THE HISTORIC BENTON LAKE ECOSYSTEM

GEOLOGY, SOILS, TOPOGRAPHY

The geology of the Benton Lake Basin is characterized by gently dipping sedimentary bedrock overlain in many places by unconsolidated glacial and alluvial deposits (Maughan 1961). Bedrock in most of the Benton Lake Basin is seleniferous marine shale of the Cretaceous Colorado Group, often referred to as "Colorado Shale." The Colorado Group, in ascending order, consists of the Lower and Upper Cretaceous Blackleaf Formation and the Upper Cretaceous Marias River Shale. These formations are dark-gray shale with some interbedded siltstone, standstone, and bentonite. The combined thickness of both formations is about 1,500 feet (Condon 2000). A second bedrock unit, the Upper Cretaceous Montana Group, is exposed along the western margin of the Benton Lake Basin and consists of relatively non-seleniferous mudstone, siltstone, and sandstone. Unconsolidated deposits in the basin are mostly Quaternary gravel terraces, 4-50 feet thick, deposited by an ancestral Sun River and glacial material. These deposits underlay the topographically isolated "Greenfields Bench", which is a prairie plateau of Cretaceous age (Vuke et al. 2002). Detailed geologic mapping has been completed for the Benton Lake area (Maughan 1961, Lemke 1977, Maughan and Lemke 1991) and includes the extent of the last Pleistocene continental ice sheet into the region (Alden 1932, Colton et al. 1961).

The last Pleistocene ice sheet dammed the ancestral Missouri River and formed glacial Lake Great Falls, which covered low-lying parts of the Benton Lake region. Glacial lake deposits near Benton Lake are primarily clay and silty clay and are up to 100 feet thick (Lemke 1977). Glacial drift associated with the last ice sheet was deposited northeast of Benton Lake and east of Priest Butte Lakes and formed the "closed" Benton Lake Basin and the Benton Lake bed depression that received most water runoff in the basin. Glacial drift deposits are primarily glacial till consisting of unsorted and unstratified clay, silt, sand, and some coarser material. Locally, glacial drift includes stratified sand and gravel alluvial deposits (Mudge et al 1982, Lemke 1977).

Most geomorphic surfaces on Benton Lake NWR are Quaternary lake "Ql" deposits from glacial Lake Great Falls and the Benton Lake depression (Fig. 2). A second surface of Quaternary alluvium and

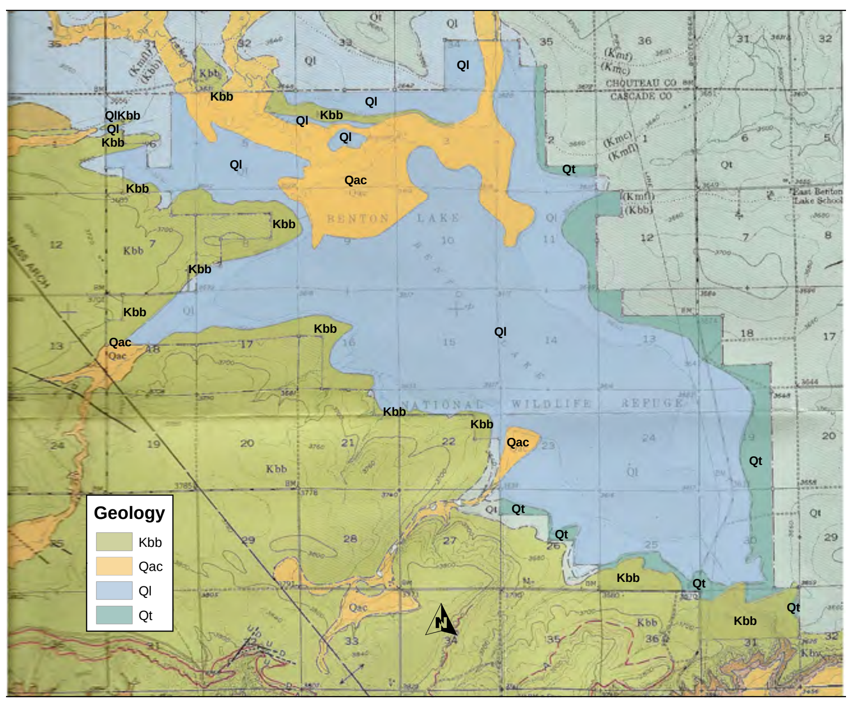

Figure 2. Geomorphology maps of the Benton Lake region (from Maughan 1961)

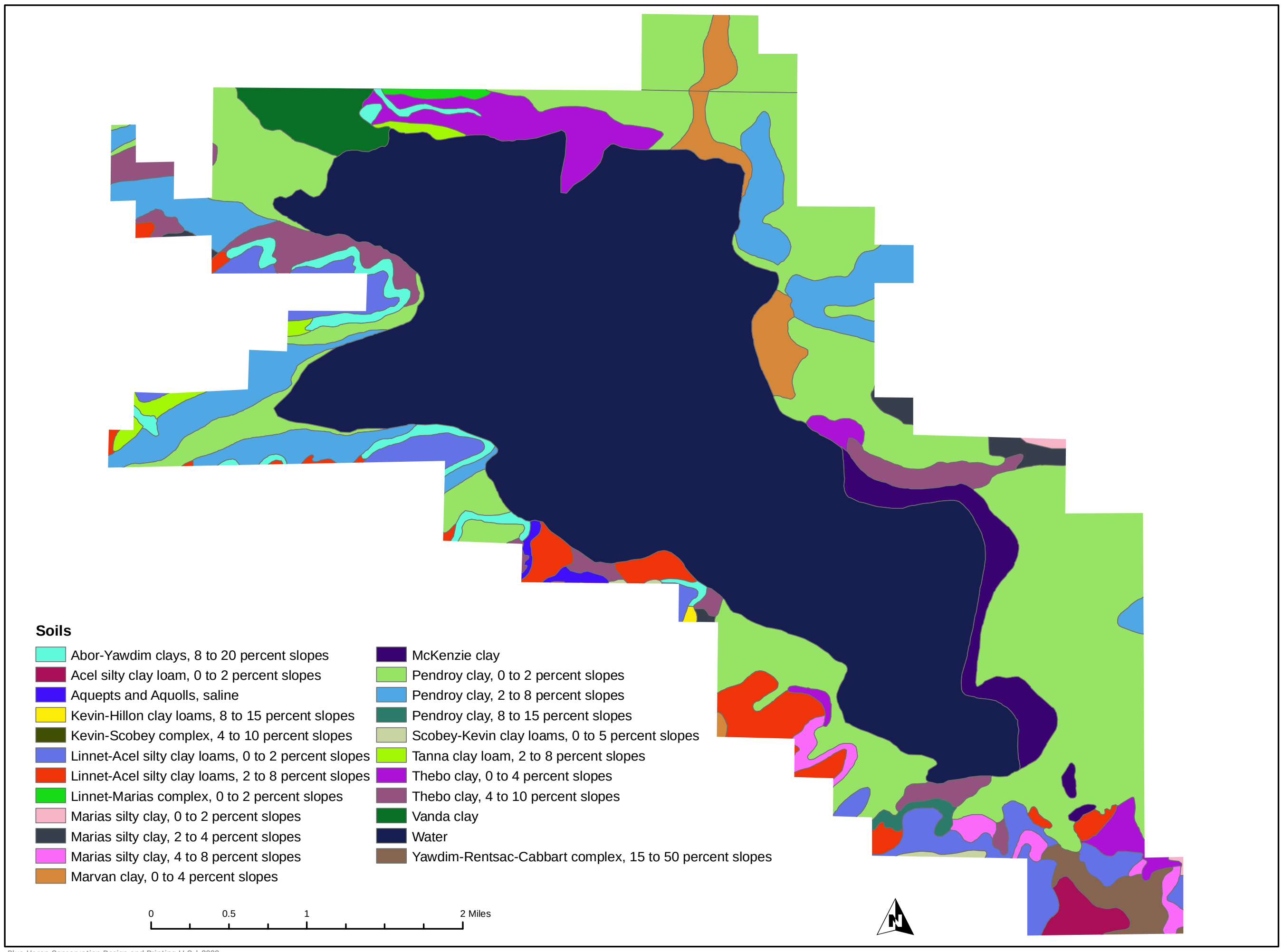

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Figure 3. Soils on Benton Lake National Wildlife Refuge (from U.S. Department of Agriculture, Natural Resources Conservation Service www.websoilsurvey.nrcs.usda.gov).

colluvium “Qac” deposits covered a small area along the Lake Creek drainage on the north, and a small tributary drain on the southwestern, sides of Benton Lake. “Qac” deposits are comprised of local stream and sheetwash alluvium, floodplain and tributary channel alluvium, and undivided colluvium (Vuke et al. 2002). “Qac” deposits were formed by overbank deposition and scouring of sediments along the drainages that entered Benton Lake and resemble small natural levee and alluvial/colluvial fans that are slightly higher elevation than the adjacent “Ql” deposits within the current Benton Lake bed. Some “Qac” deposits date to about 6,800 years before the present (BP) (Bacon 1983, Vuke et al. 2002). Alluvial Quaternary terrace “Qt” deposits occur on the upland edges of the historic Benton Lake bed, and are most extensive on the east side of the lake. Most “Qt” terraces were formed by glacial till Holocene deposits and extend to the Sun River, Muddy Creek, and Teton River regions (Maughan and Lemke 1991). The highest ridges on the west side of Benton Lake NWR are Bootlegger Member (Upper Cretaceous) “Kbb” deposits (named after the Bootlegger Trail north of Great Falls). Upper portions of “Kbb” contain well cemented beds of sandstone and siltstone interbedded with dark-gray silty shale and several yellowish-gray bentonite beds. These upper regions of “Kbb” contain abundant fish scales and fish bones in some locations and indicate historic marine and lacustrine environments. The middle parts of “Kbb” deposits are dark-gray shale with some fine-grained, medium-gray sandstone and bentonite. The basal parts of “Kbb” deposits are mostly light-gray, fine-to medium-grained sandstone separated by dark-gray silty shale. “Kbb” deposits range from 150 to 330 feet thick.

Surface soils at Benton Lake NWR are predominantly clays and silty clays deposited in the lacustrine environments of glacial Lake Great Falls and Benton Lake (Fig. 3). “Ql” lacustrine-type soils consist mostly of plastic clays and exceed 100 feet deep under

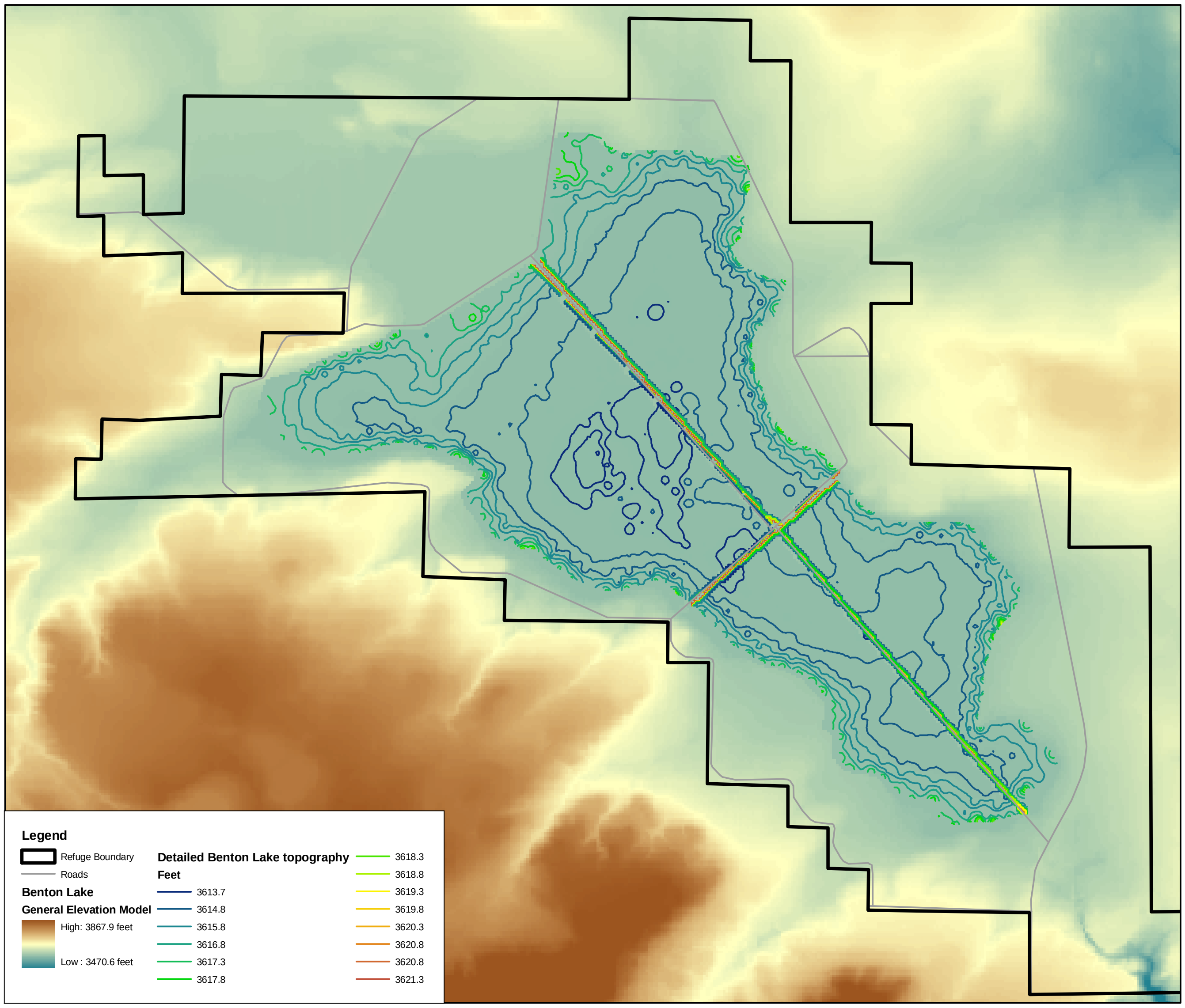


Figure 4. General elevation map of the Benton Lake region.

parts of Benton Lake. "Qac" soils are mostly silt and sand with minor clay and gravel present in soil stratigraphy. Thickness of "Qac" soils ranges from 10 to 40 feet where they then become intermixed with underlying lacustrine-type deposits. "Qt" terrace-type soils are mostly 10-30 feet thick clay loam types overlying reddish-brown, poorly sorted sand and gravel dominantly of subangular to slabby sandstone and subrounded quartzite, shale, granite, and argillite (Maughan and Lemke 1991). "Kbb" surfaces have interesting, stratified soils indicating various depositions from historic marine environments, Lake Great Falls, and underlying Colorado Shale (Condon 2000).

The topography of Benton Lake NWR reflects the dominant geological surfaces and features of the region. Within Benton Lake proper, elevation gradients are relatively subtle ranging from about 3,614 feet above mean sea level (amsl) in the lowest depressions in the middle of the historic lake bed to about 3,622 feet amsl on the edge of the lake that defines its "full-pool" water level (Fig. 4). A detailed elevation map of the south part of Benton Lake prepared in the early 2000s indicates several deeper depressions historically were present in the lake bed, and likely reflected glacial scouring when the basin was created. The "Qac" surfaces along Lake Creek and the small tributary on the southwest side of Benton Lake are 2-8 feet higher than Benton Lake surfaces and form the small alluvial fans in these areas. "Qt" terraces range from about 3,622 to 3,700 feet amsl and the "Kbb" ridges on the edge of the

Benton Lake Basin rise to about 3,850 feet amsl. In general, the gradual sloping of the historic Lake Great Falls region and the contemporary Benton Lake bed produced a low-gradient topographic and hydrological setting within the closed Benton Lake Basin. This low gradient and closed system produced relatively little scouring and depositional surfaces within the basin, with the small exception of the slightly raised alluvial fan/natural levee along Lake Creek where it entered Benton Lake.

CLIMATE AND HYDROLOGY

The climate of the Benton Lake region is generally characterized by pleasant summers with warm, mostly sunny, days and cool nights (National Oceanic and Atmospheric Administration (NOAA) 2009). Winters are cold but warmer than expected for its latitude because of frequent Chinook winds; average wind speed for the year is 14.2 miles/hour (Clark et al. 1979). Sub-zero weather normally occurs several times during a winter, but the duration of cold spells typically lasts only several days to a week after which it can be abruptly terminated by strong south-westerly Chinook winds. The sudden warming associated with these winds can produce temperature rises of nearly 40 degrees in less than a day. Conversely, strong intrusions of bitterly cold arctic air moves south from Canada several times each winter and can drop temperatures 30 to 40 degrees within 24 hours. The dynamic Chinook winds prohibit large accumulation of snow over winter and reduce large spring runoffs, because snow melts in smaller increments throughout winter and is mostly absorbed into the ground. The average annual daily maximum temperature at Great Falls is 45.3 degrees Fahrenheit (Table 1). Average frost-free days that define the growing season at Great Falls is 121 days usually ranging from mid April to mid September (Table 2).

The Benton Lake Basin is classified as "semiarid" with 70-80% of total annual precipitation falling during April to September (about 10 inches of rainfall at this time, Table 1). Highest rainfall months are May and June. Precipitation generally falls as snow during winter, late fall, and early spring. Rain intermittently occurs during these periods, but freezing rain is rare. Average annual precipitation at Great Falls is 14.98 inches. During the period of record at Great Falls, yearly precipitation extremes have ranged from 25.24 inches in 1975 to 6.68 inches in 1904. Average snowfall is 63.5 inches. Thunderstorms occur on about 50 days each year, about 90% during May-August. The sun shines about 64% of possible time during the year ranging from 46% sun in November to 80% sun in July. Average relative humidity at 5:00 am ranges from 63% in July and August to 74% in June; relative humidity at 5:00 pm ranges from 62% in January to 29% in August.

Table 1. Mean annual and monthly temperatures and precipitation at Great Falls, Montana (from Clark et al. 1979).

Month	Temperature		2 years in 10 will have at least 4 days with--		Precipitation
	Average daily maximum[1]	Average daily minimum[1]	Maximum temperature equal to or higher than--[2]	Minimum temperature equal to or lower than--[2]	Average[1]
	°F	°F	°F	°F	In
January------	29.3	11.6	48	-25	0.9
February-----	35.9	17.2	57	- 2	0.8
March--------	40.4	20.6	63	- 3	1.0
April--------	54.5	32.3	70	+ 8	1.2
May----------	65.0	41.5	82	+23	2.4
June---------	72.1	49.5	93	+32	3.1
July---------	83.7	54.9	94	+42	1.3
August-------	81.8	53.0	95	+38	1.1
September----	70.0	44.6	89	+23	1.2
October------	59.4	37.1	75	+14	0.7
November-----	43.4	25.7	59	-15	0.8
December-----	34.7	18.2	54	-20	0.7
Year-------	45.9	33.8			15.2

[1]Period of record 1941-70.
[2]Period of record 1961-70.

Long-term temperature and precipitation data indicate dynamic patterns of recurring peaks and lows. Regional precipitation decreased and temperatures rose from the late 1910's to the late 1930s (NOAA 2009). A steady rise in precipitation and declining temperatures occurred from the early 1940s to the mid 1950s followed by another decline in precipitation and local runoff in the 1960s. Precipitation rose again during the late 1970s and early 1990s, and remained about average during the 1980s and late 1990s to early 2000s (Fig. 5). Regional precipitation appears to be gradually increasing again in the late 2000s.

Because Benton Lake is a closed basin, natural water inputs to the lake come primarily (average of 65-70% of annual natural input) from the 137 mile^2 Lake Creek watershed (Fig. 6); the remainder is derived from on-site precipitation and runoff from several small local drainages and surrounding uplands. Surface water entering Benton Lake historically flowed across the lake bed in a "sheetflow" manner to gradually inundate lowest depressions first and then spread to higher lake bed surfaces and eventually to alluvial benches and lake-edge terraces as more water entered the basin during wet seasons and years.

Generally, the hydrological regime in Benton Lake mirrors seasonal and long-term regional precipitation patterns (e.g., Nimick 1997). Natural runoff from Lake Creek into Benton Lake is strongly correlated with seasonal and annual precipitation in the region (Fig. 5). Consequently, historic water levels in Benton Lake basin were highly dynamic and had a strong seasonal pattern of increased water inputs and rising water levels in spring and early summer followed by gradual declines during summer and fall. This seasonal flooding pattern was superimposed on a long term pattern of regularly fluctuating peaks and lows in precipitation, runoff, and water levels in the lake at 15-20 years intervals (Fig. 7). Historic records, articles, General Land Office (GLO) survey notes, and aerial photographs indicate Benton Lake had high water levels in the early 1920s, late 1930s, and late 1950s prior to major water delivery and control infrastructure developments on Benton Lake NWR in the late 1950s and early 1960s (e.g., Fig. 8). Since the 1960s, high runoff and flooding conditions at Benton Lake occurred in the mid 1970s and early 1990s (Fig. 5). These wet, highly flooded periods, at Benton Lake were intercepted by dry periods when the lake bed was mostly dry during the late 1920s and early 1930s, late 1940s, early 1960s, mid 1980s, and late 1990s and early 2000s.

Lake Creek, the largest tributary to Benton Lake, is an intermittent, ephemeral, stream with greatest flows during spring and early summer following snowmelt and increased spring rains. Although ground-water discharge maintains a small base flow in Lake Creek and some of its tributaries during spring and fall, and sometimes in wet summers, most ground water discharged to seeps and tributaries does not reach Benton Lake (Nimick 1997). Natural runoff in Lake Creek and other small tributaries to Benton Lake generally is a magnesium-sodium-sulfate type water and is acidic (Nimick 1997). During periods of greater regional precipitation and

Table 2. Mean number of frost-free days annually at Great Falls, Montana (from Clark et al. 1979).

[Recorded in the period 1961-70 at Great Falls Weather Bureau, Great Falls, Montana]

Probability	Dates for given probability and temperature: 24°F or lower	28°F or lower	32°F or lower
Spring:			
1 year in 10 later than-----	March 28	April 12	April 28
2 years in 10 later than-----	March 30	April 17	April 30
5 years in 10 later than-----	April 22	April 27	May 13
Fall:			
1 year in 10 earlier than---	Sept. 18	Sept. 14	Sept. 7
2 years in 10 earlier than---	Oct. 6	Sept. 16	Sept. 11
5 years in 10 earlier than---	Oct. 20	Oct. 11	Sept. 21

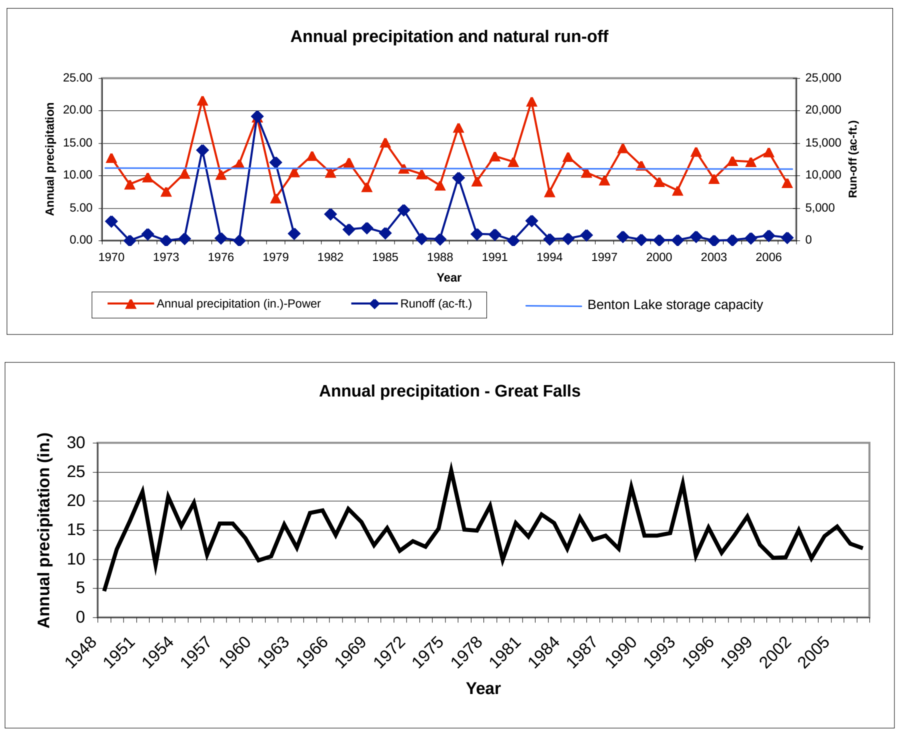


Figure 5. Long term precipitation at Great Falls and Power, Montana and annual runoff from Lake Creek into Benton Lake (from NOAA 2009 and USFWS, Benton Lake National Wildlife Refuge, unpublished files).

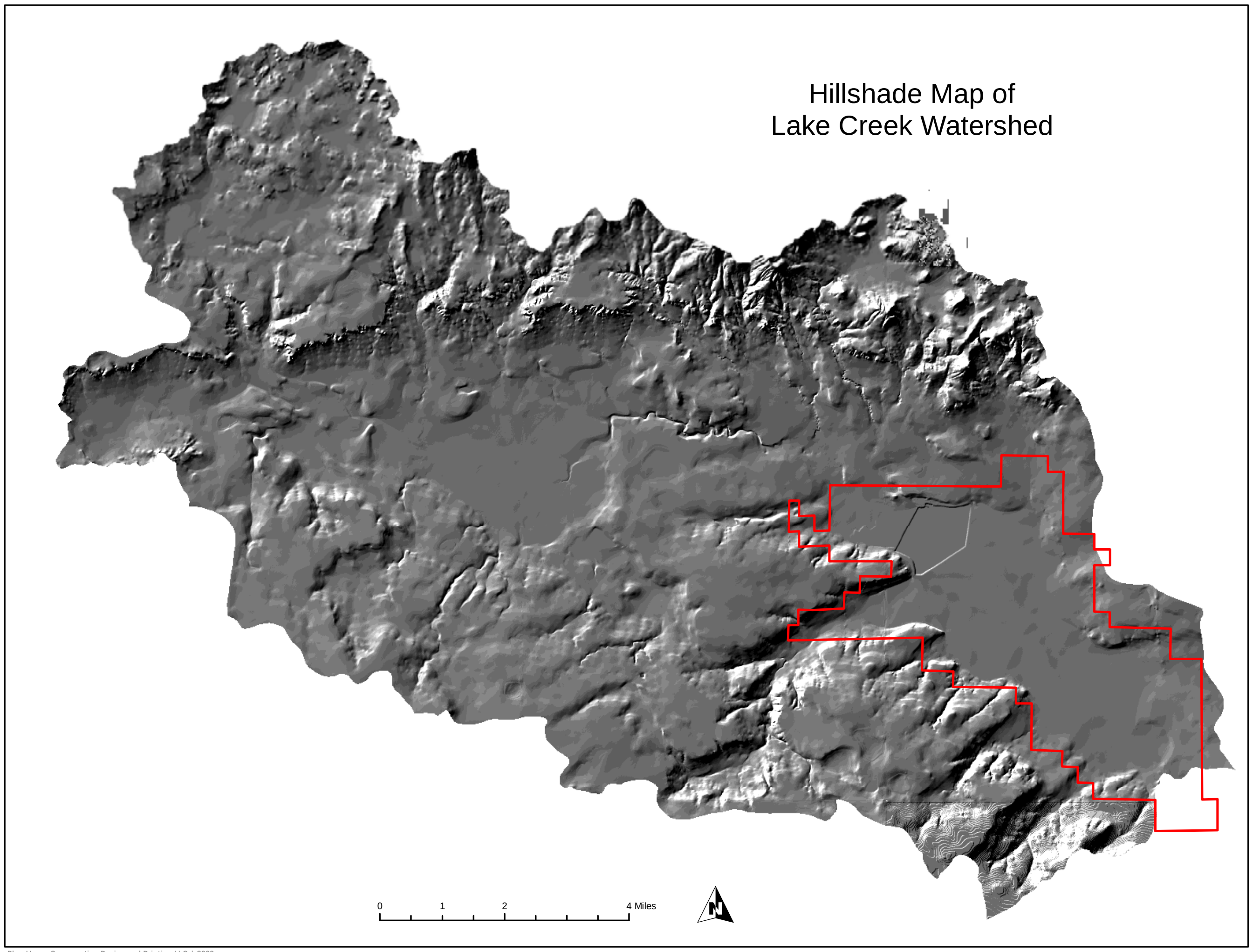


Figure 6. Lake Creek watershed map.

snowmelt runoff, more relatively dilute water flowed in Lake Creek and entered Benton Lake (Fig. 5) and periodically caused very high water levels, e.g. peak levels in 1954 (Fig. 8). Typically, regional precipitation and runoff declined for several years following precipitation peaks, and annual water levels in Benton Lake gradually declined to low levels due to evapotranspiration, which averages about 40-41 inches/year (U.S. Soil Conservation Service 1970). Surface water remaining in Benton Lake during dry seasons and years was confined to the lowest elevation depressions (e.g., GLO 1920).

The ground water aquifer beneath the Benton Lake Basin is confined mainly to the basal Colorado Shale formation (Nimick 1997, Miller et al. 2002). A number of sandstone beds, which are porous and transmit water freely, occur in this formation. Water quantity in this aquifer is poor quality; chloride concentrations are low, dissolved-solid concentrations are moderate, pH is basic (8-9), sulfate and bicarbonate are predominant anions, redox conditions are reducing, and selenium levels are low (Nimick 1997). The poor quality of this deep aquifer discouraged well drilling for water sources in the region and a basin-wide potentimetric-surface map is not available. Shallow ground water (< 100 feet deep) in the Benton Lake region has different chemical constituents than the deep Colorado Shale aquifer; shallow water typically is acidic with higher levels of calcium, sulfate, chloride and magnesium. The thick lacustrine-type clay surfaces in Benton Lake prohibit water movement, or recharge, from the lake into ground water (Nimick et al. 1996, Nimick 1997). Other ground water in the Benton Lake Basin appears to move slowly to the east and discharges to some shallow wetland depressions between Benton Lake and the Missouri River (Nimick 1997).

Historically, the relatively low annual amount of surface precipitation falling on uplands surrounding Benton Lake was typically was captured quickly and used by native grassland; little water moved deeply into soil and subsoil layers. Where water did percolate downward, it subsequently moved slowly into aquifers and occasionally exited slopes as springs or saline seeps. The historically sparse saline seeps in the Benton Lake Basin undoubtedly discharged dissolved solids and elements like selenium into basin streams and drainages into Benton Lake at certain times. Deposition of salts and elements in Benton Lake did not historically accumulate to high levels, however, because of elemental volatilization in water, sediment, and wetland plants during dry periods of the long-term hydrological cycle (Zhang and Moore 1997a). Higher temperatures, higher airflow, drier sediments, and decomposition of wetland plants increase removal rates of selenium. Additionally, selenium volatilization is more efficient in seasonally flooded wetland areas than in permanently flooded wetlands. Eventually, salts and elements in annually dynamic western wetlands, with functional seasonal and long-term hydrology, such as in the historic Benton Lake, reach a dynamic equilibrium where the amount of salts and elements removed by wind erosion and volatilization equaled the amount of input and solute accumulation or movement into deeper lakebed sediments from diffusion and advection (Zhang and Moore 1997b).

VEGETATION COMMUNITIES

Historic vegetation communities on Benton Lake NWR ranged from dense emergent wetland vegetation in the lowest elevation depressions of Benton Lake to upland grassland on higher elevation terraces and benches adjacent to the lake bed (Figs. 9, 10; Appendix A). This gradation of plant communities is typical of wetland basins in the Northern Great Plains of Montana (Hansen et al. 1995). Plant species distribution reflected tolerance to timing, depth, and duration of annual flooding, salinity, and underlying soils and geomorphic surfaces (Table 3). The precise distribution of historic wetland vegetation species groups in Benton Lake proper undoubtedly varied over time as surface water coverage and depth changed in the long-term wet to dry cycles (e.g., Van der Valk and Davis 1978, Van der Valk 1989). The relative juxtaposition of historic plant communities occurred along a wetness continuum where specific groups expanded or contracted and moved either up or down elevation gradients as water levels rose and fell in Benton Lake over time (Table 4). Further, some communities with specific distribution associations, such as saltgrass that was associated with higher alkaline or saline conditions, also probably changed locations somewhat over time depending on intensity and location of saline seeps as saline conditions in the lake became more or less concentrated/diluted during more extreme flooding vs. drawdown phases of the long term hydrological cycle.

Table 3. Hydrogeomorphic (HGM) matrix of historic distribution of vegetation communities/habitat types on Benton Lake National Wildlife Refuge. Relationships were determined from land cover maps prepared by the GLO (1920), geomorphology maps (Maughan 1961), soils maps prepared by NRCS, hydrological data (NOAA and USFWS, Benton Lake National Wildlife Refuge, unpublished files), and various naturalist/botanical/settler accounts and publications from the late 1800s and early 1900s.

Habitat Type	Geomorphic surface[a]	Soil type	Flood frequency[b]	Elevation[c]
Robust emergent	Ql	clay	A-PM	< 3614.5
Sedge/rush	Ql	clay	A–SP	3614.6 – 3615.7
Sedge/rush alkaline	Qac	clay	A–SP	3614.6 – 3615.7
Seasonal Herbaceous	Ql	silt-clays	A–SE	3615.8 – 3616.3
Cordgrass/ saltgrass	Qac	silt-clays	A–SE	3615.8 – 3616.3
Wet grassland	Ql	silty/clay	I–SE	3616.4 – 3622
Wet grassland alkaline	Qac	silty/clay	I–SE	3616.4 – 3622
Upland Grassland	Qt and Kbb	silty clay	R	3622

[a] Ql = Quaternary lake, Qac = Quaternary alluvium/colluviums, Qt = Quaternary terrace, Kbb = Cretaceous Bootlegger.
[b] A–PM = annually flooded permanent, A-SP = annually flooded semipermanent, A-SE = annually flooded seasonal, I-SE = irregularly flooded among years seasonal, R = rarely if ever flooded.
[c] Feet above mean sea level.

Table 4. Temporal occurrence of representatives from six plant communities on alluvial fans and depressional wetlands in a closed basin during wet and dry seasons.

	Alluvial Fan		Low Depression		High Depression	
	Wet Year	Dry Year	Wet Year	Dry Year	Wet Year	Dry Year
Robust emergents	0	0	X	X	X	0
Sedge/rush	X	X	0	X	X	X
Seasonal herbaceous	X	X	0	X	X	0
Wet grassland	X	0	0	0	X	0
Upland grassland	0	X	0	0	0	X

Recognizing the annual variation in flooding regimes and latent chronological and distribution response dynamics of wetland plant species to changing moisture conditions, we developed an HGM matrix of potential vegetation communities related to geomorphologic, soil, elevation, and hydrology conditions historically present at Benton Lake (Table 3). The distribution of these HGM-predicted vegetation communities assumes average long-term flooding and drying periods of 15-20 years with peak highs and lows lasting about 5-6 years. This duration of peaks and lows is based primarily on historic aerial photographs of Benton Lake, especially the sequential basin photographs from 1950, 1951, 1954, 1956, and 1957. This HGM matrix was extrapolated to a historic (i.e., pre-levee and water-control structure construction) spatial resolution using the geographical information data sets on geomorphology, soils, and elevation (Fig. 11).

Using this HGM matrix (Table 3) and potential historic vegetation map (Fig. 11), about 73 acres of the lowest elevations in Benton Lake (< 3,614.2 feet amsl) contained some surface water throughout most years and supported "open water" aquatic plant communities surrounded by concentric bands of robust emergent vegetation including cattail (Typha latifolia and Typha angustifolia) and hardstem bulrush (Scirpus acutus). Soils in these depressions were heavy clays and within the "Ql" geomorphic surface formed by historic lacustrine environments. Water in these depressions was fresh, with little salt concentration. Historic aerial photographs and survey/naturalist accounts from the Benton Lake region indicate that dense emergent vegetation was present in the deeper depressions at Benton Lake, at least during wet years of the long term flooding cycle, but it is unclear which emergent species were present. We suspect most emergent vegetation was hardstem bulrush, but some cattail probably was present also, based on similar wetland conditions in western Montana (Hansen et al. 1995) and the extensive presence of cattail within Benton Lake at present. The width of this emergent vegetation band varied depending on extent and duration of flooding and chronological position of the long-term hydrological cycle. Submergent aquatic plants such as pondweeds (Potamogeton spp.), naiads (Najas sp.), coontail (Ceratophyllum sp.), wigeon grass (Ruppia sp.), and milfoil (Myriophyllum spp.) were present in the deepest open areas and rich algal blooms occurred in these areas.

Semipermanently flooded sites that were slightly higher elevation (3,614.3 to 3,615.2 feet amsl) adjacent to cattail and bulrush zones contained slightly less permanent water regimes and supported diverse sedge and rush species such as Carex, Sagittaria, and Juncus (Table 3, Fig. 11). These "sedge/rush" communities covered about 1,728 acres and supported diverse herbaceous wetland plants including alkali bulrush (Scirpus maritimus), three-square rush (Scirpus pungens), Nutall's alkaligrass (Puccinellia nuttaliana), beaked sedge (Carex rostrata), Nebraska sedge (Carex nebrascensis), and water smartweed (Polygonum coccineum). Sedge/rush communities were almost entirely on "Ql" surfaces and had clay soils, similar to robust emergent communities. The small area (53 acres) of sedges/rush vegetation on "Qac" may have contained slightly more alkaline species, but this is unclear. The sedge/rush community apparently covered more area within the Benton Lake bed than other communities and historic accounts of the lake (e.g., GLO 1920) comment on the wide bands and extensive coverage of sedges and rushes. This sedge/rush community may have expanded during wet periods to even higher

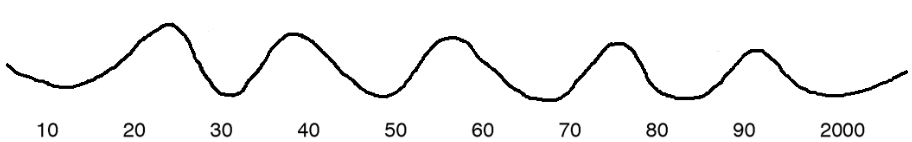


Figure 7. Model of long-term dynamics of water levels in Benton Lake (extrapolated from historic aerial photographs; USFWS Benton Lake National Wildlife Refuge, unpublished files; NOAA 2008, naturalist observations, and published articles).

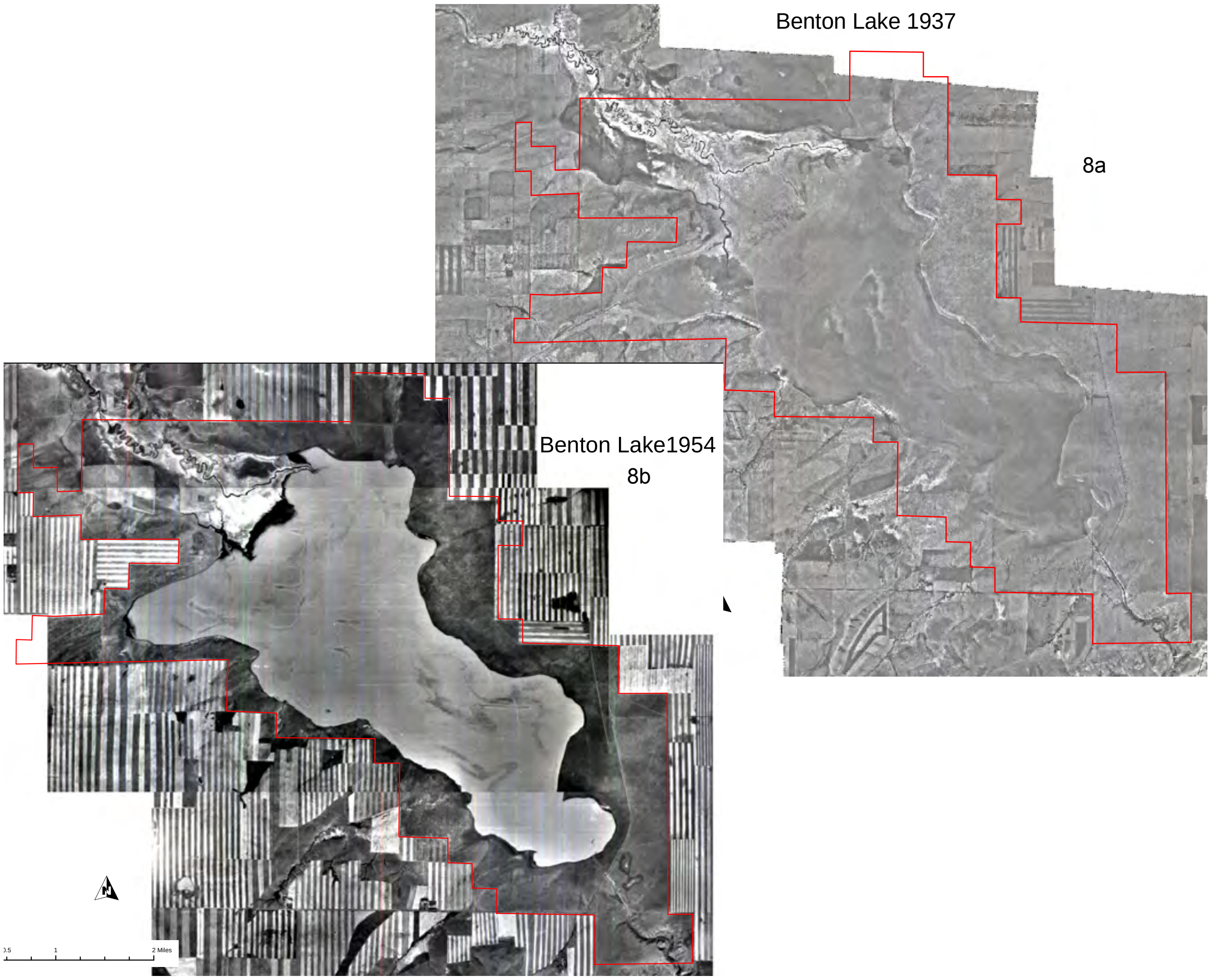
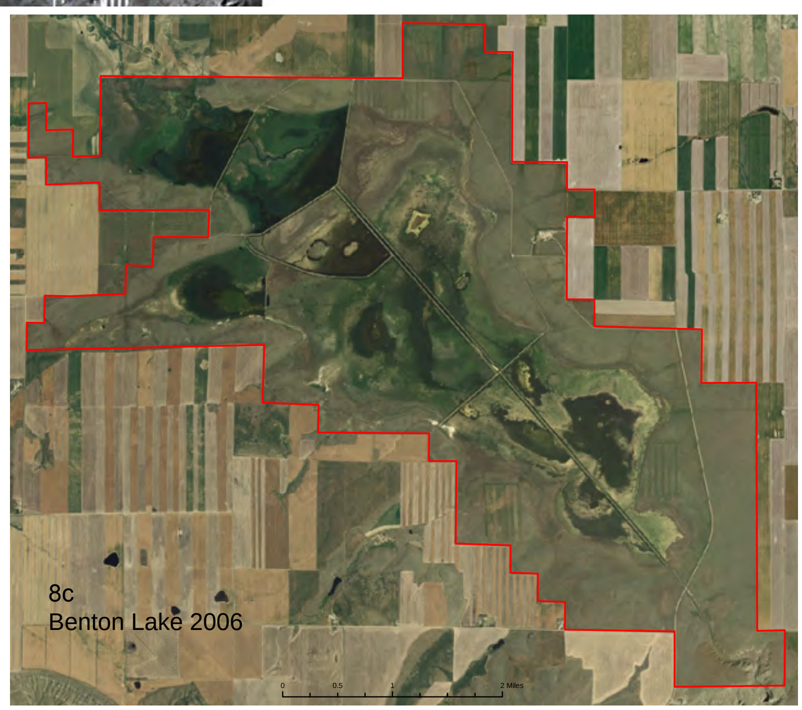


Figure 8. Sequence of old aerial photos (1937-current). 8a: 1937; 8b: 1954; 8c: 2006.



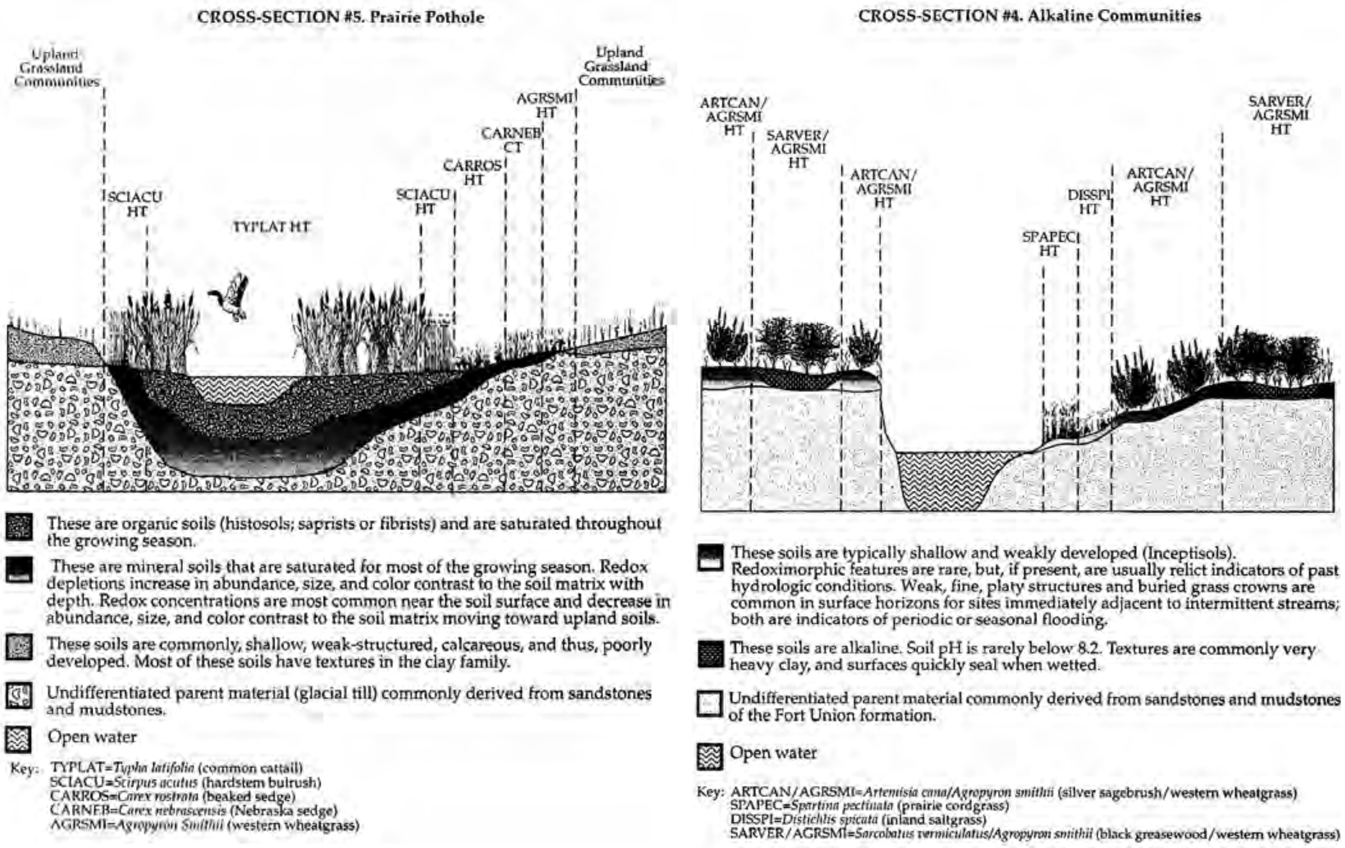


Figure 9. Cross-section of vegetation communities typically found in Northern Prairie and alkaline flat wetlands in western Montana (from Hansen et al. 1995).

elevation edges of Benton Lake and then contracted to lower elevations during extended dry periods. The periodic flooding and drying of these vegetation zones likely caused moderate alkaline soil conditions.

Seasonally flooded areas adjacent to sedge/rush communities (3,615.3 to 3,615.7 feet amsl) contained diverse annual and perennial herbaceous plants and wet prairie/meadow grasses such as spikerush (Eleocharis spp.), lambsquarter (Chenopodium album), annual smartweeds (Polygonum spp.), prairie cordgrass (Spartina pectinata), and saltgrass (Distichlis spicata). Most seasonally flooded communities were within “Ql” surfaces (1,040 acres), but 143 acres of “Qac” also supported more distinctive species groups (Fig. 11). For example, prairie cordgrass apparently occurred in temporary and overflow areas along streams and the edges of marsh sites that had silty clay soils, less alkaline conditions, and where seasonal (usually spring) sheetflow of surface water occurred. Eleocharis usually was in relatively narrow bands along yearly flooded stream and tributary sites and the margins of lake communities. In contrast, saltgrass was most common in more saline or alkali sites including areas where seeps flowed into Benton Lake and in some overflow areas adjacent to Lake Creek.

The highest elevation edges of Benton Lake (3,615.8 to 3,620 feet amsl) typically had short duration seasonal flooding regimes and represented the transition zone from wetland to upland grassland plant communities (Table 3, Fig. 11). These sites included both “Ql” (3,167 acres) and “Qac” (1,216 acres) geomorphic surfaces and usually had more silty clay soils compared to dense heavy clays within depressions of Benton Lake. Foxtail barley (Hordeum jubatum) was present on the higher annually drawn down margins of the lake basin and in some ephemeral depressions. Foxtail barley gradually graded to western wheatgrass (Agropyron smithii) and silver sagebrush (Artemisia cana) on “Qt” alluvial terraces adjacent to the lake. Eventually, these wetland-edge grass communities graded into about 4,802 acres of upland grassland (elevations > 3,620 feet amsl) present on “Qt” and “Kbb” surfaces that supported many native grass species and numerous shrubs and forbs typical of this part of Montana including bluebunch wheat-

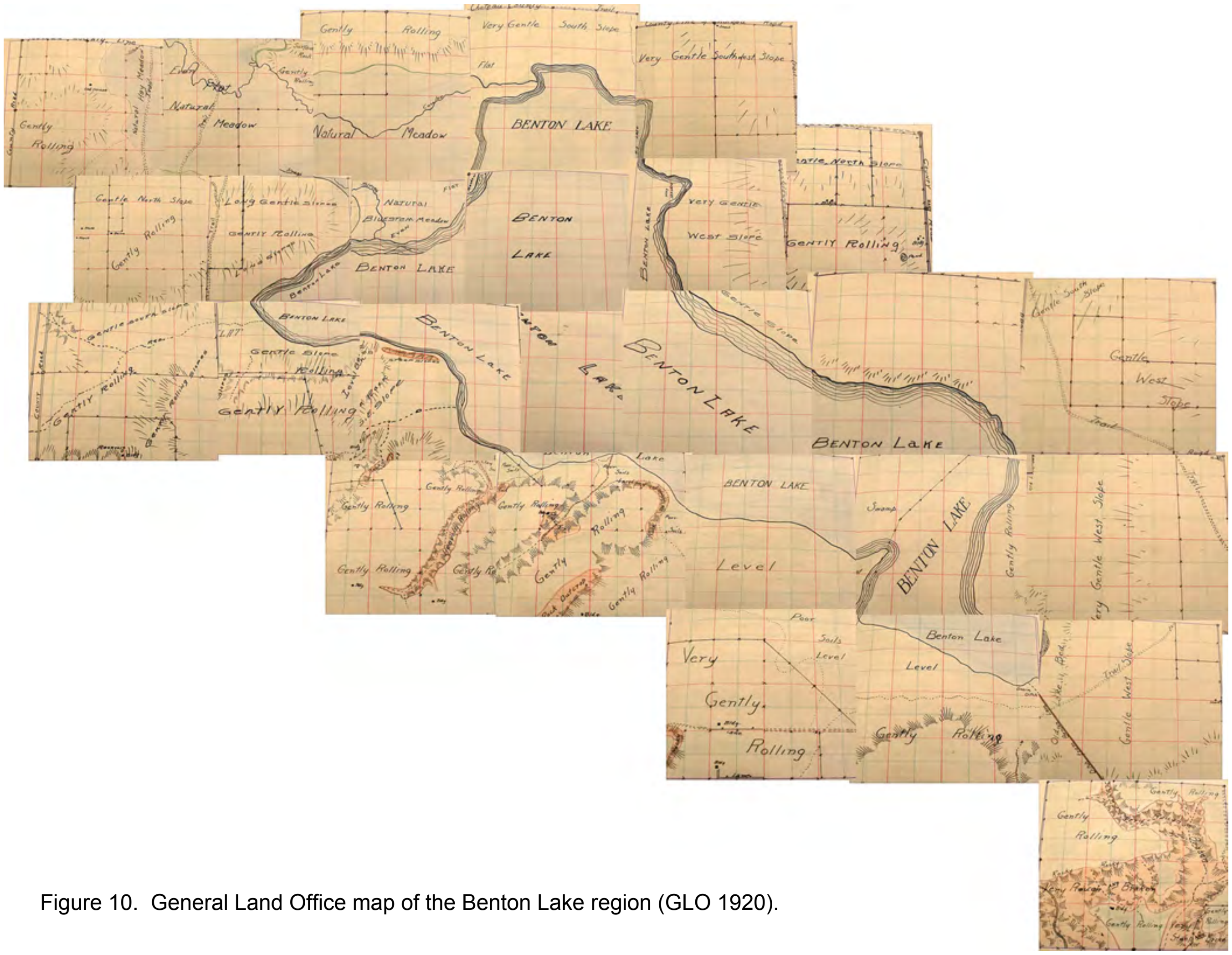


Figure 10. General Land Office map of the Benton Lake region (GLO 1920).

grass (Agropyron spicatum), green needlegrass (Stipa viridula), and prairie junegrass (Koeleria macrantha).

Recently developed models of water coverage in Benton Lake, assuming complete restoration of the hydrology and topography of the lake bed by removal of all levees, water-control structures, and ditches and no pumping of water from Muddy Creek, demonstrate the long-term dynamics of water area and potential effects on vegetation distribution and coverage in the basin (Fig. 12, Nimick and Fields, unpublished data). This "cycle" of increasing water area throughout the lake bed during wet years and gradual drying to very limited water area during dry years is similar to long-term dynamics in other larger Northern Prairie wetland basins and creates dynamic distribution of vegetation communities and animal responses (Weller and Spatcher 1965, Weller and Fredrickson 1974, Van der Valk and Davis 1978, Kantrud et al. 1989). These dynamics suggest historic relative changes in communities and resources at Benton Lake over time in a recurring long-term pattern (Fig. 13, 14).

KEY ANIMAL COMMUNITIES

A rich diversity of animal species historically used the Benton Lake ecosystem (Appendix B). The relative abundance of species and specific food and cover resources used by animals varied with the long term dynamics of flooding and drying in the system. Over 100 bird species from 12 taxonomic orders have been documented at Benton Lake during various seasons. More birds were present during spring and fall migration than in other seasons; abundance in winter was low because of extensive ice, snow, and cold temperatures.

Many waterbirds historically bred in the Benton Lake area, but species richness, abundance, and production apparently varied related to extent and duration of flooding in the basin. The most common

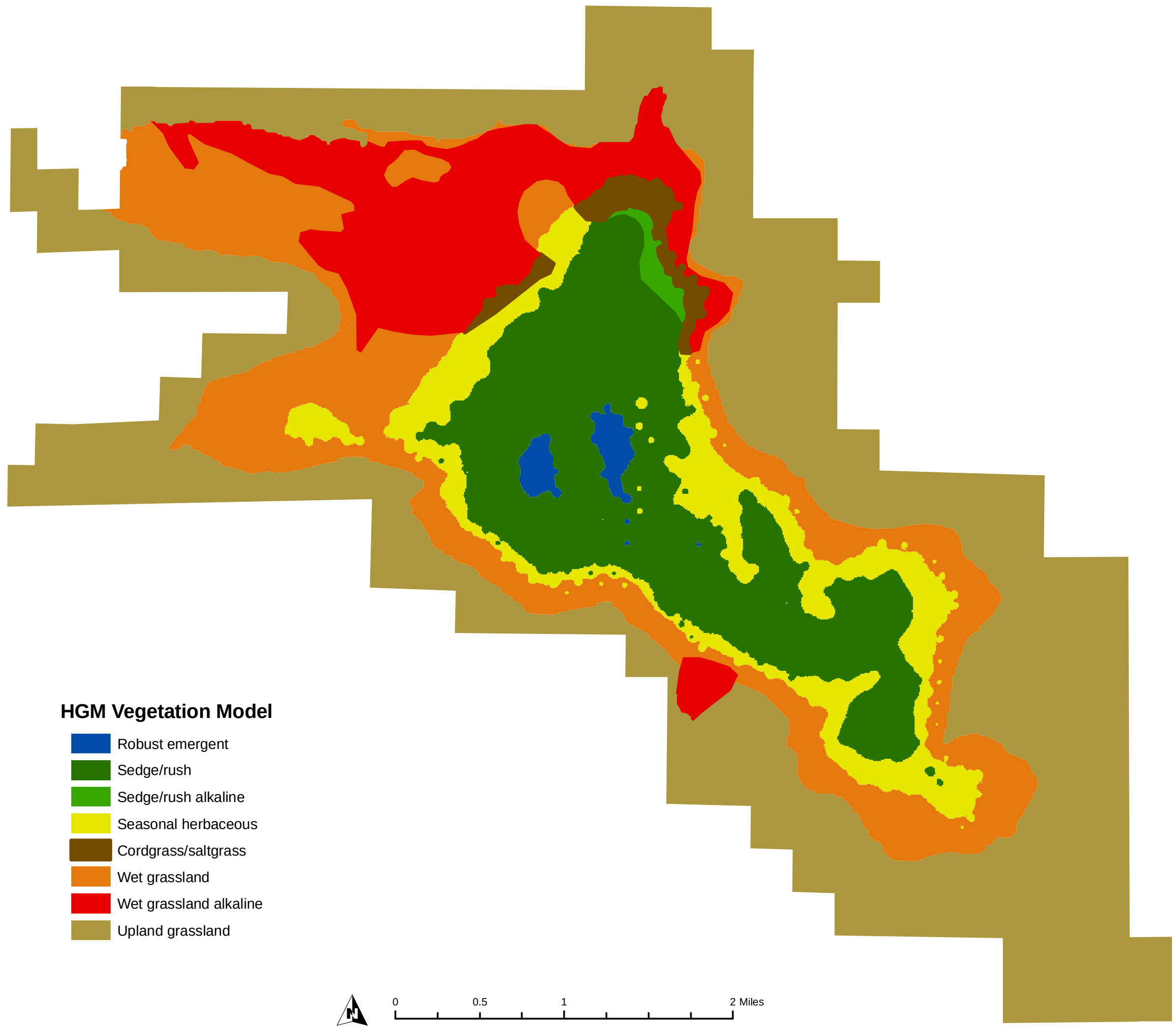
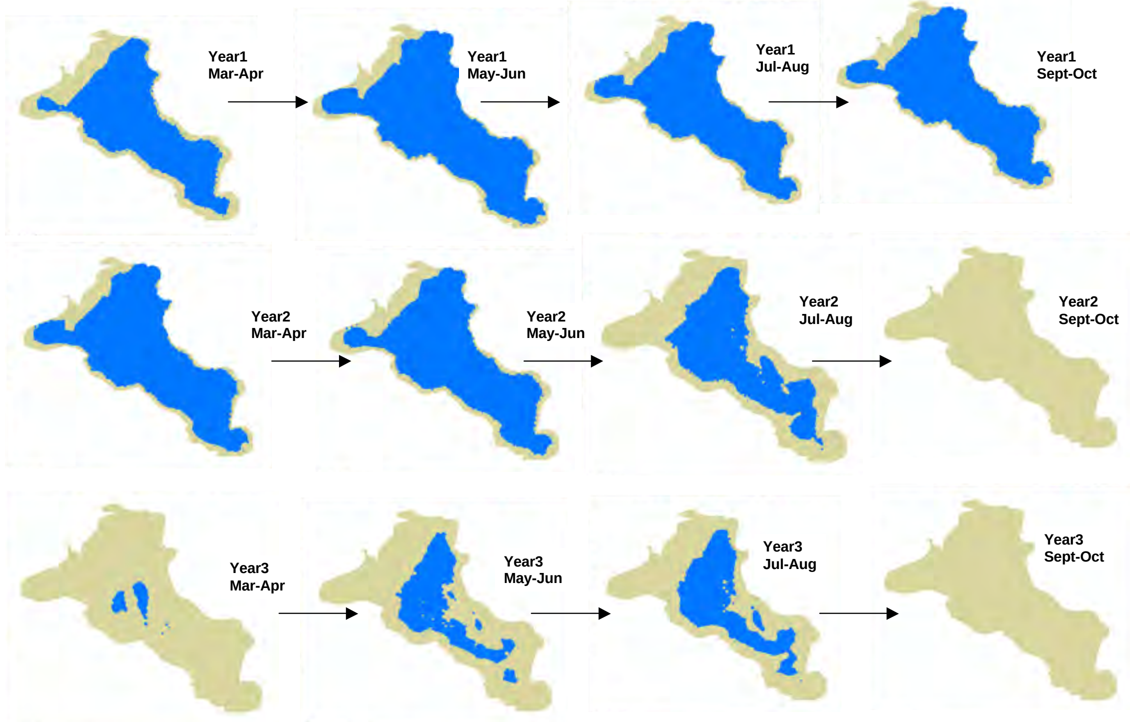


Figure 11. Map of potential historic vegetation communities on Benton Lake National Wildlife Refuge (determined from various HGM data sets listed in Table 3 including geomorphology, soils, topography, hydrological, and botanical accounts).

breeding species included eared grebe (Podiceps nigricollis), mallard (Anas platyrhynchos), northern pintail (Anas acuta), gadwall (Anas strepera), blue-winged teal (Anas discors), cinnamon teal (Anas cyanoptera), American wigeon ((Anas Americana), northern shoveler (Anas clypeata), redhead (Aythya americana), lesser scaup (Aythya affinis), ruddy duck (Oxyura jamaicensis), Canada geese (Branta Canadensis) American coot (Fulica americana), American avocet (Recurvirosta americana), Wilson's phalaropes (Phalaropus tricolor), marbled godwits (Limosa fedoa), willets (Catoptrophorus semipalmatus), Franklin's gull (Larus pipixcans), white-faced ibis (Plegadis chihi), black tern (Chlidonias niger), common tern (Sterna hirundo), Forster's tern (Sterna forsteri), and black-necked stilt (Himantopus mexicanus). During wetter periods of the long term precipitation and flooding cycle many waterfowl, shorebirds, wading birds, gulls and terns, and other wetland-dependent species were present and production was high. Breeding waterbird productivity in the Benton Lake ecosystem likely followed long term dynamics of production in other northern prairie systems as vegetation, invertebrate, and nutrient cycling changes when wetlands dry, reflood, reach peak flooding extent, and then begin drying again (e.g., Murkin et al. 2000). Aquatic invertebrates reach high abundance and biomass during wet periods of long-term water cycles in High Plains wetlands and include a rich diversity of Crustacea such as Daphnia sp., Gammarus sp., and Hyalella azteca) and insects such as Corixid beetles, damselflys and dragonflys, Notonectid backswimmers, and Chironomids. During dry periods of the long term hydrological cycle, fewer waterbirds bred at Benton Lake, and the smaller area, more concentrated, and ephemeral nature of

Complete restoration (no pumping) -- Wet Cycle (1989-1991)



Complete restoration (no pumping) – Dry Cycle (2006-2008)

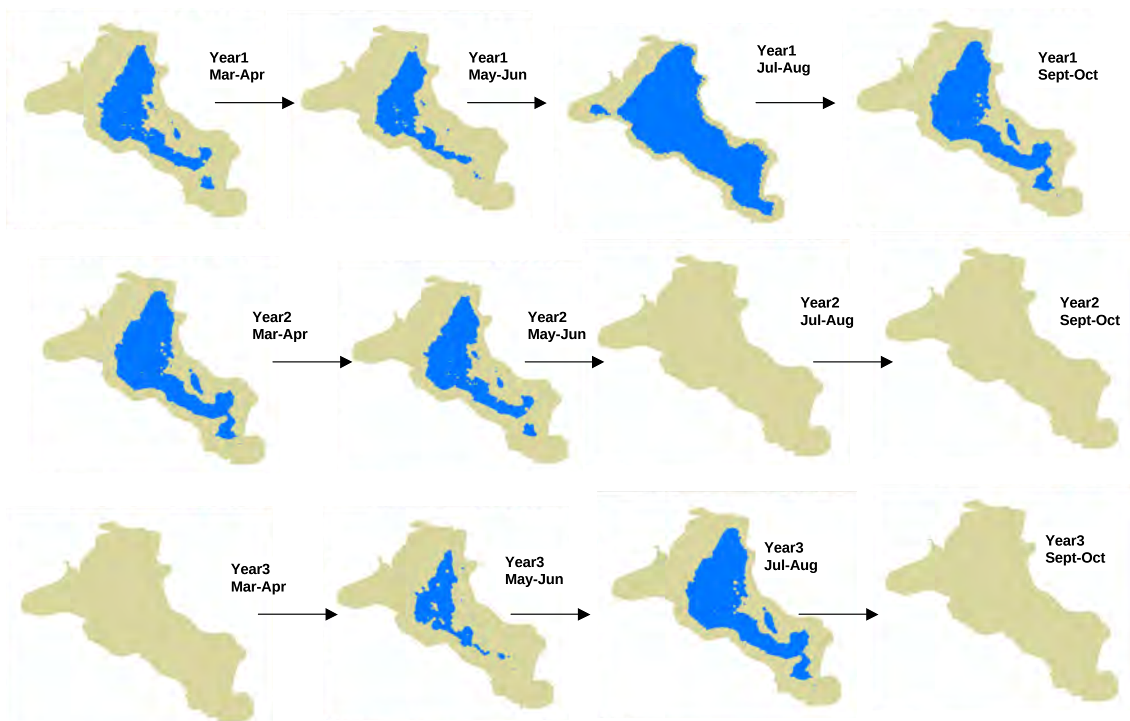


Figure 12. Predicted extent of flooding (blue) and drying (tan) within the Benton Lake basin without artificial pumping or infrastructure. Models were run for a series of 3 wet years and 3 dry years using actual precipitation and run-off data.

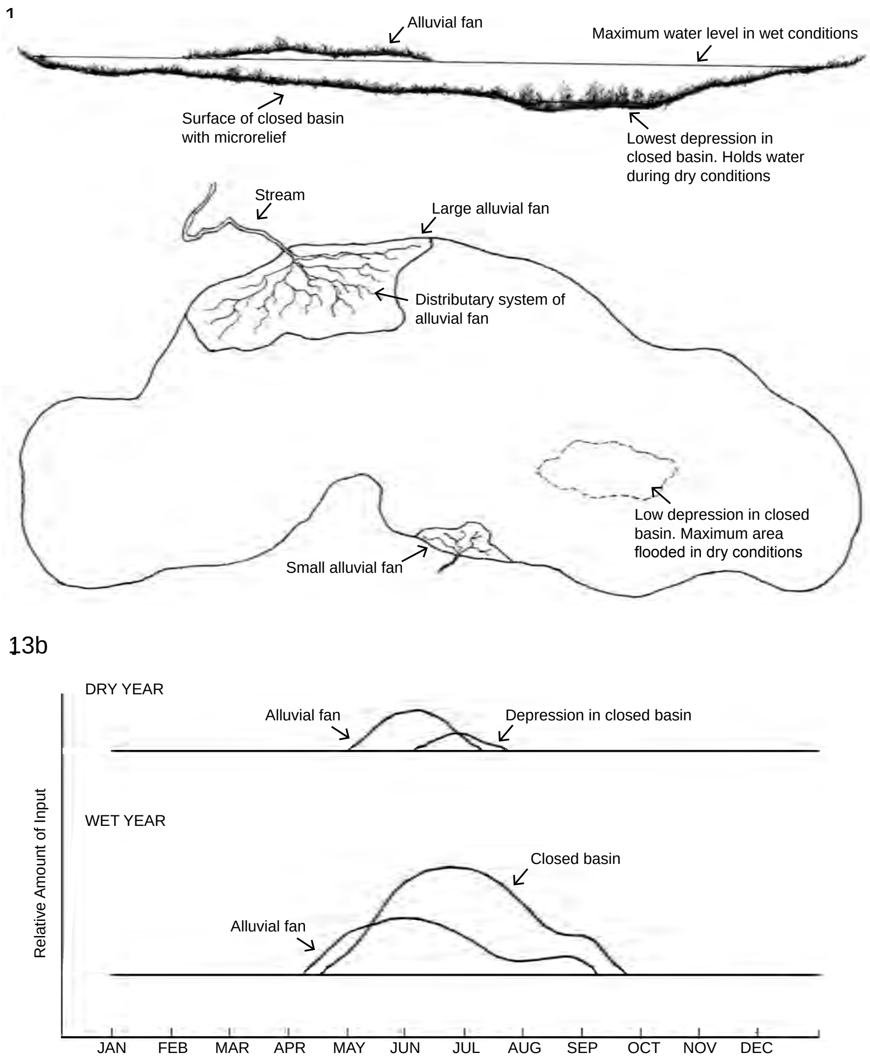


Figure 13. (a) A conceptual schematic of a closed basin with hydrologic inputs entering across a large and a small alluvial fan that receive inputs from small streams with variable annual flows. A deeper depression has the only robust emergent vegetation in the basin. (b) The hydrograph for a closed basin is highly variable within and among years with alluvial fans receiving the most consistent inputs.

summer water probably reduced nesting attempts and success.

Waterbird use of Benton Lake historically was high during fall and spring migration periods both in wet and dry periods. During drier periods, extensive mudflat areas likely were present as surface water evaporated and receded to deeper depressions. These mudflats likely attracted large numbers of shorebirds that utilized rich benthic and terrestrial invertebrate resources and drying wetlands concentrated aquatic prey that was utilized by wading birds, some terrestrial birds, and mammals that ranged into the basin. As water in Benton Lake rose during wetter periods, more of the basin was flooded in both spring and fall (e.g., Fig. 12) and provided critical migration stopover areas for waterfowl, shorebirds, wading birds, and other species such as birds of prey, songbirds, rails, and blackbirds. Bald eagle (Haliaeetus leucocephalus) and peregrine falcon (Falco peregrines), now raptor species of concern, were attracted to the region when large numbers of waterfowl and waterbirds were present.

Mammal species diversity and abundance in the Benton Lake ecosystem was low, except for many small rodents such as mice and voles. The relative abundance and productivity of wetland-dependent species like muskrat, mink, etc. probably tracked long term hydrological and vegetation dynamics. Additionally, many mammal species that mostly used the uplands surrounding Benton Lake, such as coyote (Canis lutrans), white-tailed deer (Odocoileus virginianus), mule deer (Odocoileus hemionus), pronghorn antelope (Antilocapra americana), and elk (Cervus canadensis) moved into the lake basin during dry seasons and years to forage and breed.

Several amphibian and reptile species also used Benton Lake and surrounding uplands, historically. Similar to birds and mammals, the presence and abundance of some species like tiger salamanders (Ambystoma tirgrinum) varied among years as flooding and drying changed resource availability and species susceptibility to being prey for other species groups. Only a few small stream fishes imported from Lake Creek, occurred in Benton Lake, and their presence likely was limited and ephemeral during extremely wet years.

The Benton Lake ecosystem played an important role in providing key resources that helped sustain populations of the above species throughout the Northern Great Plains and Intermountain regions of North America. These species included those that had continental, regional, and local mobility (Laubhan and Fredrickson 1997). Birds were the predominant

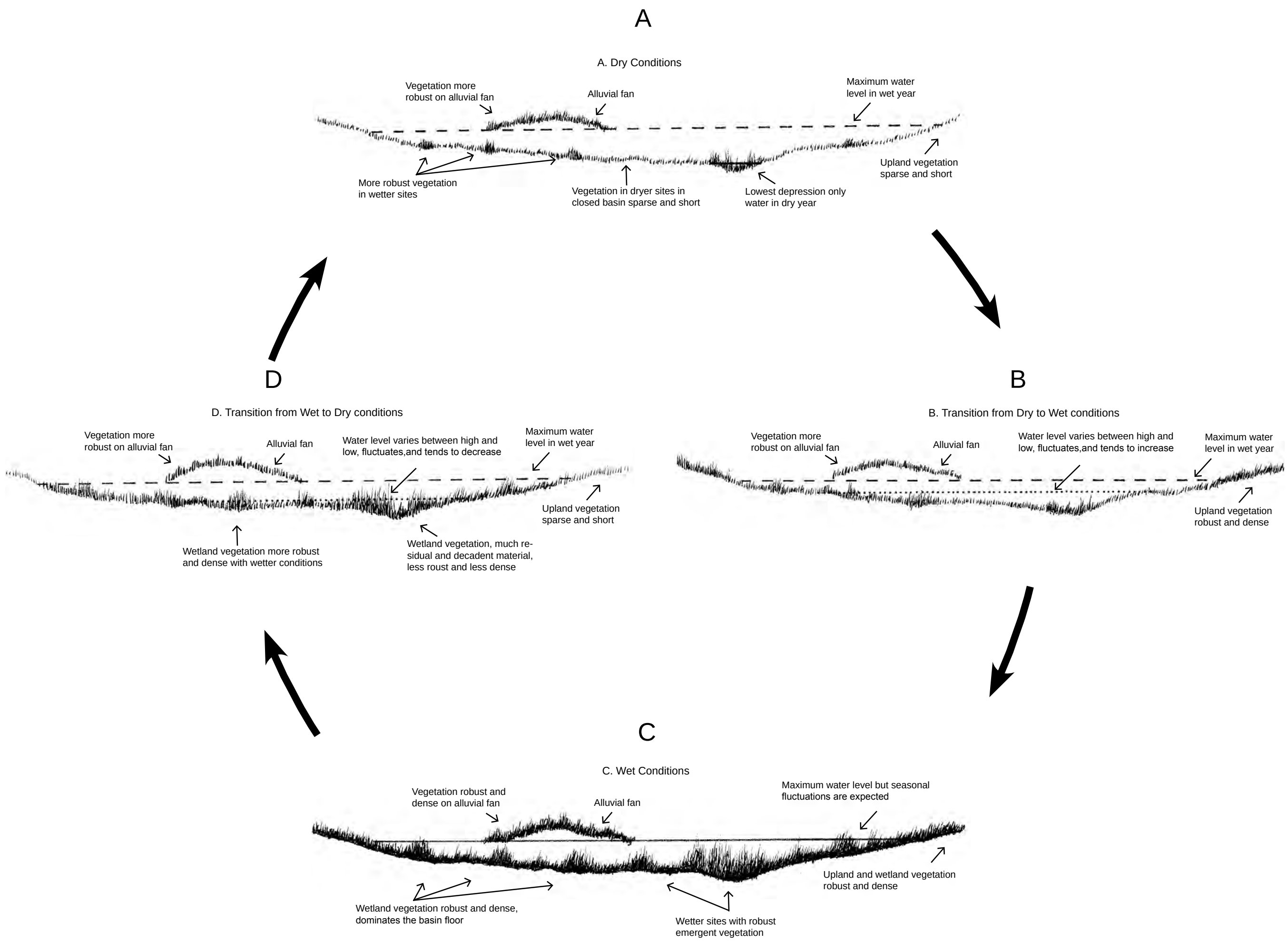


Figure 14. A conceptual model of the variability within a closed basin associated with water levels, wetland vegetation and wetland dependent animals that characterize wetland dynamics in an arid region during the wet/dry cycle. (A) Dry Conditions: Dry conditions are recurring and often last for 3 or more years in a 15-20 year cycle. The large alluvial fan receives limited water annually and is the wettest site in the basin during this phase. The area of wetland vegetation and the vigor of these wetland plants are reduced whereas the extent of terrestrial plants expands. Wetland dependent species richness is low but limited breeding of wetland associated species adapted to conditions on alluvial fans may occur. (B) Transition from Dry to Wet Conditions: Once drought conditions are broken, the basin may flood rapidly when sufficient precipitation occurs, whether fall or spring. The newly flooded conditions may attract thousands of migrant birds immediately and some may stay and nest. Invertebrates respond immediately and occur in great abundance. The upland vegetation responses rapidly and tends to be robust and dense whereas wetland vegetation within the basin may take a season or more to develop the composition and structure characteristic of a wetland with a longer hydroperiod. (C) Wet Conditions: If adequate precipitation continues for more than a season, the area of wetland vegetation expands rapidly and creates a diversity of conditions suitable for nesting as well as for use by migrant species. These wet periods occur for 3 or more years in the 15-20 year cycle. Wetland foods are abundant. Reproductive response and success of wetland-dependent species tends to be high. (D) Transition from Wet to Dry Conditions: As precipitation declines inputs into the basin are insufficient, water levels decline from transpiration, and vegetation shifts from wetland to a more terrestrial phase. Wetland species richness declines and reproductive response and success decline.

vertebrates with continental mobility and Benton Lake provided varying resources during wet and dry periods that contributed to breeding and migration periods of the annual cycle. Because of its size, many bird populations undoubtedly depended on Benton Lake for specific resources during at least some periods of their life spans. The most common large waterbirds in the Great Plains (e.g., wading birds, waterfowl, etc.) have average life spans (excluding human-caused mortality) of >10 years (Palmer 1978, Bellrose 1980). For these species that occasionally bred at Benton Lake (during wet years), the long-term flooding cycles of peak water and habitat about every 10-15 years offered at least one option for potentially abundant nesting habitat and breeding resources during their life span. For other shorter lived species, the intermittent wet or dry state more regularly provided late spring and early summer habitats and resources for migration and breeding, and occasional flooding and regular mudflat conditions for fall migration. For all species with continental mobility, Benton Lake undoubtedly was a critical, albeit annually dynamic, habitat for western populations of many birds, especially waterbirds.

Mammals were the most common vertebrates that exhibited regional mobility in the Benton Lake Basin. Although most mammals in the Northern Great Plains have widespread distributions, individual animals typically are restricted to much smaller areas. Consequently, portions or even subpopulations of some mammal species in the Western Great Plains apparently likely were dependent on seasonal resources provided in the Benton Lake ecosystem. Mammals that regularly use or depend on wetland resources required a variety of wetland basins and types within their home range. However, the reduced mobility of this group dictates that the distribution of wetland types must be closer to each other if recolonization is to occur after extended drought or floods. Otter, beaver, mink, and fish are examples of regionally mobile species dependent on aquatic habitats – and, none of these species apparently were historically common at Benton Lake. In contrast, more common mammals at Benton Lake were species that ranged into the lake bed during either dry or wet periods, such as ungulates, but generally were supported more by upland habitats and resources.

Species with limited mobility tend to be small and include amphibians, reptiles, and small mammals. Nearly 40 species of herpetofauna in the Northern Great Plains are primarily aquatic or require surface water during some stage of their life cycle (Corn and Peterson 1996). Many species are capable of exploiting seasonally, or periodically, flooded wetlands such as Benton Lake because of behavioral adaptations that enable survival during drought. For example, leopard frogs (Rana blairi) can survive dry periods by migrating short distances or remaining in depressions (Grzimek 1974). Undoubtedly, Benton Lake was critical to sustaining populations of many limited mobility species in the region.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