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

Estimates of Evapotranspiration from the Ruby Lake National Wildlife Refuge Area, Ruby Valley, Northeastern Nevada, May 1999–October 2000

By David L. Berger, Michael J. Johnson, *and* Mary L. Tumbusch, U.S. Geological Survey, *and* Jeffrey Mackay, U.S. Fish & Wildlife Service

Water-Resources Investigations Report 01-4234

Prepared in cooperation with the
NEVADA DIVISION OF WATER RESOURCES and the
U.S. FISH & WILDLIFE SERVICE

Carson City, Nevada
2001

- a krypton hygrometer to measure instantaneous changes in air-vapor density in combination with changes in vertical wind speed, which are used to determine latent-heat flux;
- a net radiometer to measure net radiation;
- a set of soil-heat flux plates and thermocouples to compute subsurface-heat flux; and
- a solid-state temperature and relative humidity probe to measure air temperature and relative humidity, respectively, at one height (fig. 4*B*).

Data were stored on data loggers and were retrieved during site visits.

EVAPOTRANSPIRATION FROM HABITATS

Micrometeorological data used in estimating the energy budget were collected at nine sites that represented five of the most aerially extensive habitats in the refuge (table 1). The source and amount of water consumed by ET, in part, is a function of the conditions at each site. Daily ET rates, computed by summing ET calculations made for each 20-minute period, are given in appendices 1–5. The period of data collection at Bowen-ratio sites began in early summer 1999 and ended in November 2000. Data at eddy-correlation sites were acquired at different times during the summer of 2000.

Site Locations and Conditions

The open-water and bulrush-marsh sites were selected primarily to measure the amount of water consumed by ET in the wetland area (fig. 2). The Bowen-ratio method was used to estimate daily ET for more than 540 consecutive days at both sites (apps. 1 and 2). Ruby Lake is the primary source of water for ET in the wetland. Water within the lake is derived principally from springs discharging along the west and southwest side of the refuge and beneath the lake, and from precipitation that falls directly on the lake.

The open-water site was located in the extreme southern part of the South Marsh (figs. 2 and 5*A*; table 1). Historically, the South Marsh has remained at least partially flooded during prolonged dry periods while other water bodies in the refuge desiccate. In June 1985, open water covered about 1,030 acres in the South Marsh (Nichols, 2000, C17). During this study, the water level at the open-water site initially was 4.3 ft in May 1999, but fell 1.5 ft by September 1999. During the winter (October 1999–April 2000) the water level rose about 1.0 ft, but dropped 2.3 ft by September 2000. The bulrush-marsh site was located in a moderately dense stand of bulrush (*Scirpus robustus*) with scattered cattails (*Typha* spp.) in the southern part of the North Marsh (figs. 2 and 5*B*; table 1). The initial water level at the bulrush-marsh site was about 3.0 ft in May 1999 and declined by 1.6 ft in September 1999. In March 2000 the water level was about 2.8 ft and dropped 1.6 ft by September 2000. The extent of the wetland area decreased by about 4,500 acres between March and September 2000.

In general, surface-water levels throughout the wetland were 1.0 ft lower in the summer of 2000 (May–September) than in the summer of 1999 (USFWS, written commun., 2000). This decline in water level is largely due to the smaller amount of precipitation during the 1999–2000 winter (October 1999–April 2000) than during the preceding winter (October 1998–April 1999; fig. 3).

Meadows along the western and southern parts of the refuge are found in association with springs and areas of frequent flooding from rising ground water. Eddy-correlation instrumentation was set up in a meadow in the southern part of the refuge, less than 1/4 mi from the South Marsh (figs. 2 and 6*A*; table 1). Daily ET at the meadow site was computed from data collected continuously from May 26 through August 29 except for 19 days at the end of July when the data logger malfunctioned (app. 5). Plants at the meadow site consist primarily of sedges (*Carex* spp.), rushes (*Juncus* spp.), and some grasses and herbaceous species. Depth to ground water beneath the site was estimated to be less than 2 ft during the period of data collection and the soil generally was moist. Although the meadow site has been subject to periodic flooding in years of above-average precipitation, the site was not flooded during this study.

Mixed phreatophytic shrubs and associated areas of bare soil are found in a broad expanse along the east, northeast, and southeast sides of the refuge that is not subject to flooding (fig. 7). ET typically exceeds seasonal precipitation in these areas because the plants have access to ground water for transpiration. Five sites were selected to estimate ET from various mixtures of phreatophytic shrubs using both the Bowen-ratio and eddy-correlation methods (fig. 2; table 1). The plant species of interest at the phreatophyte sites include

Table 4. Area and estimated annual evapotranspiration for major habitats within Ruby Lake National Wildlife Refuge, September 1999–October 2000, northeastern Nevada

Habitat	Area (acres) [1]		Evapotranspiration (feet) [2]		Evapotranspiration (acre-feet per year) [3]
	Winter	Summer	Winter	Summer	
Open water	5,700	3,700	1.99	3.32	23,600
Bulrush marsh	8,100	5,600	1.10	3.09	26,200
Meadow	4,100	4,100	1.08	2.11	13,100
Grassland	3,100	3,100	.87	1.49	7,320
Mixed phreatophytes	5,500	5,500	.50	.83	7,320
Desert-shrub upland	4,800	4,800	.51	.48	4,750
Playa and bare soil	6,300	10,800	.46	.34	6,570
Total	**37,600**	**37,600**			**89,000**

[1] Area in winter (October 1999–April 2000) determined in March 2000 during maximum extent of wetland; area in summer (May 2000–September 2000) determined in September 2000 during minimum area of wetland.

[2] See table 2 for seasonal ET rates for open water, bulrush marsh, mixed phreatophytes, and desert-shrub upland. Annual ET rates for other habitats equal sum of seasonal precipitation (winter, 0.42 ft; summer, 0.23 ft) measured at Ruby Lake NWR and annual ground-water ET rate of 2.54 ft/yr for meadow; 1.71 ft/yr for grassland; and 0.15 ft/yr for areas of playa and bare soil determined from Landsat data (Nichols, 2000) and proportioned seasonally based on 26 percent of annual ET occurring during winter and 74 percent occurring during summer (Nichols, 2000, p. C12).

[3] Computed as sum of products of estimated seasonal habitat area and seasonal evapotranspiration.

phreatophytic shrubs, and desert-shrub uplands (table 4). Similarly, summation of monthly totals for May 2000 through September 2000 was used to compute summer ET rates. To determine total ET for the remaining major habitats (meadow, grassland, and playa and bare soil), annual ground-water ET rates were derived on the basis of satellite data, adjusted to reflect total ET by adding precipitation, and seasonally proportioned to correspond with changes in habitat area.

Satellite data recently has been used in east-central Nevada to estimate regional ground-water ET based on relations between vegetation indices derived from Landsat data and measured plant cover (Nichols, 2000). Nichols (2000, p. A6, eq. 3) determined that ground-water ET could be estimated as a function of plant cover. Plant cover, in turn, can be determined on a regional scale from Landsat data using easily calculated vegetation indices (Nichols, 2000, p. B6, eqs. 9 and 10). The relation between vegetation indices and plant cover was used together with the relation between plant cover and ground-water ET to determine annual estimates of ground-water ET for meadow, grassland, and areas of playa and bare soil in Ruby Lake NWR. Satellite data used to derive plant cover and compute annual ET rates were obtained on June 10, 1985, and June 29, 1989. Based on this analysis, annual ground-water ET in Ruby Lake NWR is 2.54 ft/yr for meadow, 1.71 ft/yr for grassland, and 0.15 ft/yr for areas of playa and bare soil.

Nichols (2000, p. C12) suggests that winter ground-water ET by vegetation in east-central Nevada accounts for about 26 percent of the annual ground-water ET. Applying this percentage to the annual estimates derived from the Landsat data produces a winter ground-water ET of about 0.66 ft/yr for meadow, about 0.45 ft/yr for grassland, and about 0.04 ft/yr for areas of playa and bare soil. Similarly, estimates of summer ground-water ET are about 1.88 ft/yr for meadow, about 1.26 ft/yr for grassland, and about 0.11 ft/yr for areas of playa and bare soil. Finally, the seasonal rates of ground-water ET were adjusted to account for the volume of precipitation that fell during the data-collection period to arrive at total annual ET.

Total annual ET for meadow, grassland, and playa and bare soil were computed by adding the seasonal amount of precipitation measured at the refuge headquarters to the estimated rate of seasonal ground-water ET. Limited bulk-precipitation gage data, which was