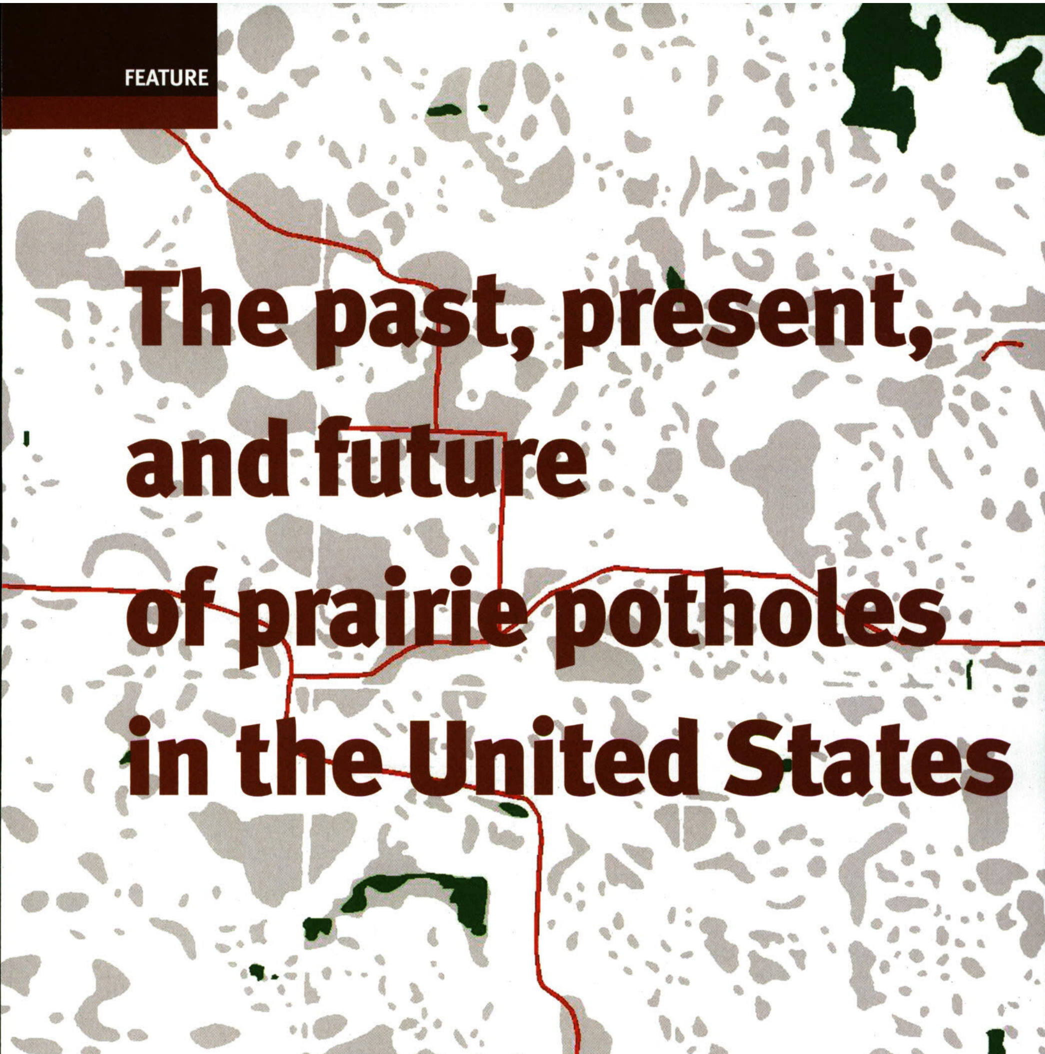

The past, present, and future of prairie potholes in the United States

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Small prairie wetlands left in the wake of retreating glaciers are commonly known as potholes. The US prairie pothole region (PPR), the area covered by late Wisconsin Pleistocene glaciation and historically dominated by tall and mixed grasslands, covers north central Iowa and western Minnesota, the area of North and South Dakota east and north of the Missouri River, and northeastern Montana. Potholes formed when ice blocks buried in glacial till melted over a period of hundreds or thousands of years and the till slumped creating a closed depression.

Opposite: Drained potholes (gray), remaining potholes (green), and public drainage ditches (red) in a typical 23-km² (9-mi²) area of the Minnesota prairies pothole region. From Rex R. Johnson, unpublished data. County-scale spatial data available at http://prairie.ducks.org/index.cfm?&page=minnesota/restorablewetlands/home.htm.

Prairie potholes are highly productive ecosystems of unparalleled importance to breeding waterfowl and many other species of wetland wildlife. Moreover, they are important nutrient sinks, store runoff that reduces flooding, sequester carbon, and provide other environmental and socioeconomic values. Prairie potholes are also perceived to reduce agricultural land value and to impede large-scale mechanized farming.

Prairie potholes are routinely classified by how long they remain ponded during the growing season, from temporary potholes (ponded for 1 to 3 weeks) to seasonal potholes (ponded for 3 weeks to 90 days) to semipermanent potholes that are usually ponded throughout the growing season and may have surface water present for many consecutive years (Stewart and Kantrud 1971). Size generally increases with duration of ponding.

The PPR is a dynamic subhumid to semi-arid region prone to regular periods of drought interspersed with periods of abundant precipitation. During extended wet periods, temporary potholes take on the appearance and functions of seasonal potholes, which in turn become more like semipermanent potholes. In fact, wet years when seasonal basins retain water throughout the breeding season are a main factor causing periodic eruptions in North American duck populations. Conversely, during drought, semipermanent potholes may be the only basins with surface water and may begin to function like seasonal or temporary basins. Thus, potholes exist along a continuum of permanence and functions. A single intact pothole slides along that continuum depending on recent precipitation. This sliding functional continuum made the historic PPR a more resilient ecoregion than it is today.

AN HISTORIC OVERVIEW

Prairie potholes historically covered over 20% of many PPR landscapes and often numbered more than 40 km^{-2} (103 mi^{-2}) (Johnson and Higgins 1997; Rex R. Johnson, unpublished data for Minnesota). Because glaciated landscapes were geologically young, networks of streams were poorly developed and over 80% of the land surface drained into potholes rather than streams and rivers (Johnson and Higgins 1997; Johnson et al. 1997). From potholes most of the runoff was evaporated, and the remainder seeped into the ground and recharged the local groundwater table (Lissey 1971; Winter and Rosenberry 1995). Grassland-covered uplands reduced runoff of water and sediment into potholes so that water levels were more stable and wetland plant communities were diverse and dominated by native grasses, sedges, rushes, and submersed vegetation that provided abundant food for many species of wildlife.

Temporary and seasonal potholes historically comprised nearly 60% and 35%, respectively, of all potholes with semipermanent potholes and lakes making up less than 5% of the total (Johnson and Higgins 1997). Each type of pothole had different wildlife and hydrologic functions. For example, temporary and seasonal potholes tend to warm up first in the spring and provided rich food sources and privacy to pre-nesting duck pairs. These wetlands determined the local breeding population of ducks and determined the frequency of re-nesting following nest loss to predation. They also were the primary sites of groundwater recharge that maintained the local water table. Semipermanent potholes provided late season brood rearing habitat for waterfowl and had other functions. All potholes retained surface runoff. An historic landscape of prairie potholes acted as a community of wetland basins with complimentary functions.

POTHOLE DRAINAGE

Drainage began with the advent of European settlement of the PPR. The earliest drainage systems were small, short, hand-dug ditches that were later replaced with oxen-driven scrapers capable of digging deeper, longer ditches draining larger wetlands. By the early 20th century, steam power ditching machines were being employed. Some of these machines were enormous, employing multiple crews working 24 hours per day with living facilities on an upper deck. By this time public subsidies were being provided for drainage, and buried drainage tile, initially made of clay or concrete and later plastic, was increasingly being used. Following World War II, the federal government escalated payments to individual farmers for draining wetlands. These direct incentives persisted until the late 1970s.

By the 1980s, Dahl (1990) estimated the historic loss of potholes at about 35% in South Dakota, 50% in North Dakota, and 90% in Iowa. Bishop (1981) estimated that Iowa pothole drainage exceeded 95%, and based on restorable wetland maps covering more than 56,000 km² (21,600 mi²), we estimate that more than 85% of Minnesota potholes have been drained.

Today, because of "Swampbuster," a subtitle of the 1985 Food Security Act and subsequent farm bills, most drainage in landscapes with a long history of agriculture is related to the maintenance and improvement of outdated drainage systems and to intercepting runoff in uplands before it reaches wetlands via pattern tiling of fields. We reviewed potholes mapped by the National Wetlands Inventory in Minnesota within 179 10.2-km² (4-mi²) plots to determine the current accuracy of National Wetlands Inventory data for conservation planning. We used multiple years of color infrared photography for the comparison. From this sample, we estimated a net loss of 10.4% of potholes (2.6% of pothole area) mapped by the National Wetlands Inventory from circa 1980 aerial photos. In most cases, the losses are probably due to renovation of drainage systems in place prior to 1985. Farther west in the PPR of the Dakotas, net losses were lower (R. Reynolds and C. Loesch, US Fish and Wildlife Service, personal communication); however, expansion of agriculture into heretofore grassland-dominated landscapes is creating incentives to drain historically intact wetlands.

A ditching machine used in the early 20th century to drain large marshes and lakes in southern Minnesota. Photo courtesy of Michael A. Johnson.

DRAINAGE CONSEQUENCES

For wildlife, pothole drainage imposes a condition of permanent drought since temporary and seasonal potholes are the most affected. Consequently, the abundance of most species of wetland wildlife has declined drastically. For example, in one five-county area of west-central Minnesota, we used models to estimate that remaining potholes can support 58,600 breeding pairs of dabbling ducks in a year with average wetland conditions. However, based on maps of historic wetlands, this same area once supported just under 300,000 breeding pairs (–80.5%). The Iowa PPR once supported about 2 million breeding duck pairs (Dinsmore 1994), but models estimate that the same area supports just over 151,000 pairs per year today (–92.5%).

In many areas of the PPR, particularly in the eastern part of the region where large public-sponsored ditches are most common, pothole drainage has vastly increased the percent of the landscape that contributes to stream flows. Whereas less than 20% of many watersheds contributed to stream flows historically (Johnson and Higgins 1997; Johnson et al. 1997), in parts of Minnesota and Iowa, nearly 100% of the land area now drains via private tiles, public tiles, and public drainage ditches into streams, rivers, or lakes. In eastern South Dakota, Whittmier and Mack (1982) estimated that 87% of drained potholes contributed to stream flows in the Yellow Bank River. The consequence is that the frequency and severity of flooding along mainstem rivers have increased dramatically (Rainnie 1980; Vining et al. 1983).

Potholes are natural filters for nutrients such as nitrogen and phosphorous-bearing sediments and thus help maintain water quality. The same drainage systems that exacerbate flooding speed the movements of nutrients and sediment into streams, rivers, and lakes. Nitrate concentrations in the Minnesota and Des Moines River arising in PPR have increased 13.1 times and 5.6 times, respectively, between 1906 and 1996, making these Mississippi River tributaries two of the greatest contributors to hypoxia in the Gulf of Mexico (Goolsby et al. 1999).

POSSIBLE FUTURE SCENARIOS

Many prairie potholes are easily restored. In the upper reaches of watersheds or drainage systems, tiles can be broken or earthen ditch plugs installed for about $600 to 1,000 per wetland (US Fish and Wildlife Service estimate). However, in the lower reaches of watersheds that receive abnormally high runoff volumes because of upslope drainage and loss of grasslands, engineering and construction costs can exceed tens of thousands of dollars. Restored potholes function like historically intact potholes in most respects; however, seed banks of potholes with long agricultural use may be depleted of native species because of prolonged agricultural use and sediment accumulation from surrounding uplands. Without regular postrestoration disturbance such as grazing, haying, or fire, potholes may develop solid stands of cattail (usually *Typha angustifolia* or *Typha x glauca*) or reed canarygrass (Phalaris arundinacea). Accumulated sediment removal during restoration may help native species reestablish. The wet prairie vegetative zone and associated wildlife surrounding most potholes may be the slowest to recover

A restored prairie pothole in a healthy landscape.

(Delphy 1991; Galatowitsch and van der Valk 1994).

Recreating the prairie pothole region as it once existed is neither practical nor desirable. The balance between agriculture conservation is in continual flux. Recently, the balance appeared to have shifted toward more conservation. However, farming subsidies and recent developments in genetically modified organism crops have spawned expanding agriculture in the western PPR, and the current focus on corn-based ethanol production makes the future of remaining prairie potholes and surrounding grassland highly uncertain.

However, hope for restoring a significant percentage of historic potholes may stem from their importance to water quality, flood abatement, and carbon sequestration. An Iowa Conservation Reserve Enhancement Program compensates landowners to restore or create wetlands for nitrogen removal from runoff. On average, these wetlands remove 30% of nitrogen from the runoff they intercept (Crumpton 2006). The potential of prairie potholes to sequester carbon also offers hope. An average American releases approximately 5,200 kg of CO_2 in vehicle emissions (Heavenrich 2006). The same average driver may offset their annual emissions by restoring as little as 0.5 ha (1.24 ac) of semipermanent potholes and grassland buffers from cropland each year (US Fish and Wildlife Service analysis based on Euliss et al. 2006).

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