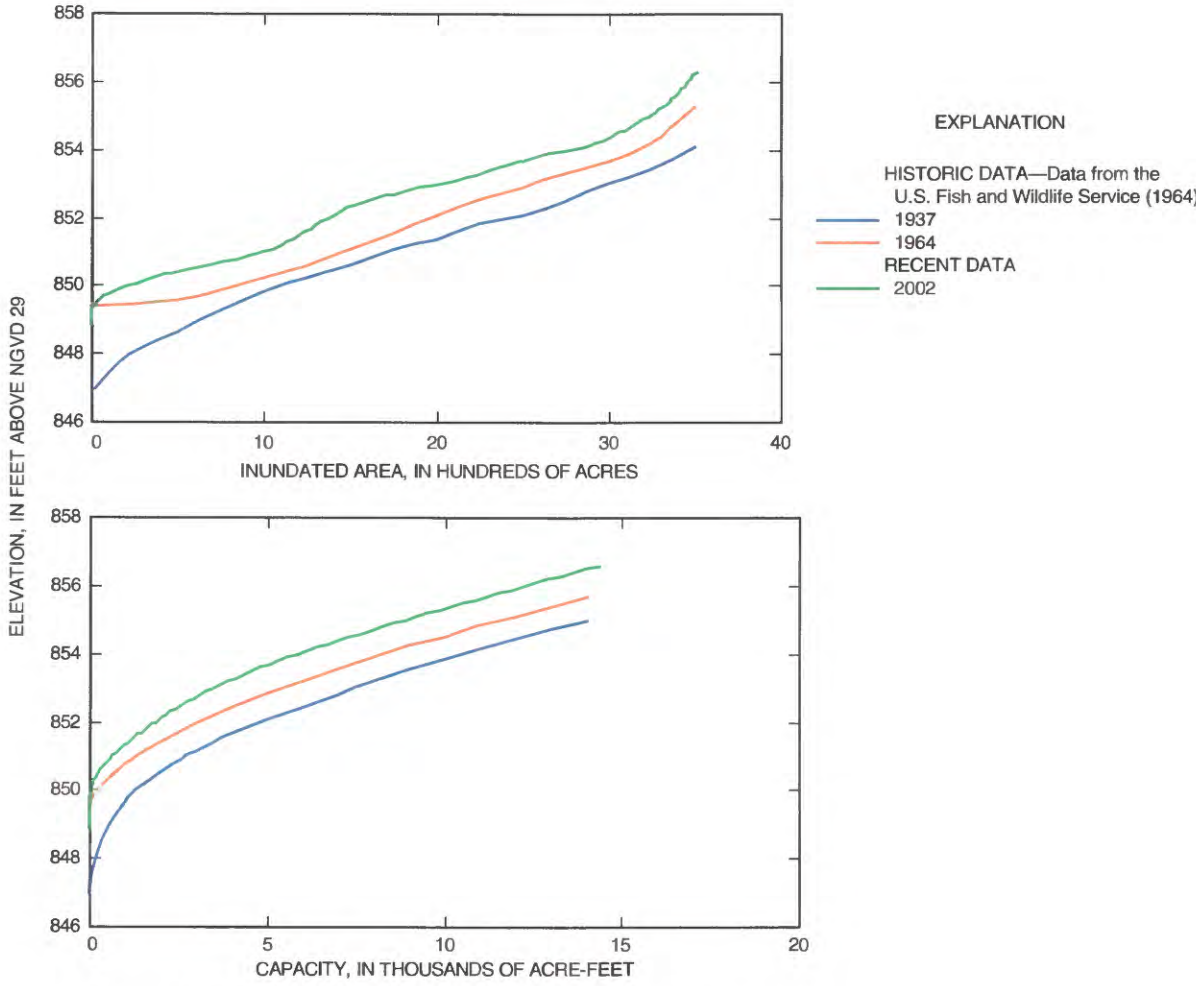


Figure 11. Elevation-area and elevation-capacity data for Snowgoose, Northeast Main, Northwest Main, Cattail Complex/Moist Soil Units, Eagle North, Eagle South, and Pelican pools at the Squaw Creek National Wildlife Refuge.

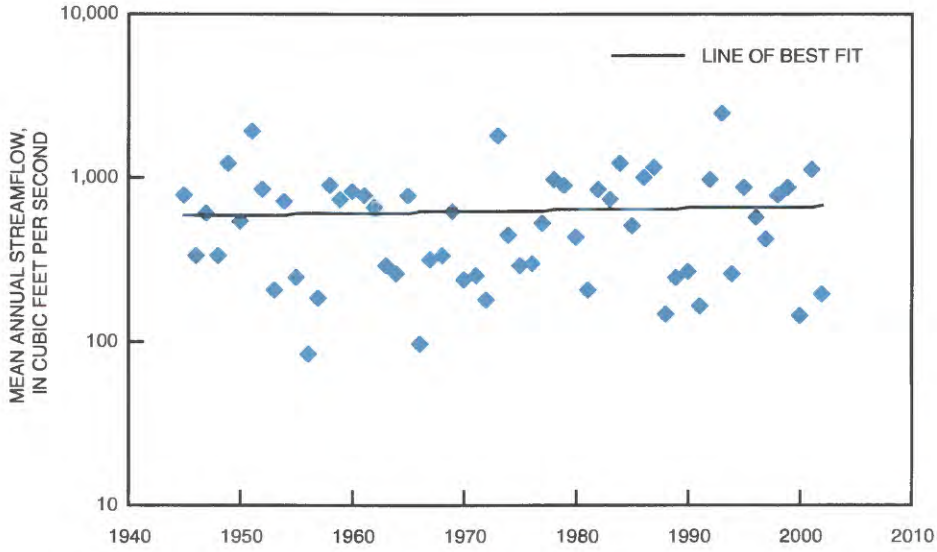


Figure 12. Mean annual flow at Big Nemaha River at Falls City, Nebraska (streamflow gaging station 06815000), 1944 to 2002.

SUMMARY AND CONCLUSIONS

The Squaw Creek National Wildlife Refuge (hereafter referred to as the Refuge) in Holt County, Missouri, was established in 1935 and is managed for the primary purpose of providing habitat for migratory birds and wildlife. Results of topographic surveys in 1937 and 1964 indicated that sedimentation, primarily from Squaw and Davis Creeks, had substantially reduced Refuge pool volumes and depths, resulting in a substantial loss of waterfowl habitat and a reduction in the ability of managers to manipulate existing habitat conditions. A study was undertaken of topography and sedimentation characteristics to quantify and spatially analyze historic rates of sedimentation in the Refuge, and determine the surface elevations, depths, and capacities for selected pools based on 1937, 1964, and 2002 topographic surveys.

From 1937 to 1964, the mean sediment deposition for the entire Refuge was about 1.37 ft (feet) or 0.051 ft/yr (foot per year). Mean annual rates of deposition by pool between 1937 and 1964 varied from 0.016 ft/yr in the Snowgoose pool A East to 0.083 ft/yr in the Mallard North pool.

From 1964 to 2002, the total average sediment deposition in the 2002 surveyed pool area (all pools except Bluff and the Cattail Complex/Moist soil units) was 0.753 ft, or 0.020 ft/yr. The 1937 to 1964 mean total deposition for the same pool areas was 1.26 ft, or 0.047 ft/yr. The mean rate of sediment-depth accumulation, therefore, from 1964 to 2002, was about 42 percent of the mean of the 1937 to 1964 rate, or a 58 percent reduction in the mean rates of accumulation. Mean annual rates of deposition by pool from 1964 to 2002 varied from 0.010 ft/yr in the Northeast Main pool and Pelican pool, to 0.049 ft/yr in Snowgoose pool A West. Despite a substantial reduction in the average rate of sediment accumulation for the Refuge, 5 of the 15 separate pools for which annual rates were calculated for 1937 to 1964 and 1964 to 2002 indicated an increase in the deposition rates between the two periods, albeit the maximum increase was only 0.008 ft/yr in Snowgoose A West.

The greatest amounts of sediment deposition in the Refuge from 1937 to 2002 have been near the Squaw and Davis Creek inflow spillways, which have been located at various locations in the northwest and northeast sections of the Refuge. When an inflow spillway was relocated, additional sediment deposition was reduced at the original location, while sedimentation

American lotus *(Nelumbo lutea)* in bloom in Eagle pool at the Squaw Creek National Wildlife Refuge.

increased at the new inflow location. An example of this is found in the North pool that directly received Squaw Creek inflows from 1937 to 1964 and had a deposition rate of 0.081 ft/yr, reduced to 0.012 ft/yr from 1964 to 2002, after inflows were redirected. The current inflows from Squaw Creek are closer to the Snowgoose complex and Pintail pools, and many of these pools received greater mean annual accumulations of sediment from 1964 to 2002 than from 1937 to 1964.

While the Squaw and Davis Creek Basins were the primary contributors of sediment to the Refuge between 1937 and 2002, sediment contributions also could have been made by flooding from the Missouri River although such contributions were likely not substantial. Missouri River floods in 1952 and 1993 were the largest in the area but there are no records or observations of possible sediment contributions to the Refuge from either of these floods. The strong association between Squaw and Davis Creek spillway locations and Refuge sediment deposits, the lack of measurable deposition over some areas in the Refuge that were inundated during the 1993 flood (areas of Northeast, Northwest Main pool, eastern section of North pool, and central Eagle pools that in 2002 were unchanged from 1937 topography), and the distance of the Refuge from the Missouri River (approximately 5 miles) indicate or suggest that sediment contributions from the Missouri River floods were not substantial.

Sediment deposits have resulted in a substantial cumulative loss of pool volume in the Refuge pools since 1937. The volume of sediment deposited between 1937 to 1964 for all areas included in the 2002 survey was about 6,200 acre-ft (acre-feet), or 230 acre-ft/yr

(acre-feet per year). For 1964 to 2002, the total deposition was about 3,700 acre-ft, or 97.3 acre-ft/yr. The 1937 to 2002 total sediment volume, for pools surveyed in 2002, was about 9,900 acre-ft, or 152 acre-ft/yr.

The total computed sediment mass deposited between 1937 and 1964 in the 2002 surveyed Refuge pool area (excluding the Cattail Complex/Moist soil unit and Bluff pool) was about 6,510,000 tons, or an average of 49.1 tons/acre/yr (tons per acre per year). The total 1964 to 2002 mass for surveyed pools was about 3,830,000 tons, or an average of 20.5 tons/acre/yr. The 1964 to 2002 rate of sediment mass deposition, as with sediment depth, was about 42 percent of that from 1937 to 1964, or a 58 percent reduction. Overall, from 1937 to 2002, about 10,300,000 tons of sediment were deposited in the surveyed area, or 32.4 tons/acre/yr.

The differential sediment thickness maps indicate that Squaw Creek was the primary contributor of sediment to the Refuge during 1937 to 2002 and suspended-sediment data from Squaw Creek and Davis Creek for the 2001 and 2002 water years supports these findings. The total annual sediment loads from the Squaw Creek Basin exceeded those of Davis Creek for the 2001 and 2002 monitored water years; however, the 2001 basin-area adjusted sediment yield from the Davis Creek Basin exceeded that from the Squaw Creek Basin.

The combined suspended-sediment load from Squaw and Davis Creeks during a water year of average flow (2001) was about 76,200 tons, while the mean deposition in the Refuge was about 241,000 tons/yr (tons per year) from 1937 to 1964, and about 101,000 tons/yr from 1964 to 2002. The differences in deposition rates between 1937 and 1964 compared with 1964 to 2002, and the higher deposition rates of 1964 to 2002 compared with the sediment load from the two creeks during an average recent flow year (2001), do not seem to be the result of higher historic streamflows. Higher rates of deposition may have occurred during the early years of the 1964 to 2002 period, when erosion-control programs were just becoming widespread and before the establishment of more effective control gates on the inflow spillways by the early 1970's. Additional data during a range of flow conditions would be required to determine more reliable annual yields and conclusive relations between Squaw and Davis Creek sediment transport and Refuge deposition.

Measures taken in the Refuge to limit flooding and control the timing of inflows, along with erosion-control measures in the Squaw and Davis Creek Basins, seem to have resulted in a substantial reduction in the average rate of sediment deposition for 1964 to 2002, compared to 1937 to 1964. Current (2003) deposition patterns are still related to the proximity to inflow spillway locations and deposition rates in individual pools are variable. Known rates of sediment deposition in the Refuge can be used to develop long-term management strategies for individual pools or the Refuge as a whole.

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TABLE

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

Mallard North

Outlet location 4441177.603 305596.239

Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
3.23	854.5	0.00	0.00	0.00	5.73	857	118	64.6	0.55	8.23	859.5	258	533	2.07
3.33	854.6	.00	.00	.03	5.83	857.1	125	76.8	.62	8.33	859.6	261	559	2.14
3.43	854.7	.04	.00	.04	5.93	857.2	129	89.5	.69	8.43	859.7	264	585	2.22
3.53	854.8	.16	.01	.07	6.03	857.3	134	103	.76	8.53	859.8	266	611	2.29
3.63	854.9	.38	.04	.10	6.13	857.4	139	116	.83	8.63	859.9	269	638	2.37
3.73	855	.79	.09	.11	6.23	857.5	145	131	.90	8.73	860	273	665	2.44
3.83	855.1	1.23	.19	.15	6.33	857.6	151	145	.96	8.83	860.1	275	693	2.52
3.93	855.2	1.68	.34	.20	6.43	857.7	156	161	1.03	8.93	860.2	278	720	2.59
4.03	855.3	2.12	.53	.25	6.53	857.8	161	177	1.09	9.03	860.3	280	748	2.67
4.13	855.4	2.58	.76	.29	6.63	857.9	167	193	1.15	9.13	860.4	282	776	2.75
4.23	855.5	3.24	1.04	.32	6.73	858	175	210	1.20	9.23	860.5	284	804	2.83
4.33	855.6	4.61	1.43	.31	6.83	858.1	180	228	1.27	9.33	860.6	286	833	2.91
4.43	855.7	6.30	1.98	.31	6.93	858.2	184	246	1.33	9.43	860.7	289	862	2.99
4.53	855.8	8.11	2.70	.33	7.03	858.3	189	265	1.40	9.53	860.8	291	891	3.06
4.63	855.9	11.2	3.64	.32	7.13	858.4	193	284	1.47	9.63	860.9	293	920	3.14
4.73	856	17.6	5.02	.29	7.23	858.5	198	303	1.53	9.73	861	296	949	3.21
4.83	856.1	22.1	7.01	.32	7.33	858.6	203	323	1.59	9.83	861.1	298	979	3.29
4.93	856.2	27.7	9.49	.34	7.43	858.7	209	344	1.65	9.93	861.2	300	1,010	3.36
5.03	856.3	33.5	12.5	.37	7.53	858.8	214	365	1.71					
5.13	856.4	43.4	16.4	.38	7.63	858.9	220	387	1.76					
5.23	856.5	55.3	21.3	.39	7.73	859	236	409	1.73					
5.33	856.6	67.4	27.4	.41	7.83	859.1	241	433	1.80					
5.43	856.7	79.6	34.8	.44	7.93	859.2	245	457	1.87					
5.53	856.8	91.2	43.3	.48	8.03	859.3	249	482	1.94					
5.63	856.9	108	53.3	.49	8.13	859.4	253	507	2.00					

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

Mallard South
Outlet location 4440638.929 306066.986

Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
4.40	855.1	0.00	0.00	0.00	6.90	857.6	158	190	1.20	9.40	860.1	180	619	3.44
4.50	855.2	.00	.00	.01	7.00	857.7	160	206	1.29	9.50	860.2	180	637	3.53
4.60	855.3	.11	.01	.05	7.10	857.8	162	222	1.37	9.60	860.3	181	655	3.62
4.70	855.4	.32	.03	.08	7.20	857.9	164	239	1.46	9.70	860.4	181	673	3.71
4.80	855.5	.68	.07	.11	7.30	858	165	255	1.55	9.80	860.5	182	691	3.81
4.90	855.6	1.14	.16	.14	7.40	858.1	166	272	1.64	9.90	860.6	182	710	3.90
5.00	855.7	1.97	.31	.16	7.50	858.2	167	288	1.73					
5.10	855.8	5.45	.66	.12	7.60	858.3	168	305	1.82					
5.20	855.9	12.8	1.49	.12	7.70	858.4	169	322	1.91					
5.30	856	35.3	3.88	.11	7.80	858.5	170	339	2.00					
5.40	856.1	52.7	8.28	.16	7.90	858.6	170	356	2.09					
5.50	856.2	64.8	14.2	.22	8.00	858.7	171	373	2.18					
5.60	856.3	77.9	21.3	.27	8.10	858.8	172	390	2.27					
5.70	856.4	93.3	29.9	.32	8.20	858.9	173	407	2.36					
5.80	856.5	108	39.9	.37	8.30	859	173	425	2.45					
5.90	856.6	117	51.2	.44	8.40	859.1	174	442	2.54					
6.00	856.7	122	63.1	.52	8.50	859.2	175	459	2.63					
6.10	856.8	127	75.6	.60	8.60	859.3	175	477	2.72					
6.20	856.9	131	88.5	.67	8.70	859.4	176	495	2.81					
6.30	857	135	102	.75	8.80	859.5	177	512	2.90					
6.40	857.1	139	116	.83	8.90	859.6	177	530	2.99					
6.50	857.2	144	130	.90	9.00	859.7	178	548	3.08					
6.60	857.3	148	144	.97	9.10	859.8	178	565	3.17					
6.70	857.4	152	159	1.05	9.20	859.9	179	583	3.26					
6.80	857.5	156	175	1.12	9.30	860	179	601	3.35					

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

North

Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
855.1	0.00	0.00	0.00	857.6	33.3	6.98	0.21	860.1	724	1,060	1.47	862.6	1,070	3,360	3.13
855.2	.00	.00	.04	857.7	57.1	11.5	.20	860.2	746	1,130	1.52	862.7	1,080	3,470	3.20
855.3	.01	.00	.08	857.8	83.4	18.5	.22	860.3	766	1,210	1.58	862.8	1,090	3,570	3.28
855.4	.02	.00	.12	857.9	112	28.2	.25	860.4	785	1,290	1.64	862.9	1,100	3,680	3.36
855.5	.03	.00	.15	858	147	41.0	.28	860.5	802	1,370	1.71	863	1,110	3,790	3.43
855.6	.04	.01	.19	858.1	190	57.8	.30	860.6	819	1,450	1.77	863.1	1,110	3,900	3.50
855.7	.06	.01	.23	858.2	237	79.1	.33	860.7	836	1,530	1.83	863.2	1,120	4,020	3.58
855.8	.09	.02	.24	858.3	291	106	.36	860.8	853	1,620	1.89	863.3	1,130	4,130	3.67
855.9	.13	.03	.24	858.4	341	137	.40	860.9	868	1,700	1.96	863.4	1,130	4,240	3.76
856	.19	.05	.25	858.5	384	173	.45	861	882	1,790	2.03	863.5	1,130	4,350	3.84
856.1	.27	.07	.26	858.6	413	213	.52	861.1	896	1,880	2.10	863.6	1,140	4,470	3.93
856.2	.36	.10	.28	858.7	436	256	.59	861.2	909	1,970	2.17	863.7	1,140	4,580	4.02
856.3	.46	.14	.31	858.8	458	300	.66	861.3	921	2,060	2.24	863.8	1,140	4,700	4.11
856.4	.57	.19	.34	858.9	478	347	.73	861.4	933	2,150	2.31	863.9	1,140	4,810	4.21
856.5	.72	.26	.36	859	496	396	.80	861.5	945	2,250	2.38	864	1,150	4,920	4.29
856.6	.91	.34	.37	859.1	519	447	.86	861.6	957	2,340	2.45				
856.7	1.14	.44	.39	859.2	539	500	.93	861.7	968	2,440	2.52				
856.8	1.43	.57	.40	859.3	558	554	.99	861.8	979	2,540	2.59				
856.9	1.81	.73	.40	859.4	575	611	1.06	861.9	990	2,630	2.66				
857	2.33	.93	.40	859.5	592	669	1.13	862	1,000	2,730	2.73				
857.1	3.05	1.20	.39	859.6	609	729	1.20	862.1	1,020	2,830	2.79				
857.2	4.85	1.57	.32	859.7	629	791	1.26	862.2	1,030	2,940	2.85				
857.3	7.77	2.20	.28	859.8	650	855	1.32	862.3	1,040	3,040	2.91				
857.4	11.5	3.15	.27	859.9	675	921	1.37	862.4	1,050	3,150	2.98				
857.5	17.5	4.58	.26	860	701	990	1.41	862.5	1,060	3,250	3.05				

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

Pintail North
Outlet location 4439197.138 306658.881

Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
2.64	852.7	0.00	0.00	0.00	5.14	855.2	141	101	0.71	7.64	857.7	183	510	2.78
2.74	852.8	.00	.00	.03	5.24	855.3	144	115	.80	7.74	857.8	185	529	2.86
2.84	852.9	.00	.00	.07	5.34	855.4	146	129	.89	7.84	857.9	186	547	2.95
2.94	853	.00	.00	.10	5.44	855.5	148	144	.97	7.94	858	187	566	3.03
3.04	853.1	.00	.00	.13	5.54	855.6	150	159	1.06	8.04	858.1	188	585	3.11
3.14	853.2	.00	.00	.17	5.64	855.7	152	174	1.14	8.14	858.2	189	604	3.20
3.24	853.3	.00	.00	.20	5.74	855.8	154	189	1.23	8.24	858.3	190	622	3.28
3.34	853.4	.01	.00	.24	5.84	855.9	156	205	1.32	8.34	858.4	191	642	3.36
3.44	853.5	.10	.01	.06	5.94	856	157	221	1.40	8.44	858.5	192	661	3.45
3.54	853.6	.69	.03	.05	6.04	856.1	159	236	1.49	8.54	858.6	193	680	3.53
3.64	853.7	2.65	.19	.07	6.14	856.2	160	252	1.57	8.64	858.7	194	699	3.61
3.74	853.8	4.88	.57	.12	6.24	856.3	162	269	1.66	8.74	858.8	194	719	3.70
3.84	853.9	7.38	1.18	.16	6.34	856.4	164	285	1.74	8.84	858.9	195	738	3.79
3.94	854	10.6	2.07	.19	6.44	856.5	165	301	1.82	8.94	859	196	758	3.87
4.04	854.1	15.7	3.36	.21	6.54	856.6	167	318	1.91	9.04	859.1	196	777	3.96
4.14	854.2	30.6	5.55	.18	6.64	856.7	168	335	1.99	9.14	859.2	197	797	4.05
4.24	854.3	46.2	9.42	.20	6.74	856.8	170	352	2.07	9.24	859.3	197	816	4.14
4.34	854.4	61.1	14.8	.24	6.84	856.9	171	369	2.15	9.34	859.4	198	836	4.23
4.44	854.5	73.9	21.6	.29	6.94	857	173	386	2.23	9.44	859.5	198	856	4.32
4.54	854.6	88.2	29.6	.34	7.04	857.1	174	403	2.31	9.54	859.6	199	876	4.41
4.64	854.7	101	39.1	.39	7.14	857.2	176	421	2.39	9.64	859.7	199	896	4.50
4.74	854.8	110	49.6	.45	7.24	857.3	177	438	2.47	9.74	859.8	199	916	4.59
4.84	854.9	118	61.0	.52	7.34	857.4	179	456	2.55	9.84	859.9	200	936	4.68
4.94	855	130	73.3	.56	7.44	857.5	180	474	2.63	9.94	860	200	956	4.78
5.04	855.1	138	86.7	.63	7.54	857.6	182	492	2.71					

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

Pintail South

Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
852.4	0.00	0.00	0.00	854.9	10.4	7.99	0.77	857.4	27.0	59.0	2.19	859.9	29.3	130	4.44
852.5	.00	.00	.03	855	11.2	9.07	.81	857.5	27.2	61.7	2.27	860	29.4	133	4.53
852.6	.00	.00	.08	855.1	12.1	10.2	.84	857.6	27.4	64.4	2.35				
852.7	.01	.00	.12	855.2	13.1	11.5	.88	857.7	27.6	67.2	2.44				
852.8	.01	.00	.15	855.3	14.2	12.9	.91	857.8	27.7	69.9	2.52				
852.9	.01	.00	.17	855.4	15.3	14.4	.94	857.9	27.8	72.7	2.61				
853	.02	.00	.18	855.5	16.4	15.9	.97	858	27.9	75.5	2.70				
853.1	.03	.01	.23	855.6	17.3	17.6	1.02	858.1	28.0	78.3	2.79				
853.2	.06	.01	.18	855.7	18.0	19.4	1.08	858.2	28.2	81.1	2.88				
853.3	.15	.02	.14	855.8	18.8	21.2	1.13	858.3	28.3	83.9	2.97				
853.4	.35	.04	.13	855.9	19.4	23.1	1.19	858.4	28.4	86.8	3.06				
853.5	.86	.10	.11	856	20.1	25.1	1.25	858.5	28.5	89.6	3.15				
853.6	1.65	.22	.14	856.1	20.8	27.2	1.30	858.6	28.6	92.5	3.24				
853.7	2.35	.42	.18	856.2	21.6	29.3	1.36	858.7	28.6	95.3	3.33				
853.8	2.99	.69	.23	856.3	22.4	31.5	1.40	858.8	28.7	98.2	3.42				
853.9	3.63	1.02	.28	856.4	23.0	33.8	1.47	858.9	28.8	101	3.51				
854	4.26	1.42	.33	856.5	23.4	36.1	1.54	859	28.8	104	3.60				
854.1	4.91	1.88	.38	856.6	23.9	38.4	1.61	859.1	28.9	107	3.70				
854.2	5.58	2.40	.43	856.7	24.4	40.8	1.68	859.2	29.0	110	3.79				
854.3	6.28	2.99	.48	856.8	24.8	43.3	1.74	859.3	29.0	113	3.88				
854.4	6.97	3.65	.52	856.9	25.4	45.8	1.81	859.4	29.1	116	3.97				
854.5	7.64	4.38	.57	857	25.8	48.4	1.87	859.5	29.1	118	4.07				
854.6	8.32	5.18	.62	857.1	26.2	51.0	1.94	859.6	29.2	121	4.16				
854.7	9.00	6.05	.67	857.2	26.5	53.6	2.02	859.7	29.2	124	4.25				
854.8	9.71	6.98	.72	857.3	26.8	56.3	2.10	859.8	29.3	127	4.34				

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

Snowgoose A West

Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
854	0.00	0.00	0.00	856.5	16.7	15.0	0.90	859	35.6	82.7	2.32
854.1	.00	.00	.01	856.6	17.6	16.7	.95	859.1	36.0	86.3	2.40
854.2	.02	.00	.05	856.7	18.5	18.6	1.00	859.2	36.2	89.9	2.48
854.3	.10	.00	.04	856.8	19.3	20.4	1.06	859.3	36.4	93.5	2.57
854.4	.74	.04	.06	856.9	20.1	22.4	1.11	859.4	36.6	97.2	2.66
854.5	2.04	.21	.10	857	21.0	24.5	1.16	859.5	36.8	101	2.74
854.6	2.51	.44	.17	857.1	22.0	26.6	1.21	859.6	36.9	105	2.83
854.7	2.86	.71	.25	857.2	23.1	28.9	1.25				
854.8	3.17	1.01	.32	857.3	24.1	31.2	1.30				
854.9	3.46	1.34	.39	857.4	25.0	33.7	1.35				
855	3.77	1.70	.45	857.5	25.8	36.2	1.40				
855.1	4.09	2.09	.51	857.6	26.6	38.8	1.46				
855.2	4.42	2.52	.57	857.7	27.4	41.5	1.51				
855.3	4.81	2.98	.62	857.8	28.2	44.3	1.57				
855.4	5.33	3.49	.65	857.9	28.8	47.2	1.63				
855.5	5.98	4.05	.68	858	29.5	50.1	1.70				
855.6	6.71	4.69	.70	858.1	30.2	53.1	1.76				
855.7	7.59	5.40	.71	858.2	30.8	56.1	1.82				
855.8	8.47	6.20	.73	858.3	31.4	59.2	1.89				
855.9	9.21	7.09	.77	858.4	31.9	62.4	1.96				
856	10.0	8.05	.80	858.5	32.5	65.6	2.02				
856.1	11.9	9.12	.77	858.6	33.1	68.9	2.08				
856.2	14.0	10.4	.75	858.7	33.9	72.2	2.13				
856.3	14.9	11.9	.80	858.8	34.6	75.7	2.19				
856.4	15.8	13.4	.85	858.9	35.2	79.2	2.25				

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

Snowgoose A East
Outlet location 4440114.771 307229.945

Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
3.54	853.2	0.00	0.00	0.00	6.04	855.7	36.9	40.1	1.09	8.54	858.2	47.9	152	3.18
3.64	853.3	.00	.00	.01	6.14	855.8	37.8	43.8	1.16	8.64	858.3	48.0	157	3.27
3.74	853.4	.02	.00	.05	6.24	855.9	38.7	47.7	1.23	8.74	858.4	48.1	162	3.37
3.84	853.5	.06	.00	.07	6.34	856	39.6	51.6	1.30	8.84	858.5	48.2	167	3.46
3.94	853.6	.15	.01	.10	6.44	856.1	40.6	55.6	1.37	8.94	858.6	48.3	172	3.55
4.04	853.7	.25	.03	.14	6.54	856.2	41.9	59.7	1.43	9.04	858.7	48.4	176	3.64
4.14	853.8	.39	.07	.17	6.64	856.3	43.3	64.0	1.48	9.14	858.8	48.5	181	3.74
4.24	853.9	1.21	.14	.12	6.74	856.4	44.3	68.4	1.54	9.24	858.9	48.6	186	3.83
4.34	854	2.49	.32	.13	6.84	856.5	45.0	72.8	1.62	9.34	859	48.6	191	3.92
4.44	854.1	5.60	.72	.13	6.94	856.6	45.4	77.4	1.70	9.44	859.1	48.7	196	4.02
4.54	854.2	8.03	1.39	.17	7.04	856.7	45.7	81.9	1.79	9.54	859.2	48.8	201	4.11
4.64	854.3	10.6	2.33	.22	7.14	856.8	45.9	86.5	1.88	9.64	859.3	48.8	206	4.21
4.74	854.4	13.5	3.53	.26	7.24	856.9	46.1	91.1	1.98	9.74	859.4	48.9	210	4.30
4.84	854.5	16.6	5.04	.30	7.34	857	46.3	95.7	2.07	9.84	859.5	49.0	215	4.40
4.94	854.6	19.5	6.84	.35	7.44	857.1	46.5	100	2.16	9.94	859.6	49.0	220	4.49
5.04	854.7	22.3	8.94	.40	7.54	857.2	46.6	105	2.25					
5.14	854.8	24.8	11.3	.46	7.64	857.3	46.8	110	2.35					
5.24	854.9	27.7	13.9	.50	7.74	857.4	46.9	114	2.44					
5.34	855	29.5	16.8	.57	7.84	857.5	47.0	119	2.53					
5.44	855.1	30.8	19.8	.64	7.94	857.6	47.1	124	2.63					
5.54	855.2	31.9	22.9	.72	8.04	857.7	47.3	128	2.72					
5.64	855.3	32.9	26.2	.79	8.14	857.8	47.4	133	2.81					
5.74	855.4	33.9	29.5	.87	8.24	857.9	47.5	138	2.90					
5.84	855.5	34.8	33.0	.95	8.34	858	47.6	143	3.00					
5.94	855.6	35.8	36.5	1.02	8.44	858.1	47.8	148	3.09					

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

Snowgoose B
Outlet location 4440052.454 307235.314

Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
3.27	852.9	0.00	0.00	0.00	5.77	855.4	15.9	5.20	0.33	8.27	857.9	37.0	86.9	2.35
3.37	853	.00	.00	.02	5.87	855.5	19.1	6.95	.36	8.37	858	37.1	90.6	2.44
3.47	853.1	.00	.00	.05	5.97	855.6	21.8	9.00	.41	8.47	858.1	37.1	94.3	2.54
3.57	853.2	.00	.00	.05	6.07	855.7	24.5	11.3	.46	8.57	858.2	37.2	98.0	2.64
3.67	853.3	.01	.00	.08	6.17	855.8	26.8	13.9	.52	8.67	858.3	37.2	102	2.73
3.77	853.4	.02	.00	.11	6.27	855.9	28.4	16.6	.59	8.77	858.4	37.3	105	2.83
3.87	853.5	.04	.01	.13	6.37	856	29.6	19.6	.66	8.87	858.5	37.3	109	2.93
3.97	853.6	.07	.01	.16	6.47	856.1	30.8	22.6	.73	8.97	858.6	37.4	113	3.02
4.07	853.7	.11	.02	.19	6.57	856.2	32.2	25.7	.80	9.07	858.7	37.4	117	3.12
4.17	853.8	.16	.03	.21	6.67	856.3	33.7	29.0	.86	9.17	858.8	37.4	120	3.22
4.27	853.9	.21	.05	.24	6.77	856.4	34.5	32.4	.94	9.27	858.9	37.5	124	3.31
4.37	854	.28	.08	.27	6.87	856.5	35.1	35.9	1.02	9.37	859	37.5	128	3.41
4.47	854.1	.37	.11	.29	6.97	856.6	35.6	39.4	1.11	9.47	859.1	37.6	132	3.51
4.57	854.2	.47	.15	.32	7.07	856.7	35.9	43.0	1.20	9.57	859.2	37.6	135	3.60
4.67	854.3	.58	.20	.35	7.17	856.8	36.0	46.6	1.29	9.67	859.3	37.6	139	3.70
4.77	854.4	.72	.27	.37	7.27	856.9	36.2	50.2	1.39	9.77	859.4	37.7	143	3.79
4.87	854.5	.96	.35	.36	7.37	857	36.3	53.8	1.48	9.87	859.5	37.7	147	3.89
4.97	854.6	1.37	.46	.34	7.47	857.1	36.4	57.5	1.58					
5.07	854.7	1.84	.62	.34	7.57	857.2	36.6	61.1	1.67					
5.17	854.8	2.42	.84	.35	7.67	857.3	36.6	64.8	1.77					
5.27	854.9	3.28	1.12	.34	7.77	857.4	36.7	68.5	1.86					
5.37	855	4.50	1.50	.33	7.87	857.5	36.8	72.1	1.96					
5.47	855.1	6.23	2.04	.33	7.97	857.6	36.9	75.8	2.06					
5.57	855.2	8.41	2.77	.33	8.07	857.7	36.9	79.5	2.15					
5.67	855.3	12.2	3.79	.31	8.17	857.8	37.0	83.2	2.25					

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

Snowgoose C Outlet location 4439437.062 307242.261									
Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
1.74	852.6	0.00	0.00	0.00	4.24	855.1	72.8	75.7	1.04
1.84	852.7	.00	.00	.02	4.34	855.2	73.2	83.0	1.13
1.94	852.8	.01	.00	.05	4.44	855.3	73.5	90.3	1.23
2.04	852.9	.02	.00	.08	4.54	855.4	73.8	97.7	1.32
2.14	853	.04	.00	.11	4.64	855.5	74.2	105	1.42
2.24	853.1	.06	.01	.15	4.74	855.6	74.5	113	1.51
2.34	853.2	.10	.02	.18	4.84	855.7	74.8	120	1.60
2.44	853.3	.14	.03	.20	4.94	855.8	75.1	127	1.70
2.54	853.4	.20	.05	.23	5.04	855.9	75.4	135	1.79
2.64	853.5	.27	.07	.26	5.14	856	75.7	143	1.88
2.74	853.6	.33	.10	.30	5.24	856.1	77.5	150	1.94
2.84	853.7	.56	.14	.26	5.34	856.2	77.7	158	2.03
2.94	853.8	1.68	.24	.14	5.44	856.3	77.9	166	2.13
3.04	853.9	8.17	.64	.08	5.54	856.4	78.0	174	2.22
3.14	854	25.8	2.26	.09	5.64	856.5	78.2	181	2.32
3.24	854.1	59.4	6.37	.11	5.74	856.6	78.3	189	2.41
3.34	854.2	65.4	12.7	.19	5.84	856.7	78.5	197	2.51
3.44	854.3	67.4	19.3	.29	5.94	856.8	78.6	205	2.61
3.54	854.4	68.3	26.1	.38	6.04	856.9	78.7	213	2.70
3.64	854.5	69.1	33.0	.48	6.14	857	78.8	221	2.80
3.74	854.6	69.9	40.0	.57	6.24	857.1	78.9	228	2.89
3.84	854.7	70.6	47.0	.67	6.34	857.2	79.0	236	2.99
3.94	854.8	71.2	54.1	.76	6.44	857.3	79.2	244	3.09
4.04	854.9	71.8	61.2	.85	6.54	857.4	79.2	252	3.18
4.14	855	72.4	68.4	.95	6.64	857.5	79.3	260	3.28

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

Snowgoose D Outlet location 4439120.602 307229.448														
Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
1.20	852.3	0.00	0.00	0.00	3.70	854.8	22.4	13.7	0.61	6.20	857.3	39.6	99.7	2.51
1.30	852.4	.00	.00	.03	3.80	854.9	24.1	16.0	.66	6.30	857.4	39.8	104	2.60
1.40	852.5	.00	.00	.06	3.90	855	25.9	18.5	.71	6.40	857.5	39.9	108	2.70
1.50	852.6	.01	.00	.09	4.00	855.1	27.1	21.1	.78	6.50	857.6	40.0	112	2.79
1.60	852.7	.06	.00	.06	4.10	855.2	28.2	23.9	.85	6.60	857.7	40.1	116	2.88
1.70	852.8	.14	.01	.09	4.20	855.3	29.4	26.8	.91					
1.80	852.9	.26	.03	.12	4.30	855.4	30.6	29.8	.97					
1.90	853	.44	.07	.15	4.40	855.5	31.7	32.9	1.04					
2.00	853.1	.70	.12	.17	4.50	855.6	32.7	36.1	1.10					
2.10	853.2	1.02	.21	.20	4.60	855.7	33.7	39.4	1.17					
2.20	853.3	1.36	.33	.24	4.70	855.8	34.6	42.9	1.24					
2.30	853.4	1.75	.48	.28	4.80	855.9	35.2	46.4	1.31					
2.40	853.5	2.11	.67	.32	4.90	856	35.9	49.9	1.39					
2.50	853.6	2.50	.90	.36	5.00	856.1	36.5	53.5	1.47					
2.60	853.7	2.94	1.18	.40	5.10	856.2	37.0	57.2	1.54					
2.70	853.8	3.50	1.50	.43	5.20	856.3	37.5	60.9	1.62					
2.80	853.9	4.39	1.89	.43	5.30	856.4	37.9	64.7	1.71					
2.90	854	5.68	2.40	.42	5.40	856.5	38.1	68.5	1.80					
3.00	854.1	7.79	3.05	.39	5.50	856.6	38.4	72.3	1.89					
3.10	854.2	10.0	3.95	.39	5.60	856.7	38.6	76.2	1.97					
3.20	854.3	12.0	5.05	.42	5.70	856.8	38.8	80.0	2.06					
3.30	854.4	13.9	6.34	.46	5.80	856.9	39.0	83.9	2.15					
3.40	854.5	16.0	7.84	.49	5.90	857	39.2	87.8	2.24					
3.50	854.6	18.5	9.56	.52	6.00	857.1	39.3	91.8	2.33					
3.60	854.7	20.5	11.5	.56	6.10	857.2	39.5	95.7	2.42					

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

South Eagle West Stage—Continued Outlet location 4436195.324 308158.066				
Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
5.7	856.5	2,340	8,850	3.79
5.8	856.6	2,340	9,080	3.88
5.9	856.7	2,340	9,320	3.98
6	856.8	2,340	9,550	4.07
6.1	856.9	2,350	9,780	4.17
6.2	857	2,350	10,000	4.27
6.3	857.1	2,350	10,300	4.36
6.4	857.2	2,350	10,500	4.46
6.5	857.3	2,350	10,700	4.56
6.6	857.4	2,350	11,000	4.66
6.7	857.5	2,350	11,200	4.76

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

South Eagle Gate Stage
Outlet location 4436124.546 308288.241

Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
-2.16	849	0.00	0.00	0.00	0.34	851.5	628	588	0.94	2.84	854	1,810	3,380	1.86
-2.06	849.1	.00	.00	.02	.44	851.6	657	652	.99	2.94	854.1	1,870	3,560	1.91
-1.96	849.2	.05	.00	.04	.54	851.7	687	720	1.05	3.04	854.2	1,930	3,750	1.94
-1.86	849.3	.17	.01	.07	.64	851.8	715	790	1.10	3.14	854.3	1,990	3,950	1.99
-1.76	849.4	.36	.04	.11	.74	851.9	742	863	1.16	3.24	854.4	2,030	4,150	2.04
-1.66	849.5	.79	.09	.12	.84	852	769	938	1.22	3.34	854.5	2,070	4,350	2.10
-1.56	849.6	3.12	.26	.08	.94	852.1	794	1,020	1.28	3.44	854.6	2,100	4,560	2.17
-1.46	849.7	11.8	.92	.08	1.04	852.2	820	1,100	1.34	3.54	854.7	2,120	4,770	2.25
-1.36	849.8	26.2	2.78	.11	1.14	852.3	845	1,180	1.40	3.64	854.8	2,150	4,990	2.32
-1.26	849.9	51.1	6.56	.13	1.24	852.4	869	1,270	1.46	3.74	854.9	2,170	5,200	2.39
-1.16	850	82.7	13.2	.16	1.34	852.5	896	1,350	1.51	3.84	855	2,200	5,420	2.47
-1.06	850.1	123	23.4	.19	1.44	852.6	929	1,450	1.56	3.94	855.1	2,220	5,640	2.54
-.96	850.2	166	37.8	.23	1.54	852.7	975	1,540	1.58	4.04	855.2	2,230	5,860	2.63
-.86	850.3	213	56.8	.27	1.64	852.8	1,040	1,640	1.58	4.14	855.3	2,240	6,090	2.71
-.76	850.4	264	80.5	.31	1.74	852.9	1,110	1,750	1.58	4.24	855.4	2,250	6,310	2.80
-.66	850.5	313	109	.35	1.84	853	1,170	1,860	1.59	4.34	855.5	2,270	6,540	2.89
-.56	850.6	350	143	.41	1.94	853.1	1,240	1,980	1.60	4.44	855.6	2,280	6,770	2.97
-.46	850.7	385	179	.47	2.04	853.2	1,320	2,110	1.60	4.54	855.7	2,290	6,990	3.05
-.36	850.8	422	220	.52	2.14	853.3	1,400	2,250	1.61	4.64	855.8	2,300	7,220	3.14
-.26	850.9	455	264	.58	2.24	853.4	1,470	2,390	1.63	4.74	855.9	2,310	7,450	3.23
-.16	851	482	311	.64	2.34	853.5	1,530	2,540	1.66	4.84	856	2,310	7,680	3.32
-.06	851.1	511	360	.71	2.44	853.6	1,580	2,700	1.70	4.94	856.1	2,320	7,920	3.42
.04	851.2	540	413	.76	2.54	853.7	1,640	2,860	1.74	5.04	856.2	2,320	8,150	3.51
.14	851.3	570	468	.82	2.64	853.8	1,700	3,020	1.77	5.14	856.3	2,330	8,380	3.60
.24	851.4	600	527	.88	2.74	853.9	1,760	3,200	1.81	5.24	856.4	2,330	8,610	3.69

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

South Eagle Gate Stage—Continued
Outlet location 4436124.546 308288.241

Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
5.34	856.5	2,340	8,850	3.79	7.84	859	2,370	14,700	6.23
5.44	856.6	2,340	9,080	3.88	7.94	859.1	2,370	15,000	6.33
5.54	856.7	2,340	9,320	3.98	8.04	859.2	2,370	15,200	6.42
5.64	856.8	2,340	9,550	4.07	8.14	859.3	2,370	15,400	6.52
5.74	856.9	2,350	9,780	4.17	8.24	859.4	2,370	15,700	6.62
5.84	857	2,350	10,000	4.27	8.34	859.5	2,370	15,900	6.72
5.94	857.1	2,350	10,300	4.36	8.44	859.6	2,370	16,200	6.82
6.04	857.2	2,350	10,500	4.46	8.54	859.7	2,370	16,400	6.92
6.14	857.3	2,350	10,700	4.56	8.64	859.8	2,370	16,600	7.01
6.24	857.4	2,350	11,000	4.66	8.74	859.9	2,370	16,900	7.11
6.34	857.5	2,350	11,200	4.76	8.84	860	2,370	17,100	7.21
6.44	857.6	2,350	11,400	4.85	8.94	860.1	2,370	17,300	7.31
6.54	857.7	2,360	11,700	4.95	9.04	860.2	2,370	17,600	7.41
6.64	857.8	2,360	11,900	5.05	9.14	860.3	2,370	17,800	7.51
6.74	857.9	2,360	12,100	5.15	9.24	860.4	2,370	18,100	7.61
6.84	858	2,360	12,400	5.25	9.34	860.5	2,370	18,300	7.71
6.94	858.1	2,360	12,600	5.34	9.44	860.6	2,370	18,500	7.80
7.04	858.2	2,360	12,800	5.44	9.54	860.7	2,370	18,800	7.90
7.14	858.3	2,360	13,100	5.54	9.64	860.8	2,370	19,000	8.00
7.24	858.4	2,360	13,300	5.64	9.74	860.9	2,370	19,200	8.10
7.34	858.5	2,360	13,600	5.74	9.84	861	2,370	19,500	8.20
7.44	858.6	2,360	13,800	5.83	9.94	861.1	2,380	19,700	8.30
7.54	858.7	2,360	14,000	5.93	10.04	861.2	2,380	20,000	8.40
7.64	858.8	2,370	14,300	6.03	10.14	861.3	2,380	20,200	8.50
7.74	858.9	2,370	14,500	6.13					

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

					Outlet location	Pelican 4436102.595	308146.091							
Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
-2.12	849.4	0.00	0.00	0.00	0.38	851.9	519	563	1.09	2.88	854.4	572	1,960	3.42
-2.02	849.5	.00	.00	.02	.48	852	524	615	1.17	2.98	854.5	573	2,020	3.52
-1.92	849.6	.72	.02	.03	.58	852.1	531	668	1.26	3.08	854.6	573	2,070	3.62
-1.82	849.7	2.86	.20	.07	.68	852.2	537	722	1.34	3.18	854.7	574	2,130	3.71
-1.72	849.8	4.82	.59	.12	.78	852.3	543	776	1.43	3.28	854.8	574	2,190	3.81
-1.62	849.9	6.66	1.16	.17	.88	852.4	548	830	1.52	3.38	854.9	575	2,240	3.91
-1.52	850	8.58	1.92	.22	.98	852.5	551	885	1.61	3.48	855	575	2,300	4.00
-1.42	850.1	13.3	2.99	.23	1.08	852.6	554	940	1.70	3.58	855.1	576	2,360	4.10
-1.32	850.2	19.6	4.62	.24	1.18	852.7	556	996	1.79	3.68	855.2	576	2,420	4.20
-1.22	850.3	30.0	7.04	.23	1.28	852.8	558	1,050	1.88	3.78	855.3	577	2,480	4.29
-1.12	850.4	48.8	11.0	.22	1.38	852.9	560	1,110	1.98	3.88	855.4	577	2,530	4.39
-1.02	850.5	79.7	17.2	.22	1.48	853	561	1,160	2.07	3.98	855.5	577	2,590	4.49
-.92	850.6	125	27.3	.22	1.58	853.1	563	1,220	2.17	4.08	855.6	578	2,650	4.58
-.82	850.7	195	43.1	.22	1.68	853.2	564	1,280	2.26	4.18	855.7	578	2,710	4.68
-.72	850.8	264	66.2	.25	1.78	853.3	565	1,330	2.36	4.28	855.8	578	2,760	4.78
-.62	850.9	327	95.8	.29	1.88	853.4	566	1,390	2.46	4.38	855.9	579	2,820	4.87
-.52	851	374	131	.35	1.98	853.5	566	1,450	2.55	4.48	856	579	2,880	4.97
-.42	851.1	418	171	.41	2.08	853.6	567	1,500	2.65	4.58	856.1	580	2,940	5.07
-.32	851.2	457	214	.47	2.18	853.7	568	1,560	2.75	4.68	856.2	580	3,000	5.17
-.22	851.3	482	261	.54	2.28	853.8	568	1,620	2.84	4.78	856.3	580	3,050	5.26
-.12	851.4	492	310	.63	2.38	853.9	569	1,670	2.94	4.88	856.4	580	3,110	5.36
-.02	851.5	498	360	.72	2.48	854	570	1,730	3.04	4.98	856.5	581	3,170	5.46
.08	851.6	504	410	.81	2.58	854.1	570	1,790	3.13	5.08	856.6	581	3,230	5.56
.18	851.7	509	460	.90	2.68	854.2	571	1,840	3.23	5.18	856.7	581	3,290	5.65
.28	851.8	514	512	1.00	2.78	854.3	571	1,900	3.33	5.28	856.8	581	3,340	5.75

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

Pelican—Continued				
Outlet location		4436102.595	308146.091	
Pool stage, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
5.38	856.9	582	3,400	5.85
5.48	857	582	3,460	5.95
5.58	857.1	582	3,520	6.04
5.68	857.2	582	3,580	6.14
5.78	857.3	582	3,630	6.24

Table 4. Elevation/stage-area, elevation/stage-capacity, and elevation/stage-depth relations for selected Squaw Creek Wildlife Refuge pools—Continued

[Note: Datum is referenced to the North American Datum of 1983 (NAD 83) and North American Vertical Datum of 1988 (NAVD 88); outlet location in Universal Transverse Mercator (UTM) coordinates; ft, feet; acre-ft, acre-foot]

Bluff

Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft	Elevation, in ft	Area, in acres	Capacity, in acre-ft	Mean water depth, in ft
854.2	0.00	0.00	0.00	856.7	213	316	1.48	859.2	315	996	3.16	861.7	372	1,870	5.03
854.3	23.0	1.06	.05	856.8	219	338	1.54	859.3	318	1,030	3.23	861.8	372	1,910	5.12
854.4	30.1	3.71	.12	856.9	224	360	1.60	859.4	321	1,060	3.30	861.9	373	1,940	5.21
854.5	37.7	7.10	.19	857	231	383	1.66	859.5	325	1,090	3.36	862	373	1,980	5.31
854.6	45.9	11.3	.25	857.1	237	406	1.71	859.6	328	1,120	3.42	862.1	374	2,020	5.40
854.7	54.7	16.3	.30	857.2	244	430	1.76	859.7	332	1,160	3.49	862.2	374	2,060	5.49
854.8	64.1	22.2	.35	857.3	249	455	1.82	859.8	335	1,190	3.55	862.3	375	2,100	5.58
854.9	73.7	29.1	.39	857.4	253	480	1.90	859.9	338	1,220	3.62	862.4	375	2,130	5.68
855	83.8	37.0	.44	857.5	256	505	1.97	860	342	1,260	3.68	862.5	376	2,170	5.77
855.1	94.3	45.9	.49	857.6	260	531	2.04	860.1	345	1,290	3.75	862.6	377	2,210	5.86
855.2	105	55.9	.53	857.7	263	557	2.12	860.2	348	1,330	3.81	862.7	377	2,240	5.95
855.3	136	68.0	.50	857.8	267	584	2.19	860.3	351	1,360	3.88	862.8	378	2,280	6.04
855.4	142	81.9	.58	857.9	270	611	2.26	860.4	353	1,400	3.96	862.9	378	2,320	6.14
855.5	148	96.4	.65	858	274	638	2.33	860.5	355	1,430	4.04	863	379	2,360	6.23
855.6	154	112	.72	858.1	278	665	2.40	860.6	357	1,470	4.12				
855.7	160	127	.79	858.2	282	693	2.46	860.7	358	1,500	4.20				
855.8	166	144	.86	858.3	291	722	2.48	860.8	360	1,540	4.28				
855.9	172	160	.93	858.4	294	751	2.55	860.9	362	1,580	4.35				
856	179	178	1.00	858.5	297	781	2.63	861	364	1,610	4.43				
856.1	185	196	1.06	858.6	300	811	2.70	861.1	365	1,650	4.52				
856.2	191	215	1.13	858.7	303	841	2.77	861.2	367	1,690	4.60				
856.3	196	234	1.20	858.8	306	871	2.85	861.3	368	1,720	4.68				
856.4	200	254	1.27	858.9	308	902	2.93	861.4	369	1,760	4.77				
856.5	204	274	1.34	859	310	933	3.01	861.5	370	1,800	4.85				
856.6	209	295	1.41	859.1	313	964	3.08	861.6	371	1,830	4.94				

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