

Prepared in cooperation with North Dakota State University Extension Service

Runoff and Water-Quality Characteristics of Three Discovery Farms in North Dakota, 2008–16



Scientific Investigations Report 2017–5124

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

Cover. Photographs from top to bottom: Runoff in flume at Underwood farm site U1, June 6, 2008 (photograph by William Damschen, U.S. Geological Survey [USGS]); standing water in field at Embden farm near sites E2 and E3, March 15, 2010 (photograph by William Damschen, USGS); and spring calving area between site D1a and site D2 at Dazey farm, May 15, 2008 (photograph by Kathleen Rowland, USGS). Background photograph: Winter feeding area near site D1b at Dazey farm, July 9, 2009 (photograph by Kathleen Rowland, USGS).

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By Joel M. Galloway and Rochelle A. Nustad

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

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Conversion Factors

U.S. customary units to International System of Units

Multiply	By	To obtain
Length		
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
Area		
square mile (mi ²)	2.5900	square kilometer (km ²)
acre	0.004047	square kilometer (km ²)
Volume		
acre-foot (acre-ft)	1,233	cubic meter (m ³)
acre-foot (acre-ft)	0.001233	cubic hectometer (hm ³)
Flow rate		
acre-foot per year (acre-ft/yr)	1,233	cubic meter per year (m ³ /yr)
acre-foot per year (acre-ft/yr)	0.001233	cubic hectometer per year (hm ³ /yr)
cubic foot per second (ft ³ /s)	0.028317	cubic meter per second (m ³ /s)
Mass		
pound, avoirdupois (lb)	0.4536	kilogram (kg)
pound, avoirdupois, per year (lb/yr)	0.4536	kilograms per year (kg/yr)
pound, avoirdupois, per year per acre (lb/yr/acre)	0.4536	kilograms per year per square kilometer (kg/yr/ km ²)
pound, avoirdupois, per year per square mile (lb/yr/mi ²)	112.083	kilograms per year (kg/yr/km ²)
tons, short, per year (tons/yr)	907.185	kilograms per year (kg/yr)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

$$^{\circ}\text{F} = (1.8 \times ^{\circ}\text{C}) + 32.$$

Datum

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to North American Datum of 1983 (NAD 83).

Elevation, as used in this report, refers to distance above the vertical datum.

Supplemental Information

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius ($\mu\text{S}/\text{cm}$ at 25 °C).

Concentrations of chemical constituents in water are given in milligrams per liter (mg/L).

Application rates are given in pounds per year per acre (lb/yr/acre).

Abbreviations

NWIS	National Water Information System
SPARROW	SPAtially Referenced Regressions On Watershed attributes [U.S. Geological Survey model]
USGS	U.S. Geological Survey

Runoff and Water-Quality Characteristics of Three Discovery Farms in North Dakota, 2008–16

By Joel M. Galloway and Rochelle A. Nustad

Abstract

Agricultural producers in North Dakota are aware of concerns about degrading water quality, and many of the producers are interested in implementing conservation practices to reduce the export of nutrients from their farms. Producers often implement conservation practices without knowledge of the water quality of the runoff from their farm or if conservation practices they may implement have any effect on water quality. In response to this lack of information, the U.S. Geological Survey, in cooperation with North Dakota State University Extension Service and in coordination with an advisory group consisting of State agencies, agricultural producers, and commodity groups, implemented a monitoring study as part of a Discovery Farms program in North Dakota in 2007. Three data-collection sites were established at each of three farms near Underwood, Embden, and Dazey, North Dakota. The purpose of this report is to describe runoff and water-quality characteristics using data collected at the three Discovery Farms during 2008–16. Runoff and water-quality data were used to help describe the implications of agricultural conservation practices on runoff and water-quality patterns.

Runoff characteristics of monitoring sites at the three farms were determined by measuring flow volume and precipitation. Runoff at the Underwood farm monitoring sites generally was controlled by precipitation in the area, antecedent soil moisture conditions, and, after 2012, possibly by the diversion ditch constructed by the producer. Most of the annual runoff was in March and April each year during spring snowmelt. Runoff characteristics at the Embden farm are complex because of the mix of surface runoff and flow through two separate drainage tile systems. Annual flow volumes for the drainage tiles sites (sites E2 and E3) were several orders of magnitude greater than measured at the surface water site E1. Site E1 generally only had runoff briefly in March and April during spring snowmelt and during only a few large rain events throughout 2009–16. Flow was somewhat continuous at sites E2 and E3 throughout the year during years of increased precipitation, such as in 2010 and 2011. At Dazey farm, annual flow volumes at the most downstream site D3 for 2010–15 ranged from 88 acre-feet (2012) to 12,060 acre-feet (2010). The largest monthly runoff volumes at D1 (most upstream site; combination of data from site D1a [original site] and site D1b

[relocated site]) and D3 were in March and April during spring snowmelt runoff and rain events.

At Underwood farm, total ammonia and total phosphorus had the highest concentrations at the most upstream site (U1) and decreased sequentially at sites U2 and U3 downstream. Total ammonia and total phosphorus concentrations at the sites for Underwood farm also generally were higher than measured at sites for the Dazey and Embden farms. At Embden farm, nitrate plus nitrite concentrations were lowest at site E1 (surface-water site) and highest at sites E2 and E3 (drainage tile sites). Nitrate plus nitrite concentrations at sites E2 and E3 also were the highest among all the sites at all three farms. Median total nitrate plus nitrite concentrations for sites E1, E2, and E3 were 0.22, 13, and 10 milligrams per liter as nitrogen, respectively. Nutrient concentrations generally were greater at site D1 (most upstream site) compared to site D3 (most downstream site) at Dazey farm. Higher concentrations at site D1, which is farther upstream and closer to potential sources of nutrients, compared to lower concentrations at site D3, which is farther downstream and receives more runoff, indicates that dilution may be the reason concentrations decrease downstream.

Annual loads for chloride at all three Underwood sites were the greatest in 2011 and the least in 2012, which coincided with years of the greatest and least annual flow volume, respectively. Total ammonia had a similar pattern at the three sites. Nitrate plus nitrite loads displayed a different pattern than chloride and total ammonia, indicating possible different sources. Chloride, total ammonia, total phosphorus, and suspended sediment were transported past site U1 mostly in March and the least from July through October. Monthly nitrate plus nitrite loads had a different pattern than the other constituents, indicating other possible sources such as fertilizer application in the surrounding cropland.

Annual loads for Embden farm were considerably greater at sites E2 and E3 compared to site E1. Annual yields for all constituents also were substantially greater at sites E2 and E3 compared to site E1, mainly because of a combination of higher flow volumes and small contributing drainage areas at sites E2 and E3 compared to site E1.

The greatest annual loads at Dazey farm site D3 for chloride, nitrate plus nitrite, and suspended sediment were in 2010 and 2011, and zero loads were estimated for 2012 because no

flow was measured at the site. Mean monthly loads generally were greatest for most constituents in March and April at sites D1 and D3 except for suspended sediment that had the greatest monthly loads in May.

To mitigate runoff and water-quality effects of their operations, the producers implemented various agricultural conservation practices before and during the Discovery Farms monitoring. Even though it was difficult to quantify the effects of the agricultural conservation practices implemented at the farms, the data collected from the Discovery Farms program provided a better understanding of some of the variables that affect runoff and water quality.

Introduction

Of the 45.3 million acres of land in North Dakota, 39.4 million acres, or 87 percent of North Dakota's land area, are used for agriculture (North Dakota, 2017). According to the U.S. Environmental Protection Agency (2017a), agricultural nonpoint source pollution is the leading source of water-quality effects on rivers and streams. In 2016, 33.9 percent of North Dakota rivers and streams had water quality that did not support the designated use for fish and other aquatic biota (U.S. Environmental Protection Agency, 2017b). Much work has been done to improve water quality, including implementing various agricultural conservation practices on cultivated cropland. On a regional scale, in the Upper Mississippi River Basin, application of the U.S. Geological Survey (USGS) SPATIally Referenced Regressions On Watershed attributes (SPARROW) model has indicated that conservation practices have had a statistically significant effect on reducing nitrogen and a lesser effect on phosphorus loads (Garcia and others, 2016). Within North Dakota, in the Souris-Red-Rainy Basin, recent research by the U.S. Department of Agriculture (2014) indicated that the Conservation Effects Assessment Project has improved water quality. Agricultural producers in North Dakota are aware of concerns about degrading water quality, and many of the producers are interested in implementing conservation practices to reduce the export of nutrients from their farms—not only because it reduces the effect on receiving waters, but also because it is beneficial to the producer to retain nutrients. Producers often implement conservation practices without knowledge of the water quality of the runoff from their farm or if conservation practices they may implement have any effect on water quality. In response to this lack of information, the USGS, in cooperation with North Dakota State University Extension Service and in coordination with an advisory group consisting of State agencies, agricultural producers, and commodity groups, implemented a monitoring study as part of a Discovery Farms program in North Dakota in 2007. Several States have developed a Discovery Farms program, and the intent of the program is to collect and analyze water-quality information from agricultural lands and livestock feeding areas and to document the effectiveness of

producer-driven solutions at minimizing negative effects on water quality (University of Wisconsin, 2017; University of Arkansas, 2017; Minnesota Department of Agriculture, 2017; North Dakota State University, 2009). As part of the Discovery Farms program, hydrologic and water-quality data were collected at three Discovery Farms in North Dakota (fig. 1) during 2008–16.

Purpose and Scope

The purpose of this report is to describe the runoff and water-quality characteristics using data collected at three Discovery Farms in North Dakota (fig. 1) during 2008–16. Runoff and water-quality data were used to help describe the implications of agricultural conservation practices on runoff and water-quality patterns.

Description of the Study Areas

Discovery Farms in North Dakota were established in late 2007 near Underwood, North Dakota, in McLean County (hereafter referred to as “Underwood farm”); in late 2008 near Embden, N. Dak., in Cass County (hereafter referred to as “Embden farm”); and in early 2008 near Dazey, N. Dak., in Barnes County (hereafter referred to as “Dazey farm”) (fig. 1). Each farm had three data-collection sites.

Underwood Farm

Underwood farm is a crop and cattle operation about 8 miles (mi) west of Underwood, N. Dak., and about 3 mi east of the Missouri River (fig. 1). A feedlot is at the south-east quadrant of the farm, and cropland makes up most of the surrounding area (fig. 2). Surrounding cropland generally was planted with a mix of mostly spring wheat, but some fields periodically were planted with corn, soybeans, barley, and sunflowers during the period of runoff and water-quality data collection at this site (2008–15) (Joao Paulo Flores, North Dakota State University Extension Service, written commun., 2017). Beef cows are placed in the feedlot during the winter months and remain there through the early spring until they are ready for calving. Once the cows are ready for calving, they are moved to an offsite pasture (not shown) with their calves during the summer months and are kept together until weaning in early fall (Nustad and others, 2015). Weaned calves also are placed in the feedlot in the fall and remain there until late winter before being moved to finishing lots in other parts of the State. Most of the pens in the feedlot are empty during the summer months. Manure accumulation from the winter months is scraped and piled in the pens after the cows and calves are sent to pasture. Manure is stored in the empty pens until late summer when it is spread on surrounding cropland to be used as a crop fertilizer.

Runoff from the farm and feedlot enters a waterway that generally trends from north to south (fig. 2). Runoff from the

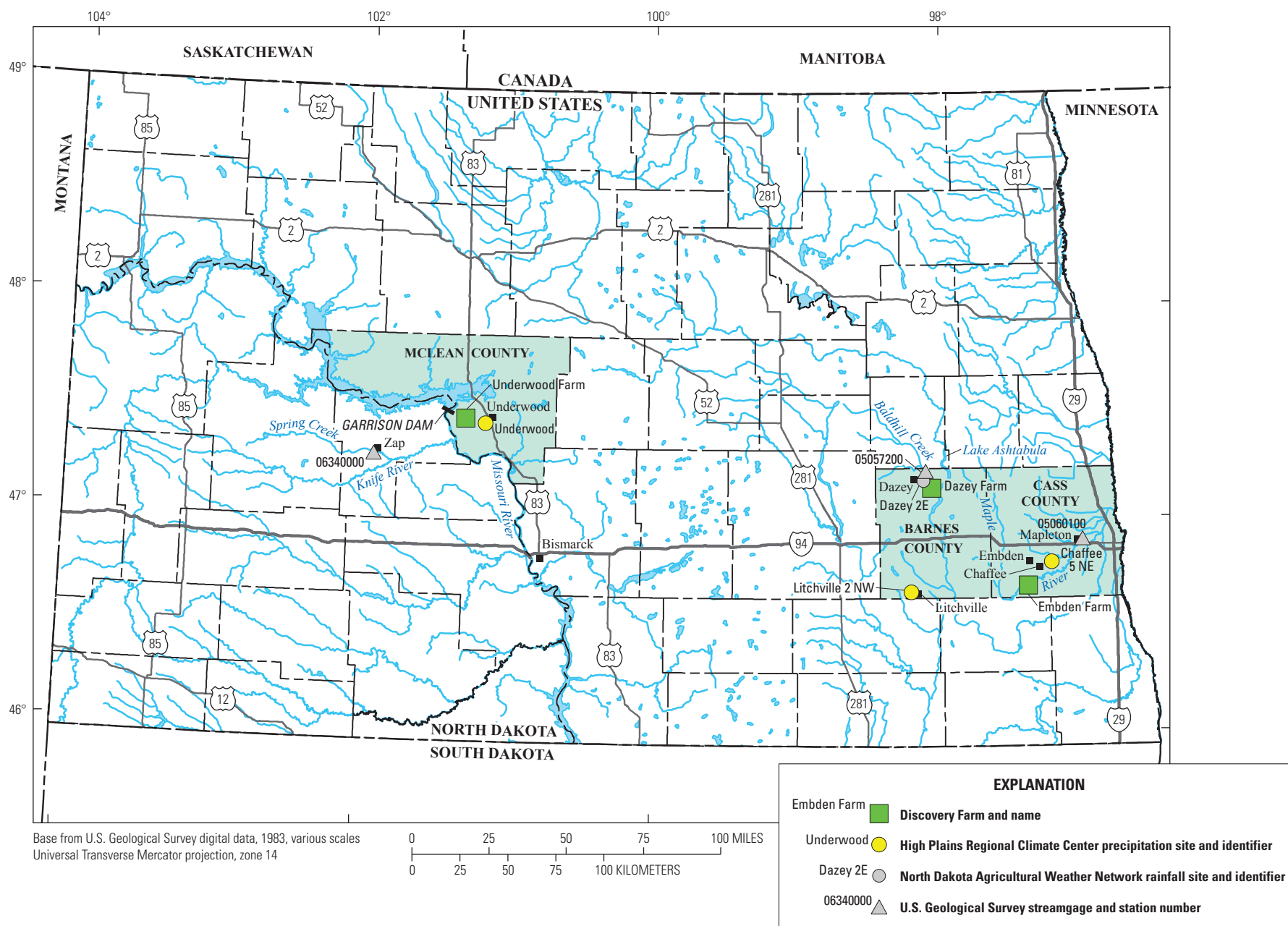


Figure 1. Locations of Discovery Farms sites and other associated sites, North Dakota.

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Table 1. Site information for monitoring locations at Discovery Farms, North Dakota.

[USGS, U.S. Geological Survey; SW, surface water; DT, drainage tile]

Station number	USGS station name	Abbreviated name	Drainage area, acres	Site type	Period of record
Underwood Farm, McLean County					
472731101175500	Discovery Farms Waterway Site 1 near Underwood, North Dakota	U1	87	SW	May 2008–October 2015.
472727101175000	Discovery Farms Waterway Site 2 near Underwood, North Dakota	U2a	1,918	SW	June 2008–October 2014.
472709101175100	Discovery Farms Waterway Site 3 near Underwood, North Dakota	U3	1,976	SW	June 2008–October 2015.
Embden Farm, Cass County					
464115097255000	Discovery Farms Waterway Site 1 near Embden, North Dakota	E1 ^a	164	SW	April 2009–October 2016.
464115097254700	Discovery Farms Waterway Site 2 near Embden, North Dakota	E2	66 ^b	DT	June 2009–October 2016.
464114097260900	Discovery Farms Waterway Site 3 near Embden, North Dakota	E3	70 ^b	DT	April 2009–October 2016.
Dazey Farm, Barnes County					
470856098050600	Discovery Farms Waterway Site 1 near Dazey, North Dakota	D1 ^a	30	SW	October 2008–October 2012.
470856098050600	Discovery Farms Waterway Site 1 near Dazey, North Dakota	D1 ^b	24	SW	October 2012–October 2015.
470856098045800	Discovery Farms Waterway Site 2 near Dazey, North Dakota	D2	80	SW	Mar 2009–April 2011.
470850098044500	Discovery Farms Waterway Site 3 near Dazey, North Dakota	D3	341	SW	April 2009–October 2015.

^aPrecipitation gage installed at site.

^bDrainage area is an estimate based on configuration of drainage tile.

farm contributes to a small drainage basin that flows into the Missouri River. Three data-collection sites were along the waterway south of the farm (fig. 2). The drainage area for each of the sites ranges from 87 to 1,976 acres (Nustad and others, 2015) (table 1).

The feedlot is managed by the producer to reduce effects to downstream receiving water bodies, and in response to data collected from the Discovery Farms program, a conservation practice was implemented during the program. Data collected during the first 2 years (2008–10) indicated large loads of chloride, nutrients, and sediment were coming from the flow of water across the feedlot into the waterway, especially during spring months (Nustad and others, 2015). In response to these data, the producer constructed a diversion ditch in 2012 to divert runoff around the feedlot to reduce the transport of material from the feedlot (fig. 2).

Embden Farm

Embden farm is a crop and cattle production operation about 8 mi south of Embden, N. Dak., and about 1 mi north of the Maple River (fig. 1). Although Embden farm has a cattle operation, the data collection sites are in an area only affected by runoff from cropland (fig. 3). The owners of the Embden farm have been implementing conservation practices such as crop rotation, no-till, split-applied fertilizer application, and cover crops for several years before the Discovery Farms program and continue to implement these practices.

Crops grown on the farm include corn, soybeans, wheat, and alfalfa. The soils vary from well drained to somewhat poorly drained soils, and runoff is generally slow (Nustad and others, 2015). Subsurface drainage tiles were installed in an agricultural field at the farm in 2009, and water from the

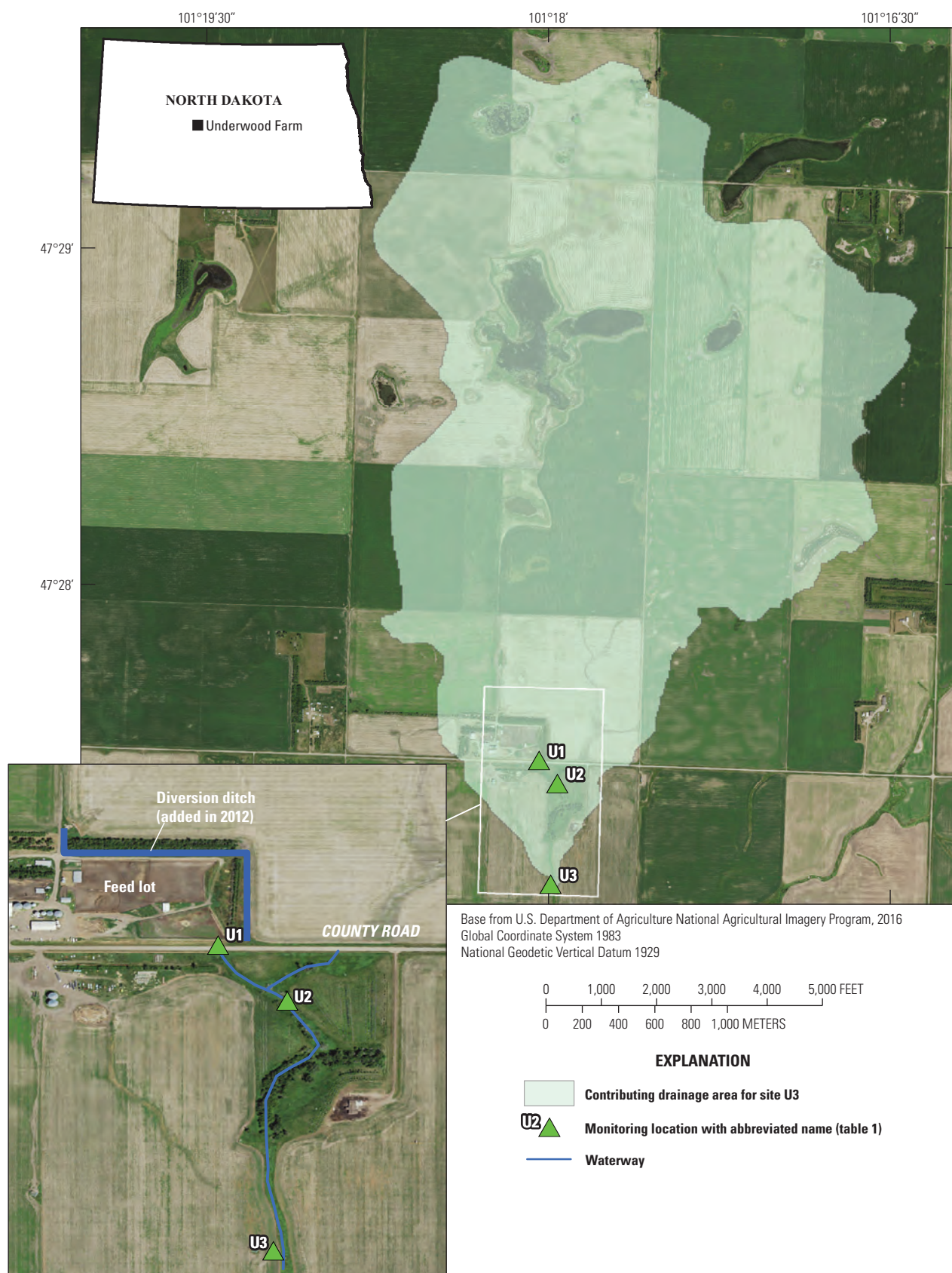


Figure 2. Location of monitoring sites and study area for Underwood farm in North Dakota.

drains can flow into the Maple River (fig. 3). The field being monitored has two separate subsurface drainage tile systems that drain the east (field 1) and west (field 2) halves of the field (fig. 3). Historically, the east and west fields have been farmed as one unit; therefore, the two subsurface drainage tile systems provide a paired drainage system for comparative analyses. On the east field (field 1), most of the field surface drainage exits in the southeast corner for the east subsurface drainage system and is monitored at site E1. The drainage tile outlet for the east field is managed by a flume and is monitored at site E2. The drainage tile outlet for the west field (field 2) is managed by a flume inserted into the drainage tile underground and is monitored at site E3. Drainage areas based on surface topography are provided in table 1, but because of fluctuating water-table elevations the exact land acreage drained by the subsurface

drainage sites could not be determined for sites E2 and E3 (Nustad and others, 2015).

Dazey Farm

Dazey farm is a crop and cattle operation about 6 mi east and 2 mi south of Dazey, N. Dak., and 3 mi west of Lake Ashtabula (fig. 1). Spurred by the initiation of the Discovery Farms program, but before data collection, the producer implemented changes in their farming operation to reduce their effect on downstream water quality. The feedlot was relocated from the east side of the tree row, near the farmhouse, to the west side of the tree row (fig. 4). The new location of the feedlot is on a flat area, farther upslope from the natural drainage,

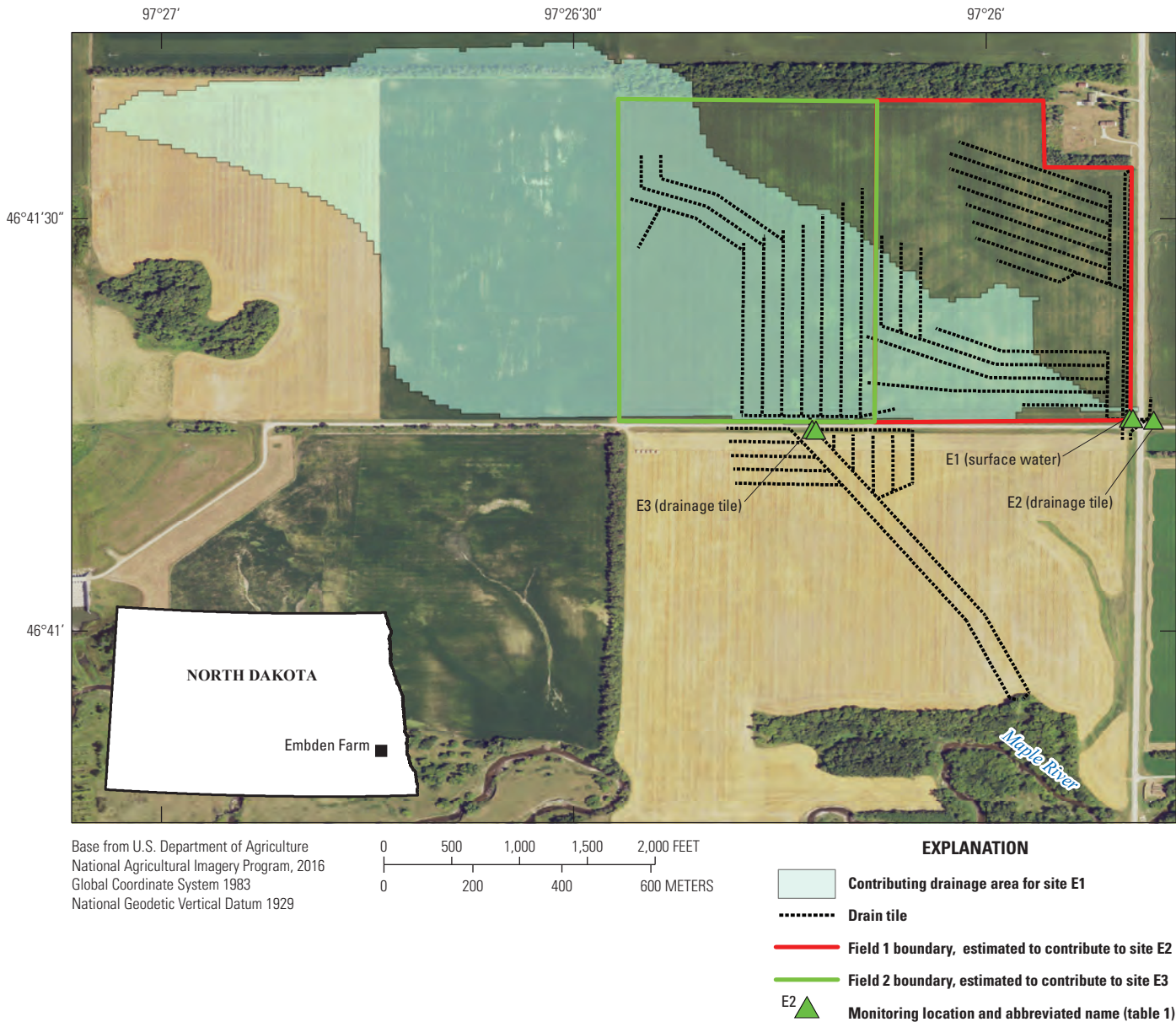


Figure 3. Location of monitoring sites and study area for Embden farm in North Dakota.

and runoff is filtered by a tree row and vegetation before flowing into the waterway in the pasture. Also before data collection, the feeding area was expanded during the winter months, and cattle graze on crop residue.

The feedlot and winter cattle feeding area are to the west of the farmhouse, and cropland makes up most of the surrounding area (fig. 4). After being brought in from pasture in the fall, the beef cows are wintered on the cattle feeding area, which is primarily cropland. The cattle graze on crop residue and, if supplemented with stored feed, the feeding areas are randomly located in the cropland area to decrease the amount of concentrated feeding areas (Nustad and others, 2015). Feeding area runoff from the cropland, which can flow rapidly, travels mostly eastward along a waterway into Baldhill Creek (fig. 4) and then into Lake Ashtabula (about 3 mi downstream, fig. 1). The waterway traverses through a pasture, which serves as a calving area for the beef cows in early spring (fig. 4). Three data-collection sites were established along the waterway and were operated from 2009 to 2015, although one site (site D2) was only operated from 2009 to 2011 because it was destroyed by excess runoff and sedimentation in April 2011. The most upstream site (site D1a) was moved about 300 feet (ft) upstream in the drainage to site D1b in 2011 because heavy sedimentation made collecting good quality flow data difficult. The most downstream site (D3) receives runoff from the cattle feeding area and runoff from cropland on neighboring farms. The drainage area for the three original sites ranges from 30 to 341 acres (Nustad and others, 2015), and the drainage area of site D1b is 24 acres (table 1). Crop information was not available for the farm.

Methods

Discharge, rainfall, and water-quality data were collected at Underwood, Embden, and Dazey farms. Flow volume, derived from discharge measurements, and concentration data were summarized in graphical and tabular form, and the data were used to estimate constituent loads and yields for each site. Data that were not available at the farm sites but were needed for further analyses were obtained from other sources, such as precipitation data and loads and yields data for larger streams to compare to the monitoring sites.

Data Collection

Each monitoring site contained a refrigerated, automated water sampler that held 24 1-liter sample bottles, a datalogger, a bubble-gage system (Sauer and Turnipseed, 2010), and a flume. At Embden farm, an extra-large 60-degree *V* trap-ezoidal flume was installed underground at sites E2 and E3 to capture runoff from subsurface drainage tiles. A tipping-bucket rain gage was installed at one site on each farm. Additional location information for the farms is presented in table 1, and

information on the instrumentation and monitoring methods is described in Nustad and others (2015).

Samples were collected by automatic samplers and manually at all the sites. Samples were analyzed for several constituents including chloride, nutrients (ammonia, nitrate plus nitrite, and phosphorus), total suspended solids, and suspended sediment. A subset of the samples was analyzed for additional constituents such as major ions, iron, and manganese (appendix table 1–1). All laboratory analyses were completed by the North Dakota Department of Health Laboratory in Bismarck, N. Dak., following procedures described in Clesceri and others (1999) or the U.S. Environmental Protection Agency (2017c). All water-quality data for these sites are stored and are available from the USGS National Water Information System (NWIS) database (U.S. Geological Survey, 2017).

Quality-assurance samples (blank and replicate water-quality samples) also were collected at the sites to determine adequate reproducibility and proper cleaning conditions of equipment. In total, 4 blank samples and 38 replicate samples were collected at sites. Field blank samples were collected from the automatic sampler intake lines and had some detections that were greater than the laboratory reporting levels, but well below environmental sample concentrations, indicating that the flushing or cleaning of the line between samples was adequate to prevent cross contamination of samples. The analytical variability of replicate samples for constituents was assessed using relative percent difference (calculated as the absolute difference in concentration divided by the mean concentration multiplied by 100 for the environmental/replicate sample pair). Mean relative percent differences for chloride, total ammonia, and total phosphorus were 4.6, 9.5, and 2.1, respectively (table 2), indicating satisfactory quality assurance on these constituents. Variability for total nitrate plus nitrite and suspended sediment was higher with mean relative percent differences of 14.9 and 18.3, respectively (table 2). Quality-assurance sample data were stored in the USGS NWIS database (U.S. Geological Survey, 2017) and are presented in appendix table 1–2.

Data Analyses

Discharge data are described in this report in terms of flow volume and runoff at each site. Daily mean discharge values were computed for each site using techniques described in Sauer and Turnipseed (2010). Annual and monthly flow volumes were computed by converting the daily mean discharge values (in cubic feet per second) into daily flow volumes by multiplying the value by time and converting the volume to acre-feet, then accumulating the daily flow volumes for each month and year. Generally, many of the sites only had flow in March through November, with the exception of the two drainage tile sites at Embden farm, which had flow throughout the winter months in 2010 and 2011. Annual and monthly runoff volumes were computed by dividing the annual and monthly flow volumes by the respective

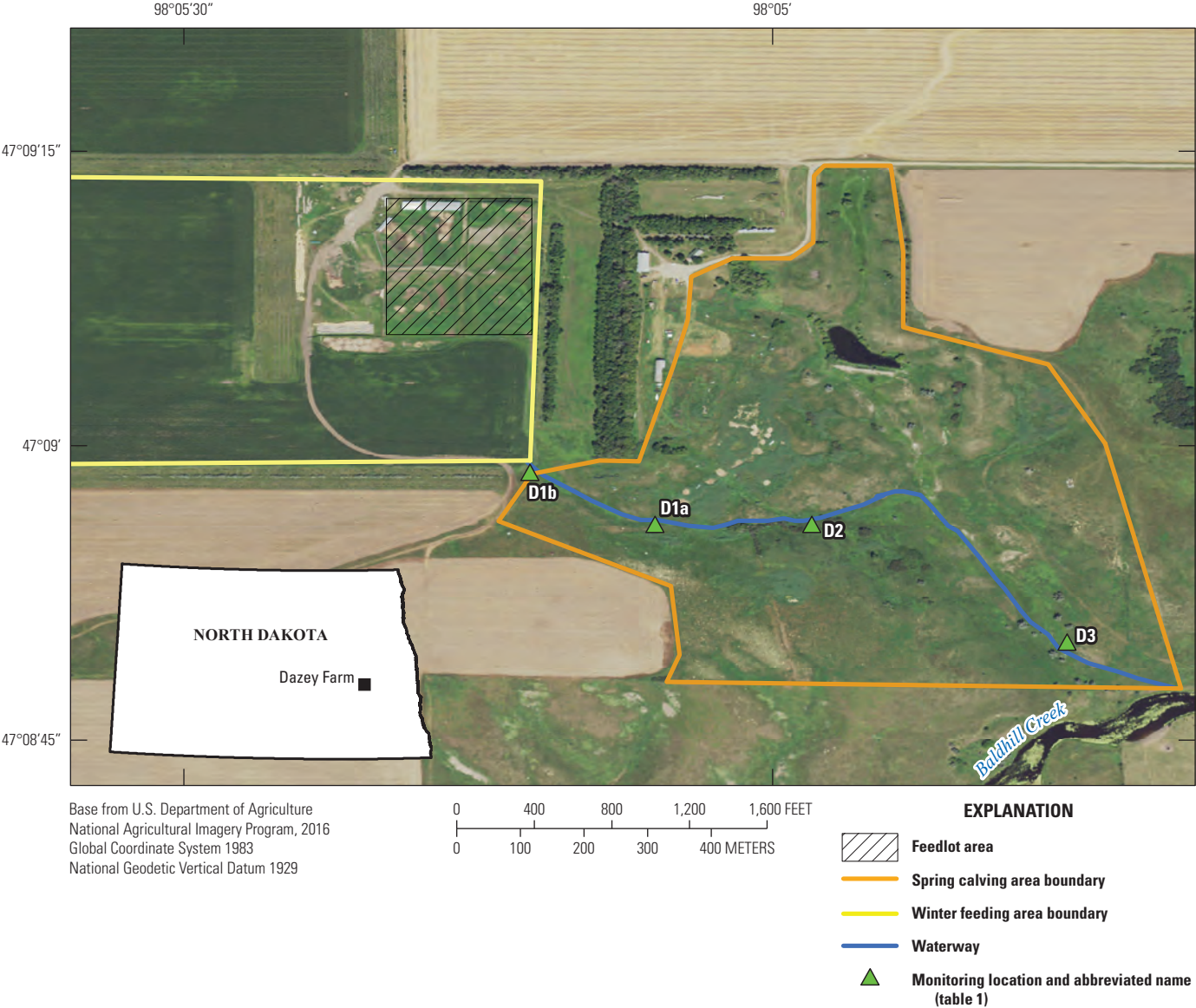


Figure 4. Location of monitoring sites and study area for Dazey farm in North Dakota.

Table 2. Relative percent differences of replicate samples for chloride, nutrient, and suspended-sediment concentrations for samples collected at Discovery Farms, North Dakota, 2008–16.

[Calculation of percent difference is: $|(x_1 - x_2)/(x_1 + x_2)/2| \times 100$, where x_1 is environmental sample, x_2 is sequential replicate]

Constituent	Number of samples	Mean relative percent difference
Chloride	32	4.6
Total ammonia	25	9.5
Total nitrate plus nitrite	34	14.9
Total phosphorus	29	2.1
Suspended sediment	12	18.3

contributing drainage areas estimated for each site and multiplying by a unit conversion factor. Flow volumes and runoff were compared to precipitation data for each farm in graphical and tabular form.

Concentration data were presented for selected constituents using boxplot graphs to show the distribution of data for each constituent at each site and summary statistics in tables. Data not described in the report are summarized in appendix table 1–1. All concentration data from samples collected for Discovery Farms are stored in the USGS NWIS database (U.S. Geological Survey, 2017).

Concentration and discharge data were used to compute constituent loads and yields for each of the sites. Daily loads were computed for sites using estimated daily mean values of constituent concentration and discharge data for the periods

of record from selected Discovery Farm sites. The daily loads were summed into monthly and annual loads for presentation in this report. To compare sites with different contributing drainage areas, the annual loads were divided by the contributing drainage areas for each site to produce annual yields in pounds per year per acre. Computation of loads is described in further detail in Nustad and others (2015).

Other Data Sources

Precipitation data for winter months (November–March) were obtained from other sites near the respective farms (High Plains Regional Climate Center, 2017) (fig. 1; table 3). Data were obtained for the winter months from other sources because snowfall was not measured at the sites. Rainfall data were supplemented with data from other sites during periods of missing data at the Discovery Farm sites. At Underwood farm, the rainfall gage at U2 did not function properly for 2013–15, so a site near Underwood, N. Dak., was used for monthly precipitation values for that period (fig. 1; High Plains Regional Climate Center, 2017). At Dazey farm, precipitation data from a nearby North Dakota Agricultural Weather Network site were used for rainfall data because of periods of missing rainfall data at site D1 (fig. 1; North Dakota Agricultural Weather Network, 2017).

Estimated load and yield data were obtained for selected sites from Galloway and others (2012) for comparison to the loads and yields for the Discovery Farm sites. Loads and yields in Galloway and others (2012) were computed using 30 years of data for individual sites and normalized to a single year. Normalized annual loads were presented in tons per year and were converted to pounds per year for comparison to the Discovery Farm sites. Likewise, normalized annual yields were presented in Galloway and others (2012) in units of pounds per year per square mile and were converted to pounds per year per acre for comparison.

Crop and fertilizer application data were provided by the producers at Underwood and Embden farm to help understand runoff and water quality at the sites. Fertilizer application data were estimated only for the area of the farms operated by the producers, and several of the sites had contributing drainage much larger than the area where data were available. Fertilizer was applied at different rates, using different fertilizer types, and at different times of the year at each farm. Individual applications were documented mostly as handwritten notes and, where data were available, were summarized and presented as total annual nitrogen and phosphorus, in pounds applied to fields.

Runoff and Flow Characteristics

Runoff characteristics of monitoring sites at the three farms were determined by measuring flow volume and precipitation. A wide range of hydrologic conditions were measured at all three farms during 2008–16. At all the farm monitoring sites, the greatest annual precipitation (rainfall and snowfall) was measured in 2010, and the least annual rainfall was measured in 2012 (tables 4–6). At Underwood farm, annual precipitation ranged from 12.6 to 24.8 inches (in.) (2008–15), at Embden farm the annual precipitation ranged from 13.8 to 31.0 in. (2009–16), and at Dazey farm the annual precipitation ranged from 9.4 to 20.6 in. (2010–15) (tables 4–6, respectively).

Underwood Farm

Runoff at the Underwood farm monitoring sites generally was controlled by precipitation in the area, antecedent soil moisture conditions, and, after 2012, possibly by the diversion ditch constructed by the producer (fig. 2). Flow volume was highest at the most downstream site U3; annual flow volumes

Table 3. Location information for additional precipitation data used for Discovery Farms, North Dakota, 2008–16.

[NDAWN, North Dakota Agricultural Weather Network; HPRCC, High Plains Regional Climate Center]

Data source	Station name (fig. 1)	Station number	Latitude	Longitude	Data type	Farm where data were used	Period that data was used
NDAWN	Dazey 2E	19	47.183	–98.138	Rainfall	Dazey farm	April 2010–October 2015.
HPRCC	Underwood	UNDN8	47.455	–101.14611	Precipitation (rainfall and snowfall)	Underwood farm	November–March 2008–2012, entire year 2013–2015.
HPRCC	Chaffee 5 NE	CHFN8	46.79583	–97.26862	Precipitation (rainfall and snowfall)	Embden farm	November–March 2008–2016.
HPRCC	Litchville 2 NW	LTHN8	46.66111	–98.22667	Precipitation (rainfall and snowfall)	Dazey farm	November–March 2009–2015.

10 Runoff and Water-Quality Characteristics of Three Discovery Farms in North Dakota, 2008–16

Table 4. Annual precipitation, flow volume, and runoff for monitoring sites at Underwood farm, North Dakota, 2008–15.

[--, not available, <, less than]

Year	Total annual precipitation, in inches ¹	U1			U2			U3		
		Flow volume, in acre-feet	Runoff, in inches	Runoff as a percentage of rainfall	Flow volume, in acre-feet	Runoff, in inches	Runoff as a percentage of rainfall	Flow volume, in acre-feet	Runoff, in inches	Runoff as a percentage of rainfall
2008	16.7	128	0.12	0.7	569	0.02	0.1	401	0.02	0.1
2009	18.2	3,720	3.56	19.5	12,500	0.54	3.0	14,400	0.61	3.3
2010	24.8	3,150	3.02	12.2	7,960	0.35	1.4	12,200	0.51	2.1
2011	18.0	6,210	5.95	33.1	11,600	0.50	2.8	15,200	0.64	3.6
2012	12.6	347	0.33	2.6	111	<0.01	<0.1	136	0.01	<0.1
2013 ²	20.1	1,950	1.87	9.3	2,070	0.09	0.4	2,290	0.10	0.5
2014 ²	20.1	1,460	1.40	7.0	8,960	0.39	1.9	11,200	0.47	2.3
2015 ²	17.9	1,310	1.26	7.0	--	--	--	4,950	0.21	1.2

¹Data from April through October are from site U2, data for November–March is from a High Plains Regional Climate Center site near Underwood, North Dakota.

²All data from a High Plains Regional Climate site near Underwood, North Dakota.

Table 5. Annual precipitation, flow volume, and runoff for monitoring sites at Embden farm, North Dakota, 2009–16.

[<, less than]

Year	Total annual precipitation, in inches ¹	E1			E2			E3		
		Flow volume, in acre-feet	Runoff, in inches	Runoff as a percentage of rainfall	Flow volume, in acre-feet	Runoff, in inches	Runoff as a percentage of rainfall	Flow volume, in acre-feet	Runoff, in inches	Runoff as a percentage of rainfall
2009	22.2	5	<0.01	<0.1	2,280	2.88	13.0	7,220	8.59	38.7
2010	31.0	917	0.47	1.5	22,600	28.56	92.1	24,800	29.50	95.2
2011	18.7	1,820	0.93	5.0	19,600	24.78	132.5	19,000	22.65	121.1
2012	13.8	113	0.06	0.4	72	0.09	0.7	772	0.92	6.7
2013	17.4	4	<0.01	<0.1	324	0.41	2.4	2,470	2.94	16.9
2014	21.3	120	0.06	0.3	377	0.48	2.2	4,790	5.70	26.7
2015	18.1	72	0.04	0.2	203	0.26	1.4	3,840	4.57	25.2
2016	18.4	478	0.24	1.3	1,290	1.62	8.8	2,280	2.72	14.8

¹Data from April through October are from site E1, data for November through March are from a High Plains Regional Climate site near Chaffee, North Dakota.

Table 6. Annual precipitation, flow volume, and runoff for monitoring sites at Dazey farm, North Dakota, 2010–15.

[--, not available]

Year	Rainfall April–October, in inches	D1b			D3		
		Flow volume, in acre-feet	Runoff, in inches	Runoff as a percentage of rainfall	Flow volume, in acre-feet	Runoff, in inches	Runoff as a percentage of rainfall
2010	20.6	--	--	--	12,100	2.95	14.3
2011	18.1	--	--	--	8,080	1.97	10.9
2012	9.4	--	--	--	88	0.02	0.2
2013	15.8	49	0.13	0.9	2,830	0.69	4.4
2014	16.8	1,190	3.31	19.7	1,710	0.42	2.5
2015	14.9	82	0.23	1.5	3,740	0.91	6.1

ranged from 136 acre-feet (acre-ft) (2012) to 15,200 acre-ft (2011) (table 4). Site U1 had annual flow volumes ranging from 347 acre-ft (2012) to 6,210 acre-ft (2011). Measured runoff (flow volume divided by contributing drainage area multiplied by a conversion factor to obtain inches) consistently was highest at site U1 and was lowest at site U2. Annual runoff for site U1 ranged from 0.12 in. (2008) to 5.95 in. (2011) and for site U2 ranged from less than 0.01 in. (2012) to 0.54 in. (2009) (table 4). Most of the annual runoff was in March and April each year during spring snowmelt (fig. 5). The four highest monthly runoff values were measured at U1 in April 2009, March 2010, and March and April 2011 (fig. 5). The monthly runoff for these periods were considerably higher than any other monthly runoff totals from 2008 through 2015. The large monthly totals were not in months with high rainfall totals but were preceded by wet conditions in the previous fall months (September and October) and higher precipitation (rain or snow) in the preceding winter months (November–March). During 2013–15, there were several months with some of the highest precipitation values for 2008–15; however, these rain

events were in the summer months when vegetation in the channel and surrounding cropland were actively growing and could uptake more moisture. In addition, the diversion ditch constructed in 2012 altered the flow of water, which may have had an effect on the runoff characteristics at sites U1 and U2, but because winter precipitation in 2013–15 was considerably less than 2009–12, it was difficult to quantify the effects of the diversion (fig. 5).

Embsden Farm

Runoff characteristics at the Embsden farm are complex because of the mix of surface runoff (measured at site E1) and flow through two separate drainage tile systems (sites E2 and E3; fig. 3). Annual flow volume at the surface runoff site (E1) ranged from 4 acre-ft (2013) to 1,820 acre-ft (2011) (table 5). Annual flow volumes for the drainage tiles sites were much greater than measured at site E1. Annual flow volumes for E2 ranged from 72 acre-ft (2012) to 22,600 acre-ft (2010). Annual

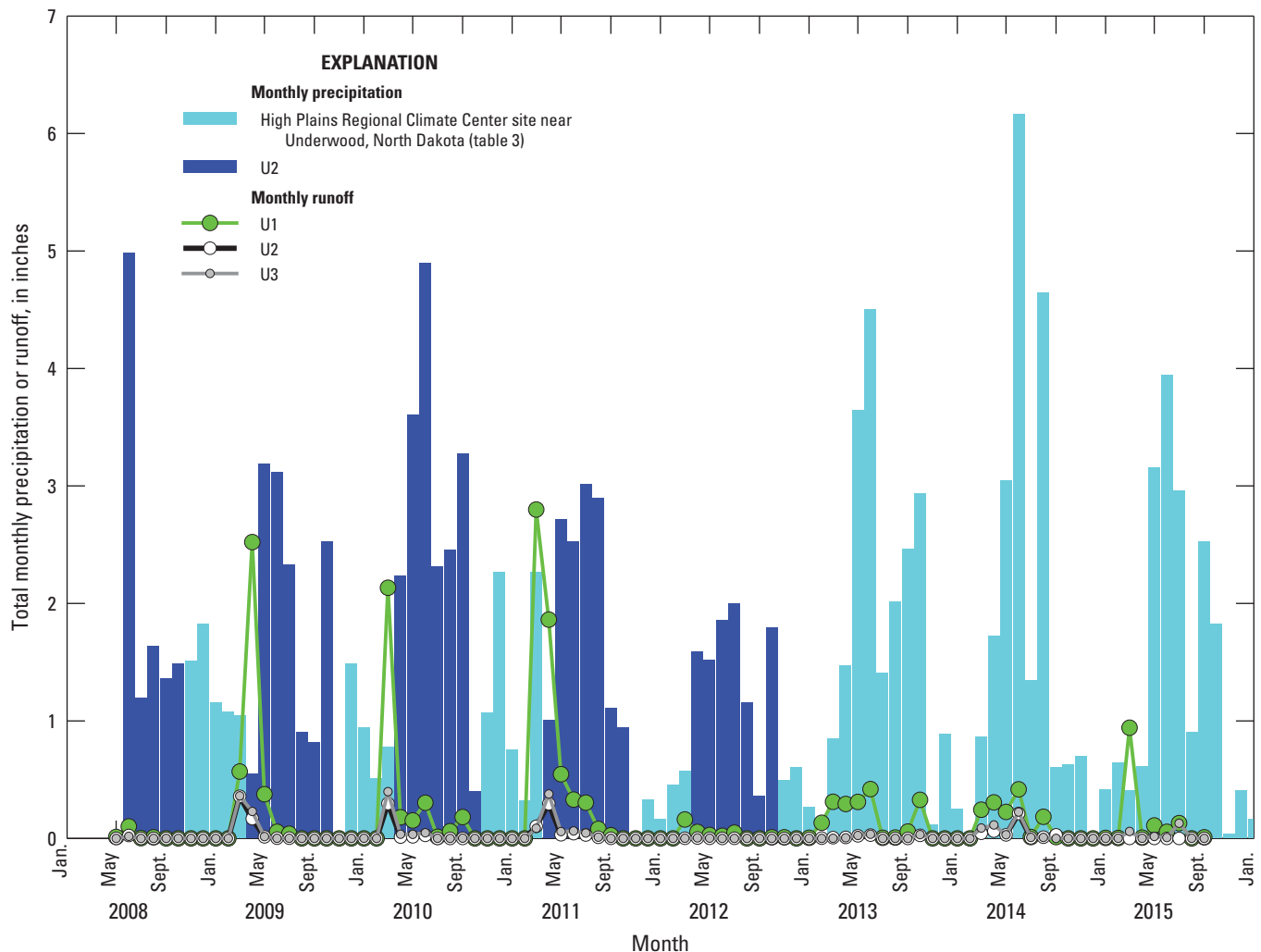


Figure 5. Monthly precipitation and runoff for monitoring sites at Underwood farm, North Dakota, 2008–16.

flow volumes for E3 ranged from 772 acre-ft (2012) to 24,800 (2010) acre-ft. (table 5).

Site E1 generally only had runoff briefly in March and April during spring snowmelt events and during only a few large rain events throughout 2009–16; however, runoff was somewhat continuous at sites E2 and E3 throughout the year during years of increased precipitation such as in 2010 and 2011 (fig. 6). The largest monthly runoff at site E2 was in March 2010 at 7.5 in. and in April 2011 at 11.3 in. Likewise, site E3 had the largest runoff in March 2010 and April 2011 at 9.6 and 11.2 in., respectively (fig. 6). These large runoff volumes were preceded by high precipitation in the fall and winter. Although high monthly rainfall amounts were during summer months in subsequent years, the runoff amounts in the drainage tile sites were considerably less. Winter precipitation was considerably less in 2012–16 compared to 2009–11 (fig. 6). In 2010, sites E2 and E3 had monthly runoff that exceeded 0.5 in. every month from March 2010 through July 2011. Runoff at the drainage tiles also exceeded the amount of rainfall recorded at the site (table 5). This would indicate a large amount of stored moisture in the unsaturated zone and possibly water from a high shallow groundwater table from consecutive wet years being drained through the drainage tile sites E2 and E3 in this period. In subsequent years, most of the runoff flow through the drainage tile sites was measured in the

summer months (May through July) and during months with increased rainfall amounts (fig. 6).

Dazey Farm

Runoff characteristics were difficult to determine because of equipment issues and environmental factors at sites D1a and D2 at Dazey farm. Flow volumes were measured for only a part of 2010 at sites D1a and D2 before site D2 was destroyed by high flows and sedimentation, after which the site was discontinued. Site D1a was later moved to another location (site D1b) farther upslope in 2013 (fig. 4).

Annual flow volumes at the most downstream site D3 for 2010–15 ranged from 88 acre-ft (2012) to 12,100 acre-ft (2010) (table 6). Runoff at site D3 ranged from 0.02 in. (2012) to 2.95 in. (2010). Annual flow volumes for site D1b for 2013–15 ranged from 49 acre-ft (2013) to 1,190 acre-ft (2014), and runoff ranged from 0.13 in. (2013) to 3.31 in. (2014) (table 6). The largest monthly runoff volumes at sites D1b and D3 were in March and April during spring snowmelt runoff and rain events. Site D1b had only one period of measurable monthly runoff that was in March and April 2014. Monthly runoff at site D3 was the greatest in March 2010 (1.9 in.) and in April 2011 (1.5 in.) (fig. 7). Winter

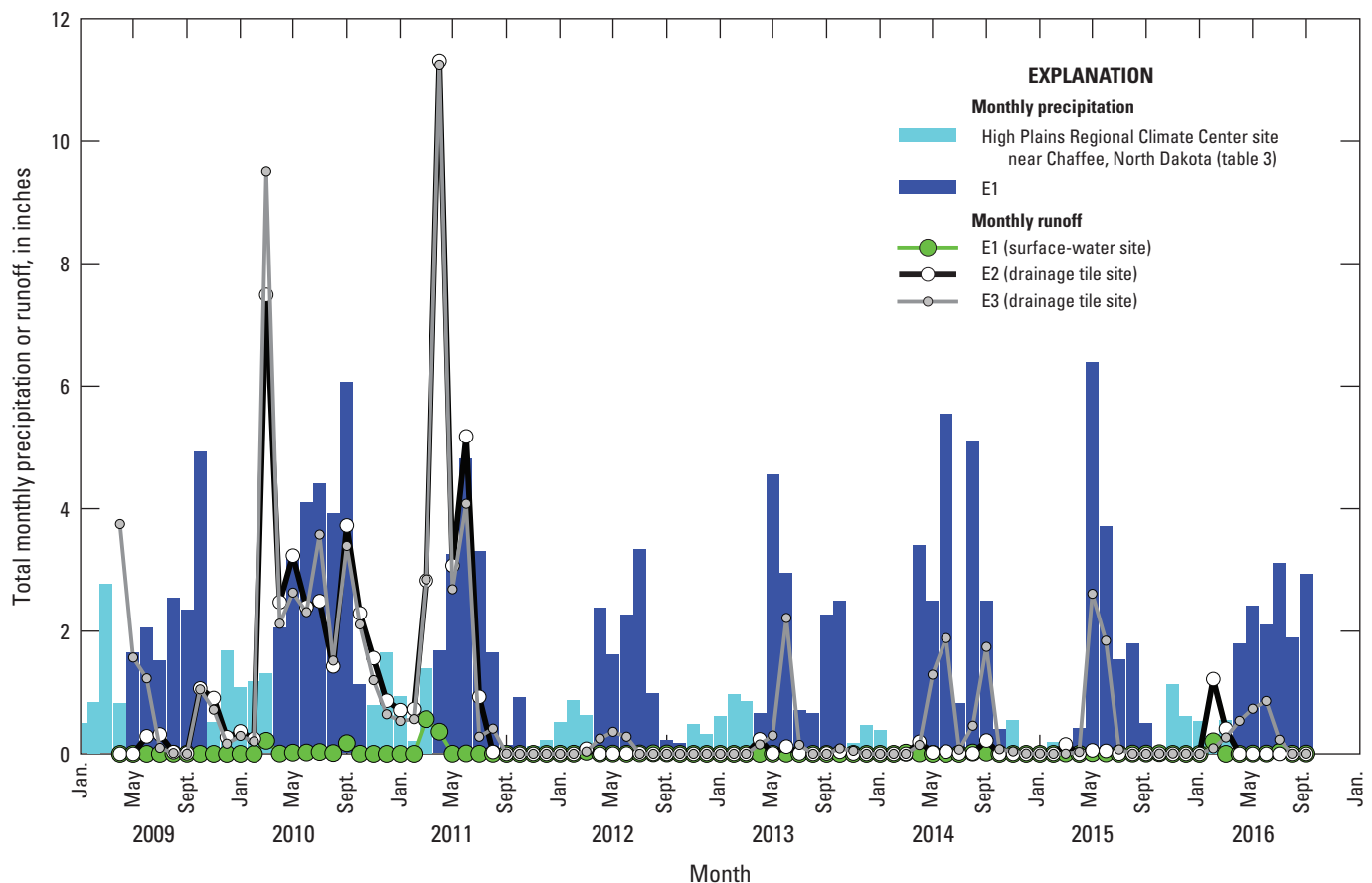


Figure 6. Monthly precipitation and runoff for monitoring sites at Embden farm, North Dakota, 2009–16.

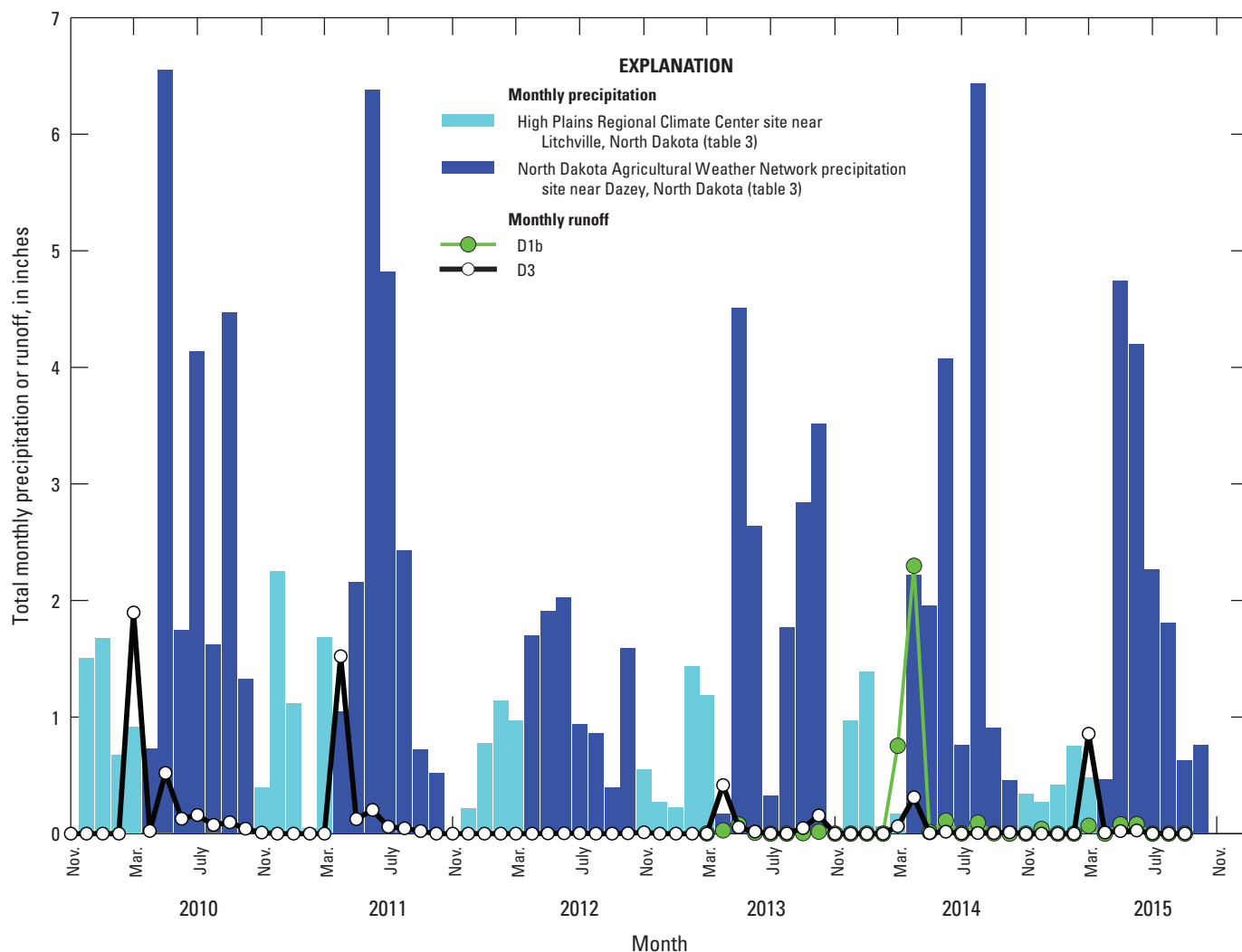


Figure 7. Monthly precipitation and runoff for monitoring sites at Dazey farms, North Dakota, 2010–15.

precipitation used for comparison may not accurately reflect the conditions at the Dazey farm because the nearest site that recorded winter precipitation was about 47 mi south of Dazey farm near Litchville, N. Dak. (High Plains Regional Climate Center, 2017) (fig. 1).

of samples were analyzed for additional constituents such as major ions, iron, and manganese, but these constituents are not extensively discussed in this report and are presented in appendix table 1–1. All water-quality data for these sites are stored and available from the USGS NWIS database (U.S. Geological Survey, 2017).

Water-Quality Characteristics

Water-quality characteristics of sites at each farm are described in terms of constituent concentrations, loads, and yields. Loads (mass per time) were estimated to determine the mass of constituents being transported at the sites associated with the three farms. Yields (load per drainage area) provide a way to compare constituent transport among sites with different drainage areas. Data analysis in this section mainly is focused on chloride, total ammonia, total nitrate plus nitrite, total phosphorus, and suspended sediment. A small number

Underwood Farm

At Underwood farm from June 2008 through September 2015, about 227 samples were collected from site U1, 135 samples from site U2, and 174 samples from site U3 (table 7). Not all samples were analyzed for the same constituents, so the number of values for individual constituents varied throughout the period (table 7). Runoff was sampled generally during spring snowmelt and during rainfall events at the sites (fig. 8).

Table 7. Summary of water-quality constituent concentrations for monitoring sites at Underwood farm, North Dakota, 2008–15.

[Number in parentheses is the U.S. Geological Survey National Water Information System parameter code; ft³/s, cubic foot per second; μ S/cm at 25 °C, microsiemen per centimeter at 25 degrees Celsius; mg/L, milligram per liter; N, nitrogen; P, phosphorus, <, less than]

Site (fig. 2)	Description	Instantaneous discharge, in ft ³ /s (00061)	Specific conductance, laboratory, μ S/cm at 25 °C (90095)	Suspended solids, in mg/L (00530)	Chloride, in mg/L (00940)	Dissolved (filtered) ammonia, in mg/L as N (00608)	Total (unfiltered) ammonia, in mg/L as N (00610)	Dissolved (filtered) nitrate plus nitrite, in mg/L as N (00631)	Total (unfiltered) nitrate plus nitrite, in mg/L as N (00630)	Dissolved (filtered) phosphorus, in mg/L as P (00666)	Total (unfiltered) phosphorus, in mg/L as P (00665)	Total dissolved (filtered) nitrogen, in mg/L as N (62854)	Total (unfiltered) nitrogen, in mg/L as N (62855)	Suspended- sediment, in mg/L (80154)
U1	Number of samples	233	227	225	225	87	223	87	223	87	226	83	222	209
	Minimum	0.0	275	<5	7	0.54	0.39	<0.03	<0.03	1.3	0.59	7.4	4.6	17
	Maximum	8.2	6,990	11,300	523	179	299	641	654	35	117	904	924	9,280
	Median	0.3	2,080	255	129	5.6	5.9	2.3	1.3	10	14	31.6	34	465
	Mean	0.8	2,245	519	159	18	18	9.9	5.8	11	16.6	56.7	56	811
U2	Number of samples	137	135	135	135	81	133	81	133	81	135	79	133	127
	Minimum	0.0	73	5	3	<0.03	0.05	<0.03	<0.03	0.35	0.30	1.8	1.1	5
	Maximum	21.0	3,160	1,310	306	48	51	26	28	14	21	57	97	1,830
	Median	0.7	1,030	39	41	1.1	1.3	2.3	2.5	2.9	5.1	10	15	89
	Mean	2.3	1,029	139	59	3.4	3.7	3.2	3.8	3.4	6.0	13	18	227
U3	Number of samples	169	174	165	172	58	164	58	164	58	165	57	164	168
	Minimum	0.0	87	<5	<3	<0.03	<0.03	<0.03	<0.03	0.73	0.46	2.1	1.8	1
	Maximum	26.0	2,750	360	183	15	15	19	20	8.4	9.7	38	43	610
	Median	0.7	1,220	20	60	0.95	0.97	1.6	1.4	2.9	3.7	9.3	11	29
	Mean	1.8	1,287	42	62	2.4	2.0	2.8	3.0	3.2	4.0	11	12	73

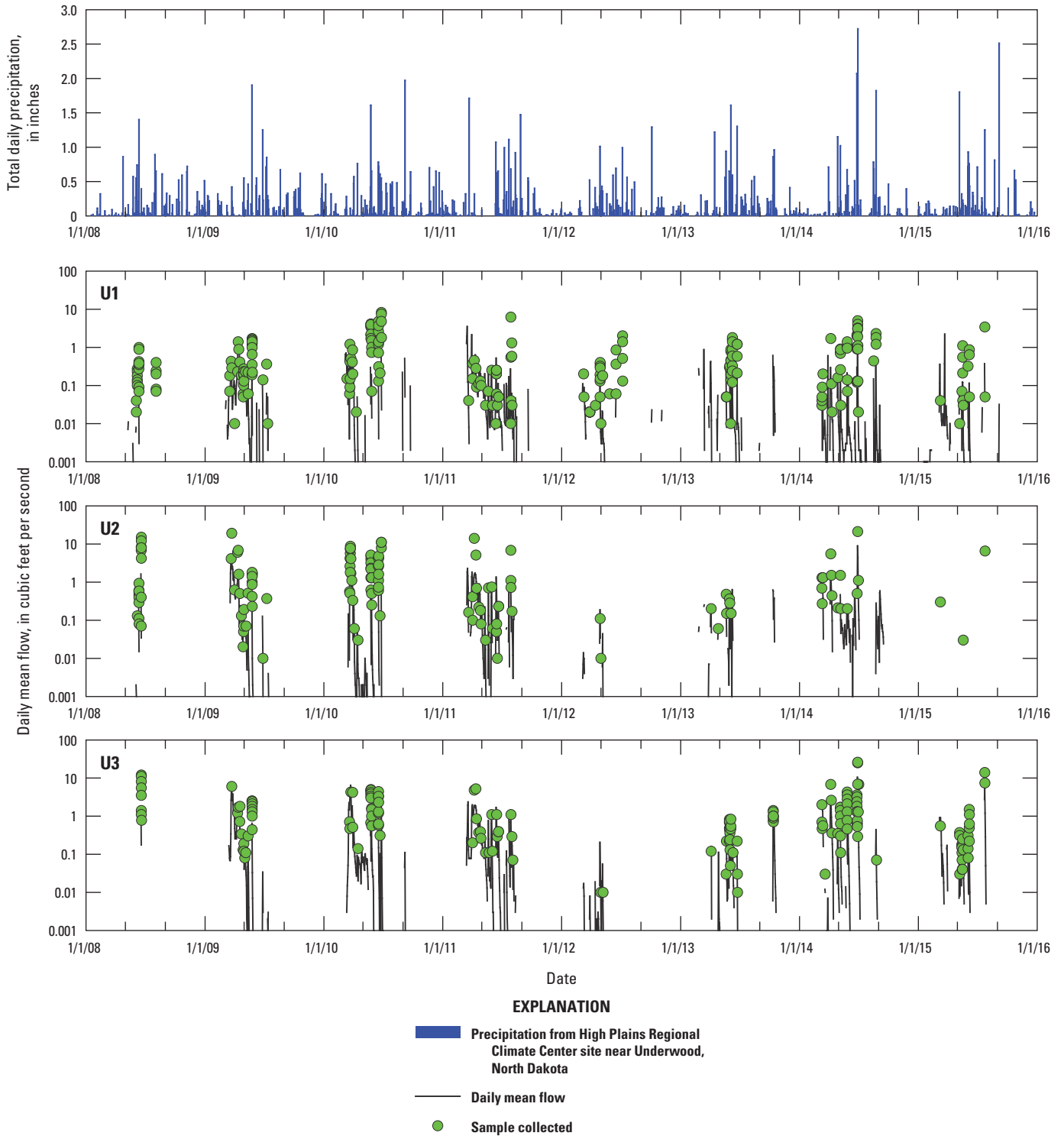


Figure 8. Daily mean flow, daily precipitation, and samples collected at monitoring sites at Underwood farm, North Dakota, 2008–15.

Concentrations

Chloride concentrations measured at Underwood farm generally were highest at site U1 and lowest at site U2 (fig. 9). In general, chloride concentrations also were higher at Underwood farm compared to Dazey and Embden farms (fig. 9). Potential sources of chloride at Underwood farm could include soils in the area and feedlot manure that may have feed additives that include salts (Mullaney and others, 2009; Hem, 1985). Site U1 had much higher chloride concentrations than the downstream sites with a median of 129 milligrams per liter (mg/L; fig. 9; table 7), indicating sources from the feedlot. Concentrations decreased substantially at site U2 with a median concentration of 41 mg/L. The channel is highly vegetated between sites U1 and U2, and it is likely that most of the chloride was attenuated by plant uptake (White and Broadley, 2001) and dilution from additional runoff at site U2. Site U3 had slightly higher concentrations than site U2 with a median concentration of 60 mg/L. The higher concentrations at site U3 may be the result of timing of the runoff sampled or from runoff from the surrounding cropland. Chloride concentrations from samples collected during spring snowmelt runoff may not be attenuated as much in the spring when there is a lack of active plant growth compared to samples collected later in the summer months during rainfall events.

Nutrient concentrations varied among sites at Underwood farm depending on the nitrogen and phosphorus species. Potential sources of nutrients related to agricultural activities could include animal manure in the feedlot, and fertilizer and manure applications to the surrounding cropland. Natural sources of nitrogen and phosphorus could include fixation of atmospheric nitrogen by plants and animals, dissolution of phosphorus-bearing rocks or minerals in the soil, and oxidation of organic matter, including soil organic matter and decaying plants and animals (Hem, 1985). Nitrate also can be produced from ammonia through the process of nitrification where ammonia is converted to nitrate through oxidation (U.S. Environmental Protection Agency, 2015).

Total ammonia and total phosphorus had the highest concentrations at site U1 and decreased sequentially at sites U2 and U3 downstream (fig. 9). Total ammonia and phosphorus concentrations at the sites for Underwood farm also generally were higher than concentrations at Dazey and Embden farms (fig. 9). Median total ammonia concentrations at sites U1, U2, and U3 were 5.9, 1.3, and 0.97 mg/L as nitrogen, respectively (table 7). Median total phosphorus concentrations at sites U1, U2, and U3 were 14, 5.1, and 3.7 mg/L as phosphorus, respectively. The decrease in total ammonia and phosphorus from upstream to downstream sites likely is due to plant uptake in the vegetated channel and dilution during runoff (Hem, 1985). In addition, ammonia could be decreasing due to nitrification. Phosphorus also can be attached to sediment, so some of the phosphorus could be removed as sediment from the feedlot is trapped by the vegetation as runoff travels through the channel downstream.

Nitrate plus nitrite generally had the lowest concentrations at site U1 and the highest concentrations at site U2, although median concentrations did not vary substantially among sites (fig. 9). Median total nitrate plus nitrite concentrations for sites U1, U2, and U3 were 1.3, 2.5, and 1.4 mg/L as nitrogen, respectively. Several reasons are possible for why nitrate plus nitrite values for site U2 were highest among the three sites. Most of the nitrogen from animal manure that would be present in the feedlot is likely in the form of ammonia (U.S. Environmental Protection Agency, 2015), resulting in low nitrate plus nitrite values at site U1. As runoff travels down the channel, the ammonia could be converted to nitrate through nitrification creating higher concentration at site U2. In addition, site U2 receives additional runoff from a culvert east of site U1 that gathers runoff from croplands north of the county road that could have higher concentrations of nitrate plus nitrite. Site U3 could have slightly lower concentrations because of plant uptake in the vegetated channel.

Suspended-sediment concentrations decreased from site U1 downstream to site U3 (fig. 9). Higher concentrations at site U1 are likely from soil that is exposed and loosened in the feedlot and is readily transported during runoff. As runoff travels through the vegetated channel to sites U2 and U3, the sediment likely is deposited and caught up in the vegetation and is diluted by additional runoff from flow into site U2. Median suspended-sediment concentrations for sites U1, U2, and U3 were 465, 89, and 29 mg/L, respectively (table 7).

Loads and Yields

Annual loads (March through October) were estimated for the three sites at Underwood farm for 2009–15 (fig. 10; table 8). Data collection began in June 2008, so annual loads were not estimated for that year because the dataset was incomplete. Annual loads for chloride at all three sites were the greatest in 2011 and the least in 2012, which coincided with years of the greatest and least annual flow volume, respectively (tables 4, 8). Annual chloride loads ranged from 1,800 to 16,100 pounds per year (lb/yr) at site U1, from 453 to 6,420 lb/yr at site U2, and from 386 to 9,890 lb/yr at site U3 (fig. 10; table 8). Total ammonia had a similar pattern at sites U1 and U3; annual loads were the greatest in 2011 and the least in 2012. Site U2 had the greatest loads in 2009. Annual total ammonia loads ranged from 46 to 11,400 lb/yr as nitrogen at site U1, from 4 to 2,630 lb/yr as nitrogen at site U2, and from less than 1 to 750 lb/yr as nitrogen at site U3 (fig. 10; table 8).

In general, annual chloride loads decreased from upstream to downstream, indicating the feedlot as the likely source. Two exceptions were in 2009 and 2014, which may have been either from timing of when most of the loads were delivered or from some other unknown source. Manure from the feedlots is spread periodically on the surrounding fields and could be an additional source of chloride at sites U2

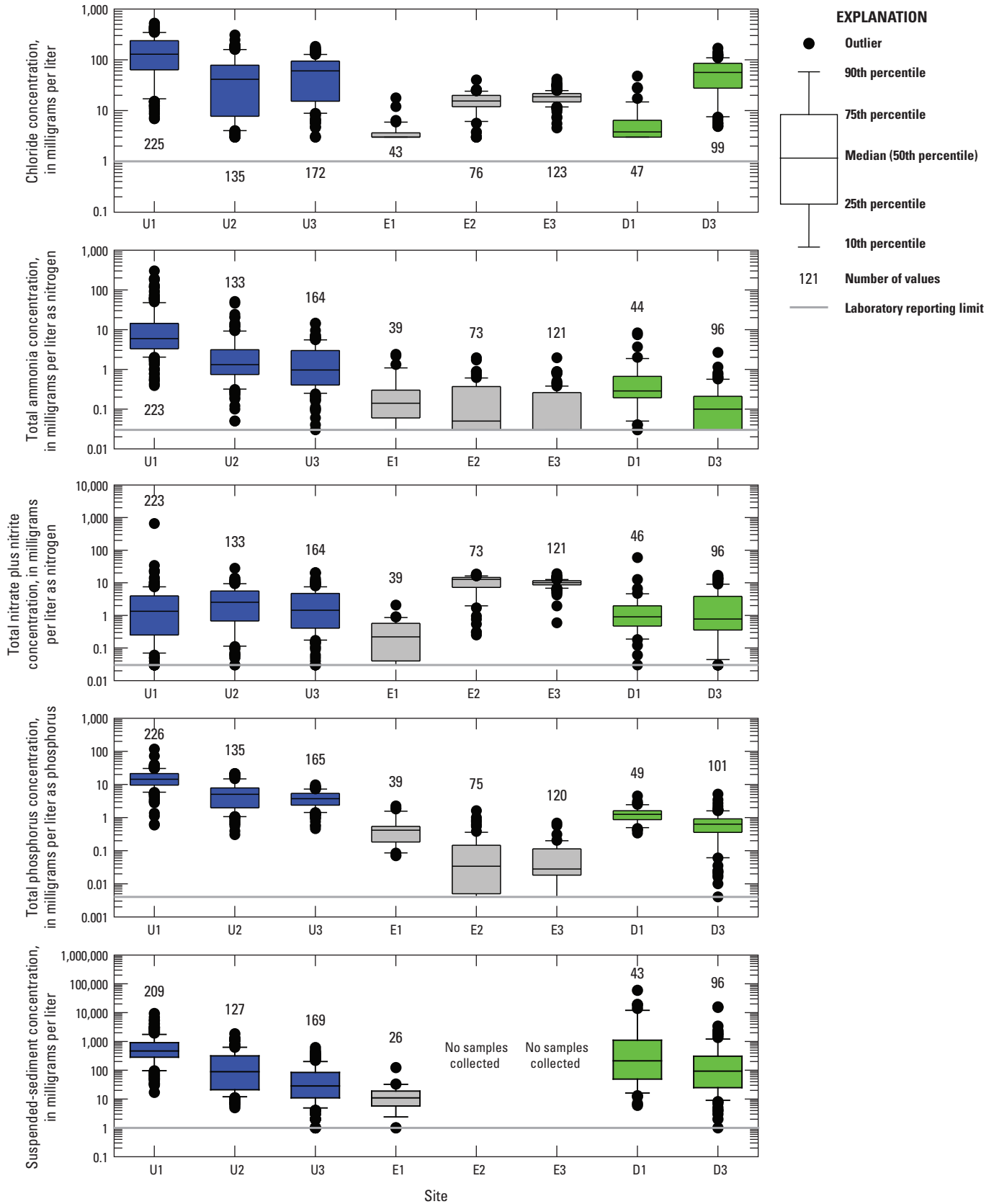


Figure 9. Distribution of constituent concentrations at monitoring sites at Underwood, Embden, and Dazey farms, North Dakota, 2008–16.

and U3. There also could be natural sources of chloride from soils in the area that contribute to the loads at the two downstream sites. Annual total ammonia loads were less at downstream sites every year from 2009 to 2015; loads at site U3 averaged 11 percent of the annual load at site U1, indicating the feedlot as the likely source, but also that a considerable amount of mass is retained by the vegetated channel and not transported past site U3, the most downstream site.

Nitrate plus nitrite loads displayed a different pattern than chloride and total ammonia, indicating possible different sources. The greatest nitrate plus nitrite loads were in 2010 at site U1 and in 2014 at sites U2 and U3. The least annual nitrate plus nitrite loads occurred in 2013 at site U1 and in 2012 at sites U2 and U3. Annual nitrate plus nitrite loads also were consistently greater at sites U2 and U3 when compared to site U1 except for 2012. Annual nitrate plus nitrite loads ranged from 30 to 87 lb/yr as nitrogen at site U1, from 7 to 628 lb/yr as nitrogen at site U2, and from 8 to 628 lb/yr as nitrogen at site U3 (fig. 10; table 8).

Annual total phosphorus loads were greatest in 2011 at sites U1 and U3 and in 2014 at site U2 and were least in 2012 at sites U1, U2, and U3. Annual total phosphorus loads ranged from 100 to 1,770 lb/yr as phosphorus at site U1, from 14 to 1,250 lb/yr as phosphorus at site U2, and from 4 to 713 lb/yr as phosphorus at site U3 (fig. 10; table 8). Phosphorus can be adsorbed and transported with sediment, and the pattern of annual total phosphorus loads may be explained by the same pattern in annual suspended-sediment load.

Suspended-sediment loads also were greatest in 2011 at sites U1 and U3 and in 2014 at site U2 and were the least in 2015 at site U1 and in 2012 at sites U2 and U3 (fig. 10; table 8). Annual suspended-sediment loads ranged from 3,060 to 69,800 lb/yr at site U1, from 338 to 15,300 lb/yr at site U2, and from 150 to 25,000 lb/yr at site U3 (fig. 10; table 8).

Patterns in annual load may be explained by when most of the load is transported during the year. Chloride, total ammonia, total phosphorus, and suspended sediment were transported past site U1 mostly in March, and the least from July through October (fig. 11; appendix table 1–3). This could be explained by hydrology and the operation of the feedlot. Beef cattle are kept in the feedlot throughout the winter months. During this time, manure in the feedlot can accumulate, the ground is continuously broken up, and there is little runoff to move any material from the feedlot. In the spring when snowmelt and spring rains occur, the material that has built up through the winter is readily available to be transported off the feedlot. After the cattle are moved out of the feedlot in the spring and vegetation is actively growing, less material is available for transport in the summer months, even during large rainfall events. In an effort to mitigate this problem, the producer constructed a ditch around the feedlot in 2012 that reduces the amount of runoff going through the feedlot, and as a result reduced the amount of material transported from the farm.

Mean monthly loads of total ammonia were considerably less at sites U2 and U3 compared to site U1 and demonstrated the same pattern of occurrence, whereas chloride, total phosphorus, and suspended-sediment loads at sites U2 and U3 had a slightly different pattern indicating that other processes may control the transport of these constituents past these sites. Larger loads in June for suspended sediment at site U2 likely were due to large June rainfall amounts when fields have been freshly plowed and planted, loosening soil material and making it more readily available for transport. Larger loads in June of total phosphorus may be attributed to fertilizer application in late May or early June in conjunction with some of the highest monthly rainfall (figs. 5 and 11). Large chloride loads in May and June at sites U2 and U3 may be attributed to natural sources such as soils that are washed off the landscape during rainfall in May and June when freshly planted fields have little vegetative cover holding the soils in place or could be from freshly applied manure being washed off the surrounding cropland during rainfall events (fig. 11).

Monthly nitrate plus nitrite loads had a different pattern than the other constituents, indicating other possible sources such as fertilizer application in the surrounding cropland. Although the greatest nitrate plus nitrite loads at site U1 were in March, a large amount of nitrate plus nitrite was transported past sites U2 and U3 in March through June, and the greatest monthly loads were in June for site U2 and in March for site U3 (fig. 11). Most of the fertilizer application in the surrounding crop was from late April into June during and after planting. The timing of the application depended on crop type and weather conditions each year. The transport of nutrients from fertilizer application is dependent on how soon rainfall occurs after fertilizer application. This also may explain the large annual loads in 2014 at sites U2 and U3 (fig. 10). June 2014 had the greatest monthly precipitation for 2009–15, which coincided closely with the period of fertilizer application in the surrounding cropland. About one-half of the annual loads of nitrate plus nitrite in 2014 at sites U2 and U3 were transported in June (appendix table 1–3).

Fertilizer application in fields surrounding the waterway where the three Underwood farm monitoring sites are located varied annually depending on crop type (table 9). Application data were only available from the producer for the fields immediately adjacent to the waterway south of the county road and for the fields directly north of the feedlot and east of the feedlot on the north side of the county road (fig. 2). Information on fertilizer application was not available for most of the northern part of the drainage area. Out of the 1,911 total acres included in the drainage area for U3, fertilizer application data were only available for about 164 acres. Within the drainage area for site U3 (that also would include drainage areas for sites U1 and U2), total annual nitrogen application ranged from 1,580 lb/yr in 2014, when mostly corn and spring wheat were planted, to 20,200 lb/yr in 2015, when spring wheat and soybeans again were planted (table 9). Annual application rates for nitrogen ranged from about 10 pounds per year per

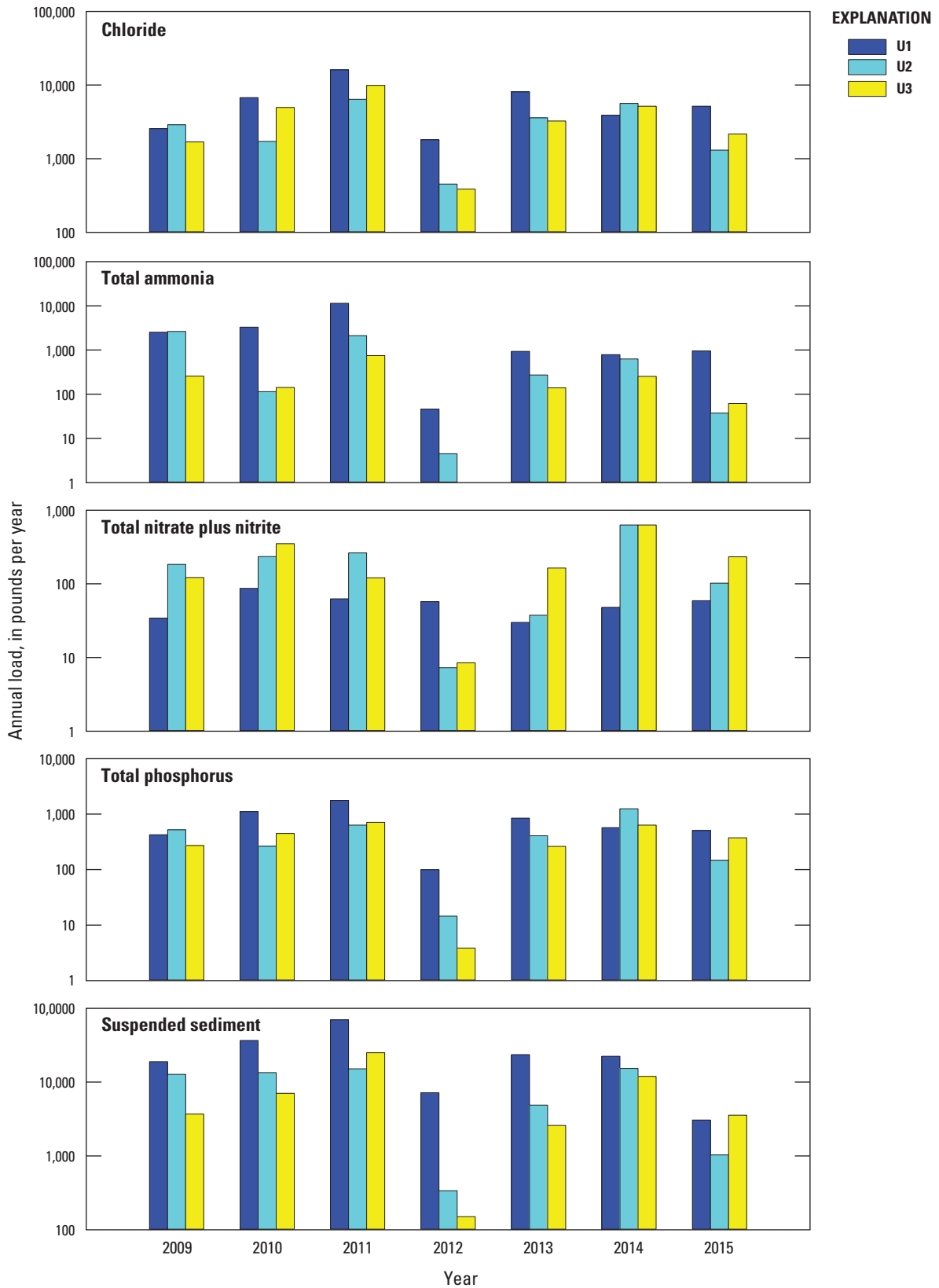


Figure 10. Annual loads estimated for monitoring sites at Underwood farm, North Dakota, 2009–15.

Table 8. Annual loads and yields for Underwood farm, North Dakota, 2009–15.

[N, nitrogen; P, phosphorus, <, less than]

Year	Flow, in acre-feet per year	Load, in pounds per year					Yield, in pounds per year per acre				
		Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	Sus- pended sediment	Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phospho- rus, as P	Sus- pended sediment
Site U1											
2009	26	2,560	2,520	34	425	19,000	29	29	0.39	4.9	218
2010	22	6,730	3,280	87	1,110	36,700	77	38	1.0	13	422
2011	43	16,100	11,400	63	1,770	69,800	185	131	0.72	20	802
2012	2	1,800	46	57	100	7,180	21	0.53	0.66	1.1	83
2013	13	8,080	931	30	846	23,500	93	11	0.34	9.7	270
2014	10	3,900	783	48	571	22,400	45	9.0	0.55	6.6	257
2015	9	5,170	953	59	505	3,060	59	11	0.68	5.8	35
Mean	18	6,330	2,840	54	761	25,900	73	33	0.62	8.7	298
Site U2											
2009	87	2,890	2,630	184	523	12,700	1.5	1.4	0.10	0.27	6.6
2010	55	1,710	114	235	263	13,400	0.89	0.06	0.12	0.14	7.0
2011	81	6,420	2,110	263	633	15,100	3.3	1.1	0.14	0.33	7.9
2012	<1	453	4	7	14	338	0.24	<0.01	<0.01	<0.01	0.18
2013	14	3,590	271	38	408	4,880	1.9	0.14	0.02	0.21	2.5
2014	62	5,620	627	628	1,250	15,300	2.9	0.33	0.33	0.65	8.0
2015	12	1,310	37	102	148	1,030	0.68	0.02	0.05	0.08	0.5
Mean	45	3,140	828	208	463	8,960	1.6	0.43	0.11	0.24	4.7
Site U3											
2009	100	1,690	256	122	272	3,680	0.86	0.13	0.06	0.14	1.9
2010	85	4,960	142	350	447	7,040	2.5	0.07	0.18	0.23	3.6
2011	105	9,890	750	121	713	25,000	5.0	0.38	0.06	0.36	13
2012	<1	386	<1	8	4	150	0.20	<0.01	<0.01	<0.01	0.08
2013	16	3,260	139	164	262	2,580	1.6	0.07	0.08	0.13	1.3
2014	78	5,170	254	628	635	11,900	2.6	0.13	0.32	0.32	6.0
2015	34	2,160	62	232	375	3,560	1.1	0.03	0.12	0.19	1.8
Mean	60	3,930	229	232	387	7,700	2.0	0.12	0.12	0.20	3.9

acre (lb/yr/acre) in 2014 to 123 lb/yr/acre in 2015 (table 9). Total annual phosphorus application ranged from 932 lb/yr in 2013 to 7,240 lb/yr in 2012 when corn was planted. Annual application rates for phosphorus ranged from 6 lb/yr/acre in 2013 to 44 lb/yr/acre in 2012 (table 9). As mentioned earlier, animal manure also was spread on various fields periodically throughout the period as a form of fertilizer.

Annual yields (load per drainage area) were computed for the three sites at Underwood farm for comparison of the sites in terms of the mass of constituents transported past each site per acre of contributing runoff to each site (fig. 12; table 8). Depending on the constituent, annual yields were

between 2 and 1,000 times greater at site U1, compared to sites U2 and U3, mainly because of a combination of higher measured concentrations and smaller contributing drainage area for site U1. Sites U2 and U3 generally had similar annual yields for all constituents. Annual chloride yields ranged from 0.20 lb/yr/acre at site U3 in 2012 to 185 lb/yr/acre at site U1 in 2011. Annual total ammonia yields ranged from less than 0.01 lb/yr/acre as nitrogen at sites U2 and U3 in 2012 and 131 lb/yr/acre as nitrogen at site U1 in 2011. Annual total nitrate plus nitrite yields ranged from less than 0.01 lb/yr/acre as nitrogen at sites U2 and U3 in 2012 to 1.0 lb/yr/acre as nitrogen at site U1 in 2010. Annual total phosphorus yields

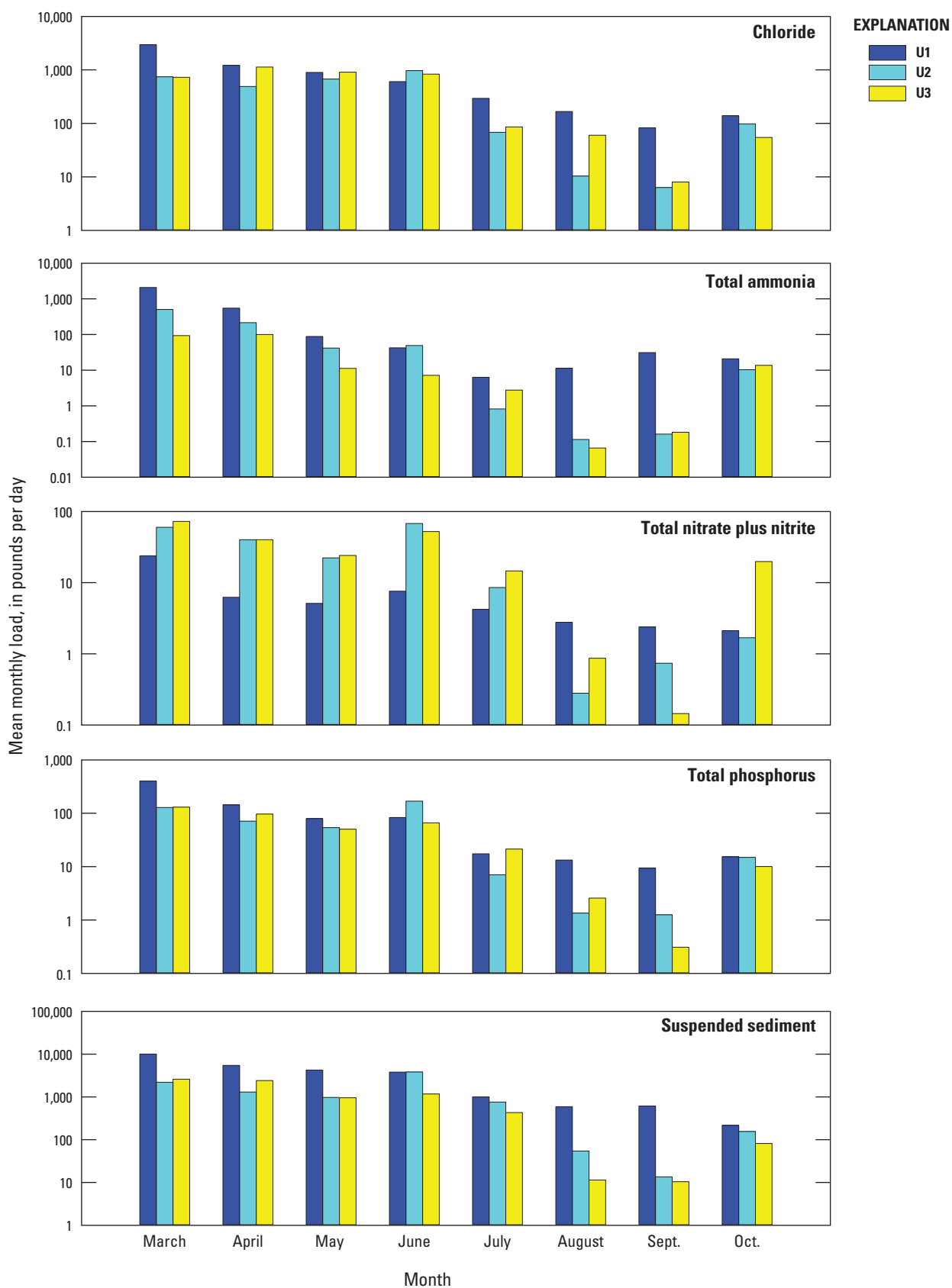


Figure 11. Mean monthly loads estimated for monitoring sites at Underwood farm, North Dakota, 2009–15.

Table 9. Fertilizer application and crop information for Underwood farm, North Dakota, 2008–15.

[lb/yr, pound per year; lb/yr/acre, pound per year per acre]

Year	Contributing area that includes crop and fertilizer application estimate, in acres	Crop	Estimated nitrogen application, in lb/yr	Estimated annual nitrogen application rate, in lb/yr/acre	Estimated phosphorus application, in lb/yr	Estimated annual phosphorus application rate, in lb/yr/acre
2008	164	Spring wheat/barley	10,800	66	3,670	22
2009	147	Corn	10,300	70	3,560	24
2010	164	Sunflowers	11,000	67	5,120	31
2011	164	Spring wheat	14,500	88	4,130	25
2012	164	Corn	16,500	101	7,240	44
2013	164	Spring wheat/soybeans	3,580	22	932	6
2014	164	Corn/spring wheat	1,580	10	2,920	18
2015	164	Spring wheat/soybeans	20,200	123	3,120	19

ranged from less than 0.01 lb/yr/acre at sites U2 and U3 in 2012 to 20 lb/yr/acre as phosphorus at site U1 in 2011. Annual suspended-sediment yields ranged from 0.08 lb/yr/acre at site U3 in 2012 to 802 lb/yr/acre at site U1 in 2011 (fig. 12; table 8).

To put the contribution of flow and constituent loads into a larger-scaled context, the loads and yields for Underwood farm were compared to loads and yields estimated for a larger receiving stream in the area. The receiving stream for the drainage from Underwood farm is the Missouri River (fig. 1). Although Galloway and others (2012) estimated loads and yields for the Missouri River, the sites may not be a good comparison because they are in a highly regulated part of the river downstream from Garrison Dam (fig. 1). Instead, a smaller stream near Underwood, Spring Creek, was selected for comparison. Spring Creek is a tributary to the Knife River and ultimately the Missouri River (fig. 1). Normalized annual loads and yields were estimated for a site on Spring Creek at Zap, N. Dak. (USGS streamgage 06340000), that has a drainage area of 351,360 acres compared to a drainage area of 1,967 acres for site U3 (fig. 1 and table 10; Galloway and others, 2012). Normalized annual loads for Spring Creek for total ammonia, nitrate plus nitrite, and total phosphorus were 12,000 lb/yr as nitrogen, 18,000 lb/yr as nitrogen, and 10,000 lb/yr as phosphorus, respectively, compared to mean annual loads (2009–15) for site U3 at Underwood farm of 229 lb/yr as nitrogen, 232 lb/yr as nitrogen, and 387 lb/yr as phosphorus, respectively (table 10). Suspended-sediment loads estimated for Spring Creek were 4,080,000 lb/yr compared to a mean load of 7,700 lb/yr at site U3. Although loads were considerably less from site U3 compared to Spring Creek, mainly because of lower flow volume, nutrient yields were slightly greater but similar. For total ammonia, the normalized annual yield estimated for Spring Creek was 0.03 lb/yr/acre as nitrogen, whereas the mean annual yield for site U3 was 0.12 lbs/yr/ac as nitrogen (table 10). The normalized annual

nitrate plus nitrite yield estimated for Spring Creek was 0.05 lb/yr/acre as nitrogen, whereas the mean annual yield for site U3 was 0.12 lb/yr/acre as nitrogen. The normalized annual total phosphorus yield estimated for Spring Creek was 0.03 lb/yr/acre, whereas the mean annual yield for site U3 was 0.20 lb/yr/acre. Suspended-sediment yields for Spring Creek were greater than mean annual yields for site U3 with a normalized annual yield of 12 lb/yr/acre compared to 3.9 lb/yr/acre at site U3.

Embden Farm

At Embden farm from March 2009 through September 2016, about 44 samples were collected from site E1, 76 samples from site E2, and 123 samples from site E3. The number of values for individual constituents varied throughout the period because not all samples were analyzed for the same constituents (table 11). Runoff was sampled generally during spring snowmelt and rainfall events at the sites. In addition, at the two drainage tile sites (E2 and E3), samples were collected intermittently during periods of continuous flow (fig. 13).

Concentrations

Chloride concentrations measured at Embden farm were similar for the two drainage tile sites (E2 and E3) and were considerably higher than at the surface-water site (E1) (fig. 9). Likely sources of chloride at Embden farm are from the native soils and possibly shallow groundwater in the area. Site E1 had the lowest chloride concentrations with a median concentration that was less than the laboratory reporting limit of 3 mg/L (table 11). Concentrations were substantially greater at sites E2 and E3 with median concentrations of 15 and 19 mg/L, respectively. The higher concentrations at sites E2 and E3 are likely from natural sources because these

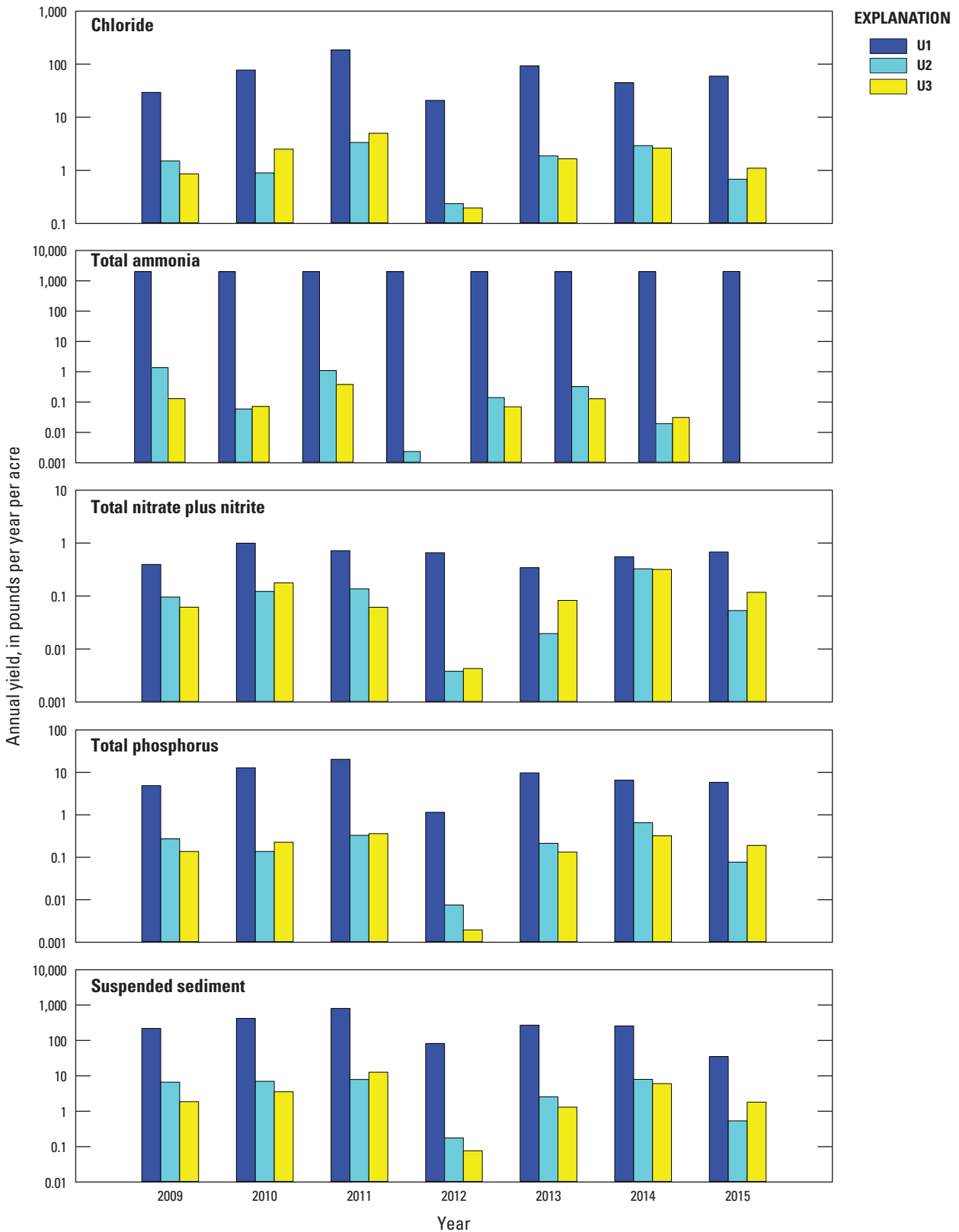


Figure 12. Annual yields estimated for monitoring sites at Underwood farm, North Dakota, 2009–15.

Table 10. Loads and yields for selected sites from Galloway and others (2012) and Discovery Farms, North Dakota.

[--, not available]

Site name	Drainage area, in acres	Load and yield calculation	Load, in pound per year				Yield, in pound per year per acre			
			Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	Suspended sediment	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	Suspended sediment
Spring Creek at Zap, N. Dak. (streamgage 06340000) (fig. 1)	351,360	Normalized annual (Galloway and others, 2012)	12,000	18,000	10,000	4,080,000	0.03	0.05	0.03	12
Maple River below Mapleton, N. Dak. (streamgage 05060100) (fig. 1)	947,200	Normalized annual (Galloway and others, 2012)	44,000	1,886,000	14,000	--	0.05	2.0	0.01	--
Baldhill Creek near Dazey, N. Dak. (streamgage 05057200) (fig. 1)	442,240	Normalized annual (Galloway and others, 2012)	10,000	36,000	16,000	--	0.02	0.08	0.04	--
U3 (fig. 2)	1,976	Annual average (2009–15)	229	232	387	7,700	0.12	0.12	0.20	3.9
E1, E2, E3 (fig. 3)	2371	Average of the annual sum of sites E1, E2, and E3 (2010–15)	43	3,130	26	--	0.18	13	0.11	--
D3 (fig. 4)	341	Annual average (2010–15)	41	201	106	62,800	0.12	0.59	0.31	184

¹Drainage area includes surface drainage to site E1 (fig. 3, 164 acres) plus portion of field 1 not included in surface drainage, but contributing to site E2 (fig. 3, 58 acres) plus portion of field 2 not included in surface drainage, but contributing to site E3 (fig. 3, 15 acres).

Table 11. Summary of water-quality constituent concentrations for monitoring sites at Embden farm, North Dakota, 2009–16.

[Number in parentheses is the U.S. Geological Survey National Water Information System parameter code; ft³/s, cubic foot per second; µS/cm at 25 °C, microsiemen per centimeter at 25 degrees Celsius; mg/L, milligram per liter; N, nitrogen; P, phosphorus, <, less than]

Site (fig. 3)	Description	Instantaneous discharge, in ft ³ /s	Specific conductance, laboratory, µS/cm at 25 °C	Suspended solids, in mg/L	Chloride, in mg/L	Dissolved (filtered) ammonia, in mg/L as N	Total (unfiltered) ammonia, in mg/L as N	Dissolved (filtered) nitrate plus nitrite, in mg/L as N	Total nitrate plus nitrite (unfiltered), in mg/L as N	Dissolved (filtered) phosphorus, in mg/L as P	Total (unfiltered) phosphorus, in mg/L as P	Total dissolved (filtered) nitrogen, in mg/L as N	Total (unfiltered) nitrogen, in mg/L as N	Suspended- sediment, in mg/L
		(00061)	(90095)	(00530)	(00940)	(00608)	(00610)	(00631)	(00630)	(00666)	(00665)	(62854)	(62855)	(80154)
E1	Number of samples	34	44	44	43	24	39	24	39	24	39	24	39	26
	Minimum	0.0	91	<5	<3	<0.03	<0.03	<0.03	<0.03	0.05	0.07	0.5	0.7	1
	Maximum	1.8	311	104	18	2.4	2.4	2.0	2.1	2.2	2.2	7.9	9.2	123
	Median	0.1	139	<5	<3	0.12	0.14	0.29	0.22	0.31	0.42	1.5	1.5	11
	Mean	0.2	157	11	4	0.47	0.34	0.41	0.36	0.60	0.55	2.1	1.9	17
E2	Number of samples	75	76	75	76	52	73	55	73	55	75	53	73	--
	Minimum	0.0	168	<5	<3	<0.03	<0.03	0.23	0.25	<0.02	<0.02	1.7	1.8	--
	Maximum	2.2	941	72	40	2.0	2.0	17	18	1.5	1.6	27	27	--
	Median	0.3	797	<5	15	0.05	0.05	12	13	<0.02	0.03	12	13	--
	Mean	0.5	722	9	16	0.22	0.25	10	11	0.14	0.14	11	12	--
E3	Number of samples	125	123	119	123	99	121	101	121	98	120	99	121	--
	Minimum	0.0	399	<5	5	<0.03	<0.03	0.60	0.59	<0.02	<0.02	1.9	2.3	--
	Maximum	2.5	1,100	60	41	2.2	2.0	19	19	0.60	0.68	23	23	--
	Median	0.2	889	<5	19	<0.03	<0.03	9.8	10	<0.02	0.03	10	11	--
	Mean	0.6	883	6	19	0.15	0.17	9.7	10	0.06	0.07	11	11	--

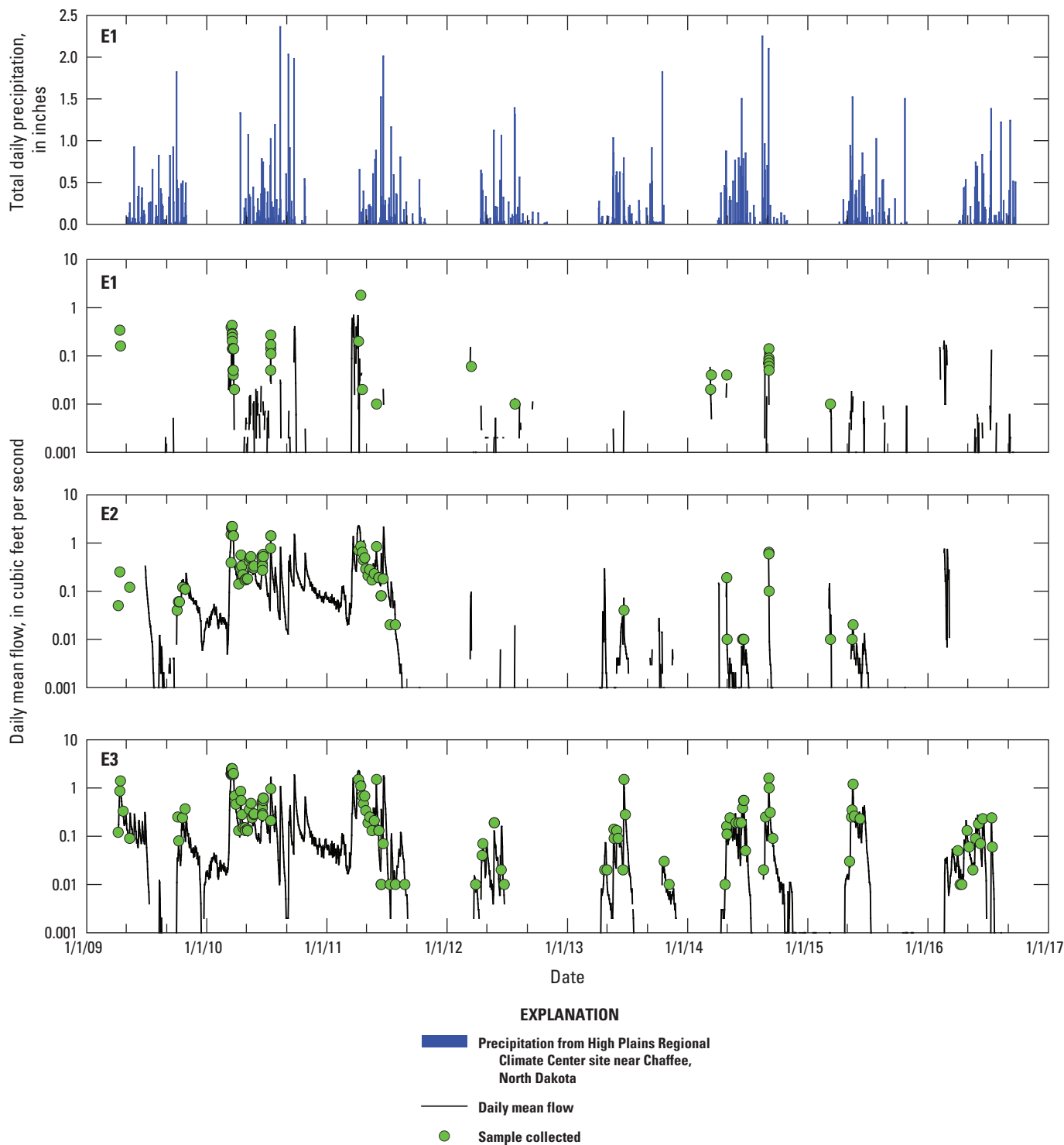


Figure 13. Daily mean flow, daily precipitation, and samples collected at monitoring sites at Embden farm, North Dakota, 2009–16.

sites represent water that has infiltrated through the soil and can dissolve naturally-occurring chlorides in the soils. During extended wet periods when groundwater levels are high, sites E2 and E3 can receive water that has had long contact time with aquifer material that may contain chlorides and are

discharged through the drainage tile. Groundwater quality was not measured in the area, so the effects of groundwater contribution to the drainage tile sites could not be definitively determined.

Nutrient concentrations generally were similar for the drainage tile sites E2 and E3; concentrations of total ammonia and total phosphorus were lower and concentrations of total nitrate plus nitrite were higher compared to the surface water site E1 (fig. 9). Potential sources of nutrients related to agricultural activities include fertilizer applications to the surrounding cropland. Although there is a cattle operation at Embden farm, it is not within the area contributing to runoff at the three monitoring sites. There was some application of manure to fields just north of site E3 (field 2, fig. 3) in 2012 that could also be a source of nutrients to the site. Total ammonia and phosphorus concentrations at the sites for Embden farm were generally lower than measured at Underwood and Dazey farms (fig. 9). Median total ammonia concentrations at sites E1, E2, and E3 were 0.14, 0.05, and less than 0.03 mg/L as nitrogen, respectively. Median total phosphorus concentrations at sites E1, E2, and E3 were 0.42, 0.03, and 0.03 mg/L as phosphorus, respectively (table 11).

Nitrate plus nitrite concentrations were lowest at site E1 and highest at sites E2 and E3. Nitrate plus nitrite concentration at sites E2 and E3 also were the highest among all the sites at all three farms (fig. 9). Median total nitrate plus nitrite concentrations for sites E1, E2, and E3 were 0.22, 13, and 10 mg/L as nitrogen, respectively (table 11). Nitrate plus nitrite has been found to be higher in drain tiles because runoff can readily transport nitrates that were applied as fertilizer into the subsurface before the nitrates can be processed by vegetation on the surface and can be leached from the soil as the water travels into the drain tiles (U.S. Environmental Protection Agency, 2015).

Suspended sediment was measured only at site E1 because of little sediment content in the drainage tiles that are measured by sites E2 and E3, and concentrations at site E1 were the lowest among all the sites at all three farms (fig. 9). The median concentration of suspended sediment at site E1 was 11 mg/L (table 11). Suspended-sediment concentrations at site E1 were probably lowest compared to sites at the other farms because the area has relatively flat terrain with little slope compared to all the other sites; therefore, there is less energy to move soil material during runoff.

Loads and Yields

Annual loads (March through October) were estimated at Embden farm for 2010–15 at sites E1 and E2 and for 2010–16 at site E3 (fig. 14; table 12). Annual loads were considerably greater at sites E2 and E3 compared to site E1. Annual loads for chloride at all three sites were the greatest in 2010 and 2011 and the least in 2012 or 2013, which coincided with years of the greatest and least annual flow volume, respectively (tables 5 and 12). Also, as described in the “Runoff and Flow Characteristics” section, sites E2 and E3 had nearly continuous flow in the drainage tiles throughout 2010 and 2011, providing transport of constituents throughout that period resulting in large annual loads, whereas site E1

only had flow to transport material during spring snowmelt or rainfall events. Annual loads also were similar between sites E2 and E3 in 2010 and 2011, but in subsequent years, site E3 generally had the greatest annual load among the three sites for all constituents. Annual chloride loads ranged from less than 1 to 193 lb/yr at site E1, from 16 to 6,700 lb/yr at site E2, and from 210 to 9,380 lb/yr at site E3 (fig. 14; table 12). Total ammonia loads were greatest at site E3 most years except for 2011 and 2013, when site E2 had the greatest load among the three sites, and 2012, when site E1 had the greatest load. Annual total ammonia loads ranged from less than 1 to 3 lb/yr as nitrogen at site E1, from less than 1 to 79 lb/yr as nitrogen at site E2, and from less than 1 to 89 lb/yr as nitrogen at site E3 (fig. 14; table 12).

Nitrate plus nitrite loads were greatest at sites E2 and E3, and the greatest annual loads were in 2010 and 2011. Sites E2 and E3 had similar annual loads in 2010 and 2011, but site E3 had the greatest annual nitrate plus nitrite loads in subsequent years (fig. 14; table 12). Annual nitrate plus nitrite loads ranged from less than 1 to 15 lb/yr as nitrogen at site E1, from 8 to 5,050 lb/yr as nitrogen at site E2, and from 125 to 4,720 lb/yr as nitrogen at site E3 (fig. 14; table 12). Annual total phosphorus loads were greatest in 2010 and 2011 at all three sites. Annual total phosphorus loads ranged from 0.12 to 5.8 lb/yr as phosphorus at site E1, from less than 0.10 to 39 lb/yr as phosphorus at site E2, and from 0.53 to 28 lb/yr as phosphorus at site E3 (fig. 14; table 12).

Some of the patterns in annual load could be explained by crop management and fertilizer application in the fields that contribute runoff to the three sites. Crop type and fertilizer application information for field 1 and field 2 that drain to the three Embden sites was provided by the producer for each year from 2010 to 2015 (tables 13 and 14, respectively). To estimate the amount of nutrients being exported from each field, the following assumptions were made: (1) the sum of the total ammonia and nitrate plus nitrite represented the total nitrogen export, (2) total phosphorus load represented phosphorus export, and (3) nutrients applied were either exported through the two drainage tile sites (E2 or E3) or through surface runoff through site E1. Based on the last assumption, a percentage of the annual load for each site can be attributed to nutrient export for a specific field. For field 1 (fig. 3), 13 percent of the surface drainage area for site E1 and 100 percent of the tile drainage area for site E2 contributes to the export of nutrients; therefore, 13 percent of the load for site E1 plus the total load for site E2 were used to represent the total load exported from field 1. For field 2 (fig. 3), 34 percent of the surface drainage area for site E1 and 100 percent of the tile drainage area for site E3 contributes to nutrient export; therefore, 34 percent of the load for site E1 plus the total load for site E3 were used to represent the total load exported from field 2. At the Embden farm, depending on hydrologic conditions, groundwater may be contributing to the amount of nutrients exported through the drainage tile sites. Because groundwater effects on nutrient export could not be quantified, a ratio was used instead of a percentage to compare exported to applied nutrients.

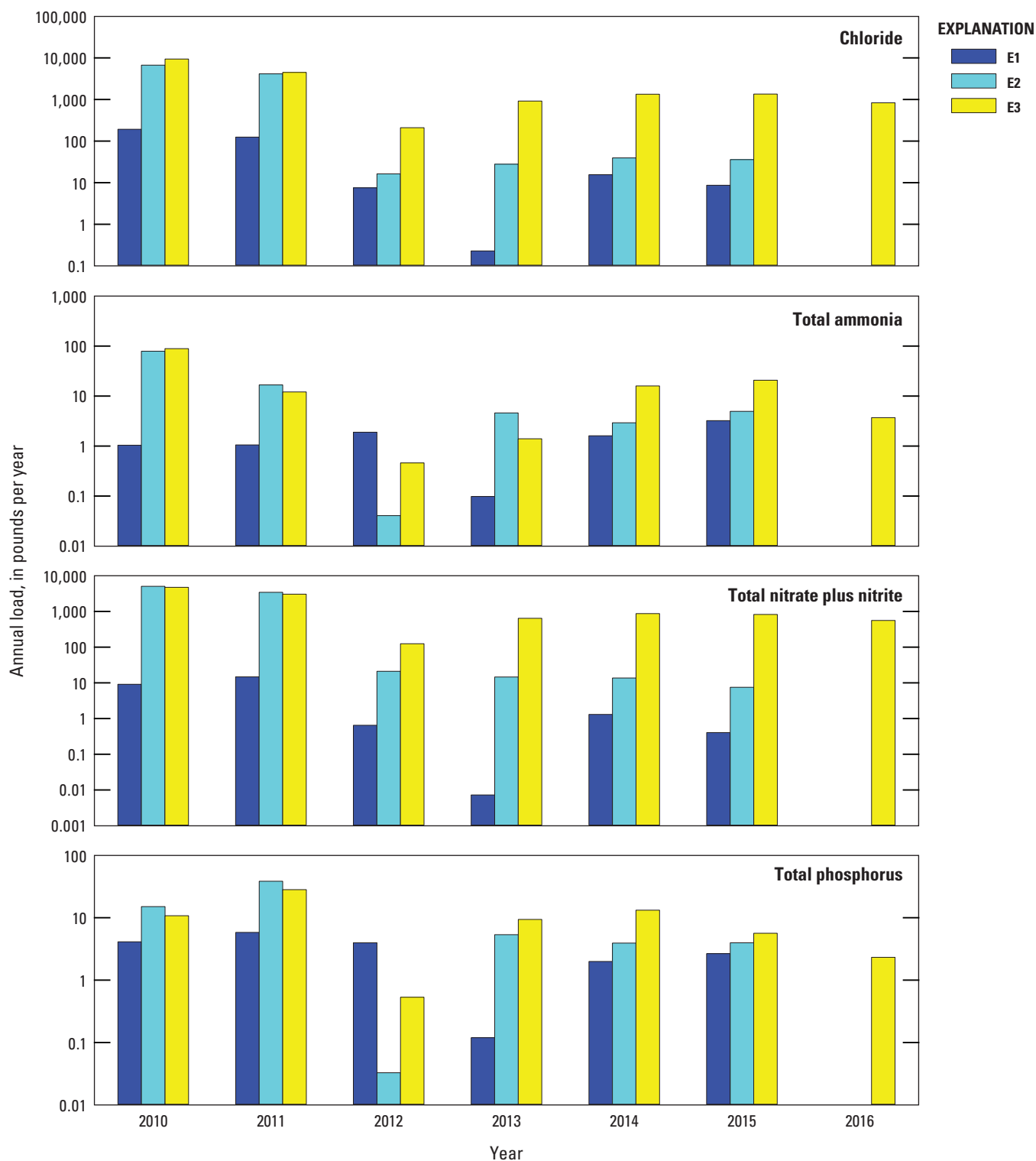


Figure 14. Annual loads estimated for monitoring sites at Embden farm, North Dakota, 2010–16.

Table 12. Annual loads and yields for Embden farm, North Dakota, 2010–16.

[N, nitrogen; P, phosphorus, <, less than]

Year	Flow, in acre-feet per year	Load, in pounds per year				Yield, in pounds per year per acre			
		Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P
Site E1									
2010	7	193	1	9	4.1	1.2	0.01	0.06	0.03
2011	13	124	1	15	5.8	0.76	0.01	0.09	0.04
2012	<1	8	2	<1	4.0	0.05	0.01	<0.01	0.02
2013	<1	<1	<1	<1	0.12	<0.01	<0.01	<0.01	<0.01
2014	<1	15	2	1	2.0	0.09	0.01	0.01	0.01
2015	<1	9	3	<1	2.7	0.05	0.02	<0.01	0.02
Mean	4	58	2	4	3.1	0.36	0.01	0.03	0.02
Site E2									
2010	140	6,700	79	5,050	15	84	0.98	63	0.19
2011	128	4,150	17	3,410	39	52	0.21	43	0.48
2012	<1	16	<1	21	<0.10	0.20	<0.01	0.26	<0.01
2013	2	28	5	15	5.4	0.35	0.06	0.18	0.07
2014	3	39	3	14	3.9	0.49	0.04	0.17	0.05
2015	1	36	5	8	4.0	0.45	0.06	0.09	0.05
Mean	46	1,830	18	1,420	11	23	0.23	18	0.14
Site E3									
2010	158	9,380	89	4,720	11	134	1.3	67	0.15
2011	126	4,480	12	3,040	28	64	0.17	43	0.40
2012	5	210	<1	125	0.53	3.0	<0.01	1.8	<0.01
2013	17	917	1	640	9.4	13	0.02	9.1	0.13
2014	33	1,350	16	870	13	19	0.23	12	0.19
2015	27	1,350	21	821	5.7	19	0.30	12	0.08
2016	15	832	4	557	2.3	12	0.05	8.0	0.03
Mean	54	2,650	20	1,540	10	38	0.29	22	0.14

Ratios of exported to applied nitrogen were greatest for both fields in 2010 and 2011, which corresponds to the years of the greatest runoff for all three sites (tables 5, 13, and 14). For field 1, the ratio of exported to applied nitrogen was 0.56 in 2010 and 0.84 in 2011 (table 13). The ratios indicate that about 44 percent of the nitrogen applied potentially was retained in the soil or used by crops in 2010 and 16 percent potentially was retained in 2011. In subsequent years (2012–15), the ratios were much less, ranging from 0.01 to 0.03, indicating greater than 97 percent of the applied nitrogen potentially was retained. For field 2, the ratio of exported to applied nitrogen was 0.49 in 2010 and 0.71 in 2011 (table 14). Similar to field 1, the ratios were less in 2013 and 2014 with ratios of 0.20 and 0.18, respectively, but these ratios were not as low as the corresponding values from field 1 during the same period. During the wet years of 2010 and 2011, it is

probable that the amount of fertilizer applied to fields 1 and 2 did not account for all nitrogen sources to the three sites. It is likely that groundwater contributed to the nitrogen exported through the drainage tile sites E2 and E3 compared to subsequent years.

The difference in exported and applied nitrogen ratios between fields 1 and 2 for 2013 and 2014 may be, in part, due to differences in crop management for the two fields. The amount of fertilizer applied did not seem to explain the larger amounts of nitrogen exported from field 2 because some of the highest application rates were in 2012 and 2015 (8,890 and 11,800 lb/yr, respectively); yet the ratios of exported nitrogen were lowest in 2012 and 2015 for field 2. Field 2 had 3,140 lb/yr of nitrogen applied and corn and soybeans planted in 2013, and 5,050 lb/yr of nitrogen applied and spring wheat planted in 2014 (table 14). For field 1, only 581 lb/yr of

Table 13. Estimate of exported and applied nutrients, ratio of exported to applied nutrients and crop type for field 1 at Embden farm, North Dakota, 2010–15.

[N, nitrogen; P, phosphorus; --, not available]

Year	Annual loads for site E1 (13 percent of total load) plus site E2, in pounds per year		Field (field 1; fig. 3) that contributes runoff to site E1 (13 percent of total drainage) and site E2						Crop type
	Total ammonia and nitrate plus nitrite, as N	Total phosphorus, as P	Estimated nitrogen application, in pounds per year	Estimated annual nitrogen applica- tion rate, in pounds per acre per year	Estimated phosphorus application, in pounds per year	Estimated annual phosphorus application rate, in pounds per acre per year	Ratio of exported nitrogen (ammonia, nitrate, and nitrite) to applied nitrogen as fertilizer	Ratio of exported phosphorus to applied phosphorus as fertilizer	
2010	5,130	16	9,240	140	--	--	0.56	--	Corn silage/soybeans.
2011	3,430	39	4,100	62	1,410	21	0.84	0.028	Spring wheat.
2012	22	1	632	10	2,990	45	0.03	<0.001	Alfalfa.
2013	19	5	581	9	2,750	42	0.03	0.003	Alfalfa.
2014	17	4	726	11	3,430	52	0.02	0.001	Alfalfa.
2015	13	4	908	14	4,290	65	0.01	0.001	Alfalfa.

Table 14. Estimate of exported and applied nutrients, ratio of exported to applied nutrients and crop type for field 2 at Embden farm, North Dakota, 2010–15.

[N, nitrogen; P, phosphorus; --, not available]

Year	Annual loads for site E1 (34 percent of total load) plus site E3, in pounds per year		Field (field 2; fig. 3) that contributes runoff to site E1 (34 percent of total drainage) and site E3						Crop type
	Total ammonia and nitrate plus nitrite, as N	Total phosphorus, as P	Estimated nitrogen application, in pounds per year	Estimated annual nitrogen applica- tion rate, in pounds per acre per year	Estimated phosphorus application, in pounds per year	Estimated annual phosphorus ap- plication rate, in pounds per acre per year	Ratio of exported nitrogen (ammonia, nitrate, and nitrite) to applied nitrogen as fertilizer	Ratio of exported phosphorus to applied phosphorus as fertilizer	
2010	4,810	12	9,800	140	--	--	0.49	--	Corn silage/soybeans.
2011	3,060	30	4,340	62	1,500	21	0.71	0.020	Spring wheat.
2012	127	2	8,890	127	3,170	45	0.01	<0.001	Corn.
2013	641	9	3,140	45	2,150	31	0.20	0.004	Corn/soybeans.
2014	886	14	5,050	72	2,180	31	0.18	0.006	Spring wheat.
2015	843	7	11,800	169	2,670	38	0.07	0.003	Corn.

nitrogen was applied in 2013 and 726 lb/yr of nitrogen applied in 2014, and alfalfa was planted in the field both years. It seems that the combination of lower application rates, subsequent years of planting alfalfa compared to the other crop rotation, and the amount of annual runoff may have affected the amount of nitrogen exported at Embden farm.

The ratio of exported phosphorus to applied phosphorus was highest in 2011 (fertilizer application data for 2010 were not available), lower in subsequent years, and much less than the ratios for nitrogen. For fields 1 and 2, the ratios in 2011 were 0.028 and 0.020, respectively. For subsequent years, the ratios were all less than or equal to 0.006 (tables 13 and 14).

Mean monthly loads indicated different patterns depending on the sites and the constituents at the Embden farm sites (fig. 15). For sites E1 and E2, most of the annual load for all constituents was transported in March and April when most of the snowmelt and rainfall runoff occurs. At site E3, the chloride load was greatest in March, June, and January on average; however, the greater loads for several constituents in the winter months (December, January, and February) only were in 2010 and 2011 (fig. 15; appendix table 1–4) when there was flow at the site. The total ammonia load at site E3 was greatest in February and May on average. The nitrate plus nitrite load was greatest in February and June, on average, with a large part also delivered in March and April (fig. 15). The total phosphorus load was greatest in May and June, on average, when most of the planting and fertilizer application occurred. In general, most of the nutrient loads were delivered when there was greater precipitation and associated runoff and little vegetative growth for uptake of nutrients. The difference in the pattern of monthly loads between sites E2 and E3 may be due to the variety of crops planted in fields that contributed to the two sites. The loads for all constituents at site E2 were greatest in March and April, and field 1, which contributes to site E2, was planted with corn silage and soybeans in 2010, spring wheat in 2011, and alfalfa in 2012–15 (fig. 15; table 13). At site E3, loads varied depending on constituent, but many of the nutrients were either greatest in the later months of May and June or in February (only in 2010 and 2011; appendix table 1–4). Field 2 (that contributes flow to site E3) had rotational planting of corn, soybeans, and spring wheat throughout 2010–15 (table 14). Although a direct correlation between crop type and load is not possible, the crop type seems to have affected when nutrients are transported at the site on a monthly and annual basis.

Annual yields were computed for the three sites for comparison of the sites in terms of how much mass of the constituents are transported past each site per acre contributing runoff to each site (fig. 16). Annual yields for all constituents were substantially greater at sites E2 and E3 compared to site E1, mainly because of a combination of higher flow volumes and small contributing drainage areas at sites E2 and E3 compared to site E1. Sites E2 and E3 had generally

similar annual yields for all constituents in 2010 and 2011, and site E3 generally had the highest yield among the three sites in subsequent years. Annual chloride yields ranged from less than 0.01 to 1.2 lb/yr/acre at site E1, 0.20 to 84 lb/yr/acre at site E2, and 3.0 to 134 lb/yr/acre at site E3 (fig. 16; table 12). Annual total ammonia yields ranged from less than 0.01 to 0.02 lb/yr/acre as nitrogen at site E1, less than 0.01 to 0.98 lb/yr/acre as nitrogen at site E2, and less than 0.01 to 1.3 lb/yr/acre as nitrogen at site E3. Annual total nitrate plus nitrite yields ranged from less than 0.01 to 0.09 lb/yr/acre as nitrogen at site E1, 0.09 to 63 lb/yr/acre as nitrogen at site E2, and 1.8 to 67 lb/yr/acre as nitrogen at site E3 (fig. 16; table 12). Annual total phosphorus yields ranged from less than 0.01 to 0.04 lb/yr/acre as phosphorus at site E1, less than 0.01 to 0.48 lb/yr/acre as phosphorus at site E2, and less than 0.01 to 0.40 lb/yr/acre as phosphorus at site E3.

To put the contribution of flow and constituent loads into a larger-scaled context, the loads and yields for Embden farm were compared to loads and yields estimated for the Maple River. The nearest site with estimated annual loads and yields from Galloway and others (2012) is below Mapleton, N. Dak., and has a drainage area of 947,200 acres (fig. 1 and table 10; USGS streamgage 05060100). The site is about 60 river miles downstream from the confluence of the drainage from Embden farm that has a total drainage of about 164 acres (table 10). Normalized annual loads for the Maple River below Mapleton for total ammonia, nitrate plus nitrite, and total phosphorus were 44,000 lb/yr as nitrogen, 1,886,000 lb/yr as nitrogen, and 14,000 lb/yr as phosphorus, respectively (table 10). In comparison, mean annual loads estimated for the total drainage from Embden farm (mean of the annual sum of loads for E1, E2, and E3 for 2010 through 2015; table 12) for total ammonia, nitrate plus nitrite, and total phosphorus were 43 lb/yr as nitrogen, 3,130 lb/yr as nitrogen, and 26 lb/yr as phosphorus, respectively (table 10). Nutrient loads from the drainage at Embden farm represents less than 0.2 percent of the nutrient loads estimated for the receiving stream, the Maple River. Although loads were considerably less from the Embden farm drainage compared to the Maple River, nitrate plus nitrite yields were much greater, and total ammonia and total phosphorus yields were slightly greater but similar to the Maple River. For total ammonia, the normalized annual yield estimated for the Maple River was 0.05 lb/yr/acre as nitrogen, whereas the mean annual yield for the Embden farm sites was 0.18 lb/yr/acre as nitrogen. The normalized annual nitrate plus nitrite yield estimated for the Maple River was 2.0 lb/yr/acre as nitrogen, whereas the mean annual yield for the sum of the three sites at Embden was 13 lb/yr/acre as nitrogen (table 10). The normalized annual total phosphorus yield estimated for the Maple River was 0.01 lb/yr/acre as phosphorus, whereas the mean annual yield for the Embden sites was 0.11 lb/yr/acre as phosphorus (table 10).

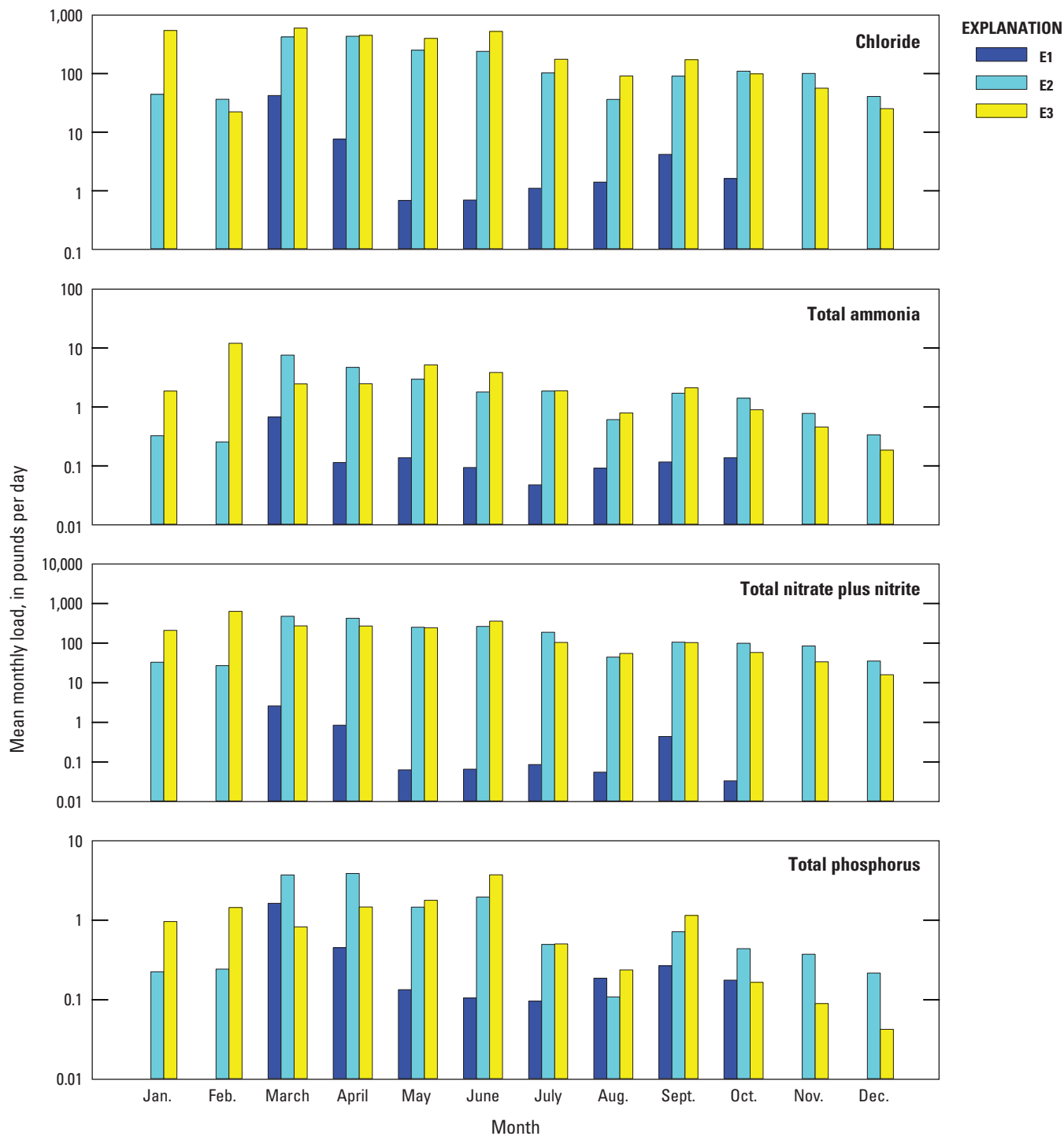


Figure 15. Monthly loads estimated for monitoring sites at Embden farm, North Dakota, 2010–16.

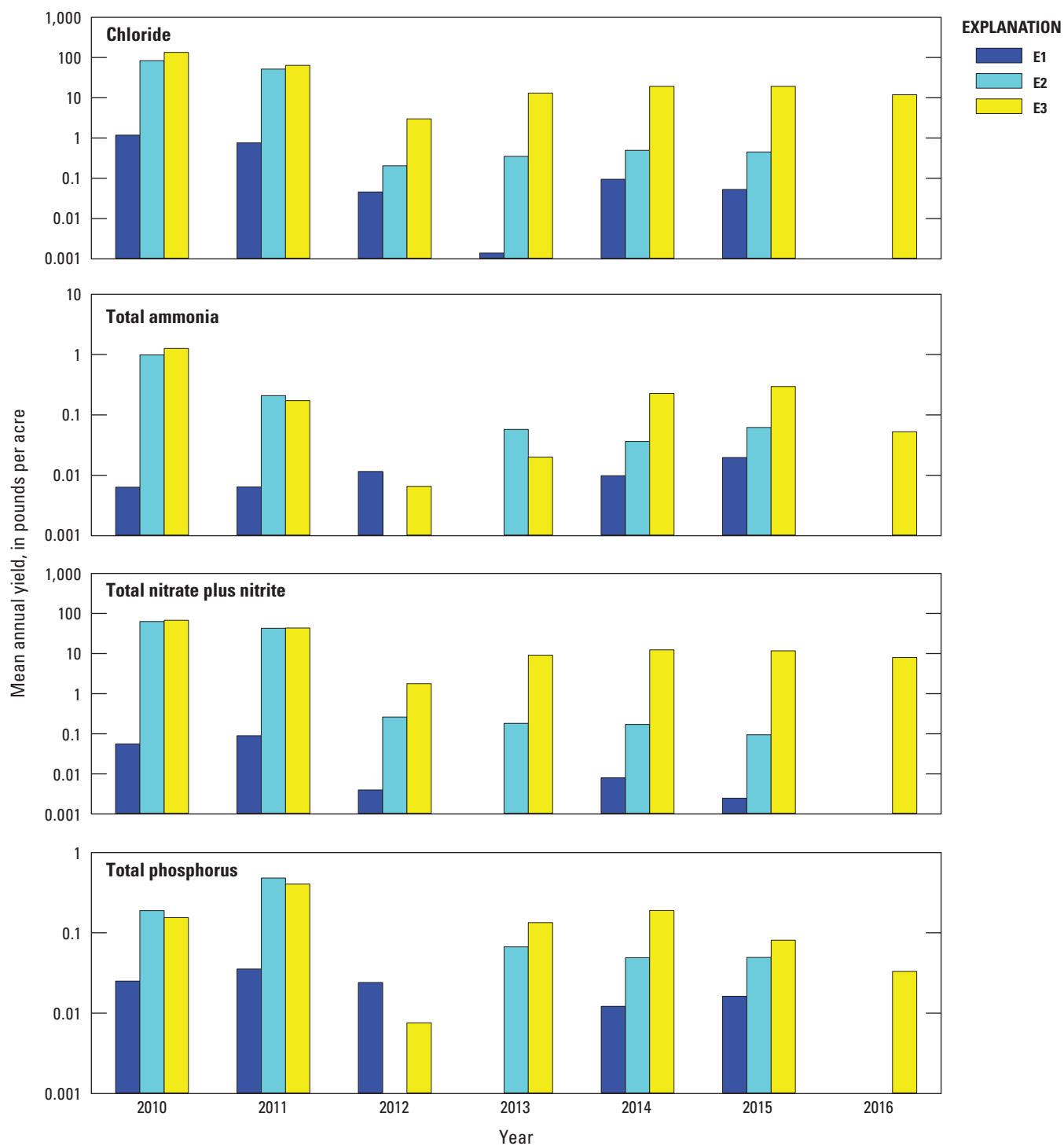


Figure 16. Annual yields estimated for monitoring sites at Underwood farm, North Dakota, 2009–15.

Table 15. Summary of water-quality constituent concentrations for monitoring sites at Dazey farm, North Dakota, 2008–15.

[Number in parentheses is the U.S. Geological Survey National Water Information System parameter code; ft³/s, cubic foot per second; µS/cm at 25 °C, microsiemen per centimeter at 25 degrees Celsius; mg/L, milligram per liter; N, nitrogen; P, phosphorus; <, less than]

Site (fig. 4)	Description	Instantaneous discharge, in ft ³ /s	Specific conductance, laboratory, µS/cm at 25 °C	Suspended solids, in mg/L	Chloride, in mg/L	Dissolved (filtered) ammonia, in mg/L as N	Total (unfiltered) ammonia, in mg/L as N	Dissolved (filtered) nitrate plus nitrite, in mg/L as N	Total nitrate plus nitrite (unfiltered), in mg/L as N	Dissolved (filtered) phosphorus, in mg/L as P	Total (unfiltered) phosphorus, in mg/L as P	Total dissolved (filtered) nitrogen, in mg/L as N	Total (unfiltered) nitrogen, in mg/L as N	Sus- pended- sediment, in mg/L
		(00061)	(90095)	(00530)	(00940)	(00608)	(00610)	(00631)	(00630)	(00666)	(00665)	(62854)	(62855)	(80154)
D1 ^a	Number of samples	46	48	48	47	27	44	29	46	29	49	26	46	43
	Minimum	0.0	52	<5	<3	<0.03	<0.03	<0.03	<0.03	0.29	0.34	0.76	0.9	6
	Maximum	8.2	2,180	7,000	48	1.6	8.3	67	59	3.1	4.5	50	61	58,900
	Median	0.2	217	115	4	0.24	0.29	1.1	0.91	0.78	1.3	3.9	4.0	213
	Mean	0.8	348	903	7	0.39	0.86	6.4	2.9	0.87	1.4	6.0	6.3	3,346
D2 ^b	Number of samples	15	17	14	17	13	16	13	16	13	16	13	16	17
	Minimum	0.0	135	6	<3	0.54	0.51	0.58	0.42	0.06	0.10	3.9	4.0	15
	Maximum	13.0	1,840	20,000	71	2.7	7.6	12	13	1.7	5.8	21	29	514,000
	Median	0.1	525	1,295	11	1.2	1.8	2.9	2.7	1.2	1.9	6.6	9.1	1,510
	Mean	1.2	607	3,815	17	1.3	2.3	4.0	3.5	1.1	2.3	8.4	11	33,642
D3	Number of samples	92	101	97	99	57	94	59	96	59	101	54	96	94
	Minimum	0.0	196	<5	5	<0.03	<0.03	<0.03	<0.03	<0.01	<0.01	0.33	0.32	1
	Maximum	48.0	3,300	6,300	169	2.6	2.7	13	17	3.2	5.1	12.7	16	15,700
	Median	0.1	1,720	42	56	0.08	0.10	0.85	0.78	0.55	0.63	3.1	2.5	94
	Mean	1.4	1,624	364	59	0.19	0.21	2.37	2.9	0.60	0.76	3.8	4.2	631

^aIncludes samples from sites D1a and D1b.

^bData only collected from March 2009 to April 2011.

Dazey Farm

At Dazey farm from October 2008 through September 2011, about 27 samples were collected from site D1a; the site was moved about 300 feet upslope to site D1b (fig. 4), and an additional 21 samples were collected from May 2012 through September 2015 (fig. 17). The data from D1a and D1b were combined and used to estimate loads and yields and is referred to as site D1 in this section. From March 2009 through April 2011, about 17 samples were collected from site D2 before the site was destroyed (table 15). Because of issues with heavy sedimentation at site D2, associated measured flow values were not recorded for the site when samples were collected, so no further analysis was done with the sample data for this report. From April 2009 through September 2015, about 101 samples were collected from site D3 (fig. 17). Not all samples were analyzed for the same constituents, so the number of values for individual constituents varied throughout the period (table 15).

Concentrations

Chloride concentrations measured at Dazey farm were highest at site D3 and lowest at site D1 (includes samples from sites D1a and D1b) (fig. 9). Potential sources of chloride at Dazey farm could include animal manure that may have feed additives including salts from the winter feeding area (fig. 4), soils that are eroded in the area (Mullaney and others, 2009; Hem, 1985), and, specifically for site D3, groundwater input (particularly in 2010 and 2011). Although groundwater quality was not measured at Dazey farm, site D3 maintained flow throughout a large part of the year in 2010 and 2011, whereas flow at site D1 was only measured during runoff events (fig. 7). Site D1 had a median chloride concentration of 4 mg/L, and site D3 had a median concentration of 56 mg/L (table 15).

Nutrient concentrations generally were greater at site D1 compared to site D3 at Dazey farm (fig. 9). Potential sources of nutrients related to agricultural activities could include animal manure in the feeding and calving areas, and fertilizer and manure applications to the surrounding cropland. Higher concentrations at site D1, which is upstream and closer to potential sources of nutrients compared to lower concentrations at site D3, which is farther downstream and receives more runoff, indicates that dilution may be the reason concentrations decrease downstream. Median total ammonia concentrations at sites D1 and D3 were 0.29 and 0.10 mg/L as nitrogen, respectively (fig. 9; table 15). Median total nitrate plus nitrite for sites D1 and D3 were 0.91 and 0.78 mg/L as nitrogen, respectively. Median total phosphorus concentrations at sites D1 and D3 were 1.3 and 0.63 mg/L as phosphorus, respectively (fig. 9; table 15).

Suspended-sediment concentrations at the Dazey farm were the highest concentrations among the sites at all three farms and decreased from upstream at site D1 downstream to site D3 (fig. 9). Median suspended-sediment concentrations

for sites D1 and D3 were 213 and 94 mg/L, respectively (table 15). Although median concentrations of suspended sediment were lower than the Underwood farm site U1, maximum concentrations at Dazey farm sites were much higher (tables 7 and 15). Site D1 had a maximum concentration of 58,900 mg/L, and site D3 had a maximum concentration of 15,700 mg/L (table 15). In the short time site D2 was active (2009–11), a maximum concentration of 514,000 mg/L was measured (table 15). The channel at Dazey farm has a much greater slope compared to the other farms, creating more energy for erosion and sediment transport during runoff. Site D2 was destroyed in 2011 because of high sedimentation from runoff.

Loads and Yields

Annual loads (March through October) were estimated at Dazey farm from 2010–15 for site D3 and from 2012–15 for site D1 (fig. 18; table 16). Samples were collected in 2009 at both sites, but loads were not computed for 2009 at both sites and in 2010–11 at site D1 because of incomplete daily flow data. The greatest annual loads at site D3 for chloride, nitrate plus nitrite, and suspended sediment were in 2010 and 2011, and zero loads were estimated for 2012 because no flow was measured at the site (fig. 18; table 16). At site D3, annual chloride loads ranged from 0 to 6,840 lb/yr, nitrate plus nitrite loads ranged from 0 to 734 lb/yr as nitrogen, and suspended-sediment loads ranged from 0 to 348,000 lb/yr (fig. 18; table 16). Total ammonia and total phosphorus loads at site D3 had the greatest loads in 2015. Annual total ammonia loads ranged from 0 to 161 lb/yr as nitrogen, and total phosphorus loads ranged from 0 to 212 lb/yr as phosphorus (fig. 18; table 16). The greatest annual loads for all constituents at site D1 were in 2014, although loads were estimated for a shorter period (2012–15) than for site D3 (2010–15). At site D1, annual chloride loads ranged from 0 to 137 lb/yr, nitrate plus nitrite loads ranged from 0 to 53 lb/yr as nitrogen, and suspended-sediment loads ranged from 0 to 3,390 lb/yr (fig. 18; table 16). Annual total ammonia loads ranged from 0 to 4 lb/yr as nitrogen, and total phosphorus loads ranged from 0 to 23 lb/yr as phosphorus (fig. 18; table 16).

Mean monthly loads were greatest for most of the constituents in March and April at sites D1 and D3, on average, except for suspended sediment that had the greatest monthly loads in May (fig. 19; appendix table 1–5). Fertilizer application and cattle management data were not available for the Dazey farm, but it does not seem as though management practices affected the timing of when loads were delivered at the sites. It seems that most of the loads are delivered based on when most of the precipitation and associated runoff occurs during the year.

Annual yields were computed for sites D1 and D3 for comparison of the sites in terms of how much mass of the constituents are transported past each site per acre contributing runoff to each site (fig. 20; table 16). At site D3, the greatest annual chloride and nitrate plus nitrite yields were in 2011,

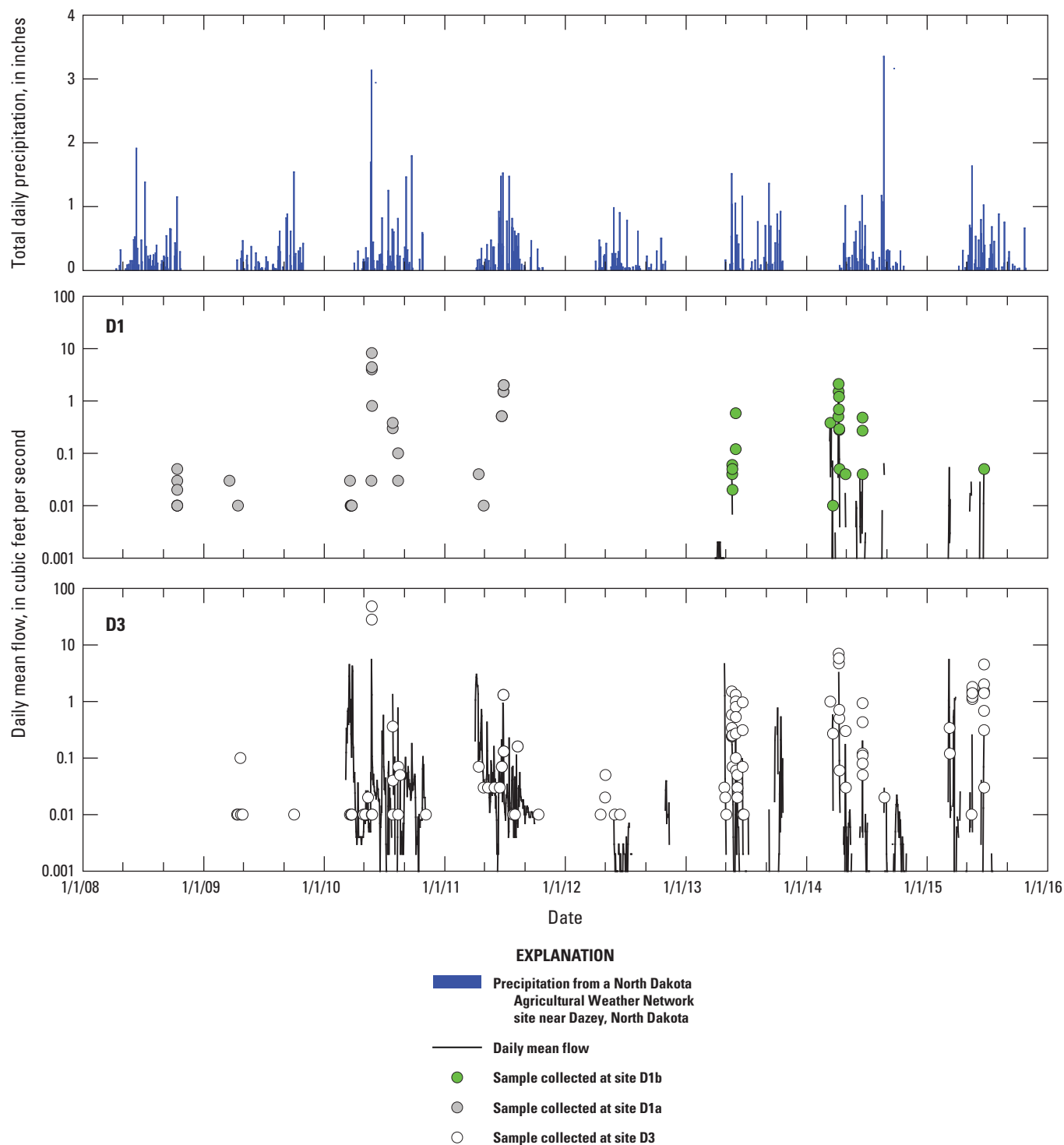


Figure 17. Daily mean flow, daily precipitation, and samples collected at monitoring sites at Dazey farm, North Dakota, 2008–15.

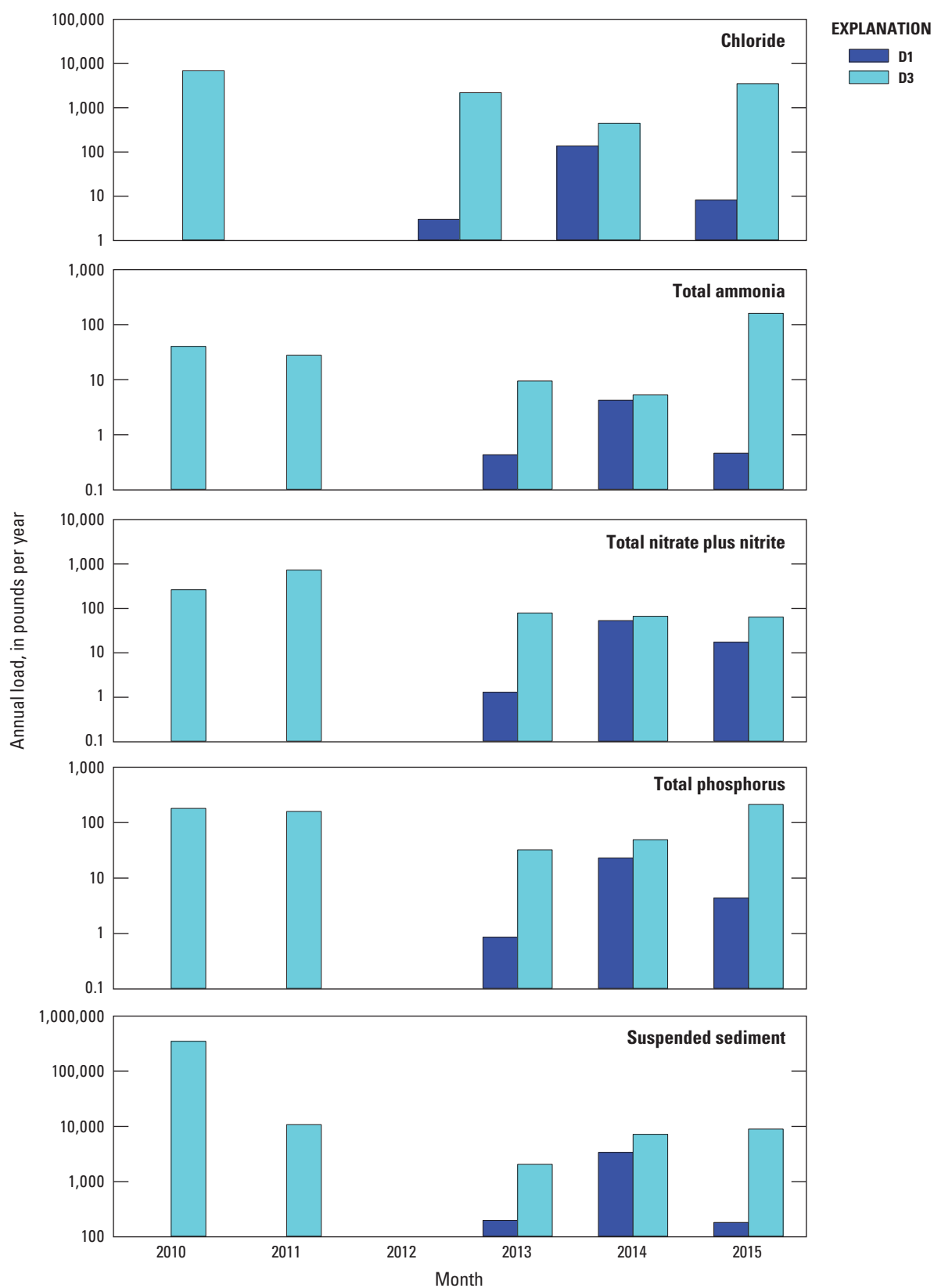


Figure 18. Annual loads estimated for monitoring sites at Dazey farm, North Dakota, 2010–15.

Table 16. Annual loads and yields for Dazey farm, North Dakota, 2010–15.

[N, nitrogen; P, phosphorus, <, less than]

Year	Flow, in acre-feet per year	Load, in pounds per year					Yield, in pounds per year per acre				
		Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	Suspended sediment	Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	Suspended sediment
Site D1											
2012	<1	0	0	0	0	0	0	0	0	0	0
2013	<1	3	<1	1	1	198	0.12	<0.01	0.05	0.04	8.3
2014	8	137	4	53	23	3,390	5.7	0.18	2.2	0.96	141
2015	1	8	<1	17	4	182	0.34	<0.01	0.73	0.18	7.6
Mean	3	37	2	18	7	943	1.5	0.05	0.75	0.30	39
Site D3											
2010	84	6,420	40	262	180	348,000	19	0.12	0.77	0.53	1,020
2011	56	6,840	28	734	159	10,700	20	0.08	2.2	0.47	31
2012	<1	0	0	0	0	0	0	0	0	0	0
2013	20	2,180	9	79	32	2,050	6.4	0.03	0.23	0.09	6.0
2014	12	447	5	66	49	7,190	1.3	0.02	0.19	0.14	21
2015	26	3,520	161	64	212	8,940	10	0.47	0.19	0.62	26
Mean	33	3,230	41	201	106	62,800	9.5	0.12	0.59	0.31	184

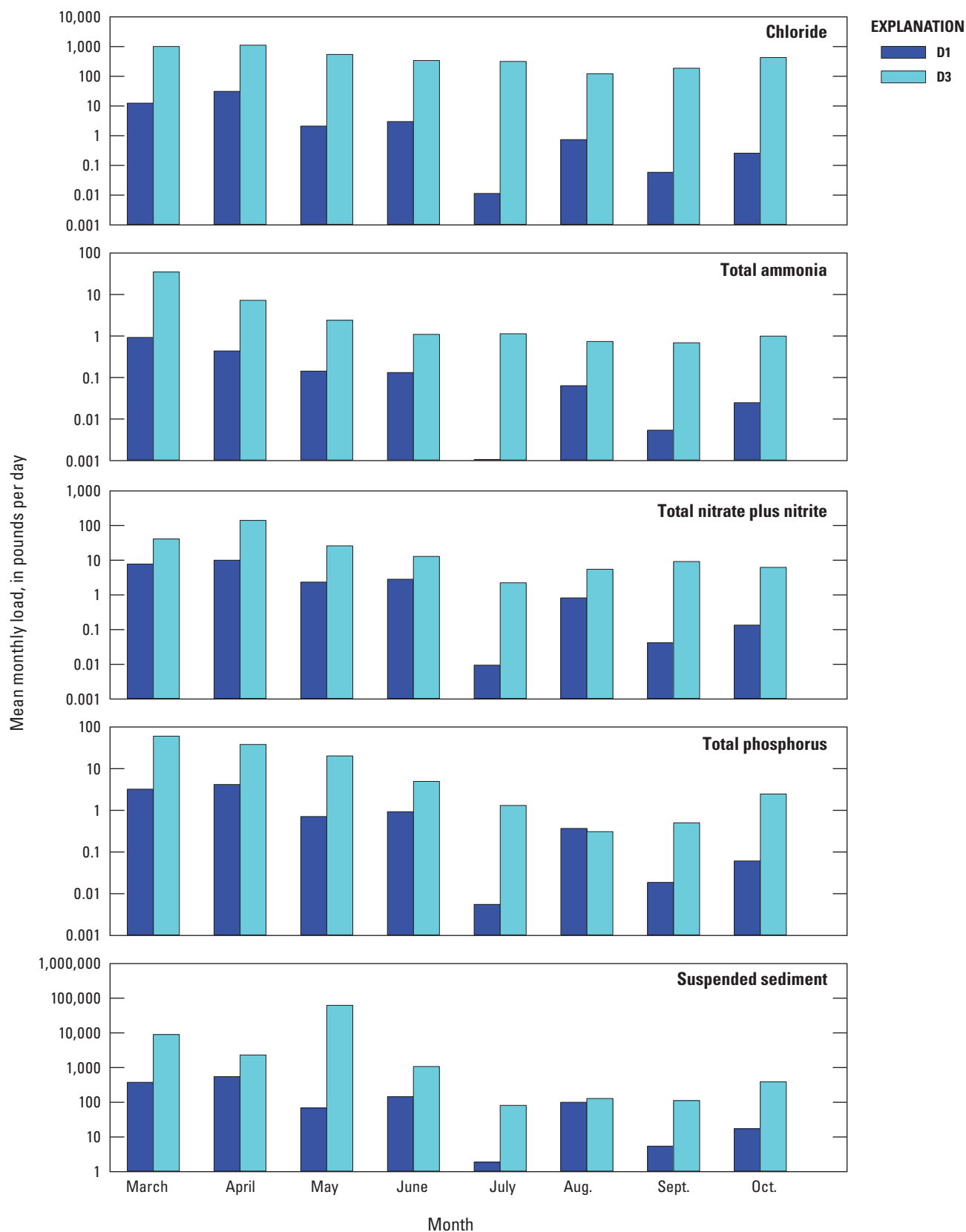


Figure 19. Monthly loads estimated for monitoring sites at Dazey farm, North Dakota, 2010–15.

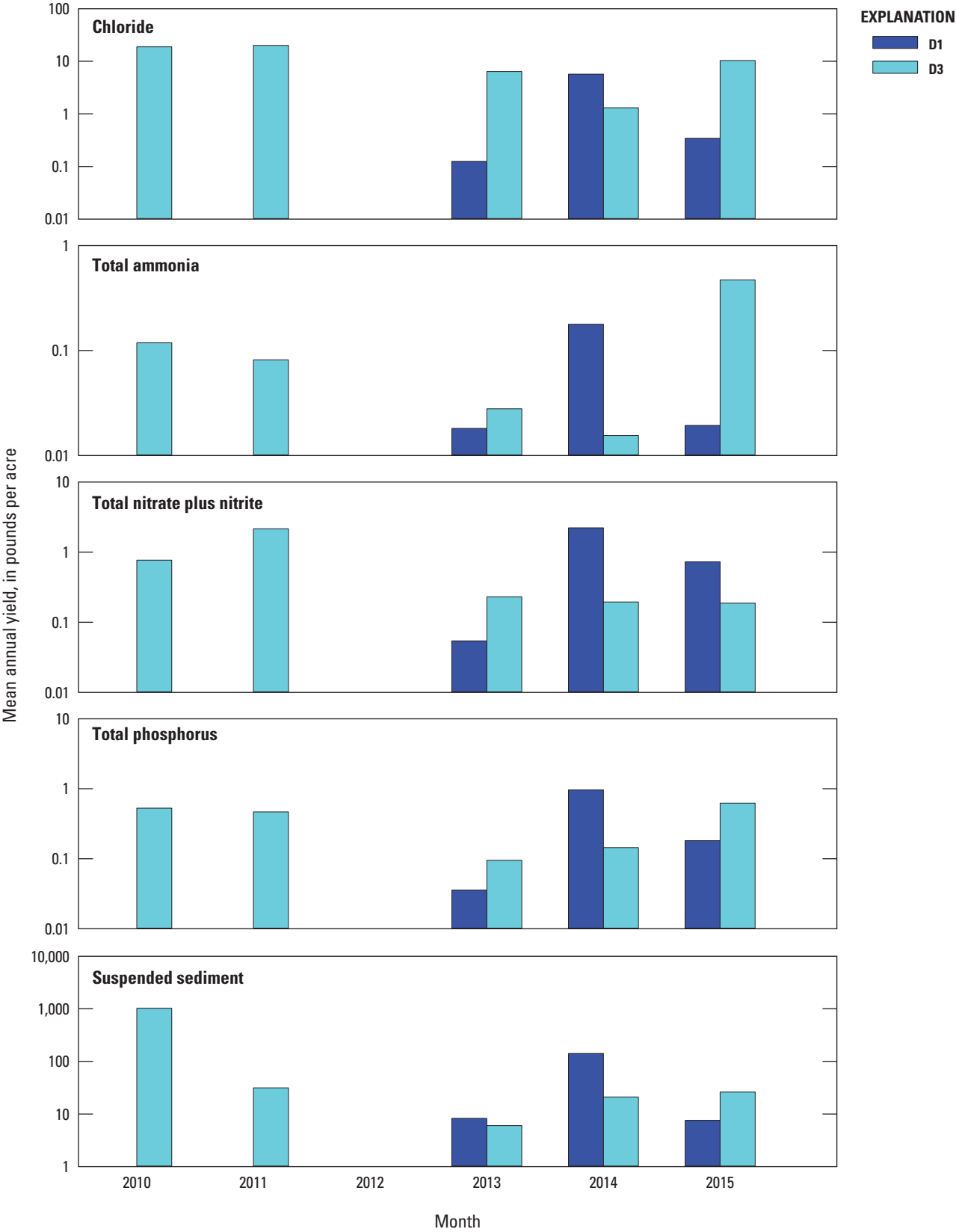


Figure 20. Annual yields estimated for monitoring sites at Dazey farm, North Dakota, 2010–15.

the greatest total ammonia and total phosphorus yields were in 2015, and greatest suspended-sediment yields were in 2010. At site D1, the greatest annual yields for all constituents were in 2014. Annual yields at site D1 also exceeded the annual yields estimated for site D3 for all constituents in 2014, for nitrate plus nitrite in 2015, and for suspended sediment in 2013. Annual chloride yields ranged from 0 to 5.7 lb/yr/acre at site D1 and 0 to 20 lb/yr/acre at site D3 (fig. 20; table 16). Annual total ammonia yields ranged from 0 to 0.18 lb/yr/acre as nitrogen at site D1 and 0 to 0.47 lb/yr/acre as nitrogen at site D3. Annual total nitrate plus nitrite yields ranged from 0 to 2.2 lb/yr/acre as nitrogen at sites D1 and D3 (fig. 20; table 16). Annual total phosphorus yields ranged from 0 to 0.96 lb/yr/acre as phosphorus at site D1, and 0 to 0.62 lb/yr/acre as phosphorus at site D3. Annual suspended-sediment yields ranged from 0 to 141 lb/yr/acre at site D1, and 0 to 1,020 lb/yr/acre at site D3 (fig. 20; table 16).

To put the contribution of flow and constituent loads into a larger-scaled context, the loads and yields for Dazey farm were compared to loads and yields estimated for Baldhill Creek. Loads and yields were estimated for a site on Baldhill Creek near Dazey, N. Dak. (USGS streamgage 05057200), about 11 river miles upstream from the confluence with the drainage from Dazey farm (fig. 1 and table 10; Galloway and others, 2012). The site on Baldhill Creek has a drainage area of 442,240 acres compared to a drainage area of 341 acres for site D3 (table 10). Normalized annual loads for Baldhill Creek for total ammonia, nitrate plus nitrite, and total phosphorus were 10,000 lb/yr as nitrogen, 36,000 lb/yr as nitrogen, and 16,000 lb/yr as phosphorus, respectively (table 10; Galloway and others, 2012). In comparison, mean annual loads (2010–15) estimated for site D3 at Dazey farms for total ammonia, nitrate plus nitrite, and total phosphorus were 41 lb/yr as nitrogen, 201 lb/yr as nitrogen, and 106 lb/yr as phosphorus, respectively (table 10). Nutrient loads from the drainage at Dazey farm represent less than 1 percent of the nutrient loads estimated for the receiving stream, Baldhill Creek. Although loads were considerably less from the Dazey farm drainage compared to Baldhill Creek, nutrient yields were slightly greater but similar. For total ammonia, the normalized annual yield estimated for Baldhill Creek was 0.02 lb/yr/acre as nitrogen, whereas the mean annual yield for site D3 was 0.12 lb/yr/acre as nitrogen (table 10). The normalized annual nitrate plus nitrite yield estimated for Baldhill Creek was 0.08 lb/yr/acre as nitrogen, whereas the mean annual yield for site D3 was 0.59 lb/yr/acre as nitrogen. The normalized annual total phosphorus yield estimated for Baldhill Creek was 0.04 lb/yr/acre, whereas the mean (2010–15) annual yield for site D3 was 0.31 lb/yr/acre (table 10). Suspended-sediment loads and yields were not available for Baldhill Creek for comparison (Galloway and others, 2012).

Implications

Data collected from 2008 to 2016 at the three Discovery Farms in North Dakota provides insight into several factors affecting runoff and water quality from the farms. A better understanding of these factors gives the producer data to inform agricultural management decisions that can help improve water quality in runoff from their farms.

One of the greatest factors contributing to nutrient export is one that cannot be controlled: the timing and amount of precipitation. The largest runoff volumes for the farms were in the spring when high winter precipitation was preceded by a wet fall resulting in the greatest monthly loads in the spring months. Other research has indicated similar findings in that the largest export of nutrients generally were during spring months with wet antecedent conditions (Stuntebeck and others, 2008; Davis and others, 2014). Agricultural conservation practices that target a reduction in runoff during these critical months could reduce the export of nutrients and other constituents.

Natural physiographic features on individual farms played a role in the export of certain constituents. At Underwood farm, chloride, total ammonia, and total phosphorus concentrations were the highest among the three farms, likely from a feedlot operation, but concentrations decreased as runoff traveled through a vegetated channel downstream. Sediment and phosphorus transport at Underwood farm was highest near the feedlot but decreased substantially as runoff traveled through the vegetated channel. Similarly, total ammonia, total phosphorus, and suspended-sediment concentrations at the Dazey farm decreased from upstream to downstream as runoff traveled through the natural drainage. Although sediment decreased from upstream to downstream at the Dazey farm, the greatest movement of sediment was at this farm, likely from the steeper drainage and channel compared to sites at the other farms. An at-grade stabilization structure installed on a Wisconsin Discovery Farm has reduced sediment to nearby waters (Minks and others, 2012). Natural vegetated waterways likely reduced the export of certain constituents from these farms, and additional structures, such as an at-grade stabilization structure, could be an effective means of improving water quality from farms with steeper landscapes.

Nitrogen export was affected by fertilizer application and was highest from drainage tile sites. At Underwood farm, downstream sites had higher nitrate plus nitrite concentrations, indicating sources such as fertilizer application to the surrounding cropland; however, nitrate plus nitrite concentrations were much higher at the drainage tile sites at Embden farm. Nitrate is highly soluble and probably infiltrated through the soil readily, particularly during very wet years such as 2010 and 2011, and was transported through the drainage tile. Nitrate plus nitrite concentrations and loads at the drainage tile sites also could have been affected by groundwater because the drainage tiles are in the subsurface. Drainage tiles are a large exporter of nitrogen, and factors affecting the export of nitrogen are complex and include site-specific soil properties,

crop rotation, timing and area of nitrogen fertilizer application, amount and distribution of precipitation, crop uptake of soil derived nitrogen, and residual nitrogen remaining after harvest (Stenberg and others, 2011; Gentry and others, 1998; University of Wisconsin, 2013). Compared to receiving water bodies, nitrogen losses from the drainage tiles are small, but cumulatively, if many farms are losing nitrogen through drainage tiles, the total loss of nitrogen can result in increasing surface-water nitrogen concentrations (Blann and others, 2009). Because of the complexity of factors affecting nitrogen export from drainage tiles, agricultural practices on tile-drained agricultural land must be taken into consideration for the individual cropping system and site-specific characteristics to reduce nutrient loss (University of Wisconsin, 2013; Stenberg and others, 2011; Gentry and others, 1998).

To mitigate runoff and water-quality effects of their operations, various agricultural conservation practices were implemented by the producers before and during the Discovery Farms monitoring. At Underwood farm, because of data collected for the Discovery Farms program, the producer installed a drainage ditch to route runoff away from the feedlot, but the effects of the ditch could not be quantified because of variability in hydrologic conditions during the monitoring period. At the Dazey farm, the producer relocated the feedlot before the start of data collection for the Discovery Farms program, and effects of the relocation could not be determined because data were not collected before the relocation. Although the effects of these agricultural conservation practices could not be quantified definitively, data collected at Underwood and Dazey farms demonstrate that runoff through a vegetated channel resulted in decreased concentrations of some constituents. This indicates that, over time, these conservation practices could reduce effects to downstream water bodies. At Embden farm, the producer rotated crops, used different fertilizer application rates, and planted alfalfa in a part of the operation for consecutive years. Direct correlations could not be made definitively from the data at Embden farm, but it did seem that some of these measures had an effect on the amount of nutrients transported from the site. Conservation practices implemented by the producers likely caused a reduction in nutrient loss, but high variability in other factors such as precipitation and runoff makes it difficult to quantify the reduction. To quantify these reductions, many years of consistent data collection is required and monitoring before and subsequent to implementation of the practices is necessary. Even though it was difficult to quantify the effects of the agricultural conservation practices implemented at the farms, the data collected from the Discovery Farms program provided a better understanding of some of the variables that affect runoff and water quality, and on the basis of this information, producers can modify their agricultural practices to more effectively protect downstream water quality.

Summary

Agricultural producers in North Dakota are aware of concerns about degrading water quality, and many of the producers are interested in implementing conservation practices to reduce the export of nutrients from their farms, not only because it reduces the effect on receiving waters, but also because it is beneficial to the producer to retain nutrients. Producers often implement conservation practices without knowledge of the water quality of the runoff from their farm or if conservation practices they may implement have any effect on water quality. In response to this lack of information, the U.S. Geological Survey, in cooperation with North Dakota State University Extension Service and in coordination with an advisory group consisting of State agencies, agricultural producers, and commodity groups, implemented a monitoring study as part of a Discovery Farms program in North Dakota in 2007. Discovery Farms in North Dakota were established in late 2007 near Underwood, North Dakota, in late 2008 near Embden, North Dakota, and in early 2008 near Dazey, North Dakota. Each farm had three data-collection sites. The purpose of this report is to describe runoff and water-quality characteristics from data collected at the three Discovery Farms from 2008 to 2016. Runoff and water-quality data were used to help describe the implication of agricultural conservation practices on runoff and water-quality patterns.

Runoff characteristics of monitoring sites at the three farms were determined by measuring flow volume and precipitation. Runoff at the Underwood farm monitoring sites generally was controlled by precipitation in the area, antecedent soil moisture conditions, and, after 2012, possibly by the diversion ditch constructed by the producer. Flow volume was highest at the most downstream site U3; annual flow volumes ranged from 136 acre-feet (2012) to 15,200 acre-feet (2011). Measured runoff consistently was highest at site U1 (most upstream site) and was lowest at site U2. Most of the annual runoff was in March and April each year during spring snowmelt. The large monthly totals did not happen in months with high rainfall totals but were preceded by wet conditions in the previous fall months and higher precipitation in the preceding winter months.

Runoff characteristics at the Embden farm are complex because of the mix of surface runoff (measured at site E1) and flow through two separate drainage tile systems (sites E2 and E3). Annual flow volume at site E1 ranged from less than 4 acre-feet (2013) to 1,820 acre-feet (2011). Annual flow volumes for the drainage tiles sites E2 and E3 were much greater than measured at site E1. Site E1 generally only had runoff briefly in March and April during spring snowmelt and during only a few large rain events throughout 2009–16; however, runoff was somewhat continuous at sites E2 and E3 throughout the year during years of increased precipitation such as in 2010 and 2011.

At Dazey farm, annual flow volumes at the most downstream site D3 for 2010–15 ranged from 88 acre-feet (2012) to 12,100 acre-feet (2010). Annual flow volumes for upstream site D1 (combination of data from site D1a [original site] and site D1b [relocated site]) for 2013–15 ranged from 49 acre-feet (2013) to 1,190 acre-feet (2014). The largest monthly runoff volumes at sites D1 and D3 were in March and April during spring snowmelt runoff and rain events. Site D1 had only one period of measurable monthly runoff that was in March and April 2014.

Data collected from 2008 to 2016 at the three Discovery Farms in North Dakota provides insight into several factors affecting runoff and water quality from the farms. A better understanding of these factors gives the producer data to inform agricultural management decisions that can help improve water quality in runoff from their farms.

Chloride concentrations measured at Underwood generally were highest at site U1 and lowest at site U2. In general, chloride concentrations also were higher at Underwood farm compared to Dazey and Embden farms. Chloride concentrations measured at Embden farm were similar for the two drainage tile sites (E2 and E3) and were considerably higher than at the surface-water site (E1). Chloride concentrations measured at Dazey farm were highest at downstream site D3 and lowest at upstream site D1.

Total ammonia and total phosphorus had the highest concentrations at Underwood farm site U1 and decreased sequentially at sites U2 and U3 downstream. Total ammonia and phosphorus concentrations at the sites for Underwood farm also generally were higher than measured at Dazey and Embden farms. Nitrate plus nitrite generally had the lowest concentrations at site U1 and the highest concentrations at site U2, although median concentrations did not vary substantially among sites. Median total nitrate plus nitrite concentrations for sites U1, U2, and U3 were 1.3, 2.5, and 1.4 milligrams per liter as nitrogen, respectively. Nutrient concentrations were similar for the Embden farm drainage tile sites E2 and E3; concentrations of total ammonia and total phosphorus were lower and concentrations of total nitrate plus nitrite were higher compared to the surface-water site E1. Nitrate plus nitrite concentration at sites E2 and E3 also were the highest among all of the sites at all three farms. Median total nitrate plus nitrite for sites E1, E2, and E3 were 0.22, 13, and 10 milligrams per liter as nitrogen, respectively. Nitrate plus nitrite has been found to be higher in drain tiles because runoff can readily transport nitrates that were applied as fertilizer into the subsurface before it can be processed by vegetation on the surface and nitrates can be leached from the soil as the water travels into the drain tiles. Nutrient concentrations generally were greater at site D1 compared to site D3 at Dazey farm. Higher concentrations at site D1, which is upstream and closer to potential sources of nutrients compared to lower concentrations at site D3, which is farther downstream and receives more runoff, indicates that dilution may be the reason concentrations decrease downstream.

Suspended-sediment concentrations decreased from upstream at site U1 downstream to site U3 at Underwood farm. Higher concentrations at site U1 are likely from soil that is exposed and loosened in the feedlot and is readily transported during runoff. At Embden farm, suspended sediment was measured only at site E1, and concentrations were the lowest at E1 among all the sites at all three farms. Suspended-sediment concentrations at the Dazey farm were the highest concentrations among the sites at all three farms and decreased from upstream at site D1 downstream to site D3.

Annual loads for chloride at all three Underwood sites were the greatest in 2011 and the least in 2012, which coincided with years of the greatest and least annual flow volume, respectively. Total ammonia had a similar pattern at sites U1 and U3; annual loads were the greatest in 2011 and the least in 2012. Nitrate plus nitrite loads displayed a different pattern than chloride and total ammonia, indicating possible different sources. The greatest nitrate plus nitrite loads were in 2010 at site U1 and in 2014 at sites U2 and U3. Annual nitrate plus nitrite loads also were consistently greater at sites U2 and U3 when compared to site U1 except for 2012. Chloride, total ammonia, total phosphorus, and suspended sediment were transported past site U1 mostly in March and the least from July through October. Monthly nitrate plus nitrite loads had a different pattern than the other constituents, indicating other possible sources such as fertilizer application in the surrounding cropland. Although the greatest loads at site U1 were in March, a large amount of nitrate plus nitrite was transported past sites U2 and U3 in March through June, and the greatest monthly loads were in June for site U2 and March for site U3. Depending on the constituent, annual yields were between 2 and 1,000 times greater at site U1, compared to sites U2 and U3, mainly because of a combination of higher measured concentrations and smaller contributing drainage area for site U1.

Annual loads for Embden farm were considerably greater at sites E2 and E3 compared to site E1. Annual loads for chloride at all three sites were the greatest in 2010 and 2011 and the least in 2012 or 2013, which coincided with years of the greatest and least annual flow volume, respectively. Total ammonia loads were greatest at site E3 most years except for 2011 and 2013, when site E2 had the greatest load among the three sites, and 2012, when site E1 had the greatest load. Annual total ammonia loads ranged from less than 1 to 3 pounds per year as nitrogen at site E1, from less than 1 to 79 pounds per year as nitrogen at site E2, and from less than 1 to 89 pounds per year as nitrogen at site E3. Nitrate plus nitrite loads were greatest at sites E2 and E3, and the greatest annual loads were in 2010 and 2011. Some of the patterns in annual load could be explained by crop management and fertilizer application in the fields that contribute runoff to the three sites. Annual yields for all constituents were substantially greater at sites E2 and E3 compared to site E1, mainly because of a combination of higher flow volumes and small contributing drainage areas at sites E2 and E3 compared to site E1.

The greatest annual loads at Dazey farm site D3 for chloride, nitrate plus nitrite, and suspended sediment were in 2010 and 2011, and zero loads were estimated for 2012 because no flow was measured at the site. Mean monthly loads were greatest for most of the constituents in March and April at sites D1 and D3, on average, except for suspended sediment that had the greatest monthly loads in May. At site D3, the greatest annual chloride and nitrate plus nitrite yields were in 2011, the greatest total ammonia and total phosphorus yields were in 2015, and greatest suspended-sediment yields were in 2010. At site D1, the greatest annual yields for all constituents were in 2014.

To mitigate runoff and water-quality effects of their operations, various agricultural conservation practices were implemented by the producers, before and during the Discovery Farms monitoring. Conservation practices implemented by the producers likely caused a reduction in nutrient loss, but high variability in other factors such as precipitation and runoff makes it difficult to quantify the reduction. Even though it was difficult to quantify the effects of the agricultural conservation practices implemented at the farms, the data collected from the Discovery Farms program provided a better understanding of some of the variables that affect runoff and water quality, and on the basis of this information, producers can modify their agricultural practices to more effectively protect downstream water quality.

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Appendix 1. Additional Runoff and Water-Quality Data for Monitoring Sites at Three Discovery Farms in North Dakota, 2008–16

Table 1–1. Summary of additional water-quality constituent concentrations for selected samples collected at Discovery Farm monitoring sites, North Dakota, 2008–16.

[Number in parentheses is the U.S. Geological Survey National Water Information System parameter code; mg/L, milligram per liter; CaCO₃, calcium carbonate; SiO₂, silica; µg/L, microgram per liter; <, less than]

Site	Number of samples	Calcium, in mg/L	Magne- sium, in mg/L	Potas- sium, in mg/L	Sodium, in mg/L	Acid neutralizing capacity, in mg/L as CaCO ₃	Fluoride, in mg/L	Silica, in mg/L as SiO ₂	Sulfate, in mg/L	Iron, filtered, in µg/L	Man- ganese, filtered, in µg/L
		(00915)	(00925)	(00935)	(00930)	(90410)	(00950)	(00955)	(00945)	(01046)	(01056)
U1	Number of samples	10	10	10	10	20	11	10	20	10	10
	Minimum	42	50	455	65	265	0.29	23	241	566	95
	Maximum	88	151	931	153	947	0.47	41	932	2,480	538
	Median	55	80	631	97	478	0.35	32	596	1,545	313
	Mean	64	91	664	111	514	0.38	32	546	1,517	316
U3	Number of samples	20	20	20	20	21	21	20	21	20	20
	Minimum	19	12	21	7	46	0.20	4	27	<50	<10
	Maximum	201	156	264	96	553	0.45	30	727	520	163
	Median	185	132	140	74	436	0.23	23	643	57	15
	Mean	159	116	140	67	403	0.24	22	542	116	40
E3	Number of samples	17	17	17	17	53	17	17	53	17	17
	Minimum	90	36	1	6	199	0.41	23	4	<50	<10
	Maximum	103	52	2	29	370	0.88	31	150	<50	<10
	Median	96	49	2	22	337	0.61	24	48	<50	<10
	Mean	96	47	2	20	320	0.61	25	50	<50	<10
D3	Number of samples	14	14	14	14	15	15	14	15	14	14
	Minimum	34	16	14	55	133	0.16	16	129	<50	11
	Maximum	224	104	45	304	506	0.54	34	992	378	1,160
	Median	89	45	25	132	211	0.29	26	343	60	156
	Mean	98	48	25	138	246	0.29	25	427	120	269

Table 1–2. Quality assurance data collected at Discovery Farm monitoring sites, North Dakota, 2008–16.

[µS/cm at 25 °C, microsiemen per centimeter at 25 degrees Celsius; mg/L, milligram per liter; N, nitrogen; P, phosphorus, <, less than; --, not available]

Site	Date	Specific conductance, laboratory, in µS/cm at 25 °C	Suspended solids, in mg/L	Chloride, in mg/L	Dissolved (filtered) ammonia, in mg/L as N	Total (unfiltered) ammonia, in mg/L as N	Dissolved (filtered) nitrate plus nitrite, in mg/L as N	Total nitrate plus nitrite (unfiltered), in mg/L as N	Dissolved (filtered) phosphorus, in mg/L as P	Total (unfiltered) phosphorus, in mg/L as P	Total dissolved (filtered) nitrogen, in mg/L as N	Total (unfiltered) nitrogen, in mg/L as N	Suspended-sediment, in mg/L
Field blanks													
U1	5/18/2011	26	6	3	<0.03	<0.03	0.07	0.07	0.01	0.024	0.1	0.2	--
U2	5/18/2011	24	<5	3	0.04	0.04	0.07	0.07	0.04	0.041	0.3	0.4	--
U3	5/18/2011	22	<5	3	<0.03	<0.03	0.06	0.06	0.01	0.007	0.1	0.1	--
E1	4/7/2016	4	11	<1	0.09	<0.03	0.03	0.03	0.02	0.020	0.1	0.1	--
Replicates													
U1	6/3/2008	4,500	42	519	--	4.3	--	4.9	--	25	--	80	653
	6/3/2008	4,500	43	523	--	4.2	--	4.9	--	25	--	83	480
U1	3/17/2009	1,680	54	66	--	42	--	0.78	--	14	--	147	293
	3/17/2009	1,700	52	62	--	43.8	--	0.77	--	17	--	149	285
D1	3/19/2009	361	10	7	--	8.5	--	<0.03	--	3.1	--	22	26
	3/19/2009	356	6	7	--	8.3	--	0.65	--	2.7	--	21	13
E1	3/24/2009	91	7	2	--	0.39	--	0.45	--	0.28	--	1.7	--
	3/24/2009	91	6	<6	--	0.38	--	0.41	--	0.28	--	1.6	--
E2	3/24/2009	168	7	4	--	0.30	--	1.7	--	0.23	--	2.8	--
	3/24/2009	168	<5	4	--	0.31	--	1.7	--	0.23	--	2.9	--
E2	4/21/2009	837	<5	24	--	<0.03	--	17	--	0.02	--	17	--
	4/21/2009	837	<5	24	--	<0.03	--	18	--	0.02	--	17	--
D3	4/21/2009	1,210	243	46	--	0.12	--	1.2	--	0.58	--	2.9	--
	4/21/2009	1,210	230	48	--	0.16	--	1.2	--	0.58	--	2.9	--
E3	4/21/2009	1,070	<5	31	--	<0.03	--	12	--	0.02	--	12	--
	4/21/2009	1,070	<5	31	--	<0.03	--	12	--	0.02	--	12	--
U1	4/22/2009	409	145	12	--	9.4	--	0.66	--	4.2	--	18	--
	4/22/2009	409	147	13	--	9.5	--	0.76	--	4.2	--	18	--
U2	4/22/2009	568	37	21	--	9.0	--	0.16	--	5.2	--	16	--
	4/22/2009	567	35	21	--	9.4	--	0.11	--	5.3	--	16	--
U3	4/22/2009	648	<5	25	--	4.6	--	0.12	--	4.1	--	13	--
	4/22/2009	648	<5	25	--	4.5	--	0.10	--	4.0	--	12	--

Table 1–2. Quality assurance data collected at Discovery Farm monitoring sites, North Dakota, 2008–16.—Continued

[μS/cm at 25 °C, microsiemen per centimeter at 25 degrees Celsius; mg/L, milligram per liter; N, nitrogen; P, phosphorus, <, less than; --, not available]

Site	Date	Specific conductance, laboratory, in μS/cm at 25 °C	Suspended solids, in mg/L	Chloride, in mg/L	Dissolved (filtered) ammonia, in mg/L as N	Total (unfiltered) ammonia, in mg/L as N	Dissolved (filtered) nitrate plus nitrite, in mg/L as N	Total nitrate plus nitrite (unfiltered), in mg/L as N	Dissolved (filtered) phosphorus, in mg/L as P	Total (unfiltered) phosphorus, in mg/L as P	Total dissolved (filtered) nitrogen, in mg/L as N	Total (unfiltered) nitrogen, in mg/L as N	Suspended-sediment, in mg/L
Replicates—Continued													
E2	10/2/2009	847	23	21	--	0.09	--	14	--	0.22	--	15	--
	10/2/2009	852	6	21	--	<0.03	--	16	--	0.15	--	17	--
U1	3/20/2010	1,140	152	31	--	30	--	0.57	--	14	--	45	301
	3/20/2010	1,140	199	31	--	31	--	0.82	--	15	--	48	302
U2	3/20/2010	255	<5	5	--	1.1	--	3.1	--	1.9	--	7.1	9
	3/20/2010	254	6	5	--	1.1	--	3.0	--	1.8	--	8.6	10
U3	3/20/2010	316	7	7	2.9	3.0	2.4	2.4	1.9	2.2	9.1	9.9	--
	3/20/2010	316	7	7	3.0	3.0	2.4	2.4	2.0	2.2	9.4	10	--
E1	3/22/2010	216	<5	4	<0.03	<0.03	0.42	0.43	0.25	0.26	1.6	1.3	2
	3/22/2010	215	<5	4	<0.03	<0.03	0.43	0.43	0.26	0.26	1.5	1.4	1
E2	3/22/2010	707	<5	17	<0.03	<0.03	11	11	0.05	0.07	12	12	--
	3/22/2010	712	<5	18	<0.03	<0.03	11	12	0.06	0.06	11	12	--
E3	3/22/2010	922	<5	21	<0.03	<0.03	9.4	9.7	0.03	0.03	10	10	--
	3/22/2010	922	<5	21	<0.03	<0.03	8.9	9.4	0.03	0.03	9.7	10	--
D3	3/23/2010	608	18	15	0.06	0.08	1.1	1.2	0.40	0.48	2.2	2.3	19
	3/23/2010	605	20	15	0.06	0.09	1.1	1.2	0.41	0.48	2.1	2.3	20
E2	5/4/2010	805	<5	20	<0.03	<0.03	16	17	<0.01	<0.01	16	16	--
	5/4/2010	804	<5	20	<0.03	<0.03	16	16	<0.01	<0.01	16	16	--
E3	5/4/2010	979	<5	22	<0.03	<0.03	11	12	<0.01	<0.01	12	12	--
	5/4/2010	979	<5	22	<0.03	<0.03	12	12	<0.01	<0.01	12	12	--
U1	3/21/2011	4,520	55	152	--	192	--	0.23	--	20	--	344	--
	3/21/2011	4,510	38	159	--	191	--	0.25	--	20	--	350	--
U2	3/21/2011	1,010	21	50	19	19	0.04	0.45	3.9	4.3	35	37	--
	3/21/2011	1,010	17	50	19	20	0.04	0.43	3.9	4.9	34	39	--
D1	4/13/2011	576	50	5	0.48	0.59	0.38	0.44	0.41	0.44	1.6	1.9	--
	4/13/2011	575	59	5	0.55	0.58	0.42	0.47	0.44	0.47	1.9	1.7	21
E1	4/13/2011	314	<5	6	<0.03	<0.03	<0.03	<0.03	0.09	0.11	1.4	1.4	--

Table 1–2. Quality assurance data collected at Discovery Farm monitoring sites, North Dakota, 2008–16.—Continued

[μS/cm at 25 °C, microsiemen per centimeter at 25 degrees Celsius; mg/L, milligram per liter; N, nitrogen; P, phosphorus, <, less than; --, not available]

Site	Date	Specific conductance, laboratory, in μS/cm at 25 °C	Suspended solids, in mg/L	Chloride, in mg/L	Dissolved (filtered) ammonia, in mg/L as N	Total (unfiltered) ammonia, in mg/L as N	Dissolved (filtered) nitrate plus nitrite, in mg/L as N	Total nitrate plus nitrite (unfiltered), in mg/L as N	Dissolved (filtered) phosphorus, in mg/L as P	Total (unfiltered) phosphorus, in mg/L as P	Total dissolved (filtered) nitrogen, in mg/L as N	Total (unfiltered) nitrogen, in mg/L as N	Suspended-sediment, in mg/L
Replicates—Continued													
D2	4/13/2011	311	<5	6	<0.03	<0.03	<0.03	<0.03	0.07	0.09	1.2	1.3	--
	4/13/2011	996	100	24	0.52	0.53	2.56	2.7	0.55	0.63	4.0	3.8	--
	4/13/2011	988	300	24	0.54	0.51	2.7	2.9	0.54	0.66	4.1	4.0	--
E2	4/13/2011	672	<5	12	<0.03	<0.03	1.0	1.0	<0.01	<0.01	10	10	--
	4/13/2011	674	<5	12	<0.03	<0.03	0.96	0.95	<0.01	<0.01	9.8	9.7	--
	4/13/2011	1,160	43	36	0.23	0.23	5.0	5.1	0.95	1.0	6.0	5.9	49
D3	4/13/2011	1,160	32	35	0.26	0.22	4.9	5.1	1.1	1.1	6.1	5.7	39
	4/13/2011	825	<5	11	<0.03	<0.03	7.5	7.3	0.16	0.16	7.1	7.1	--
	4/13/2011	825	<5	11	<0.03	<0.03	7.0	6.3	<0.01	<0.01	7.7	6.8	--
E3	4/18/2012	768	<5	17	0.03	<0.03	7.5	7.8	0.07	0.07	7.6	7.9	--
	4/18/2012	769	<5	16	<0.03	<0.03	7.7	7.8	0.05	0.07	7.9	8.2	--
	7/25/2012	154	11	3	0.68	0.70	0.22	0.24	2.1	2.2	2.9	2.8	20
U2	7/25/2012	162	11	3	0.75	0.76	0.26	0.26	2.2	2.2	2.9	2.8	33
	4/4/2013	392	43	5	0.74	0.79	2.8	2.8	0.98	1.1	5.2	5.2	16
	4/4/2013	387	5	5	0.72	0.77	2.8	2.8	0.96	1.1	5.2	5.3	18
U3	4/4/2013	392	<5	6	0.47	0.47	2.9	3.0	1.4	1.5	5.0	5.1	23
	4/4/2013	392	<5	6	0.47	0.43	2.8	3.2	1.4	1.6	5.1	5.3	27
	4/26/2013	312	<5	7	0.20	0.22	0.51	0.51	0.66	0.67	1.6	1.6	3
E3	4/26/2013	316	<5	7	0.21	0.21	0.50	0.50	0.65	0.66	1.5	1.5	3
	4/30/2013	670	<5	15	<0.03	<0.03	4.1	4.3	0.16	0.16	4.9	4.8	--
	4/30/2013	669	<5	15	<0.03	<0.03	4.2	4.3	0.17	0.16	5.0	4.9	--
E1	3/11/2014	268	12	17	1.9	2.0	2.0	2.1	1.5	1.6	7.5	8.3	15
	3/11/2014	279	11	18	2.1	2.2	2.0	2.1	1.6	1.8	7.9	9.2	16
	8/19/2014	790	<5	18	<0.03	<0.03	6.5	6.4	<0.20	<0.20	6.8	6.9	--
E3	8/19/2014	790	<5	18	<0.03	<0.03	6.5	6.5	<0.20	<0.20	6.8	6.9	--
	4/7/2016	807	153	17	0.08	<0.03	8.9	8.8	<0.20	0.19	9.1	9.2	--
	4/7/2016	809	42	17	<0.03	<0.03	8.8	8.8	<0.20	<0.20	9.3	9.1	--

Table 1–3. Monthly loads for monitoring sites at Underwood farm, North Dakota, 2008–15.

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Monthly load, in pounds per month				
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	Suspended sediment
Site U1							
2008	June	0.7	463	7	9	54	1,039
	July	0.0	3	0	0	0	10
	August	0.1	10	0	1	1	47
	September	0.0	0	0	0	0	0
	October	0.0	0	0	0	0	0
2009	March	4.1	864	1,135	4	131	4,239
	April	18	1,088	1,355	16	243	8,994
	May	3	273	25	10	42	4,916
	June	0.4	234	3	2	3	491
	July	0.3	98	1	2	6	333
	August	0.0	0	0	0	0	0
	September	0.0	0	0	0	0	0
	October	0.0	0	0	0	0	0
2010	March	15	5,535	2,898	35	932	15,276
	April	1	165	95	1	40	1,889
	May	1	300	11	8	36	7,720
	June	2	391	13	25	53	6,857
	July	0.1	13	7	1	2	273
	August	0.4	78	58	4	12	1,189
	September	1	249	196	12	37	3,461
	October	0.0	0	0	0	0	0
2011	March	20	8,335	9,302	17	1,067	32,210
	April	13	3,989	1,835	3	418	18,001
	May	4.0	2,101	169	1	130	7,057
	June	2	923	30	13	83	3,467
	July	2	562	14	21	54	6,027
	August	0.6	139	3	5	9	2,398
	September	0.2	48	1	2	4	650
	October	0.0	0	0	0	0	0
2012	March	1	589	26	43	46	5,744
	April	0.4	433	7	5	20	825
	May	0.2	226	3	2	10	366
	June	0.2	159	2	2	6	129
	July	0.4	334	5	5	14	95
	August	0.0	0	0	0	0	0
	September	0.0	0	0	0	0	0
	October	0.1	63	3	1	4	18
	November	0.1	62	3	1	4	18

Table 1–3. Monthly loads for monitoring sites at Underwood farm, North Dakota, 2008–15.—Continued

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Monthly load, in pounds per month				
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	Suspended sediment
Site U1—Continued							
2013	January	0.0	29	2	0	2	47
	February	1.0	858	80	4	69	1,657
	March	2	2,004	199	7	166	4,123
	April	2	1,876	201	5	163	4,173
	May	2	1,736	198	1	181	5,099
	June	3	1,497	190	3	229	8,575
	July	0.0	15	1	0	1	65
	August	0.0	21	2	0	2	56
	September	0.4	157	19	2	16	170
	October	2	775	122	12	88	1,276
2014	March	2	182	159	7	66	7,502
	April	2	927	345	13	115	4,232
	May	2	914	202	10	116	3,589
	June	3	812	56	8	193	6,538
	July	0.1	79	2	0	6	15
	August	1	925	17	10	70	494
	September	0.1	57	1	0	6	6
	October	0.0	0	0	0	0	0
2015	January	0.0	8	4	0	1	4
	February	0.0	7	3	0	1	4
	March	7	3,172	918	54	406	1,298
	April	0.0	23	4	0	2	8
	May	0.8	735	12	4	41	1,049
	June	0.4	218	3	0	16	500
	July	0.9	952	15	1	37	199
	August	0.0	0	0	0	0	0
	September	0.1	67	1	0	3	6
	October	0.0	0	0	0	0	0
Site U2							
2008	June	4	508	7	33	66	6,776
	July	0	0	0	0	0	0
	August	0	0	0	0	0	0
	September	0	0	0	0	0	0
	October	0	0	0	0	0	0

Table 1–3. Monthly loads for monitoring sites at Underwood farm, North Dakota, 2008–15.—Continued

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Monthly load, in pounds per month				
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	Suspended sediment
Site U2—Continued							
2009	March	57	1,976	2,368	132	370	9,376
	April	27	444	240	20	109	1,553
	May	2	297	22	25	37	1,584
	June	0.3	104	1	1	3	32
	July	0.2	66	0	6	4	172
	August	0	0	0	0	0	0
	September	0	0	0	0	0	0
	October	0	0	0	0	0	0
2010	March	47	652	86	150	167	2,897
	April	2	133	9	4	10	120
	May	2	391	7	21	33	1,979
	June	4	537	12	60	53	8,444
	July	0	0	0	0	0	0
	August	0	0	0	0	0	0
	September	0	0	0	0	0	0
	October	0	0	0	0	0	0
2011	March	16	2,191	984	18	214	2,493
	April	47	2,108	1,059	165	266	5,324
	May	5	545	40	30	53	677
	June	6	1,155	25	10	60	1,023
	July	5	352	5	39	33	5,217
	August	1	67	0	0	8	400
	September	0	1	0	0	0	6
	October	0	0	0	0	0	0
2012	March	0.1	13	1	1	2	4
	April	0.5	373	3	6	12	325
	May	0.1	40	0	0	1	4
	June	0	0	0	0	0	0
	July	0.1	28	0	0	0	4
	August	0	0	0	0	0	0
	September	0	0	0	0	0	0
	October	0	0	0	0	0	0
	November	0	0	0	0	0	0

Table 1–3. Monthly loads for monitoring sites at Underwood farm, North Dakota, 2008–15.—Continued

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Monthly load, in pounds per month				
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	Suspended sediment
Site U2—Continued							
2013	January	0	0	0	0	0	0
	February	0.2	13	0	2	1	11
	March	1	37	2	7	3	48
	April	1	21	3	11	4	62
	May	3	1,481	87	7	118	1,598
	June	4	1,367	107	1	178	2,087
	July	0	0	0	0	0	0
	August	0	0	0	0	0	0
	September	0	0	0	0	0	0
	October	4	684	72	12	104	1,089
2014	March	7	87	64	58	53	302
	April	10	348	194	74	97	1,718
	May	5	1,249	128	55	105	897
	June	34	3,857	239	432	978	12,248
	July	1	8	0	1	2	16
	August	2	16	0	2	3	34
	September	5	50	1	6	10	103
	October	0	0	0	0	0	0
2015	January	0	0	0	0	0	0
	February	0	0	0	0	0	0
	March	4	241	25	55	90	249
	April	0	0	0	0	0	0
	May	1	724	8	18	30	89
	June	1	252	3	7	10	48
	July	6	91	1	22	18	643
	August	0	0	0	0	0	0
	September	0	0	0	0	0	0
	October	0	0	0	0	0	0
Site U3							
2009	March	60	490	123	79	78	1,867
	April	38	859	125	20	160	967
	May	2	329	8	21	32	802
	June	0.1	11	0	1	1	39
	July	0	2	0	0	0	7
	August	0	0	0	0	0	0
	September	0	0	0	0	0	0
	October	0	0	0	0	0	0

Table 1–3. Monthly loads for monitoring sites at Underwood farm, North Dakota, 2008–15.—Continued

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Monthly load, in pounds per month				
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	Suspended sediment
Site U3—Continued							
2010	March	66	1,165	131	220	309	3,169
	April	6	1,119	3	21	27	418
	May	5	950	3	40	46	2,732
	June	8	1,663	3	68	63	638
	July	0	1	0	0	0	0
	August	0	0	0	0	0	0
	September	0.3	64	1	1	2	83
	October	0	0	0	0	0	0
2011	March	14	2,483	231	6	147	12,000
	April	62	4,802	484	66	350	11,517
	May	10	1,383	31	25	92	576
	June	10	760	4	17	76	337
	July	7	325	1	5	36	504
	August	2	138	0	2	12	37
	September	0	0	0	0	0	0
	October	0	0	0	0	0	0
2012	March	0.1	19	0	3	1	6
	April	1	289	0	5	2	133
	May	0.2	78	0	0	0	11
	June	0	0	0	0	0	0
	July	0	0	0	0	0	0
	August	0	0	0	0	0	0
	September	0	0	0	0	0	0
	October	0	0	0	0	0	0
	November	0	0	0	0	0	0
	2013	January	0	0	0	0	0
February		0	0	0	0	0	0
March		0	0	0	0	0	0
April		1	20	0	7	3	60
May		4	1,380	18	10	75	1,384
June		6	1,474	25	8	114	565
July		0	0	0	0	0	0
August		0	0	0	0	0	0
September		0	0	0	0	0	0
October		5	382	96	138	70	572

Table 1–3. Monthly loads for monitoring sites at Underwood farm, North Dakota, 2008–15.—Continued

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Monthly load, in pounds per month				Suspended sediment
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	
Site U3—Continued							
2014	March	14	493	127	100	168	681
	April	19	815	89	161	133	3,792
	May	5	1,176	18	52	82	1,097
	June	37	2,306	20	308	240	6,284
	July	1	34	0	2	4	30
	August	1	343	0	5	8	54
	September	0	0	0	0	0	0
	October	0	0	0	0	0	0
2015	January	0	0	0	0	0	0
	February	0	0	0	0	0	0
	March	10	443	38	99	211	410
	April	0	4	0	0	0	1
	May	3	1,041	1	20	24	88
	June	1	351	1	3	9	143
	July	21	326	21	110	131	2,916
	August	0	0	0	0	0	0
	September	0	0	0	0	0	0
	October	0	0	0	0	0	0

Table 1–4. Monthly loads for monitoring sites at Embden farm, North Dakota, 2009–16.

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Monthly load, in pounds per month			
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P
Site E1						
2009	April	1	3	0.2	0.3	0.6
	May	0	0	0	0	0
	June	0	0.2	0	0	0
	July	0.2	3	0	0	0.1
	August	0.2	5	0	0	0.1
	September	0.1	6	0	0.1	0.1
	October	0.2	8	0	0.1	0.2
	November	0	0	0	0	0
	December	0	0	0	0	0
2010	January	0	0	0	0	0
	February	0	0	0	0	0
	March	4	163	0.6	5	3
	April	0	0.3	0	0	0
	May	0.2	2	0	0.3	0.1
	June	0.3	2	0	0.4	0.1
	July	0.4	3	0.1	0.5	0.1
	August	0.2	1	0	0.2	0.0
	September	2	20	0.3	3	0.8
	October	0	0.1	0	0	0
	November	0	0	0	0	0
	December	0	0	0	0	0
2011	January	0	0	0	0	0
	February	0	0	0	0	0
	March	8	75	0.6	9	4
	April	5	49	0.4	6	2
	May	0	0	0	0	0
	June	0.1	0.5	0	0	0
	July	0	0	0	0	0
	August	0	0.1	0	0	0
	September	0	0	0	0	0
	October	0	0	0	0	0
	November	0	0	0	0	0
	December	0	0	0	0	0

Table 1–4. Monthly loads for monitoring sites at Embden farm, North Dakota, 2009–16.—Continued

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Monthly load, in pounds per month			
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P
Site E1—Continued						
2012	January	0	0	0	0	0
	February	0	0	0	0	0
	March	0.4	4	1	0.4	2
	April	0	0.4	0.1	0	0.2
	May	0	0.3	0.1	0	0.2
	June	0	0.2	0.1	0	0.1
	July	0.1	0.6	0.1	0	0.4
	August	0.1	0.9	0.2	0	0.6
	September	0.1	0.7	0.2	0	0.5
	October	0.1	0.6	0.1	0	0.4
	November	0.1	0.6	0.1	0	0.4
	December	0	0	0	0	0
2013	January	0	0	0	0	0
	February	0	0	0	0	0
	March	0	0	0	0	0
	April	0	0	0	0	0
	May	0	0.1	0	0	0
	June	0	0.1	0.1	0	0.1
	July	0	0	0	0	0
	August	0	0	0	0	0
	September	0	0	0	0	0
	October	0	0	0	0	0
	November	0	0	0	0	0
	December	0	0	0	0	0
2014	January	0	0	0	0	0
	February	0	0	0	0	0
	March	0.2	11	1	1	1
	April	0.1	0.7	0	0	0.1
	May	0	0	0	0	0
	June	0	0	0	0	0
	July	0	0	0	0	0
	August	0.3	2	0.2	0	0.4
	September	0.2	2	0.2	0	0.4
	October	0	0	0	0	0
	November	0	0	0	0	0
	December	0	0	0	0	0

Table 1–4. Monthly loads for monitoring sites at Embden farm, North Dakota, 2009–16.—Continued

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Monthly load, in pounds per month			
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P
Site E1—Continued						
2015	January	0	0	0	0	0
	February	0	0	0	0	0
	March	0.1	1	0.5	0.1	0.4
	April	0	0	0	0	0
	May	0.1	2	0.8	0.1	0.7
	June	0.1	1	0.5	0.1	0.4
	July	0	0.4	0.1	0	0.1
	August	0	0.7	0.3	0	0.2
	September	0	0.5	0.2	0	0.2
	October	0.1	2	0.8	0.1	0.7
	November	0	0	0	0	0
	December	0	0	0	0	0
2016	January	0	0	0	0	0
	February	0	0	0	0	0
	March	0	0	0	0	0
	April	0	0	0	0	0
	May	0	0	0	0	0
	June	0	0	0	0	0
	July	0	0	0	0	0
	August	0	0	0	0	0
	September	0	0	0	0	0
Site E2						
2009	June	2	93	0.1	74	0.5
	July	2	102	0.1	82	0.6
	August	0.1	8	0.0	7	0.1
	September	0	3	0.0	2	0.0
	October	6	400	3.7	229	0.5
	November	5	358	1.2	190	0.4
	December	1	111	0.5	55	0.1

Table 1–4. Monthly loads for monitoring sites at Embden farm, North Dakota, 2009–16.—Continued

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Monthly load, in pounds per month			
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P
Site E2—Continued						
2010	January	2	159	0.8	71	0.2
	February	1	111	0.6	46	0.2
	March	41	2,096	21	1,095	6
	April	14	728	14	562	0.3
	May	18	929	9	730	0.3
	June	13	625	7	479	0.2
	July	14	445	7	465	0.6
	August	8	240	4	254	0.5
	September	20	613	8	623	2
	October	13	370	4	364	2
	November	9	247	3	236	1
	December	5	134	1	122	0.9
2011	January	4	107	0.8	94	0.9
	February	4	107	0.6	89	1
	March	16	407	2	318	5
	April	62	1,847	5	1,139	15
	May	17	567	6	533	7
	June	28	937	2	1,024	9
	July	5	169	0.4	207	0.8
	August	0.2	6	0	6	0
	September	0	0	0	0.0	0
	October	0	0.3	0	0.3	0
	November	0	0	0	0	0
	December	0	0	0	0	0
2012	January	0	0	0	0	0
	February	0	0	0	0	0
	March	0.4	14	0	18	0
	April	0	0	0	0	0
	May	0	0.1	0	0.2	0
	June	0	0.5	0	0.7	0
	July	0	1	0	2	0
	August	0	0	0	0	0
	September	0	0	0	0	0
	October	0	0	0	0	0
	November	0	0	0	0	0
	December	0	0	0	0	0

Table 1–4. Monthly loads for monitoring sites at Embden farm, North Dakota, 2009–16.—Continued

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Monthly load, in pounds per month			
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P
Site E2—Continued						
2013	January	0	0	0	0	0
	February	0	0	0	0	0
	March	0	0	0	0	0
	April	1	18	3	12	3
	May	0	0.3	0.1	0.1	0.1
	June	0.6	7	2	2	2
	July	0	0.4	0.1	0.1	0.1
	August	0	0.0	0.0	0.0	0.0
	September	0	0.3	0.1	0.1	0.1
	October	0.2	2	0.3	0.3	0.4
	November	0	0.2	0	0	0.1
	December	0	0	0	0	0
2014	January	0	0	0	0	0
	February	0	0	0	0	0
	March	0	0	0	0	0
	April	1	9	0.6	2	2
	May	0.1	3	0.1	0.9	0.1
	June	0.2	8	0.2	2	0.1
	July	0	1	0	0.2	0
	August	0	0.4	0.1	0	0.1
	September	1	18	2	9	2
	October	0	0	0	0	0
	November	0	0	0	0	0
	December	0	0	0	0	0
2015	January	0	0	0	0	0
	February	0	0	0	0	0
	March	0.8	15	4	1	4
	April	0	0	0	0	0
	May	0.3	11	0.3	4	0.2
	June	0.3	10	0.3	2	0.2
	July	0	0.6	0	0.1	0
	August	0	0	0	0	0
	September	0	0	0	0	0
	October	0	0.2	0	0	0
	November	0	0	0	0	0
	December	0	0	0	0	0

Table 1–4. Monthly loads for monitoring sites at Embden farm, North Dakota, 2009–16.—Continued

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Monthly load, in pounds per month			
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P
Site E2—Continued						
2016	January	0	0	0	0	0
	February	0	0	0	0	0
	March	0	0	0	0	0
	April	0	0	0	0	0
	May	0	0	0	0	0
	June	0	0	0	0	0
	July	0	0	0	0	0
	August	0	0	0	0	0
	September	0	0	0	0	0
Site E3						
2009	April	21	1,685	2	632	2
	May	9	802	2	316	2
	June	7	630	5	240	2
	July	0.8	72	0.7	27	0.2
	August	0.1	6	0.1	2	0.0
	September	0	0.2	0.0	0.1	0.0
	October	6	488	3.3	171	0.3
	November	5	385	1.8	135	0.3
	December	1	90	0.4	31	0.1
2010	January	2	147	0.7	50	0.1
	February	1	108	0.5	36	0.1
	March	55	3,536	15	1,482	5
	April	13	771	11	381	0.2
	May	15	894	14	478	0.4
	June	13	655	12	368	0.7
	July	21	997	12	569	1
	August	9	425	5	246	0.6
	September	19	841	9	499	1
	October	13	541	5	326	0.8
	November	7	312	3	192	0.5
	December	4	151	1	95	0.3

Table 1–4. Monthly loads for monitoring sites at Embden farm, North Dakota, 2009–16.—Continued

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Monthly load, in pounds per month			
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P
Site E3—Continued						
2011	January	3	123	0.8	79	0.2
	February	3	124	0.6	82	0.2
	March	16	574	2	391	1.1
	April	65	2,126	5	1,373	9
	May	13	471	1	348	5
	June	26	905	2	655	11
	July	2	69	0.2	50	0.6
	August	2	84	0.2	65	0.7
	September	0	1	0	1	0
	October	0	0	0	0	0
	November	0	0	0	0	0
	December	0	0	0	0	0
2012	January	0	0	0	0	0
	February	0	0	0	0	0
	March	0.2	10	0	5	0.1
	April	1	61	0.1	31	0.3
	May	2	80	0.2	49	0.1
	June	2	59	0.1	40	0
	July	0	0	0	0	0
	August	0	0	0	0	0
	September	0	0	0	0	0
	October	0	0	0	0	0
	November	0	0	0	0	0
	December	0	0	0	0	0
2013	January	0	0	0	0	0
	February	0	0	0	0	0
	March	0	0	0	0	0
	April	0.9	31	0.1	7	0.4
	May	2	81	0.1	35	0.3
	June	13	713	1	547	7
	July	0.8	47	0.1	34	1
	August	0	0	0	0	0
	September	0	0	0	0	0
	October	0.5	29	0	11	0
	November	0.3	15	0	6	0
	December	0	0	0	0	0

Table 1–4. Monthly loads for monitoring sites at Embden farm, North Dakota, 2009–16.—Continued

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Monthly load, in pounds per month			
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P
Site E3—Continued						
2014	January	0	0	0	0	0
	February	0	0	0	0	0
	March	0	0	0	0	0
	April	0.8	15	0.1	11	0.1
	May	8	279	0.6	196	0.4
	June	11	504	8	344	5
	July	0.4	19	0.3	10	0.2
	August	3	129	0.4	71	0.3
	September	10	366	6	221	7
	October	0.4	22	0.2	10	0.1
	November	0.2	11	0	5	0
	December	0	1	0	0.5	0
2015	January	0	1	0	0.4	0
	February	0	0.0	0	0	0
	March	0	0.4	0	0.1	0
	April	0.2	8	0.1	3.0	0.1
	May	15	752	19	450	5
	June	11	568	2	353	0.9
	July	0.4	22	0	13	0
	August	0	0.1	0	0.1	0
	September	0	0	0	0.0	0
	October	0	1	0	0.6	0
	November	0	0.7	0	0.4	0
	December	0	0.1	0	0.1	0
2016	January	0	0	0	0	0
	February	0.5	26	0	13	0
	March	2	76	0.1	37	0.1
	April	3	141	0.3	90	0.5
	May	4	233	1	151	1
	June	5	280	1	212	0.3
	July	1	76	0.3	54	0.1
	August	0	0.3	0	0.2	0
	September	0	0.2	0	0.2	0

Table 1–5. Monthly loads for monitoring sites at Dazey farm, North Dakota, 2010–15.

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Load, in pounds per month				
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	Suspended sediment
Site D1							
2013	March	1	0	0	0	0	1
	April	23	0.6	0.1	0.3	0.2	23
	May	111	2	0.2	0.6	0.5	111
	June	19	0.2	0.0	0.0	0.0	19
	July	0.0	0.0	0.0	0.0	0.0	0.0
	August	0.0	0.0	0.0	0.0	0.0	0.0
	September	9	0.1	0.0	0.1	0.0	9.1
	October	34	0.5	0.0	0.3	0.1	34.4
2014	March	1,035	35.1	2.6	19.0	8.5	1,034.7
	April	1,626	92.2	1.2	29.8	12.3	1,625.9
	May	35	1.8	0.0	0.2	0.1	35.4
	June	383	5.8	0.2	1.6	1.1	382.7
	July	6	0.0	0.0	0.0	0.0	5.6
	August	299	2.2	0.2	2.5	1.1	298.7
	September	7	0.1	0.0	0.1	0.0	7.2
	October	0	0.0	0.0	0.0	0.0	0.0
2015	March	90	0.1	4.4	1.2	90.2	1,298.0
	April	0	0.0	0.0	0.0	0.0	7.8
	May	58	0.2	6.2	1.5	58.1	1,049.3
	June	33	0.2	6.9	1.6	33.4	500.1
	July	0	0.0	0.0	0.0	0.0	199.1
	August	0	0.0	0.0	0.0	0.0	0.0
	September	0	0.0	0.0	0.0	0.0	6.1
	October	0	0.0	0.0	0.0	0.0	0.0
Site D2							
2010	March	54	1,718	15	131	83	39,018
	April	0.6	95	0.2	1	0.5	321
	May	15	1,580	10	36	87	307,404
	June	4	577	3	13	6	749
	July	5	1,222	5	5	2	216
	August	2	265	4	27	0.7	240
	September	3	514	3	42	0.4	15
	October	1	445	0.5	6	0.1	7
	November	0.2	53	0	0.1	0.0	0.6

Table 1–5. Monthly loads for monitoring sites at Dazey farm, North Dakota, 2010–15.—Continued

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Load, in pounds per month				
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	Suspended sediment
Site D2—Continued							
2011	March	0	0	0	0.0	0.0	0.0
	April	43	4,462	25	630.3	130.1	5,717
	May	4	726	0.6	52.2	8.0	1,851
	June	6	884	1.9	44.7	15.9	2,445
	July	2	330	0.4	5.8	4.2	127
	August	1	302	0.1	0.6	0.8	385
	September	0.6	139	0	0.1	0.1	220
	October	0	0	0	0	0	0
2012	March	0	0	0	0	0	0
	April	0	0	0	0	0	0
	May	0	0	0	0	0	0
	June	0	0	0	0	0	0
	July	0	0	0	0	0	0
	August	0	0	0	0	0	0
	September	0	0	0	0	0	0
	October	0	0	0	0	0	0
2013	March	0	0	0	0	0	0
	April	12	748	6	20	20	167
	May	2	309	0.2	38	3	274
	June	0.5	88	0.1	4	0.5	168
	July	0	12	0	0	0	3
	August	0	2	0	0	0	1
	September	1	253	0.7	3	2	310
	October	4	772	2	13	7	1,131
2014	March	2	47	0.7	14	11	1,059
	April	9	179	4	50	37	5,315
	May	0.1	22	0	2	0.3	49
	June	0.5	60	0.2	0.9	0.8	673
	July	0	6	0	0.1	0.1	45
	August	0.1	33	0	0	0.1	14
	September	0.1	29	0	0	0.0	11
	October	0.3	71	0.1	0	0.1	27

Table 1–5. Monthly loads for monitoring sites at Dazey farm, North Dakota, 2010–15.—Continued

[N, nitrogen; P, phosphorus]

Year	Month	Flow volume, in acre-feet	Load, in pounds per month				Suspended sediment
			Chloride	Total (unfiltered) ammonia, as N	Total (unfiltered) nitrate plus nitrite, as N	Total (unfiltered) phosphorus, as P	
Site D2—Continued							
2015	March	24	3,283	158	61	207	4,828
	April	0.3	57	1.0	0.5	1	53
	May	0.6	83	0.9	1	2	2,709
	June	0.7	86	0.4	1	1	1,323
	July	0	3	0	0	0	17
	August	0	1	0	0	0	3
	September	0	2	0	0	0	1
	October	0	0	0	0	0	0

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