Helena Valley Non-Point Source Assessment
Ground Water Loading of Nutrients to Surface Water

Non-Point Source Nutrient Loading to Lake Helena

James Swierc, PG
Lewis & Clark Water Quality Protection District

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FINAL DRAFT

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Table of Contents

1.0 Introduction 1
2.0 Background 3
2.1 Helena Area Hydrogeology 3
2.2 Previous Nutrient Characterization Work 5
2.3 Existing Characterization Datasets 6
2.4 Helena Valley Subwatersheds 6
3.0 Project Overview 8
3.1 Assessment Strategies and Sampling Program Design 8
3.2 Project Components 9
4.0 Field Reconnaissance Sampling Program 11
5.0 Background/Recharge Water Quality 15
6.0 Drain Sampling Program 19
6.1 Overview of Sampling Results 21
6.2 Northeastern North Hills Subwatershed 24
6.2.1 D0 Ditch System 25
6.2.2 D1 Ditch System 33
6.2.3 North Lake Helena Drain Systems 42
6.2.3.1 D4 Ditch System 43
6.2.3.2 D5 Ditch System 45
6.2.3.3 Loading from D4 and D5 Drain Systems 47
6.3 Lower Silver Creek Subwatershed and D2 Ditch 48
6.3.1 Western D2 Ditch System 50
6.3.1.1 D2-1 and D2-2 Drain Systems 52
6.3.1.2 D2-3 Drain System 63
6.3.1.3 D2-4 Drain System 65
6.3.1.4 D2-5 Drain System 72
6.3.2 Northern D2 Ditch System (Ditch D2-2.3) 74
6.3.2.1 D2.2-1 and D2.2-2 Drain Systems 76
6.3.2.2 D2.2-3 Drain System 83
6.3.2.3 D2.2-4 Drain System 84
6.3.2.4 D2.2-5 Drain System 86
6.3.2.5 D2.2-6 Drain System 93
6.3.2.6 D2-6 Drain System 95

6.4 Lower Tenmile Creek Subwatershed and Southeast D2 Ditch (Ditch D2-1.1) 97
6.4.1 D2.1-1 Drain System 99
6.4.2 D2.1-2 Drain System 106
6.4.3 D2.1-3 Drain System 108
6.5 Lower Prickly Pear Creek Subwatershed 110
6.5.1 D3 Ditch System 111
6.5.1.1 D3-1 Drain System 113
6.5.1.2 D3-2 Drain System 119
6.5.1.3 D3-3 Drain System 126
6.5.1.4 D3-4 Drain System 128
6.5.2 D8 Ditch System 130
6.5.2.1 D8-1 Drain System 132
6.5.2.2 D8.1-1 Drain System 138
6.5.2.3 D8-2 Drain System 140
6.5.2.4 D8-3 Drain System 142
6.6 East Helena Valley Subwatershed 144
6.6.1 D6 Ditch System 145
6.6.2 D7 Ditch System 148
6.6.2.1 D7-1 Drain System 151
6.6.2.2 D7-2 Drain System 158
6.6.2.3 D7-3 Drain System 160
6.6.3 D9 Ditch System 162
6.7 Summary of Drain Loading 165
7.0 Ground Water Assessment 167
8.0 Surface Water Loading to Lake Helena 183
9.0 Discussion 189
10.0 References 191

List of Figures

Figure 1-1 – Study Location in the Helena Valley, Lewis and Clark County, Montana 2
Figure 1-2 – Irrigation System in the Helena Valley, and the Lake Helena Watershed 2

Figure 2-1 – Generalized Map of Ground Water Potentiometric Surface, Helena Valley 4
Figure 2-2 – Comparison of Monthly with Average Precipitation Totals during Study Period 5
Figure 2-3 – Estimated total Nitrogen (TN) and total Phosphorus (TP) Loading in Watershed 6
Figure 2-4 – Subwatersheds within the Helena Valley and Surrounding Area 7

Figure 3-1 – Comparison of Nitrate/Nitrite with Total Nitrogen in Helena Area Waters 10
Figure 3-2 – Comparison of Dissolved Orthophosphate with Total Phosphate in Area Waters 10

Figure 4-1 – Helena Valley Irrigation District Canal, Ditch and Drain Network 12

Figure 5-1 – Helena Valley Background Water Sampling Locations 18

Figure 6-1 – Drain Discharge Rates 19
Figure 6-2 – HVID Drain and other Helena Valley Water Monitoring Locations 20
Figure 6-3 – Northeastern North Hills Subwatershed 24
Figure 6-4 – D0 Ditch and Surrounding Features 25
Figure 6-5 – Photographs of Drain D0-1 Outlet 26
Figure 6-6 –Water Quality Nutrient Results for D0-1 Drain 28
Figure 6-7 – Discharge Rates and Nitrogen and Phosphorus Loading from D0-1 Drain 30
Figure 6-8 – Subwatershed Contributing Area for D0-1 Drain 31
Figure 6-9 – D1 Ditch and Surrounding Features 34
Figure 6-10 – Photographs of Drain D1-1 and D1-2 Outlets 35
Figure 6-11 –Water Quality Nutrient Results for D1-1 Drain 37
Figure 6-12 – Discharge Rates and Nitrogen and Phosphorus Loading from D1-1 Drain 39
Figure 6-13 – Subwatershed Contributing Area for D1-1 Drain 40
Figure 6-14 – Subwatershed Contributing Area for Drains North of Lake Helena 42
Figure 6-15 – D4 Ditch and Surrounding Features 43
Figure 6-16 – Drain D4-1 and LH-1 Discharge Points from Aerial Photographs 44
Figure 6-17 – D5 Ditch and Surrounding Features 45
Figure 6-18 – Drain D5-1 and LH-2 Discharge Points from Aerial Photographs 46
Figure 6-19 – Lower Silver Creek Subwatershed 48
Figure 6-20 – Layout of D2 Ditch System 49
Figure 6-21 – Western D2 Ditch Subwatershed Area 50
Figure 6-22 – Western D2 Ditch and Surrounding Features 51
Figure 6-23 – Photographs of Drain D2-1 and D2-2 outlets 52
Figure 6-24 – Water Quality Nutrient Results, D2-1 Drain 55
Figure 6-25 – Water Quality Nutrient Results, D2-2 Drain 57
Figure 6-26 – Discharge Rates and Nitrogen and Phosphorus Loading from D2-1 and D2-1 Drains 60
Figure 6-27 – Subwatershed Contributing Area for D2-1 and D2-2 Drains 61
Figure 6-28 – Photographs of Drain D2-3 Outlet 63
Figure 6-29 – Subwatershed Contributing Area for D2-3 Drain 64
Figure 6-30 – Photographs of Drain D2-4 outlet 65
Figure 6-31 – Water Quality Nutrient Results, D2-4 Drain 67
Figure 6-32 – Discharge Rates and Nitrogen and Phosphorus Loading from D2-4 Drain 69
Figure 6-33 – Subwatershed Contributing Area for D2-4 Drain 70
Figure 6-34 – Photographs of Drain D2-5 outlet 72
Figure 6-35 – Subwatershed Contributing Area for D2-5 Drain 73
Figure 6-36 – Northern D2 Ditch Subwatershed Area 74
Figure 6-37 – D2-2.3 Ditch, Lower D2 Ditch and Surrounding Features 75
Figure 6-38 – Photographs of Drain D2.2-1 and D2.2-2 outlets 76
Figure 6-39 – Water Quality Nutrient Results, D2.2-1 Drain 78
Figure 6-40 – Discharge Rates and Nitrogen and Phosphorus Loading from D2.2-1 Drain 80
Figure 6-41 – Subwatershed Contributing Area for D2.2-1 Drain 81
Figure 6-42 – Photographs of Drain D2.2-3 outlet 83
Figure 6-43 – Photographs of Drain D2.2-4 outlet 84
Figure 6-44 – Subwatershed Contributing Area for D2.2-4 Drain 85
Figure 6-45 – Photographs of Drain D2.2-5 outlet 86
Figure 6-46 – Water Quality Nutrient Results, D2.2-5 Drain 88
Figure 6-47 – Discharge Rates and Nitrogen and Phosphorus Loading from D2.2-5 Drain 90
Figure 6-48 – Subwatershed Contributing Area for D2.2-5 Drain 91

Figure 6-49 – Photographs of Drain D2.2-6 outlet 93
Figure 6-50 – Subwatershed Contributing Area for D2.2-6 Drain 94
Figure 6-51 – Photographs of Drain D2-6 outlet 95
Figure 6-52 – Subwatershed Contributing Area for D2-6 Drain 96
Figure 6-53 – Lower Tenmile Creek Subwatershed 97
Figure 6-54 – D2-1.1 Ditch, Lower D2 Ditch and Surrounding Features 98
Figure 6-55 – Photographs of Drain D2.1-1 Outlet 99
Figure 6-56 – Water Quality Nutrient Results, D2.1-1 Drain 101
Figure 6-57 – Discharge Rates and Nitrogen and Phosphorus Loading from D2.1-1 Drain 103
Figure 6-58 – Subwatershed Contributing Area for D2.1-1 Drain 104
Figure 6-59 – Photographs of Drain D2.1-2 Outlet 106
Figure 6-60 – Subwatershed Contributing Area for D2.1-2 Drain 107
Figure 6-61 – Photographs of Drain D2.1-3 Outlet 108
Figure 6-62 – Subwatershed Contributing Area for D2.1-3 Drain 109
Figure 6-63 – Lower Prickly Pear Creek Subwatershed in the Helena Valley 110
Figure 6-64 – D3 Ditch and Surrounding Features 111
Figure 6-65 – Photographs of Drain D3-1 outlet 113
Figure 6-66 – Water Quality Nutrient Results, D3-1 Drain 115
Figure 6-67 – Discharge Rates and Nitrogen and Phosphorus Loading from D3-1 Drain 117
Figure 6-68 – Subwatershed Contributing Area for D3-1 Drain 118
Figure 6-69 – Photographs of Drain D3-2 outlet 119
Figure 6-70 – Water Quality Nutrient Results, D3-2 Drain 121
Figure 6-71 – Discharge Rates and Nitrogen and Phosphorus Loading from D3-2 Drain 123
Figure 6-72 – Subwatershed Contributing Area for D3-2 Drain 124
Figure 6-73 – Photographs of Drain D3-3 outlet 126
Figure 6-74 – Subwatershed Contributing Area for D3-3 Drain 127
Figure 6-75 – Photographs of Drain D3-4 Outlets and Discharge to D-3 Ditch 128
Figure 6-76 – Subwatershed Contributing Area for D3-4 Drains 129
Figure 6-77 – D8 Ditch and Surrounding Features 130
Figure 6-78 – Photographs of Drain D8-1 Outlet 132
Figure 6-79 –Water Quality Nutrient Results, D8-1 Drain 134
Figure 6-80 – Discharge Rates and Nitrogen and Phosphorus Loading from D8-1 Drain 136
Figure 6-81 – Subwatershed Contributing Area for D8-1 Drain 137
Figure 6-82 – Photographs of Drain D8.1-1 outlet 138
Figure 6-83 – Subwatershed Contributing Area for D8.1-1 Drain 139
Figure 6-84 – Photographs of Drain D8-2 outlet 140
Figure 6-85 – Subwatershed Contributing Area for D8-2 Drain 141
Figure 6-86 – Photographs of Drain D8-3 outlet 142
Figure 6-87 – Subwatershed Contributing Area for D8-3 Drain 143
Figure 6-88 – Lower East Helena Valley Subwatershed in the Helena Valley 144
Figure 6-89 – D6 Ditch and Surrounding Features 145
Figure 6-90 – Aerial Photograph of Drain D6-1 and D6-2 Discharge Points and Receiving Pool 146
Figure 6-91 – Photographs of Drain D6-1 and D6-2 Outlets 147
Figure 6-92 – Southern D7 Ditch Components and Surrounding Features 148
Figure 6-93 – Drain D7-0 Discharge Point from Aerial Photograph 149
Figure 6-94 – Northern D7 Ditch and Surrounding Features 150
Figure 6-95 – Photographs of Drain D7-1 Outlet 151
Figure 6-96 – Water Quality Nutrient Results, D7-1 Drain 153

Figure 6-97 – Discharge Rates and Nitrogen and Phosphorus Loading from D7-1 Drain 155
Figure 6-98 – Subwatershed Contributing Area for D7-1 Drain 156
Figure 6-99 – Approximate Drain D7-2 Discharge Point from Aerial Photograph 158
Figure 6-100 – Subwatershed Contributing Area for D7-2 Drain 159
Figure 6-101 – Photographs of Drain D7-3 Outlet 160
Figure 6-102 – Subwatershed Contributing Area for D7-2 Drain 161
Figure 6-103 – D9 Ditch and Surrounding Features 162
Figure 6-104 – Drain D9-1 Discharge Points from Aerial Photograph 163
Figure 6-105 – Subwatershed Contributing Area for D9-1 Drain 164

Figure 7-1 – Ground Water Well Sampling Locations with MBMG-GWIC Identification Numbers 175
Figure 7-2 – Comparison of Nitrate with Total Nitrogen Concentrations in Ground Water 177
Figure 7-3 – Comparison of Nitrate/Total Nitrogen Ratio with Nitrate Concentrations 179
Figure 7-4 – Comparison of Cl/Br Mass Ratio with Chloride Concentrations 180
Figure 7-5 – Comparison of Nitrate with Chloride Concentrations 181
Figure 7-6 – Comparison of Cl/Br Mass Ratio with Nitrate Concentrations 182

Figure 8-1 – Surface Water Monitoring Locations and Stream Mileage Estimates 183
Figure 8-2 – Comparison of Flow Hydrographs for Prickly Pear Creek at Clancy, 2009-2012 184
Figure 8-3 – Total Nitrogen and Phosphorus Loading for Tenmile and Sevenmile Creeks 185
Figure 8-4 – Total Nitrogen and Phosphorus Loading for Silver Creek 186
Figure 8-5 – Total Nitrogen and Phosphorus Loading for Prickly Pear Creek 187

Figure 9-1 – Nitrogen and Oxygen Isotopes of Nitrate Dataset 189

List of Tables

Table 4-1 – Tile Drain Identification, Location and Reconnaissance Sample Dates 13
Table 4-2 – Summary of Reconnaissance Sampling Data Results 14

Table 5-1 – Field Parameters during Background Sampling 16
Table 5-2 – Laboratory Data Results from Background Sampling 17

Table 6-1 – Laboratory Data Results for Major Ion and Trace Metals from Drain Sampling 22
Table 6-2 – Laboratory from Sampling, D0-1 Drain 27
Table 6-3 – D0-1 Drain Discharge and Loading Rates 29
Table 6-4 – D0-1 Drain Nitrogen and Phosphorus Loading 32
Table 6-5 – Laboratory Results from Reconnaissance Sampling, D1 Ditch 33
Table 6-6 – Laboratory Results from Sampling, D1-1 Drain 36
Table 6-7 – D1-1 Drain Discharge and Loading Rates 38
Table 6-8 – D1-1 Drain Nitrogen and Phosphorus Loading 41
Table 6-9 – Estimates of D4 and D5 Drain System Nitrogen and Phosphorus Loading 47
Table 6-10 – Laboratory Results from Reconnaissance Sampling, Western D2 Ditch 51
Table 6-11 – Laboratory Results from Sampling, D2-1 Drain 54
Table 6-12 – Laboratory Results from Sampling, D2-2 Drain 56
Table 6-13 – D2-1 Drain Discharge and Loading Rates 59
Table 6-14 – D2-2 Drain Discharge and Loading Rates 59
Table 6-15 – D2-1 Drain Nitrogen and Phosphorus Loading 62

Table 6-16 – D2-2 Drain Nitrogen and Phosphorus Loading 62
Table 6-17 – Laboratory Results from Sampling, D2-4 Drain 66
Table 6-18 – D2-4 Drain Discharge and Loading Rates 68
Table 6-19 – D2-4 Drain Nitrogen and Phosphorus Loading 71
Table 6-20 – Laboratory Results from Reconnaissance Sampling, Lower D2 and D2-2.3 Ditch 75
Table 6-21 – Laboratory Results from Sampling, D2.2-1 Drain 77
Table 6-22 – D2.2-1 Drain Discharge and Loading Rates 79
Table 6-23 – D2.2-1 Drain Nitrogen and Phosphorus Loading 82
Table 6-24 – Laboratory Results from Sampling, D2.2-5 Drain 87
Table 6-25 – D2.2-5 Drain Discharge and Loading Rates 89
Table 6-26 – D2.2-1 Drain Nitrogen and Phosphorus Loading 92
Table 6-27 – Laboratory Results from Reconnaissance Sampling, D2-1.1 Ditch 98
Table 6-28 – Laboratory Results from Sampling, D2.1-1 Drain 100
Table 6-29 – D2.1-1 Drain Discharge and Loading Rates 102
Table 6-30 – D2.1-1 Drain Nitrogen and Phosphorus Loading 105
Table 6-31 – Laboratory Results from Reconnaissance Sampling, D3 Ditch 112
Table 6-32 – Laboratory Results from Sampling, D3-1 Drain 114
Table 6-33 – D3-1 Drain Discharge and Loading Rates 116
Table 6-34 – D3-1 Drain Nitrogen and Phosphorus Loading 117
Table 6-35 – Laboratory Results from Sampling, D3-2 Drain 120
Table 6-36 – D3-2 Drain Discharge and Loading Rates 122
Table 6-37 – D3-2 Drain Nitrogen and Phosphorus Loading 125
Table 6-38 – Laboratory Results from Reconnaissance Sampling, D8 Ditch 131
Table 6-39 – Laboratory Results from Sampling, D8-1 Drain 133
Table 6-40 – D8-1 Drain Discharge and Loading Rates 135
Table 6-41 – D8-1 Drain Nitrogen and Phosphorus Loading 136
Table 6-42 – Laboratory Results from Reconnaissance Sampling, D6 Ditch 146
Table 6-43 – Laboratory Results from Reconnaissance Sampling, D7 Ditch 149
Table 6-44 – Laboratory Results from Sampling, D7-1 Drain 152
Table 6-45 – D7-1 Drain Discharge and Loading Rates 154
Table 6-46 – D7-1 Drain Nitrogen and Phosphorus Loading 157
Table 6-47 – Summary of Nutrient Loading Estimates for Individual Drains 166

Table 7-1 – Monitoring Well and Potable Well Ground Water Assessment Dataset 168
Table 7-2 – Ground Water Flow Rate Estimates for Subwatersheds 176
Table 7-3 – Summary Statistics for Nitrate and Total Nitrogen in Ground Water 178
Table 7-4 – Chloride/Bromide Mass Ratio Statistics for Each Subwatershed 180

Table 8-1 – Calculation of Nutrient Loading for Tenmile Creek at Site T6 184
Table 8-2 – Nutrient Loading Estimates to Lake Helena 188

Appendices

Appendix I – Laboratory Data Reports (Electronic)
Appendix II – Best Management Practices (BMP) Assessment for Helena Area

Helena Valley Non-Point Source Assessment
Non-Point Source Nutrient Loading to Lake Helena

1.0 Introduction

The TMDL for the Lake Helena Watershed concluded that excessive nutrient loading to surface water contributes to seasonal eutrophication in Lake Helena and ultimately the Missouri River (USEPA, 2006). Nutrients within Helena Valley ground and surface waters result primarily from typical non-point sources, including with septic system drainfields, agricultural fertilizers and manure. Differentiation of nutrient sources is necessary to address the long-term goal to reduce nutrient loading to the system. This report presents the results of a detailed ground water characterization program designed to collect data to help characterize specific sources of nutrients to shallow ground water across the Helena Valley. The location of the Helena Valley study area is depicted in Figure 1-1. The primary focus area represents the central part of the valley, where agriculture and mixed residential land use are present. The Lewis and Clark Water Quality Protection District (LCWQPD) implemented the project with grant funding provided by the Montana Department of Environmental Quality (MDEQ; Grant Contract No. 212062). The project was completed with the cooperation of the Helena Valley Irrigation District (HVID).

The HVID provides irrigation waters for agricultural purposes to the central part of the Helena Valley. The layout of the HVID canal network is depicted in Figure 1-2 showing the location of primary distribution canals, tile drains and return flow ditches. A hydraulic pump system located near Canyon Ferry Dam on the Missouri River provides irrigation water to the Helena Valley from outside the natural watershed. After pumping, the water flows through a system of tunnels and ditches to the Helena Valley Regulating Reservoir, located adjacent to the eastern part of valley for storage (Figure 1-2). From the reservoir, water flows around the valley in the Helena Valley Irrigation Canal, which eventually discharges into Lake Helena. Conceptual models of the local hydrogeologic system identify Lake Helena as the downgradient discharge point for both surface and ground waters in the area (Briar & Madison, 1992). Lake Helena is connected to Hauser Lake, on the Missouri River, by the causeway on the eastern side of the lake. Water from the main canal is distributed to water users through a series of lateral distribution ditches. Return flows to Lake Helena are captured through a series of surface drain ditches, which also serve as flow-through discharge points for the lateral distribution ditches. In some locations, the surface drain ditches also intercept the top of the local water table lowering the water table in these areas. *The terminology used in this report notes **drains** as the underground tile drains, **ditches** as constructed surface channels that intercept the water table, and **distribution laterals** for the surface canals conveying water to users*.

The construction of Hauser Dam on the Missouri River flooded a series of wetlands present in the lowest part of the valley forming Lake Helena. With the establishment of the HVID bringing irrigation waters from outside the hydrologic basin to the Helena Valley, ground water levels rose in the lower elevations of the valley. In response, a series of underground tile drains were installed to lower ground water levels to facilitate productive agricultural development of the land. The tile drains discharge into the surface water return ditches. A study objective is to characterize the water quality of the tile drain effluent and compare this data with upgradient land use to see if a causal relationship exists between land use activities and shallow ground water quality. The primary project goal is to characterize non-point sources of nutrients to local surface and ground water based on land use and domestic wastewater management methods.

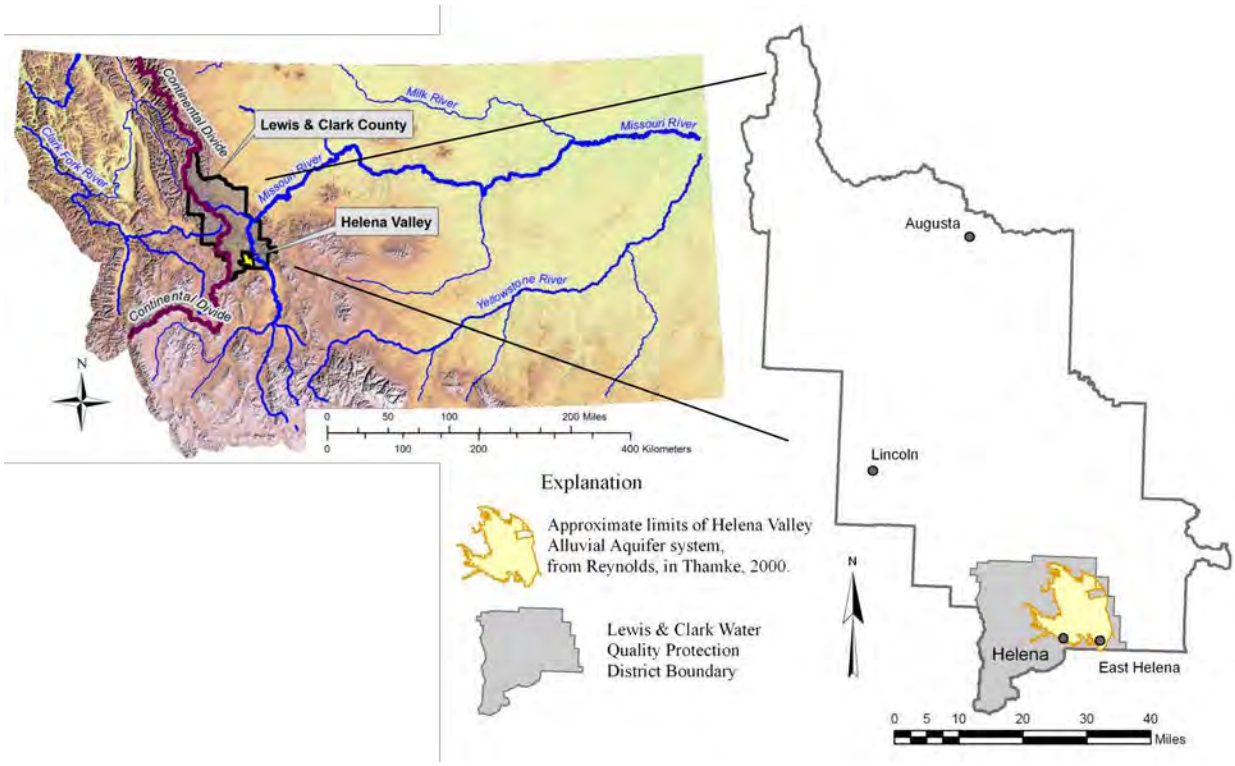


Figure 1-1 – Study location in the Helena Valley, Lewis and Clark County, Montana.

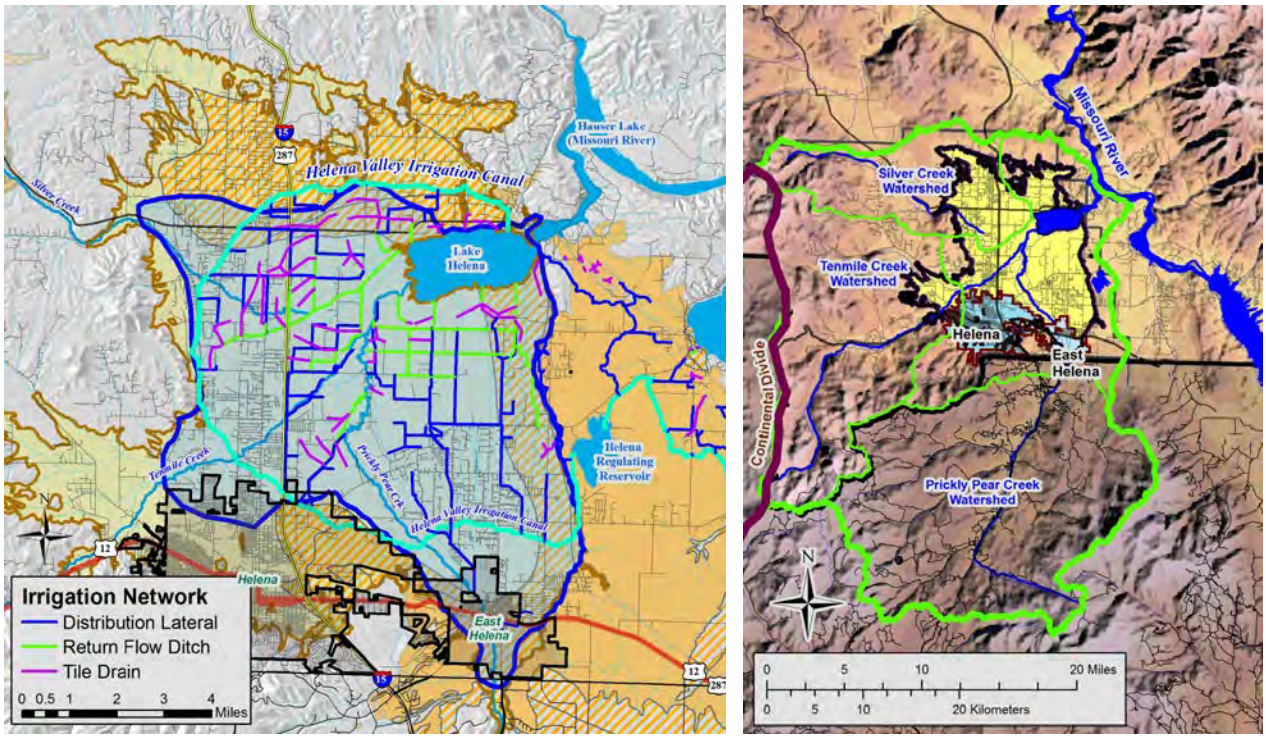


Figure 1-2 – Irrigation System in the Helena Valley, and the Lake Helena Watershed.
Approximate boundary of Helena Valley Aquifer around Helena Valley shown with tributary watershed(s)

2.0 Background

Agricultural activities have historically dominated land use in the Helena Valley, with water provided by both the HVID and from ground water irrigation wells. Research studies by USGS have shown that agricultural areas across the country have resulted in increases in nitrate levels to water resources (Mueller & Helsel, 1996). In surface water systems, this results in eutrophication from depletion of dissolved oxygen from excessive plant growth – linked to nutrient loading to the system. The TMDL studies for the Lake Helena Watershed identified nutrient impairments to local surface waters, including eutrophication issues in Lake Helena (USEPA, 2006). Traditionally, nutrient loading has been attributed to agriculture (Mueller & Helsel, 1996). The TMDL assessment used limited (non-seasonal) data collection to develop models to estimate the contribution of different nutrient sources to the system. More recently, urban growth into the valley has resulted in subdivisions generating potentially significant amounts of wastewater requiring management and disposal. As urban growth progresses, wastewater discharge from household septic systems increases nutrient levels in ground water, which ultimately can impact surface waters. This study was designed to obtain datasets to help determine and differentiate between specific nutrient sources to local waters

In order to characterize and differentiate non-point sources of nutrients to the system, the sampling and analysis program must be placed into the context of the local hydrogeologic system. This incorporates characterizing water quality of recharge sources, the interaction of surface and ground water, and flow directions and rates which can impact the capacity of the natural system to attenuate impacts from nutrients to the system. The following sections provide additional background information so that the program presented in this report may be placed into context.

2.1 Helena Area Hydrogeology

The general properties of the Helena Valley Aquifer have been characterized with previous work on the water resources of the Helena Valley. In general, previous studies have focused on the Helena Valley Aquifer from a regional perspective (Lorenz & Swenson, 1951; Wilke & Coffin, 1973; Moreland & Leonard, 1980; Briar & Madison, 1992). A more recent USGS study evaluated bedrock aquifers north, west and south of the Helena Valley (Thamke, 2000). Montana Bureau of Mines and Geology (MBMG) – Ground Water Investigation Program (GWIP) studies were recently completed in the North Hills and Scratchgravel Hills north and west of the Helena Valley (Warren et al, 2012; Bobst et al, 2014). Prior to this effort, LCWQPD completed a grant funded study to characterizer ground water quality, including data collection to characterize the interaction of surface and ground water in the area (Swierc, 2013).

The Helena Valley represents a discharge point for both surface and ground water, to Hauser Lake (and the Missouri River). Ground water in the valley occurs in the Helena Valley Aquifer comprised of fluvial/alluvial sands and gravels interspersed with finer-grained lenses, a relatively high permeable aquifer which generally supports high yields in most locations. The valley watershed includes three major stream drainages from high relief mountainous areas up to the eastern margin of the continental divide (Figure 1-2). The headwaters areas for the streams, Prickly Pear Creek to the south, Tenmile Creek to the southwest, and Silver Creek to the northwest, are characterized by forested areas with a limited amount of agricultural land use, and a limited number of small communities and subdivisions utilizing septic systems for wastewater management. Streams loss along the valley margins provides recharge into the Helena Valley Aquifer. As determined by a water balance from ground water flow models for the valley (Briar & Madison, 1992; Newfields, 2014), mountain block recharge in the subsurface provides a significant amount of recharge directly into the Helena Valley Aquifer, especially

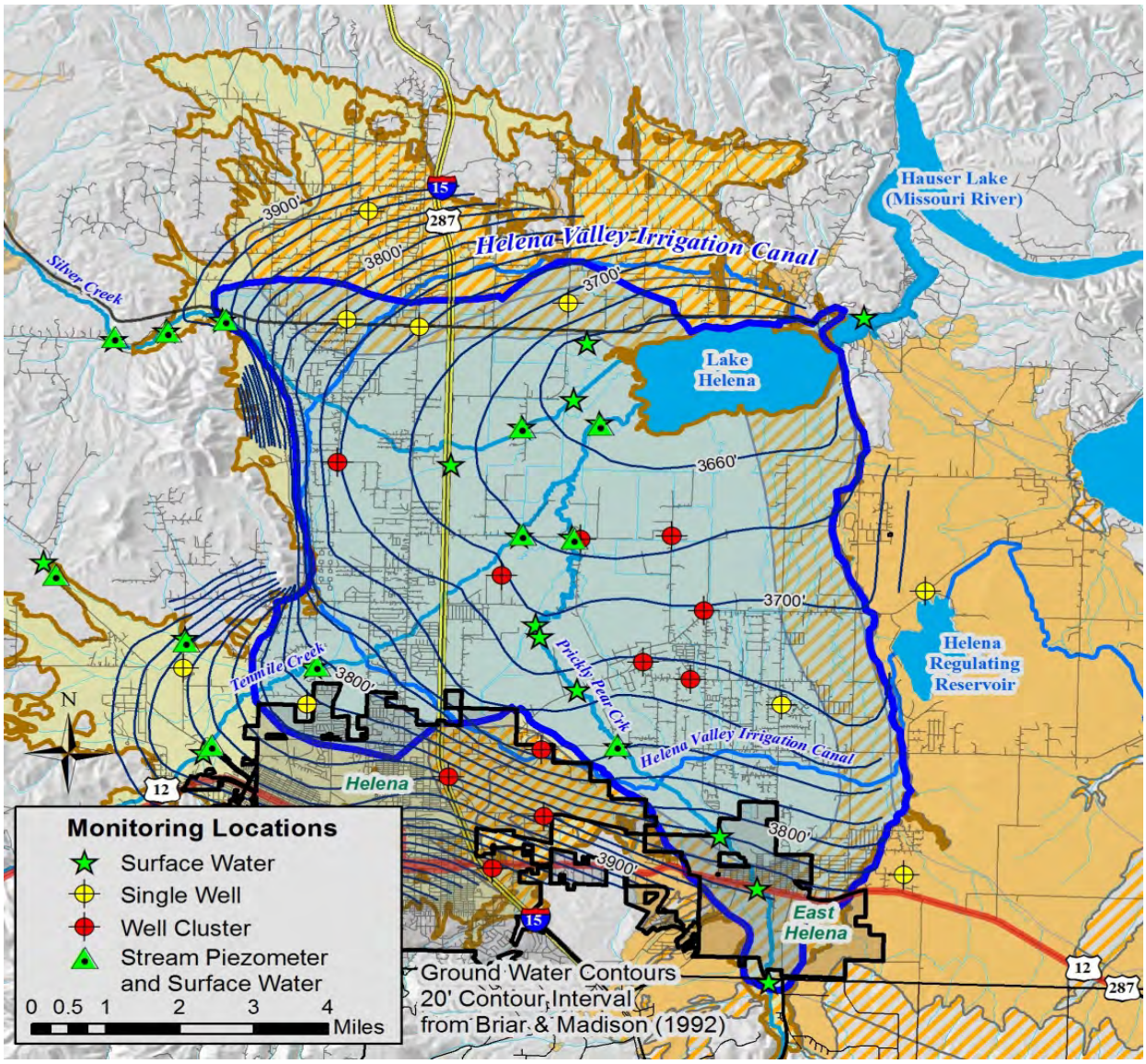


Figure 2-1 – Generalized Map of Ground Water Potentiometric Surface in Helena Valley
LCWQPD surface and ground water monitoring network and locations depicted.

with diminished surface flows during winter months. The ground water potentiometric surface for the valley is consistent with Lake Helena as a discharge point (Figure 2-1). An upward gradient is present in the central part of the Helena Valley, with upwelling into Lake Helena (Moreland & Leonard, 1980; Briar & Madison, 1992).

During the summer irrigation season, from April 15 to October 1, additional recharge to the aquifer occurs from irrigation waters. Stream loss from irrigation canals and infiltration of excess irrigation waters both provide local recharge to the Helena Valley Aquifer system. Note that irrigation waters are obtained from outside of the Lake Helena Watershed, with Missouri River water diverted to the Helena Regulating Reservoir. Regional precipitation patterns reflect the amount of recharge from direct infiltration of precipitation and stream loss. The monthly precipitation totals for the Helena area during the study period from 2013 to 2014 are depicted in Figure 2-2. During the first year of the study, the

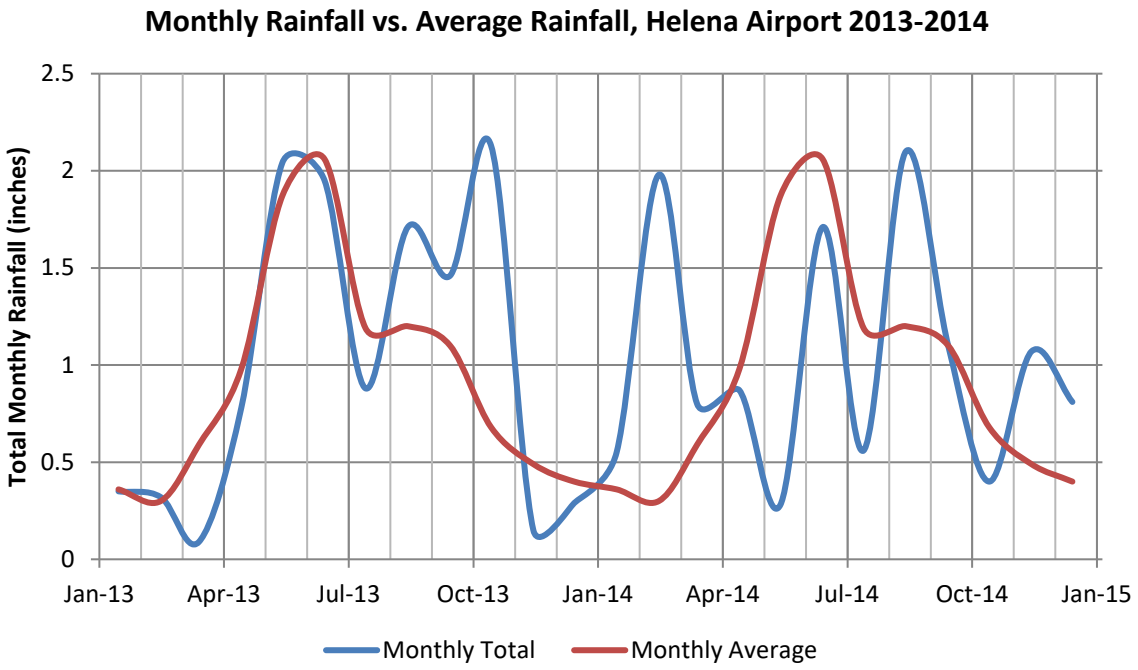


Figure 2-2 – Comparison of Monthly with Average Precipitation Totals during Study Period

summer and fall were wetter than average, while the second year shows more variability from normal. The above normal late summer and fall precipitation provides additional recharge to the system.

2.2 Previous Nutrient Characterization Work

Previous regional studies on local water resources included water quality data, including nutrient data. Based on the location in an alluvium-filled valley with high permeability and shallow water levels, the Helena Valley Aquifer is vulnerable to nutrient contamination from surficial sources (MDEQ, 1999). In this setting the impacts to local ground water quality from agriculture and urbanization have been a concern of the local health department. After formation in 1992, LCWQPD staff compiled nitrate data to characterize impacts from urbanization; however, this study did not account for seasonal variations and changes within the local ground water system (Drake, 1995). The Montana Department of Agriculture has conducted limited sampling for nitrate and nutrients in the Helena Valley (MDA, 2006). Data from these previous studies were compiled in Swierc (2013). Some of the previous data results are included in the assessment with this document.

The TMDL for the Lake Helena Watershed was developed by USEPA over a multiple year period with dedicated sampling programs for surface waters in the area (USEPA, 2006; USEPA, 2013). The TMDL summary identified several stream reaches with impacts exceeding target conditions for elevated trace metal concentrations, excess sediment, excess nutrient concentrations and elevated temperatures. The project presented in this document addresses, specifically, the impacts from non-point sources of nutrients to ground water which then discharges to surface waters . The TMDL assessment for nutrients identified different sources for nitrogen and phosphorus into the combined surface/ground water system. For non-point sources such as agriculture and septic systems, the assessment incorporated modeling to derive estimates of total contribution of nutrients for each source. The different sources are listed, with percent contribution, in Figure 2-3.

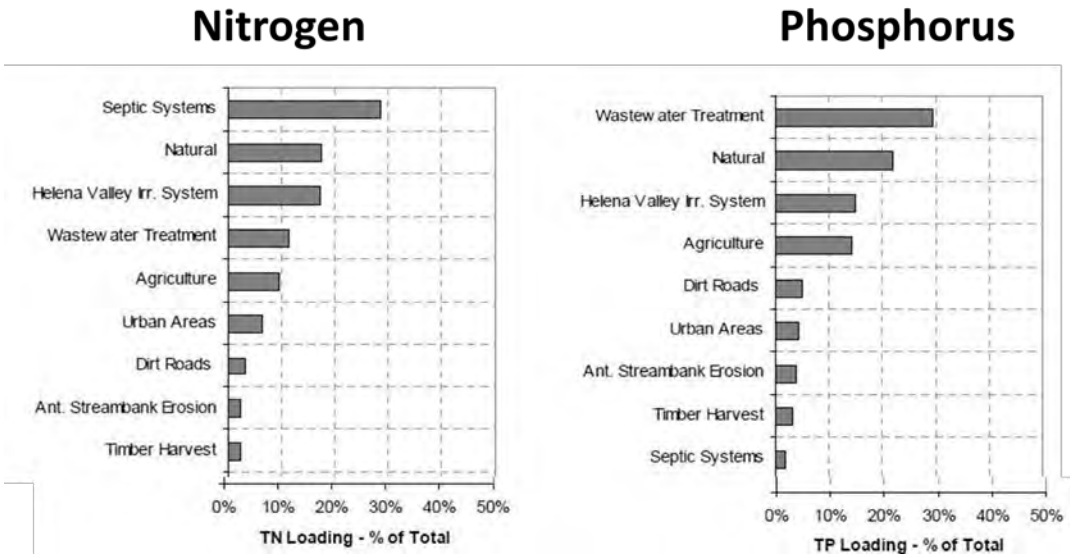


Figure 2-3 – Estimated total Nitrogen (TN) and total Phosphorus (TP) Loading, Lake Helena Watershed
Estimated contribution by source category (Figures 3-4 and 3-5 from USEPA, 2006)

2.3 Existing Characterization Datasets

Data from previous studies conducted by USGS, MBMG and LCWQPD provide baseline data for characterizing regional surface and ground water resources. As part of the assessment process, the data collected with this study is compared to regional datasets for context. The LCWQPD has been conducting surface water monitoring activities on local streams since 2008. This includes flow monitoring, and water quality sampling. The pre-existing data sets have been compiled and presented in the results of the Helena Ground Water Project (Swierc, 2013). The results presented later in this report expand on the datasets presented in this report.

2.4 Helena Valley Subwatersheds

In order to account for varying hydrogeologic conditions around the Helena Valley and to assist in the interpretation of the drain sampling results, subwatersheds were identified around each drain and return flow ditch system (Figure 2-4). The subwatersheds generally follow topographic boundaries following methods traditionally used to define watersheds; however, in some cases boundaries were identified on other criteria such as a change in aquifer properties, or the presence of recharge sources such as the main Helena Valley Irrigation Canal. Boundaries between the subwatersheds should not be considered defined at a local scale; however, each area has generally distinct aquifer geology, hydrologic properties and recharge sources. Each subwatershed is described in more detail later in the discussions included with this report.

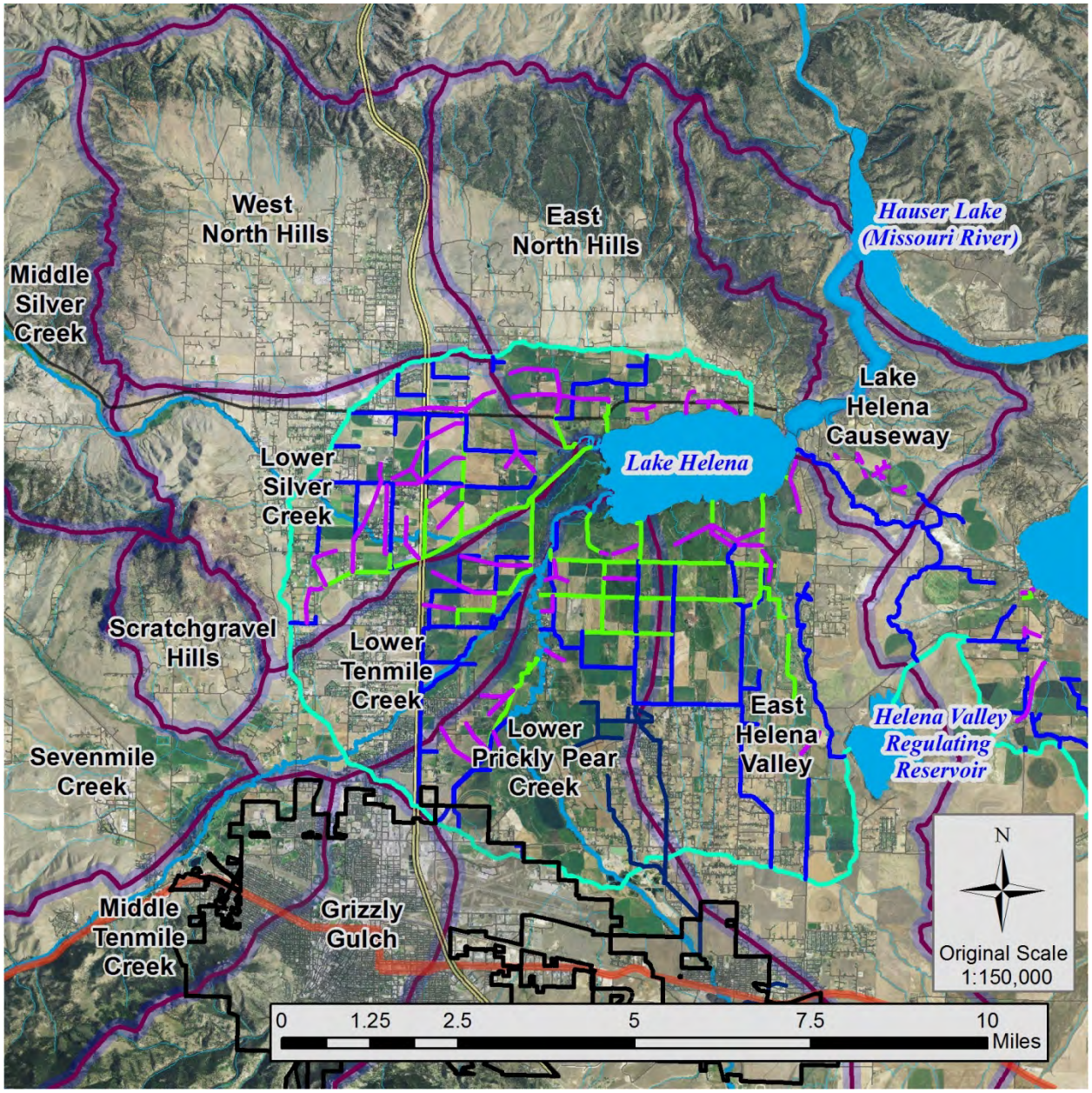


Figure 2-4 – Subwatersheds within the Helena Valley and Surrounding Area

3.0 Project Overview

The ultimate objective of this project is to characterize and differentiate between the impacts of different non-point sources on nutrient concentrations in shallow ground waters that discharge to surface waters in the Helena Valley. The sampling program was designed to build upon existing datasets (Swierc, 2013), using several datasets and methods to differentiate between nutrient sources. The sampling methods and laboratory analytical program are outlined in the project Sampling and Analysis Plan, which was revised for the second year of the program.

3.1 Assessment Strategies and Sampling Program Design

Differentiation between nutrient sources can be challenging due to different land use practices and hydrogeologic conditions. Impacts from agricultural fertilizers and manure management have both been observed at locations across the world. The impacts from onsite wastewater treatment systems (a/k/a septic systems) have also impacted ground water when proper conditions are present. The sampling program was designed to use the following methods to characterize nutrient sources:

- Quantification of loading of any contaminant reflects a comparison with background concentrations. For this study, this required determination of concentrations of nutrients in recharge sources waters, including both ground and surface waters. In addition to specific contaminants, major ion concentrations in ground waters provide additional information helping to determine specific recharge sources. Both of these assessments build upon previous area studies and data presented in Swierc (2013).

- Nitrate to chloride ratios have been used to demonstrate impacts from septic system effluent to ground water, under the assumption that chloride is released from water softeners. This approach has historically been used by local health departments and government agencies to assess the impact of the septic systems to local ground water quality. Since conditions vary with location, this assessment approach can be influenced by local sources of chloride, such as de-icing solutions. Fertilizer applications may also mimic this signal, since potassium chloride may be used to provide potassium to the system (Saffigna & Keeney, 1977)

- The ratio of chloride (Cl) to bromide (Br) in ground water can help identify septic systems as a source of nutrients to ground water (Katz et al., 2011). In many aquifer of similar geology and large aerial extent, the Cl/Br will be relatively constant, since both halogen elements are naturally occurring at small concentrations. Increases in Cl concentrations occur from water softeners, which discharge the Cl with wastewater into the septic system, infiltration gallery and ultimately ground water. Assuming the Br concentration is seasonally stable and consistent, then increases in the Cl/Br ratio occur, with septic systems as a source.

- Total Nitrogen to Nitrate ratios are used to demonstrate the efficiency of nitrification processes within the hydrogeologic system. The nutrient dataset focused on nitrate for ground water for two primary reasons (Swierc, 2013). Recent sampling results for both surface and ground water indicate that nitrate concentrations are generally equivalent to total nitrogen results (Figure 3-1). In a number of cases, the nitrate concentration results exceed the total nitrogen. This indicates that the nitrification process is efficient in Helena area ground waters. Regional ground water studies indicate dissolved oxygen in ground water is generally near saturation across the valley, providing

conditions to expect organic nitrogen converted to nitrate (Waren et al., 2012; Swierc, 2013; Bobst et al., 2014).

- Phosphorus represents the second primary nutrient which can control excessive growth within surface water systems. Sampling for phosphorus was limited to total phosphorus, since this represents how the TMDL goal is measured. Recent sampling results for dissolved orthophosphorus and total phosphorus are compared in Figure 3-2,

3.2 Project Components

The project included three major components, with an objective to collect sufficient data to begin identifying and differentiating between sources of nutrients in non-point source pollution. The program included the following components

Field Reconnaissance Program
The initial component of the project, related to drains, was to catalog, inspect and sample all of the tile drain outlets that are present in the valley. The preliminary data and field inspections were used to select sites for the detailed, longer term sampling program

Background Sampling
Impacts to water quality from anthropogenic activities result from increases in concentrations of specific compounds in water. Background concentrations of dissolved constituents in waters represent baseline conditions. For this study, sampling of recharge waters characterized background conditions. For ground water, samples were collected from wells in undeveloped areas in the Scratchgravel Hills and North Hills. For surface waters, stream samples were collected in upgradient areas where streams enter the Helena Valley; and samples were collected from the Helena Valley Irrigation Canal.

Drain Sampling and Flow Monitoring
Sampling of the tile drains represents the most extensive field effort for this project. The selected sites were sampled on an approximate bi-weekly schedule to characterize seasonal fluctuations of nutrients. The sampling program included monitoring and estimating discharge flow rates from the drains. A total of twelve drains were sampled for the initial part of the project; however, the number of sites was reduced in the second year. Discharge flow from the drains was determined by measuring the geometry of the flow leaving the drain and velocities using a Marsh-McBirney surface water flow meter.

Well Sampling
Ground water sampling was conducted in areas of known and/or suspected nutrient contamination to characterize actual ground water conditions. The well sampling program was designed to supplement and expand on the existing ground water quality database from previous area studies.

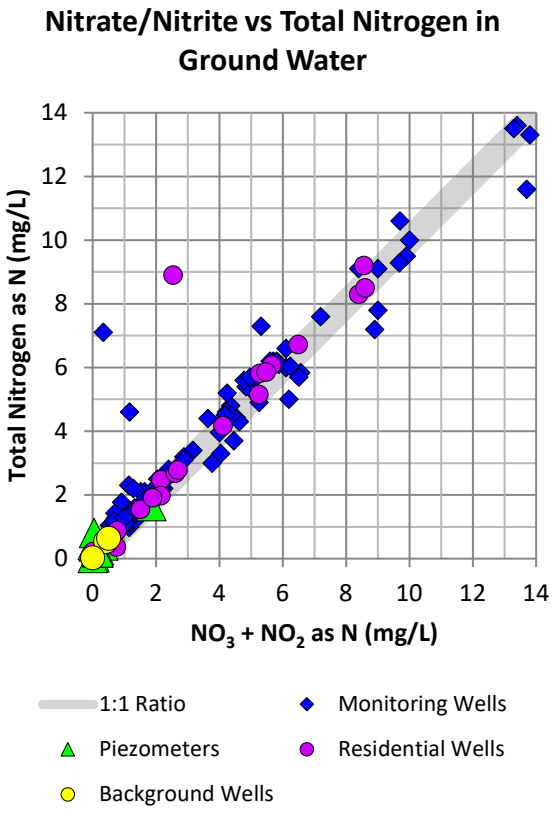


Figure 3-1a – Comparison of Nitrate/Nitrite with Total Nitrogen in Helena area ground water samples. Note elevated nitrate results commonly exceed total nitrogen concentrations. Data from Swierc (2013)

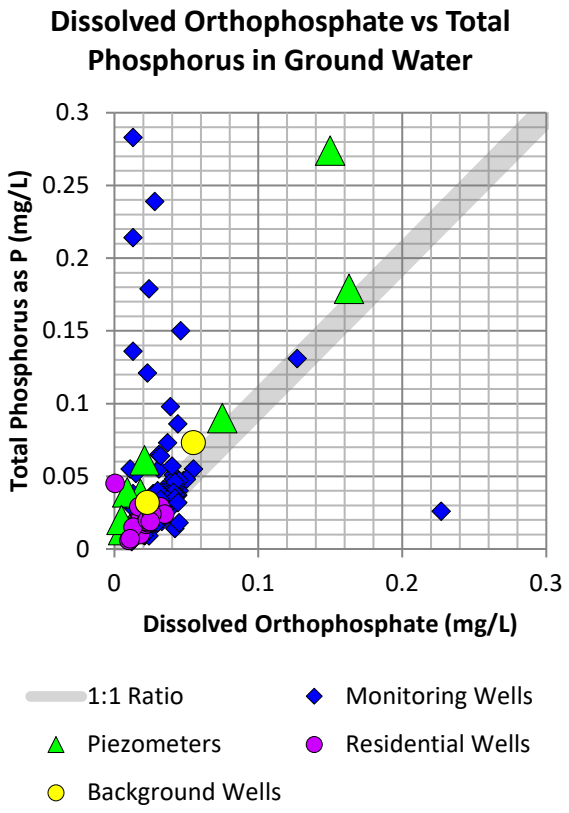


Figure 3-2a – Comparison of dissolved orthophosphate with Total Phosphate in Helena area ground water samples. Data from Swierc (2013)

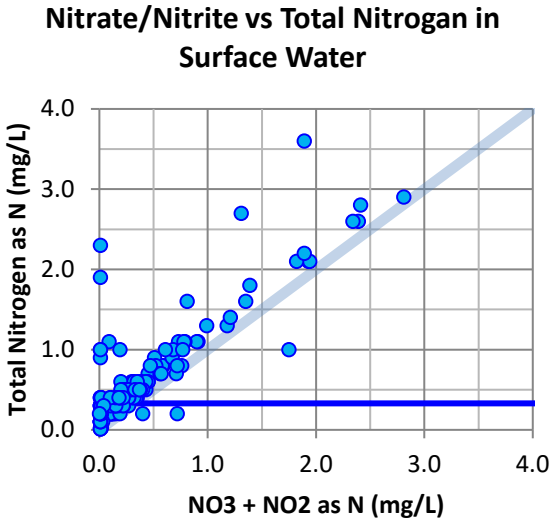


Figure 3-1b – Comparison of Nitrate/Nitrite with Total Nitrogen in Helena area surface water samples. TMDL target concentration of 0.33 mg/L for surface water is noted with line. Data from Swierc (2013)

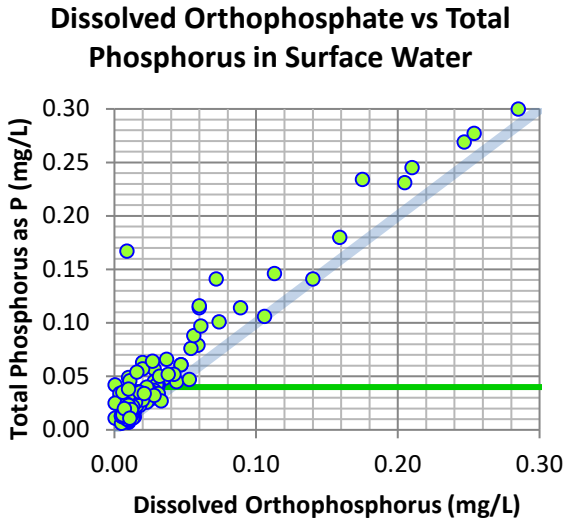


Figure 3-2b – Comparison dissolved orthophosphate with Total Phosphate in Helena area surface water samples. TMDL target concentration of 0.04 mg/L for surface water is noted with line. Data from Swierc (2013)

4.0 Field Reconnaissance Sampling Program

The field reconnaissance program was completed by identifying locations, as depicted in Figure 4-1, as potential sampling sources. The drain locations and identifying criterion are listed in Table 4-1. Tile drain discharge points were visited in May and early June 2013. Each site visit incorporated taking pictures of outlets and collecting water quality samples from drain discharge. Samples were collected as surface water samples directly from drain flows when elevated above surface water elevations in the drain. In selected cases where drain outlets were submerged and drain waters mixed with surface waters, samples were collected using a peristaltic pump drawing water from a tubing placed into the upgradient waters in the drain. Field parameters pH, specific conductivity, temperature , dissolved oxygen and oxidation/reduction potential were measured from the drains at the time of sample collection. Water quality samples were analyzed for Total Dissolved Solids (TDS), alkalinity, chloride, bromide, total phosphorus, and nitrate plus nitrite as nitrogen. All field sampling and laboratory analytical methods are reviewed in the approved Sampling and Analysis Plan for the project.

The results of the field reconnaissance program were used to select 12 additional sites for more detailed sampling through the summer. These sites are identified in Table 4-1 and can be located in Figure 4-1. The sites were generally selected at upgradient positions near the ditches, with different land uses in upgradient areas. The sampling location D8-1 was selected based on a downgradient location near sewage lagoons for the Montana Law Enforcement Academy.

The data results from the field reconnaissance program are summarized in Table 4-2. The program included samples collected from 25 drains. A total of 14 drains were not sampled for various reasons, including no flow observed (6 drains), submerged under water (2 drains), access problems or could not locate (5 drains) and one drain discharge point which appears to have been covered with a concrete culvert to pump the water for irrigation (D7-2). The results include nitrate values ranging from 0.16 mg/L up to 3.52 mg/L with generally low concentrations in the eastern part of the Helena Valley. Total phosphate values ranges from 0.007 mg/L up to 0.209 mg/L, with the highest values in the northern and eastern parts of the Helena Valley.

The program included samples from 3 smaller PVC drain pipes which were not installed as part of the Helena Valley Irrigation District System, D1-2, D3-4a and D3-4b. The source and purpose of waters discharged from the D1-2 drain pipe are not know; however, the water showed a relatively high temperature compared to other drains, high dissolved solids and total phosphorus, and low nitrate. The drain pipes D3-4a and D3-4b discharge adjacent to each other, and appear to have been installed to lower the water table near a wastewater treatment system for a subdivision.

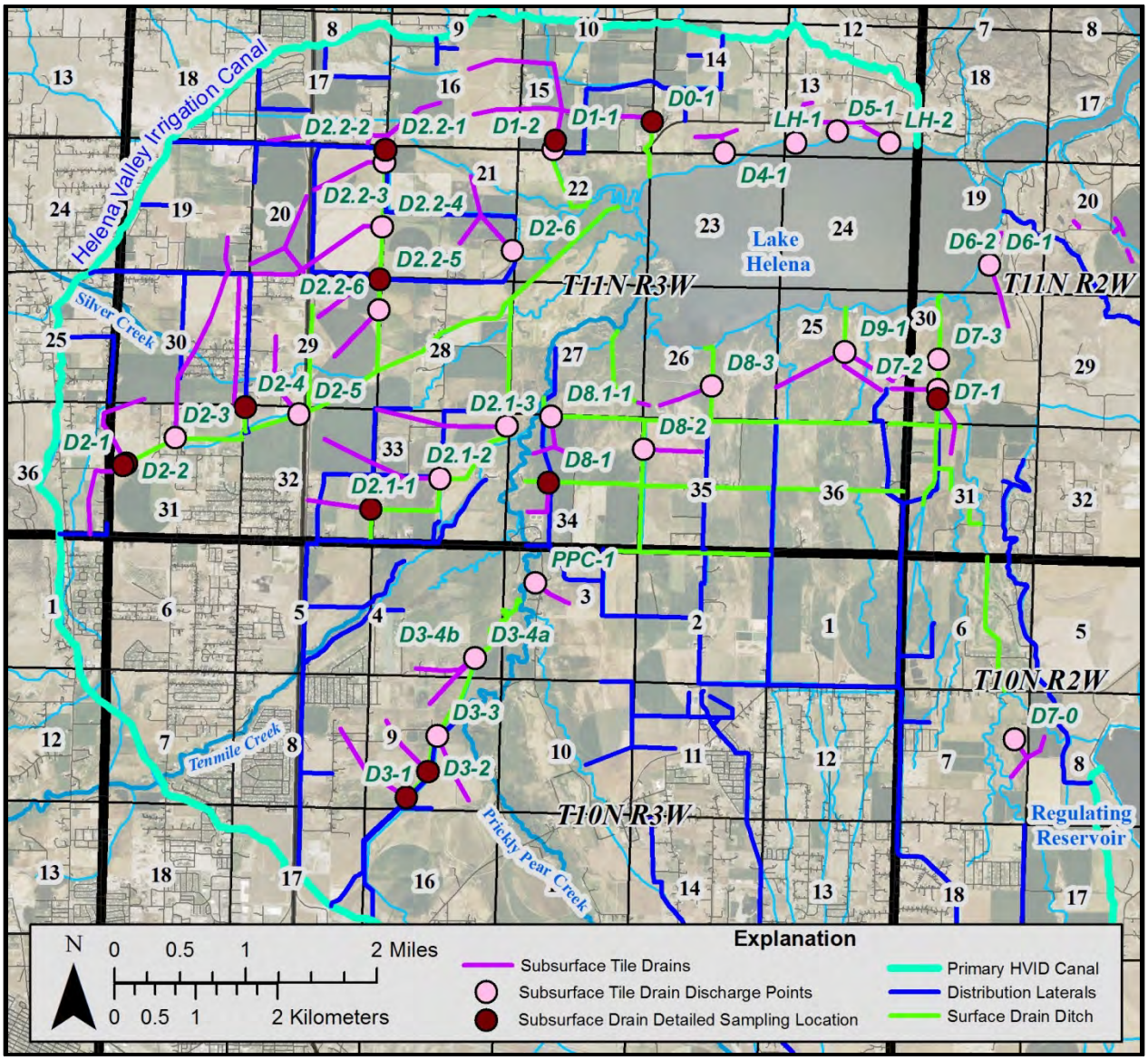


Figure 4-1 – Helena Valley Irrigation District Canal, Ditch and Drain Network

The map identifies where tile drains discharge to surface water irrigation return flow ditches. Labels for discharge points represent identifiers for specific locations.

Table 4-1 – Tile Drain Identification, Location and Reconnaissance Sampling Date

Ditch	Drain**	Location	Sample Date *	Comments
D0	**D0-1****	**11N3W15dadd**	**5/6/2013**	
D1	**D1-1****	**11N3W15cdcb**	**5/9/2013**	
	D1-2	11N3W15cdcb2	5/9/2013	
D2	**D2-1****	**11N3W31bccd**	**ns**	**No flow observed, initial site visit**
	D2-2**	**11N3W31bcdc**	**5/3/2013**	
	D2-3	11N3W31bdaa	ns	No flow observed
	D2-4**	**11N3W32bbbb**	**5/3/2013**	
	D2-5	11N3W32baaa	6/6/2013	
	D2.2-1**	**11N3W20aaaa**	**5/3/2013**	
	D2.2-2	11N3W20aaaa2	ns	No flow observed
	D2.2-3	11N3W20aada	5/3/2013	
	D2.2-4	11N3W20dada	ns	No flow observed
	D2.2-5**	**11N3W29aaaa**	**5/3/2013**	
	D2.2-6	11N3W29adaa	ns	No flow observed
	D2.1-1**	**11N3W32dadd**	**5/2/2013**	
	D2.1-2	11N3W33caaa	5/8/2013	
	D2.1-3	11N3W33aaad	5/8/2013	
	D2-6	11N3W21ddaa	5/3/2013	
D3	**D3-1****	**10N3W9cdca**	**6/6/2013**	
	D3-2**	**10N3W9cadd**	**6/6/2013**	
	D3-3	10N3W9accc	6/6/2013	
	D3-4a	10N3W4ddbc	5/22/13	7-inch diameter pipe
	D3-4b	10N3W4ddbc	5/22/13	12-inch diameter pipe
D4	D4-1	11N3W23abab	ns	Access problems, did not visit
D5	D5-1	11N3W13cdac	ns	Access problems, did not visit
D6	D6-1	11N2W19dcbb	6/6/2013	
	D6-2	11N2W19dcbb2	6/6/2013	
D7	D7-0	10N2W7adac	ns	No flow observed from aerial photo
	D7-1**	**11N2W30ccac**	**5/8/2013**	
	D7-2	11N2W30ccaa	ns	Could not locate
	D7-3	11N2W30cbaa	5/9/2013	
D8	**D8-1****	**11N3W34bdcc**	**5/8/2013**	
	D8-2	11N3W35bbcc	5/15/2013	
	D8-3	11N3W26dbcc	ns	Discharge pipe completely submerged
	D8.1-1	11N3W34baba	5/8/2013	
D9	D9-1	11N3W25accc	ns	Access problems, did not visit
PPC	PPC-1	10N3W3bbdd	ns	Flows directly into PPC, could not locate
Lake Helena	LH-1	11N3W13ccca	ns	Access problems, did not visit
	LH-2	11N2W13dcbd	ns	Access problems, did not visit

* ns – not sampled during reconnaissance program (May – Early June 2013)

** Site selected for detailed sampling program

Table 4-2 – Summary of Reconnaissance Sampling Data Results

		Field Parameters				Laboratory Data Results					
Drain	Date	pH	temp	specific conductivity	Dissolved Oxygen	Total Dissolved Solids, TDS @ 180°C	Alkalinity, Total as $CaCO_3$	Cl	Br	NO3+NO2 as N	Phosphorus, Total as P
		S.U.	°C	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
D0-1	5/6/13	7.66	6.4	461	12.93	437	300	17	0.041	3.29	0.026
D1-1	5/9/13	7.63	6.9	476	13.48	509	260	18	0.02	2.83	0.028
D1-2	5/9/13	7.62	10.5	1351	9.46	1320	330	57	0.136	0.77	0.209
D2-2	5/3/13	7.73	7.6	411	11.07	356	270	17	0.037	3.06	0.015
D2-4	5/3/13	7.54	7.3	418	12.02	369	270	18	0.036	2.91	0.023
D2-4	5/3/13			*Duplicate Sample*		362	270	18	0.049	2.89	0.023
D2-5	6/6/13	7.53	9.5	407	9.85	341	250	17	0.06	1.39	0.007
D2.1-1	5/2/13	7.24	7.7	314	11.31	269	170	19	0.05	2.49	0.027
D2.1-2	5/8/13	7.18	7.7	362	5.33	262	170	15	0.033	1.39	0.017
D2.1-3	5/8/13	7.22	6.9	276	9.52	268	170	12	0.035	0.69	0.016
D2.2-1	5/3/13	7.77	8.7	371	12.12	321	230	15	0.05	1.76	0.022
D2.2-3	5/3/13	7.53	7	364	14.03	328	250	15	0.048	1.94	0.024
D2.2-5	5/3/13	7.63	6.9	427	11.99	368	280	20	0.045	3.52	0.017
D2-6	5/3/13	7.51	6.9	--	10.68	513	330	23	0.1	1.24	0.028
D3-1	6/6/13	7.57	8.6	458	7.72	403	250	38	0.11	2.43	0.013
D3-2	6/6/13	7.55	8.5	429	8.59	377	230	33	0.09	2.51	0.010
D3-3	6/6/13	7.61	7.8	379	9.92	351	210	23	0.12	0.89	0.024
D3-4a	5/22/13	7.36	7.7	--	5.18	517	350	51	0.14	0.16	0.139
D3-4b	5/22/13	7.46	8	--	9.51	433	250	40	0.08	2.92	0.051
D6-1	6/6/13	7.6	9.7	389	9.49	336	240	14	0.08	0.62	0.069
D6-2	6/6/13	7.48	10.7	380	9.94	307	220	14	0.07	1.09	0.050
D7-1	5/8/13	7.21	8.8	310	8.78	265	180	14	0.05	0.97	0.107
D7-3	5/9/13	7.36	7.4	250	12.34	224	110	11	0.045	0.71	0.033
D8-1	5/8/13	7.62	8.3	289	3.96	256	170	10	0.041	0.55	0.025
D8-2	5/15/13	7.38	9.5	182	6.11	298	170	12	<0.02	0.37	0.043
D8.1-1	5/8/13	7.48	7.9	--	8.16	252	160	10	0.029	0.68	0.021
				(-- - not measured)							
	Max	7.77	10.7	1351	14.03	1320	350	57	0.14	3.52	0.209
	Min	7.18	6.4	182	3.96	224	110	10	0.02	0.16	0.007
	Average	7.5	8.12	414.5	9.74	386.2	234.2	21.2	0.064	1.70	0.041
	Median	7.53	7.8	380.0	9.85	346.0	245.0	17.0	0.05	1.39	0.025
	St Dev	0.16	1.16	227.2	2.63	207.3	59.7	12.4	0.034	1.05	0.045

5.0 Background/Recharge Water Quality

Background concentrations of water quality parameters represent a baseline for comparison of waters impacted by anthropogenic activities. For this study, background concentrations were determined from waters that recharge the Helena Valley Aquifer. The program comprised surface water and limited ground water sampling. Sample collection followed field protocols appropriate for each sample type. The sample locations are depicted in Figure 5-1. Table 5-1 lists the field parameter data during sample collection. Table 5-2 lists nutrient and major ion data, including water type classification proportion data. The full datasets are included with laboratory reports in Appendix I. For this study, the data indicate that bromide is not present in these recharge waters, so bromide detections represent either anthropogenic or natural sources within the subsurface along the flow path from recharge to sampling point. In addition, detected nitrate concentrations were all less than 0.5 mg/L.

The background sampling program components, and results, comprised:

- Five surface water sampling events implemented during 2014. The full program included four sample locations from local streams; and two locations from the Helena Valley Irrigation Canal which sampled three times during irrigation season. The surface water sampling program was primarily needed for bromide, since bromide analyses were not included with previous studies (USEPA, 2006; Swierc, 2013)

  The stream data shows a decrease in total dissolved solids during spring runoff, with consistent relative proportions between major ions. Data from Silver Creek shows higher concentrations of dissolved solids, with decreased sulfate concentrations during spring runoff.

  The irrigation canal data showed similar results from both locations during all three sampling events.

- Background ground water sampling evaluated concentrations with single sample events from three wells located in upgradient areas of the North Hills and Scratchgravel Hills. MBMG provided assistance to sample two wells wells in remote locations near the top of local watersheds in the North and Scratchgravel Hills. The third well, located near the northern boundary of the Helena Valley, incorporated sampling a surface flowing artesian well.

  The results indicate different water types between the North Hills and Scratchgravel Hills, with larger percentages of sodium, magnesium and sulfate in the Scratchgravel Hills.

- A single grab sample was collected from the Helena Wastewater Treatment Plant effluent ditch, since this ditch potentially provided local recharge to several drains flowing into the D-3 Ditch included within this study.

  The results show a distinctive water quality type, separate from other recharge sources, which is expected since this is the discharge effluent from municipal wastewater treatment.

Based on the background sampling results listed in Table 5-2, the background concentration for nitrogen in both surface and ground water is considered 1.0 mg/L, such that any occurrence of nitrate exceeding this is considered to occur from an anthropogenic source. Phosphate levels vary considerably more than nitrate, such that background is evaluated for each subarea evaluated with this project.

Table 5-1 Field Parameters during Background Sampling

Surface Water

Location	Sample Date	pH (s.u.)	Temp (°C)	Specific Conductivity (µs/cm)	Dissolved Oxygen (mg/L)
Tenmile Creek					
T4	9-Apr-14	8.81	8.3	163	5.89
T4	20-May-14	8.62	9.9	65	3.27
T4	9-Jul-14	9.09	21.3	253	2.34
T4	25-Sep-14	9.32	17.8	327	5.27
T4	12-Dec-14	9.13	3.1	194	18.1
Silver Creek					
SC1	9-Apr-14	8.85	10.5	488	4.92
SC1	20-May-14	8.72	14.2	474	3.59
SC1	9-Jul-14	9.04	21.1	554	2.62
SC1	25-Sep-14	9.21	16.2	509	6
SC1	12-Dec-14	9.08	0.3	357	18.41
Prickly Pear Creek					
P5	9-Apr-14	9.04	8.2	166	3.72
P5	20-May-14	8.38	11.4	114	6.24
P5	9-Jul-14	8.93	19.8	203	5.62
P5	25-Sep-14	8.91	17.8	246	8.07
P5	12-Dec-14	9.02	4.1	175	13.15
P3	9-Apr-14	8.87	7.6	167	4.25
P3	20-May-14	8.44	10.2	111	8.41
P3	9-Jul-14	8.61	17.3	190	10.28
P3	25-Sep-14	8.95	15.9	234	11.02
P3	12-Dec-14	8.98	4.2	174	12.17
Helena Valley Irrigation Canal					
HVID-LC1	1-May-14	8.91	10.8	268	11.77
HVID-LC1	9-Jul-14	9	18.8	301	5.31
HVID-LC1	25-Sep-14	9.12	16.3	244	6.6
HVID-LC5	1-May-14	8.82	14.7	298	5.13
HVID-LC5	9-Jul-14	9.49	26.9	343	2.8
HVID-LC5	25-Sep-14	9.93	20.9	250	4.8
Helena Wastewater Treatment Plant Effluent Ditch					
WWTP	21-May-14	9.37	18.5	515	4.43

Background Wells

North Hills - MBMG-SLE 2					
258294	12-Jun-14	7.46	12.2	2.43	7.94
North Hills - MBMG-HVF 1					
258401	20-Jun-14	8.09	10.7	324	3.8
Scratchgravel Hills - BLM-S.27					
257369	12-Jun-14	7.79	16	2.76	0.012

Table 5-2 Laboratory Data Results from Background Sampling

Surface Water				Anions			Nutrients		Cations					Major Ion Totals		Major Ion Percentages of Total +/- Ions					
Location	Sample Date	Total Dissolved Solids	Alkalinity (as $CaCO_3$)	Chloride (Cl)	Bromide (Br)	Sulfate (SO_4)	Nitrate (NO_3) + Nitrite (NO_2) as N	Phosphorus Total, as P	Calcium (Ca)	Iron (Fe)	Magnesium (Mg)	Potassium (K)	Sodium (Na)	Sum Cations	Sum Anions	Na+K	Ca	Mg	Cl	HCO_3	SO_4
		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	meq	meq	%	%	%	%	%	%
Tenmile Creek																					
T4	9-Apr-14	161	74	14	*< 0.01*	26	< 0.01	0.044													
T4	20-May-14	65	29	2	*< 0.01*	8	0.06	0.034	10	0.66	3	1	4	0.95	0.78	21.6	52.5	26.0	7.2	71.4	21.3
T4	9-Jul-14	167	98	6	*< 0.01*	22	0.03	0.018	34	0.32	8	3	12	2.97	2.59	20.7	57.1	22.2	6.5	75.8	17.7
T4	25-Sep-14	244	140	11	*< 0.01*	32	< 0.01	0.014	46	0.1	13	3	18	4.24	3.76	20.7	54.1	25.2	8.2	74.1	17.7
T4	12-Dec-14	217	120	10	*< 0.01*	29	0.19	0.024	38		10	2	15	3.43	3.34	20.8	55.2	24.0	8.4	73.5	18.1
Silver Creek																					
SC1	9-Apr-14	435	280	13	*< 0.01*	110	< 0.01	0.045													
SC1	20-May-14	378	240	9	*< 0.01*	72	< 0.01	0.046	78	0.37	29	4	13	6.97	6.34	9.9	55.8	34.3	4.0	72.4	23.6
SC1	9-Jul-14	378	280	7	*< 0.01*	38	< 0.01	0.047	86	0.09	27	3	14	7.21	6.23	9.7	59.5	30.8	3.2	84.1	12.7
SC1	25-Sep-14	390	280	11	*< 0.01*	45	< 0.01	0.034	81	< 0.03	32	4	17	7.54	6.49	11.5	53.6	34.9	4.8	80.8	14.4
SC1	12-Dec-14	430	280	9	*< 0.01*	74	0.06	0.027	84		32	4	15	7.60	7.37	10.2	55.1	34.6	3.4	75.6	20.9
Prickly Pear Creek																					
P5	9-Apr-14	159	69	5	*< 0.01*	45	0.17	0.066													
P5	20-May-14	101	42	2	*< 0.01*	21	0.11	0.029	18	1.01	4	2	6	1.55	1.33	20.9	57.9	21.2	4.2	62.9	32.9
P5	9-Jul-14	150	64	3	*< 0.01*	31	0.13	0.019	25	0.3	6	2	10	2.24	2.01	22.2	55.7	22.1	4.2	63.7	32.1
P5	25-Sep-14	189	78	5	*< 0.01*	43	0.23	0.022	31	0.21	8	3	13	2.86	2.58	23.0	54.0	23.0	5.5	59.8	34.7
P5	12-Dec-14	197	82	5	*< 0.01*	46	0.37	0.031	32		7	3	13	2.83	2.74	23.3	56.4	20.3	5.1	59.9	35.0
P3	9-Apr-14	180	70	5	*< 0.01*	46	0.22	0.049													
P3	20-May-14	99	42	2	*< 0.01*	21	0.07	0.038	18	1.16	4	2	6	1.55	1.33	20.9	57.9	21.2	4.2	62.9	32.9
P3	9-Jul-14	144	65	3	*< 0.01*	30	0.08	0.022	26	0.3	6	2	9	2.24	1.94	20.2	57.8	22.0	4.4	63.4	32.2
P3	25-Sep-14	186	78	5	*< 0.01*	43	0.11	0.019	32	0.88	8	3	13	2.91	2.59	22.6	54.8	22.6	5.4	60.0	34.5
P3	12-Dec-14	194	81	4	*< 0.01*	46	0.25	0.029	31		7	2	13	2.75	2.68	22.8	56.2	20.9	4.2	60.0	35.8
Helena Valley Irrigation Canal																					
HVID-LC1	1-May-14	213	140	11	0.02	31	< 0.01	0.025	37	0.05	11	4	21	3.79	3.69	27.4	48.7	23.9	8.4	74.1	17.5
HVID-LC1	9-Jul-14	211	120	10	*< 0.01*	26	0.02	0.014	37	0.06	10	4	21	3.71	3.28	28.0	49.8	22.2	8.6	74.9	16.5
HVID-LC1	25-Sep-14	187	110	8	*< 0.01*	19	0.02	0.051	32	0.04	9	3	15	3.08	2.75	24.2	51.8	24.0	8.2	77.4	14.4
HVID-LC5	1-May-14	216	140	11	*< 0.01*	30	< 0.01	0.028	36	0.22	11	4	21	3.74	3.61	27.8	48.0	24.2	8.6	74.1	17.3
HVID-LC5	9-Jul-14	201	120	10	*< 0.01*	26	< 0.01	0.015	34	0.1	11	4	22	3.68	2.79	29.4	46.1	24.6	10.1	70.5	19.4
HVID-LC5	25-Sep-14	176	110	8	*< 0.01*	18	< 0.01	0.024	28	0.05	9	3	16	2.93	2.08	27.0	47.7	25.3	10.9	71.1	18.1
Helena Wastewater Treatment Plant Effluent Ditch																					
WWTP	21-May-14	345	110	68	*< 0.01*	56	4.47	3.04	35	0.09	15	13	56	5.82	5.05	48.8	30.0	21.2	38.0	38.9	23.1
Background Wells																					
North Hills - MBMG-SLE 2																					
258294	12-Jun-14	241	200	3	*< 0.01*	10	0.42	0.073	58	< 0.03	8	< 1	13	4.13	4.23	14.4	70.0	15.9	2.0	93.1	4.9
North Hills - MBMG-HVF 1																					
258401	20-Jun-14	262	200	3	*< 0.01*	28	0.51	0.011	53	< 0.03	17	< 1	18	4.84	4.60	16.5	54.6	28.9	1.8	85.5	12.7
Scratchgravel Hills - BLM-S.27																					
257369	12-Jun-14	227	130	3	*< 0.01*	40	<0.01	0.032	31	0.04	13	< 1	23	3.63	3.54	28.0	42.5	29.4	2.4	74.1	23.5

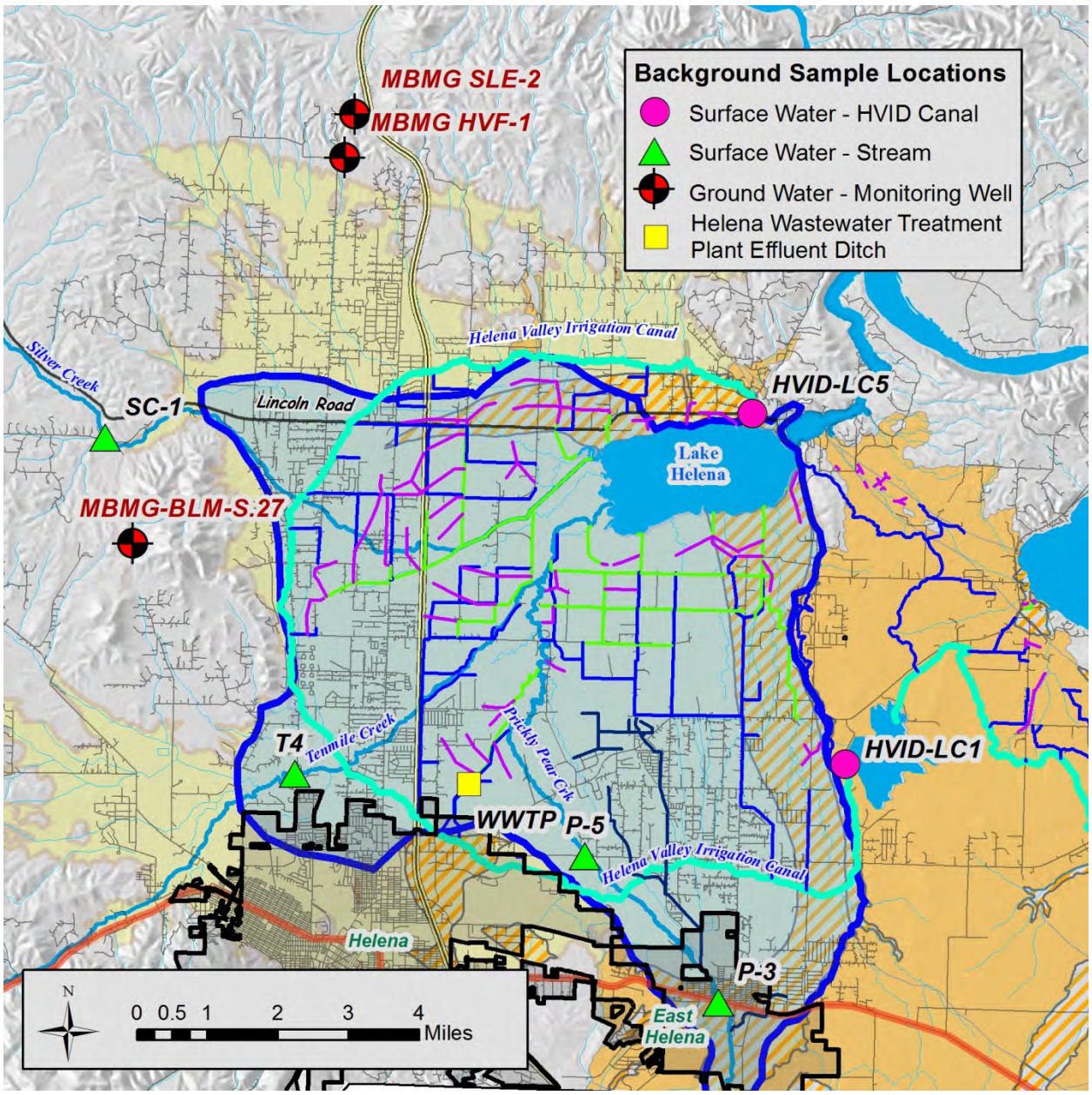


Figure 5-1 – Helena Valley Background Water Sampling Locations

Specific ground and surface water sample locations representing background water quality for the Helena area. Surface water sampling was conducted to obtain background bromide concentrations, since this was not included with TMDL characterization sampling (USEPA, 2006; Swierc, 2013)

6.0 Drain Sampling Program

The focused drain sampling program began in June 2013 with the selection of 12 sites for detailed sampling. Flows in the drains generally increased during the summer irrigation season, then decreased during the winter months (Figure 6-1). The location of the drains are depicted in Figure 6-1. The initial sampling events focused on collecting nutrient data at regular, bi-weekly intervals supplemented with two sampling events for the full analytical suite. The regular sampling program continued into late Fall, 2013, with a reduced sampling interval due to weather conditions limiting access to drains. The total number of sites was reduced to 10 for Spring 2014, and 5 in July 2014 through the end of the sampling program in November 2014. The total number of sampling events, the data results and interpretations for each specific drain are presented in the following sections.

The original project design incorporated developing flow curves within the ditches adjacent to drain discharge points to support loading estimate. Traditional surface flow monitoring methods were not appropriate since ditch water levels were controlled by irrigation return flows, and not just discharge from ditches. As a result, flow rates were estimated by multiplying cross-sectional area of the water flowing in the drain by the velocity. During each sampling event, the water depth was measured, as the discharge pipe width did not change. With the water depth, cross sectional areas were determined using standard geometric methods. Flow velocities were measured using a March McBirney flow meter. The drain discharge rates are considered approximate due to boundary conditions and changing velocities across the water profile as it discharges from the pipe.

Loading rates for each drain represent the mass of nitrogen and phosphorus discharged into the ditches over time. The time-series plot of the data allows for estimates of total mass loading over periods of time. Total mass loading was estimated by using simple interpolation of both nutrient concentration and flow discharge over time between each sampling event. The loading information for each drain is discussed in detail in the following sections.

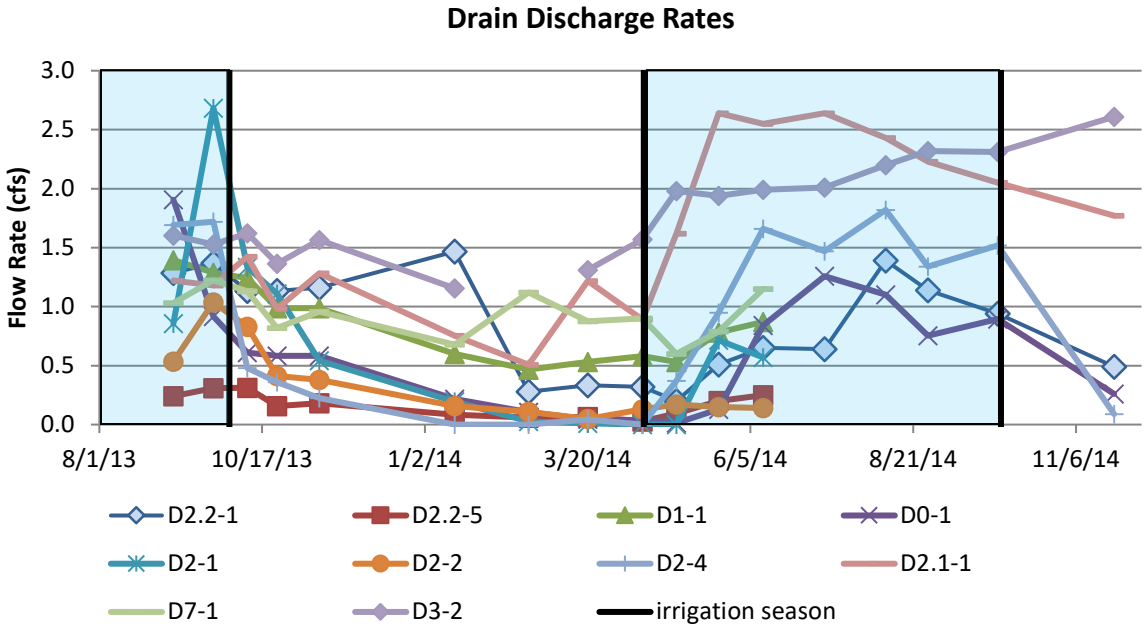


Figure 6-1 – Drain Discharge Rates
Note increase in flows during summer irrigation season, with declining flows during the winter months.

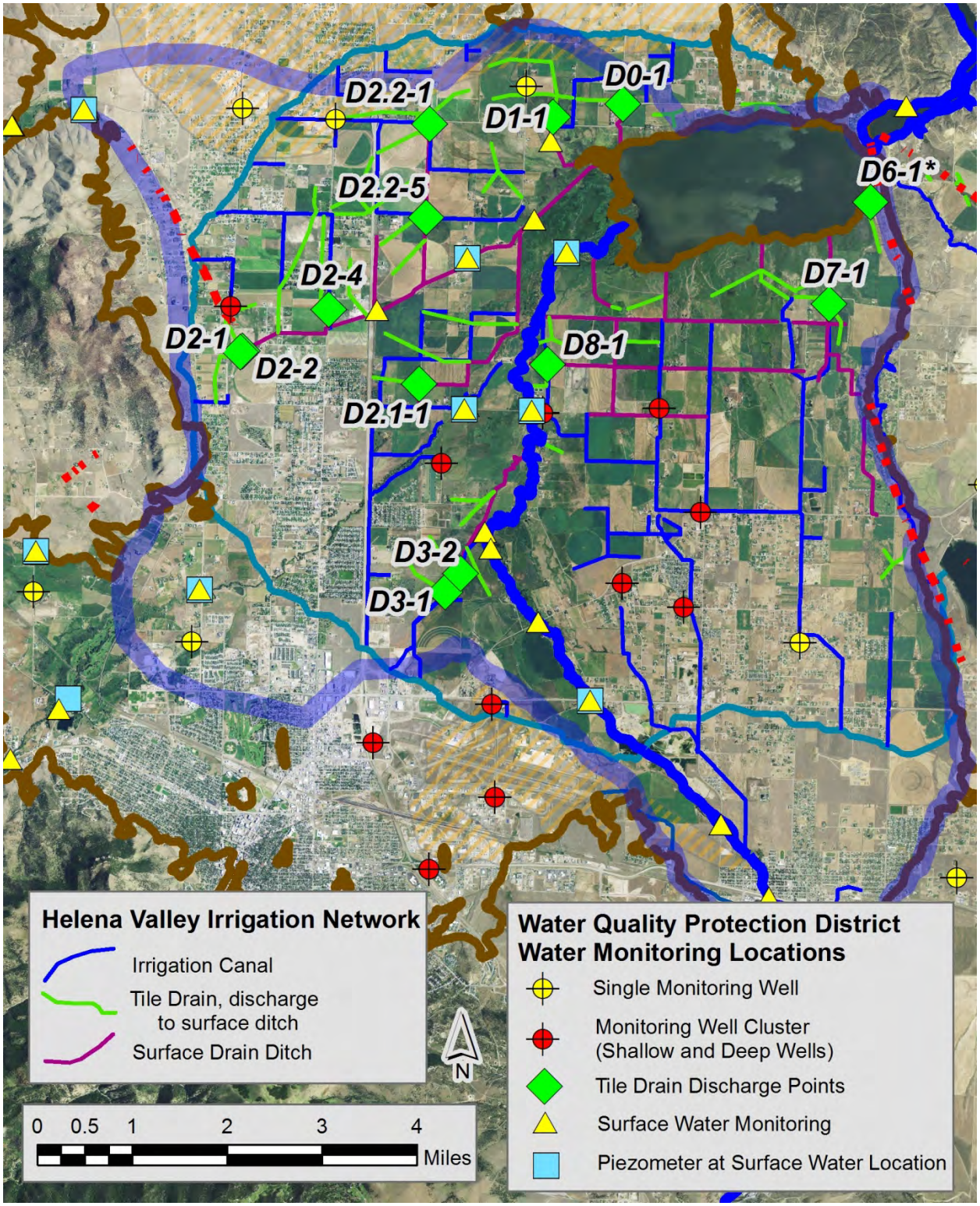


Figure 6-2 – HVID Drain and other Helena Valley Water Monitoring Locations

Tile drain locations included for detailed sampling noted. * Drain D6-1, with Drain D6-2, were sampled only during reconnaissance sampling, but for more comprehensive water chemistry analyses at that time.

6.1 Overview of Sampling Results

While the sampling and analysis program focused on nutrients in shallow ground water, additional analyses were completed during selected sample events to characterize major ions and trace metals. Major ions data allow classification of chemistry defined water types, and comparison with similar data for recent and historical water quality data for the Helena area (Swierc, 2013). The trace metal data was collected for comparison with TMDL target concentrations for regional streams impacted by historical mining activities (USEPA, 2006). The major ion and detected trace metal data for the drains is tabulated in Table 6-1. The major ion data allows for classification of water types, which relates to recharge sources as characterized by the background data (Section 5.0).

Trace metal samples were collected in August 2013 during the irrigation season when irrigation waters are likely to be present in the shallow ground water; and in December 2013 during the winter period when ground water levels are seasonally declining. Trace metals were also sampled from drains D6-1 and D6-2, from the east side of Lake Helena, during the reconnaissance sampling program. From this sampling program, a total of 27 trace metal samples were collected and analyzed. General observations from the metals data set include:

- Several trace elements were not detected in any samples above their laboratory detection limits. These include: Antimony (Sb), Cadmium (Cd), Lead (Pb), and Silver (Ag). Zinc (Zn) was detected at the detection limit in one sample.
- Selenium (Se) was detected in 5 samples, with all samples from D0-1 and D1-1 having trace levels of Se.
- Copper (Cu) was detected in 18 samples at concentrations ranging from 0.001 mg/L up to 0.006 mg/L. This is well below the recommended action level for drinking water at 1.3 mg/L.
- Arsenic was detected in all 27 samples, all below the drinking water standard of 0.01 mg/l. Detected concentrations range from 0.002 mg/L up to 0.008 mg/L, with an average of 0.005 mg/L.
- Uranium (U) was detected in all 27 samples, with concentrations ranging from 0.003 mg/L up to 0.03 mg/L. The drinking water standard is 0.03 mg/L, with the elevated sample from D7-1.

Missouri River waters, which represent the irrigation waters brought into the valley by the Helena Valley Irrigation District, are known to have elevated levels of naturally occurring Arsenic, ranging from approximately 0.022 to 0.034 mg/L (Kendy et al., 1998). The detection of lower levels of As in shallow ground water from the drains infers that As in irrigation waters is removed during percolation through soils. Based on this observation, the soil-aquifer treatment properties of the Helena Valley soils appears sufficient to mitigate the risk of As to ground water as a hazard from irrigation waters.

Table 6-1 Laboratory Data Results for Major Ions and Trace Metals from Drain Sampling

			Anions				Dissolved Trace Metals					Cations					Major Ion Totals		Major Ion Percentages of Total +/- Ions					
Location	Sample Date	Total Dissolved Solids	Alkalinity (as $CaCO_3$)	Bicarbonate (as HCO_3)	Chloride (Cl)	Sulfate (SO_4)	Arsenic (As)	Boron (B)	Copper (Cu)	Selenium (Se)	Uranium (U)	Calcium (Ca)	Iron (Fe)	Magnesium (Mg)	Potassium (K)	Sodium (Na)	Sum Cations	Sum Anions	Na+ K	Ca	Mg	Cl	HCO_3	SO_4
		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	meq	Meq	%	%	%	%	%	%
D0-1	6-Aug-13	472	350	420	18	75	0.007	0.16	0.002	0.001	0.0141	67	<0.03	44	< 1	45	8.92	8.95	21.9	37.5	40.6	5.7	76.9	17.4
D0-1	12-Dec-13	464	330	400	20	80	0.006	0.14	0.001	0.001	0.0135	56	0.09	46	1	43	8.48	8.78	22.4	32.9	44.6	6.4	74.6	19.0
D0-1	21-May-14	445	290	350	15	77	--	--	--	--	--	58	<0.03	45	< 1	40	8.34	7.76	20.9	34.7	44.4	5.4	73.9	20.7
D0-1	28-Aug-14	492	330	400	17	68	--	--	--	--	--	63	<0.03	43	< 1	45	8.67	8.45	22.9	36.2	40.8	5.7	77.6	16.8
D0-1	24-Nov-14	468	310	380	15	65	--	--	--	--	--	56	0.04	40	1	42	7.94	8.00	23.4	35.2	41.4	5.3	77.8	16.9
D1-1	6-Aug-13	490	340	420	18	90	0.005	0.19	0.003	0.002	0.015	65	<0.03	37	< 1	63	9.03	9.26	30.4	35.9	33.7	5.5	74.3	20.2
D1-1	12-Dec-13	509	330	410	20	110	0.003	0.18	0.001	0.002	0.0132	58	< 0.03	38	< 1	66	8.89	9.57	32.3	32.5	35.2	5.9	70.2	23.9
D1-1	21-May-14	463	280	340	18	96	--	--	--	--	--	59	<0.03	35	< 1	61	8.48	8.08	31.3	34.7	34.0	6.3	69.0	24.7
D2.1-1	6-Aug-13	294	210	260	17	44	0.008	0.11	0.006	<0.001	0.0098	63	<0.03	16	3	24	5.60	5.66	20.3	56.2	23.5	8.5	75.3	16.2
D2.1-1	6-Aug-13	296	210	260	17	44	0.007	0.11	0.006	<0.001	0.0096	63	<0.03	16	3	23	5.55	5.66	19.7	56.6	23.7	8.5	75.3	16.2
D2.1-1	2-Dec-13	326	190	240	22	52	0.005	0.08	< 0.001	< 0.001	0.0086	63	< 0.03	14	3	24	5.43	5.64	20.9	57.9	21.2	11.0	69.8	19.2
D2.1-1	21-May-14	290	170	200	18	45	--	--	--	--	--	60	<0.03	15	3	24	5.37	4.72	21.2	55.8	23.0	10.7	69.4	19.8
D2.1-1	28-Aug-14	338	190	230	20	45	--	--	--	--	--	64	<0.03	16	3	26	5.73	5.27	21.4	55.7	23.0	10.7	71.5	17.8
D2.1-1	24-Nov-14	327	190	230	19	46	--	--	--	--	--	59	<0.03	14	3	25	5.28	5.26	22.4	55.8	21.8	10.2	71.6	18.2
D2.2-1	6-Aug-13	432	320	390	19	70	0.004	0.14	0.001	<0.001	0.0114	69	<0.03	31	< 1	47	8.04	8.38	25.4	42.8	31.7	6.4	76.2	17.4
D2.2-1	12-Dec-13	448	310	380	20	74	0.003	0.15	< 0.001	< 0.001	0.0095	62	< 0.03	34	< 1	47	7.94	8.33	25.8	39.0	35.3	6.8	74.7	18.5
D2.2-1	21-May-14	401	270	330	17	61	--	--	--	--	--	69	<0.03	31	< 1	37	7.60	7.16	21.2	45.3	33.6	6.7	75.6	17.7
D2.2-1	21-May-14	399	270	330	17	61	--	--	--	--	--	69	<0.03	31	< 1	37	7.60	7.16	21.2	45.3	33.6	6.7	75.6	17.7
D2.2-1	28-Aug-14	427	280	340	18	60	--	--	--	--	--	65	<0.03	29	< 1	43	7.53	7.33	25.2	43.1	31.7	6.9	76.0	17.0
D2.2-1	24-Nov-14	439	280	350	18	65	--	--	--	--	--	62	<0.03	30	< 1	46	7.59	7.60	26.8	40.7	32.5	6.7	75.5	17.8
D2.2-5	6-Aug-13	381	290	350	20	57	0.003	0.1	0.001	<0.001	0.0056	68	<0.03	29	3	32	7.26	7.49	20.4	46.7	32.9	7.5	76.6	15.9
D2.2-5	12-Dec-13	446	310	380	26	70	0.003	0.09	< 0.001	< 0.001	0.0061	67	< 0.03	35	3	39	8.01	8.42	22.3	41.7	35.9	8.7	74.0	17.3
D2.2-5	21-May-14	380	250	310	18	55	--	--	--	--	--	67	<0.03	29	2	31	7.14	6.73	19.8	46.8	33.4	7.5	75.5	17.0
D2-1	6-Aug-13	392	310	380	14	46	0.006	0.12	0.002	<0.001	0.0092	71	<0.03	29	2	31	7.34	7.58	19.2	48.3	32.5	5.2	82.2	12.6
D2-1	2-Dec-13	395	300	370	19	58	0.006	0.14	0.001	< 0.001	0.0098	65	< 0.03	29	2	35	7.21	7.81	22.0	44.9	33.1	6.9	77.7	15.5
D2-1	21-May-14	371	270	320	14	44	--	--	--	--	--	67	<0.03	30	2	32	7.27	6.55	20.0	46.0	34.0	6.0	80.0	14.0
D2-2	6-Aug-13	395	310	380	16	50	0.006	0.13	0.002	<0.001	0.0092	71	<0.03	29	2	35	7.51	7.72	21.1	47.1	31.8	5.8	80.7	13.5
D2-2	2-Dec-13	394	290	350	21	65	0.006	0.17	0.001	< 0.001	0.0108	60	0.03	23	2	50	7.12	7.68	31.4	42.0	26.6	7.7	74.7	17.6
D2-2	21-May-14	377	260	320	16	27	--	--	--	--	--	64	<0.03	26	3	44	7.34	6.26	27.3	43.5	29.2	7.2	83.8	9.0
D2-4	6-Aug-13	336	250	300	17	52	0.004	0.1	0.001	<0.001	0.0031	64	<0.03	24	4	28	6.51	6.48	20.6	49.0	30.3	7.4	75.9	16.7
D2-4	2-Dec-13	368	260	320	23	69	0.003	0.1	< 0.001	< 0.001	0.0035	63	< 0.03	23	4	33	6.60	7.33	23.7	47.6	28.7	8.8	71.6	19.6
D2-4	21-May-14	352	240	290	16	55	--	--	--	--	--	67	<0.03	26	3	30	6.88	6.35	20.3	48.6	31.1	7.1	74.9	18.0
D2-4	28-Aug-14	395	260	320	16	57	--	--	--	--	--	70	<0.03	26	4	31	7.11	6.88	20.7	49.1	30.1	6.6	76.2	17.2
D2-4	24-Nov-14	371	240	290	16	47	--	--	--	--	--	60	<0.03	23	3	33	6.42	6.18	23.8	46.7	29.5	7.3	76.9	15.8

			Anions				Dissolved Trace Metals					Cations					Major Ion Totals		Major Ion Percentages of Total +/- Ions					
Location	Sample Date	Total Dissolved Solids	Alkalinity (as $CaCO_3$)	Bicarbonate (as HCO_3)	Chloride (Cl)	Sulfate (SO_4)	Arsenic (As)	Boron (B)	Copper (Cu)	Selenium (Se)	Uranium (U)	Calcium (Ca)	Iron (Fe)	Magnesium (Mg)	Potassium (K)	Sodium (Na)	Sum Cations	Sum Anions	Na+ K	Ca	Mg	Cl	HCO_3	SO_4
		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	meq	Meq	%	%	%	%	%	%
D3-1	6-Aug-13	439	260	310	38	64	0.003	0.1	0.001	<0.001	0.0039	76	0.04	25	4	32	7.37	7.48	20.6	51.5	27.9	14.3	67.9	17.8
D3-1	13-Dec-13	406	260	320	39	64	0.003	0.09	< 0.001	< 0.001	0.0037	67	< 0.03	26	4	33	7.04	7.68	22.2	47.5	30.4	14.3	68.3	17.4
D3-2	6-Aug-13	409	240	290	41	68	0.005	0.09	0.002	<0.001	0.0053	76	<0.03	23	4	34	7.29	7.32	22.0	52.0	26.0	15.8	64.9	19.3
D3-2	13-Dec-13	406	240	290	35	69	0.004	0.08	< 0.001	< 0.001	0.0048	66	< 0.03	23	4	31	6.66	7.18	22.1	49.4	28.4	13.8	66.2	20.0
D3-2	21-May-14	390	220	270	31	64	--	--	--	--	--	75	<0.03	22	4	28	6.89	6.63	19.5	54.3	26.3	13.2	66.7	20.1
D3-2	28-Aug-14	506	230	280	59	87	--	--	--	--	--	90	<0.03	27	4	37	8.45	8.06	20.5	53.2	26.3	20.6	56.9	22.5
D3-2	24-Nov-14	442	230	280	39	68	--	--	--	--	--	76	<0.03	23	4	33	7.24	7.10	21.5	52.3	26.1	15.5	64.6	19.9
D6-1	6-Jun-13	336	240	290	14	52	0.006	--	<0.001	<0.001	0.0208	64	<0.03	17	3	35	6.21	6.23	26.0	51.4	22.5	6.3	76.3	17.4
D6-2	6-Jun-13	307	220	270	14	49	0.004	--	<0.001	0.001	0.02	58	<0.03	16	7	31	5.78	5.84	27.1	50.1	22.8	6.8	75.8	17.5
D7-1	7-Aug-13	294	190	230	14	49	0.003	0.08	0.001	<0.001	0.03	53	<0.03	12	5	30	5.09	5.18	28.7	51.9	19.4	7.6	72.7	19.7
D7-1	12-Dec-13	299	190	230	15	48	0.002	0.07	0.001	< 0.001	0.0281	51	< 0.03	12	5	30	4.99	5.19	29.3	51.0	19.8	8.1	72.6	19.2
D7-1	21-May-14	295	170	200	13	45	--	--	--	--	--	55	<0.03	12	5	31	5.24	4.58	28.7	52.4	18.9	8.0	71.5	20.5
D8-1	6-Aug-13	281	210	250	12	42	0.008	0.1	0.002	<0.001	0.0054	60	0.05	15	5	21	5.30	5.31	20.2	56.5	23.3	6.4	77.2	16.5
D8-1	12-Dec-13	277	180	220	11	54	0.005	0.04	< 0.001	< 0.001	0.0041	54	< 0.03	14	4	19	4.80	5.04	19.8	56.2	24.0	6.2	71.5	22.3

6.2 Northeastern North Hills Subwatershed

The Northeastern North Hills subwatershed lies directly north of Lake Helena, with several primarily southward flowing ephemeral drainages (Figure 6-3). The northern part is located north of the major Helena Valley fault in an upland area with complex bedrock geology (Reynolds; in Thamke, 2000). The geology south of the fault comprises several hundred feet of Tertiary deposits over bedrock shales. The Tertiary deposits appear to fill a paleo-channel system which crosses the major fault system. The Helena Valley Aquifer is only present along the northern boundary of Lake Helena (see Figure 1-2). The main HVID canal crosses through the southern part of this area before discharging into Lake Helena. The area inside the canal includes irrigated farmlands, with four drain systems present. Two of these drains represent primary sampling locations for this study.

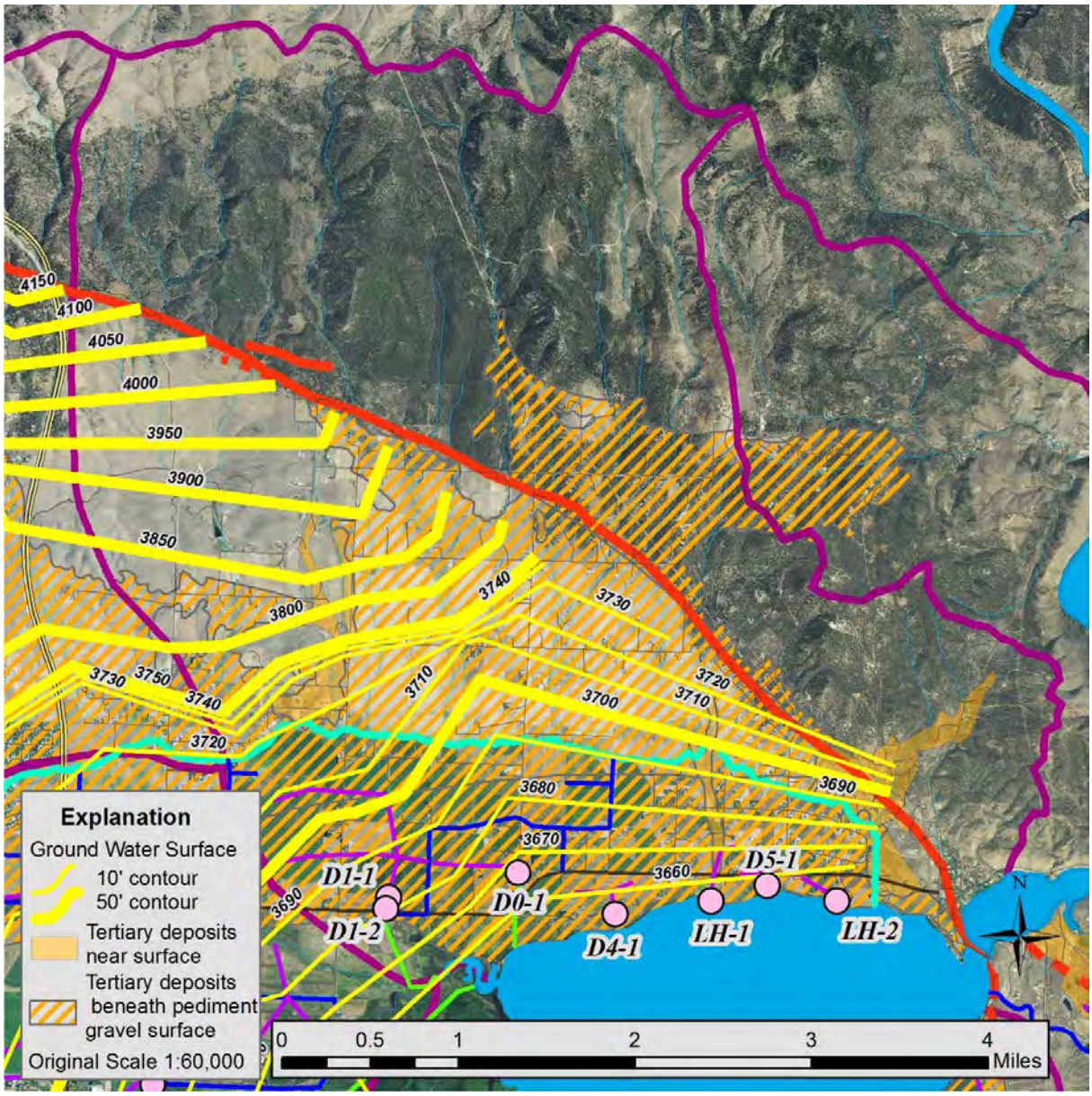


Figure 6-3 – Northeastern North Hills Subwatershed

Tile drain discharge points are noted, with ground water potentiometric surface and Tertiary geology.

6.2.1 D0 Ditch System

The D0 Ditch is a small ditch with a primary water source from a single underground tile drain. The ditch discharges directly into the northwest corner of Lake Helena. The area near the D0 Ditch is depicted in Figure 6-4. A surface water distribution lateral flows around the tile drain recharge area, which is interpreted to serve as a ground water recharge source from stream loss, in addition to irrigation waters. Ground water in this area is interpreted to flow generally south, following topography, towards Lake Helena. Photographs of the drain and discharge point are presented in Figure 6-5. Results from the reconnaissance water quality sample indicate nitrate plus nitrate nitrogen at 3.29 mg/L. The D0-1 Drain was selected as one of the primary sampling points for the project, with regular sampling through the entire project field program. The drain was sampled a total of 26 times during the program. The nutrient assessment water quality data is listed in Table 6-2, with time sequence graphs in Figure 6-6.

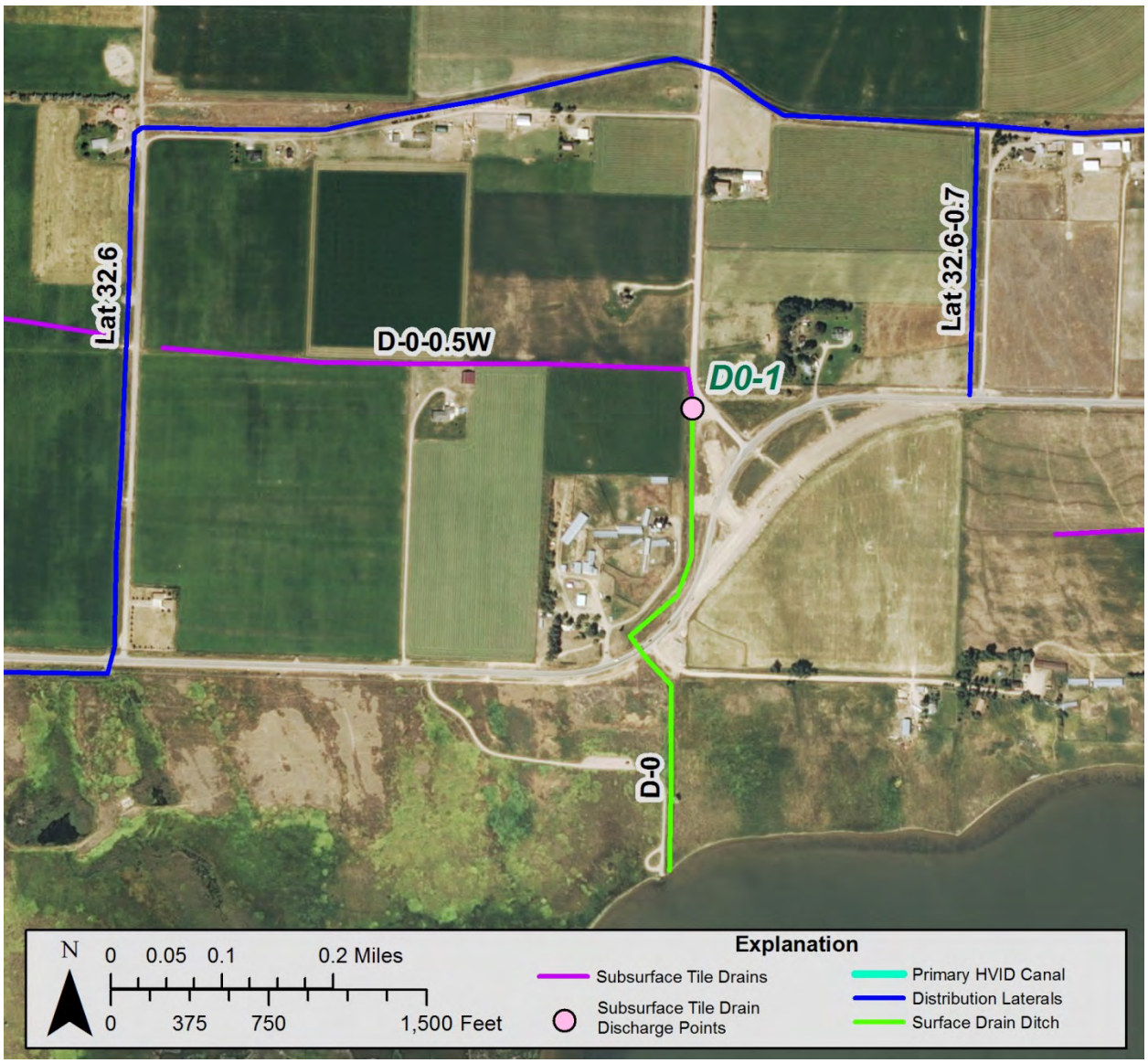


Figure 6-4 – D0 Ditch and Surrounding Features.

Tile drain discharge points are noted, with ground water potentiometric surface and Tertiary geology. See text for explanation.

D-0 Ditch with Drain discharge point located in concrete culvert beneath vehicle on road.

Flow in D-0 Ditch from Drain south towards Lake Helena

Drain outfall in concrete culvert

Organic growth in D-0 Ditch below outfall

Figure 6-5– Photographs of Drain D0-1 outlet.

Table 6-2 Laboratory Results from Sampling, D0-1 Drain

	Field Parameters				Laboratory Data Results						
D0-1	pH	Temp	specific conductivity	Dissolved Oxygen	Total Dissolved Solids, TDS @ 180°C	Alkalinity Total as $CaCO_3$	Cl	Br	SO_4	NO_3+ NO_2 as N	Phosphorus, Total as P
	S.U.	°C	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
5/6/13	7.66	6.4	461	12.93	437	300	17	0.041		3.29	0.026
6/20/13	7.69	8.9	510	11.68	466	320	20	0.07		2.65	0.043
6/28/13	7.69	9.9	507	10.89	460	320	18	0.07		2.37	0.044
7/10/13	7.70	10.9	554	9.82	486	330	19	0.06		2.27	0.042
7/26/13	7.65	10.9	562	9.09	491	350	18	0.08		2.52	0.039
7/26/13	8.65	10.9	562	9.09	486	350	18	0.08		2.51	0.04
8/6/13	7.70	11.3	565	8.6	472	350	18	0.06	75	2.26	0.043
8/23/13	7.73	11.6	583	6.62	492	340	20	0.17	83	2.29	0.039
9/5/13	7.73	11.9	588	7.9	490	350	20	0.09		2.3	0.04
9/24/13	7.79	11.8	586	8.33	479	350	19	0.07	78	2.3	0.041
10/10/13	7.82	11.3	554	7.17	483	350	19	0.024	77	2.54	0.031
10/25/13	7.81	10.7	564	6.78	483	340	19	0.07	76	2.55	0.042
11/13/13	7.89	9.8	544	5.03	485	340	19	0.08		3.29	0.042
12/12/13	7.95	8	507	8.55	464	330	20	0.08	80	3.23	0.06
1/16/14	8.08	6.3	475	10.22	450	320	18	0.08	78	3.19	0.026
2/20/14	8.27	6.3	438	8.9	464	310	17	0.1	78	1.69	0.036
3/20/14	8.12	4.7	446	7.65	456	300	18	0.04	84	2.7	0.029
4/14/14	8.34	4.9	448	6.62	451	310	18	0.1	83	3.29	0.03
5/1/14	8.49	5.6	453	5.75	447	290	16	0.03	77	2.81	0.035
5/21/14	8.23	6.5	474	5.4	445	290	15	0.06	77	3.25	0.026
6/10/14	8.12	8.5	529	6.11	491	320	14	0.04	72	2.76	0.032
7/10/14	8.26	9.8	540	5.01	476	310	15	0.03	69	2.3	0.032
8/8/14	8.16	10.8	567	6.58	470	330	15	0.017	67	2.19	0.035
8/28/14	8.29	11.9	574	5.42	492	330	17	0.08	68	1.49	0.033
9/30/14	8.32	11.2	562	5.6	475	320	18	0.05	67	2.03	0.045
11/24/14	8.59	8.8	512	6.86	468	310	15	0.08	65	2.45	0.055
Max	8.59	11.9	588	12.93	492	350	20	0.17	84	3.29	0.060
Min	7.65	4.7	438	5.01	437	290	14	0.017	65	1.49	0.026
Average	7.99	9.2	526	7.79	471.5	325.4	17.7	0.067	75.2	2.56	0.038
Median	7.92	9.9	542	7.41	473.5	325.0	18.0	0.070	77.0	2.52	0.039
Std Dev	0.29	2.4	48.9	2.12	16.5	19.2	1.8	5.9	5.9	0.48	0.008

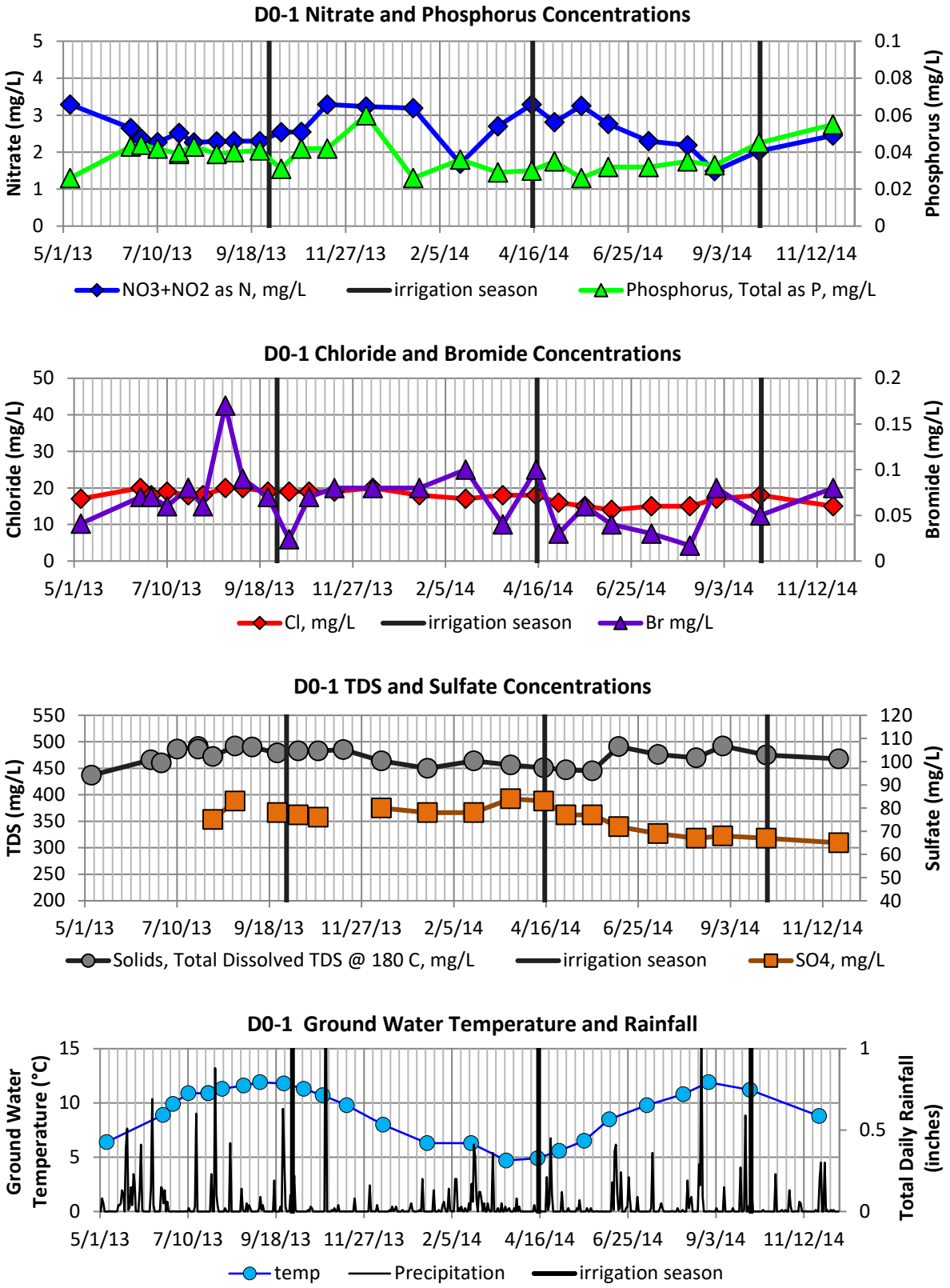


Figure 6-6–Water quality nutrient results for D0-1 Drain.

Irrigation season runs for April 15 – October 1, and represents the period when irrigation waters change the local hydrology.

D0-1 Ditch System Hydrology and Discussion

The D0-1 drain discharged continuously during the monitoring period for this study, with measured flow rates ranging from 0.013 cfs up to 1.91 cfs (Table 6-3). Flow from the drain increased during summer to maximum discharge in late summer, with the lowest flows occurring at the beginning of irrigation season (Figure 6-7). The system appears to receive primary recharge during the irrigation season, with flows depleting local storage through the winter. The maximum measured discharge rate occurred in September 2013, interpreted as a response to the late summer precipitation providing additional recharge to the system.

Combining the nutrient data with flow discharge rates allows for calculation of estimates of nutrient mass loading rates. The loading rates for the D0-1 drain reflect the flow discharge rates for the tile drain (Figure 6-7). Loading to the system occurs primarily during the summer irrigation season. Loading rates decrease during the winter as discharge decreases.

The yearly loading rate for the D0-1 drain was calculated using the data presented in Table 6-4. In order to maintain a consistent time interval for all of the drains included in this study, sample data from September 2013 to July 2014 was used. In order to complete the year, data from July 2014 was used as an estimate for July 2013. The data allows for estimates of the total amount of nitrogen and phosphorus discharged from the drain during the study year. For this drain, this corresponds to a total of 3,068 pounds (1.53 tons) of nitrogen and 45.83 pounds (0.023 tons) of phosphorus discharged from July 2013 to July 2014 (Table 6-4).

The local watershed contributing to the ground water collected from the D0-1 drain is depicted in Figure 6-8, which also shows the configuration of the local water table. For purposes of this assessment, this includes the area upgradient from the drain, estimated from the water table map, up to and including the primary HVID Canal and irrigation distribution laterals which both potentially serve to recharge local ground water. Land use in this area is primarily irrigated agriculture with a limited number of houses. Potential nutrient sources include agricultural fertilizers and manure waste, and discharge from septic system drainfields.

Table 6-3 – D0-1 Drain Discharge & Loading Rates

Sample Date	Flow Rate ft^3/s	**Nitrogen** lbs/day	**Phosphorus** lbs/day
9/5/13	1.91	23.65	0.411
9/24/13	0.92	11.37	0.203
10/10/13	0.61	8.35	0.102
10/25/13	0.58	8.02	0.132
11/13/13	0.58	10.35	0.132
12/12/13	*0.40**	6.62	0.045
1/16/14	0.22	3.73	0.030
2/20/14	0.11	0.97	0.021
3/20/14	0.045	0.66	0.007
4/14/14	0.038	0.67	0.006
5/1/14	0.013	0.20	0.002
5/21/14	0.13	2.28	0.018
6/10/14	0.84	12.50	0.145
7/10/14	1.26	15.61	0.217
8/8/14	1.10	12.99	0.208
8/28/14	0.76	6.07	0.134
9/30/14	0.89	9.79	0.217
11/24/14	0.26	3.44	0.077
Max	1.91	23.65	0.411
Min	0.013	0.20	0.0025
Average	0.59	7.63	0.117
Median	0.58	7.32	0.117
Stnd Dev	0.51	6.24	0.107

* Rate not measured in field, estimated as average between bounding measurements

The flows in the D0-1 drain can be seen to increase with the May 20, 2014 sampling event (Figure 6-7). Since irrigation season starts on April 15, this represents an approximate 35 day lag between the onset of irrigation and recovery of water from the tile drains. Nitrate values in the drain range from 1.49 to 3.29 which, when compared to irrigation waters consistently below 1.0 mg/L (see Section 5.0), infers that nitrogen is from an upgradient, anthropogenic source. The detected nitrogen concentrations do not seem to follow a seasonal trend, suggesting that storage within the unsaturated zone controls the system, with nitrate added to the system when infiltration occurs from recharge source (e.g. irrigation waters or precipitation). Since dissolved oxygen is consistently present exceeding 50 percent saturation, it is assumed that all nitrogen species are converted to nitrate within the ground water system. The variability of the bromide concentrations relative to chloride result in this assessment method being inconclusive for this system.

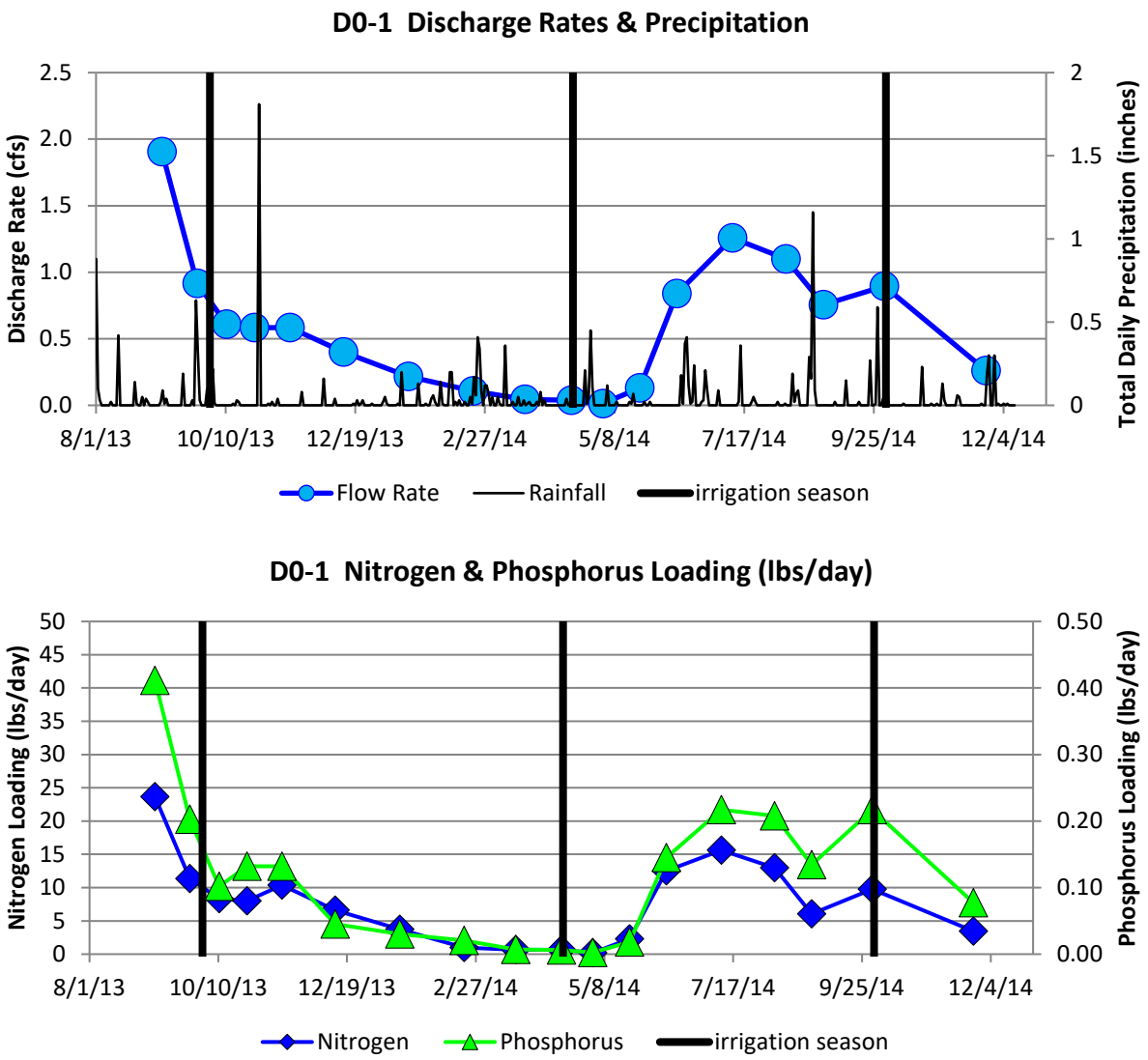


Figure 6-7 – Discharge Rates and Nitrogen and Phophorus Loading from D0-1 Drain.

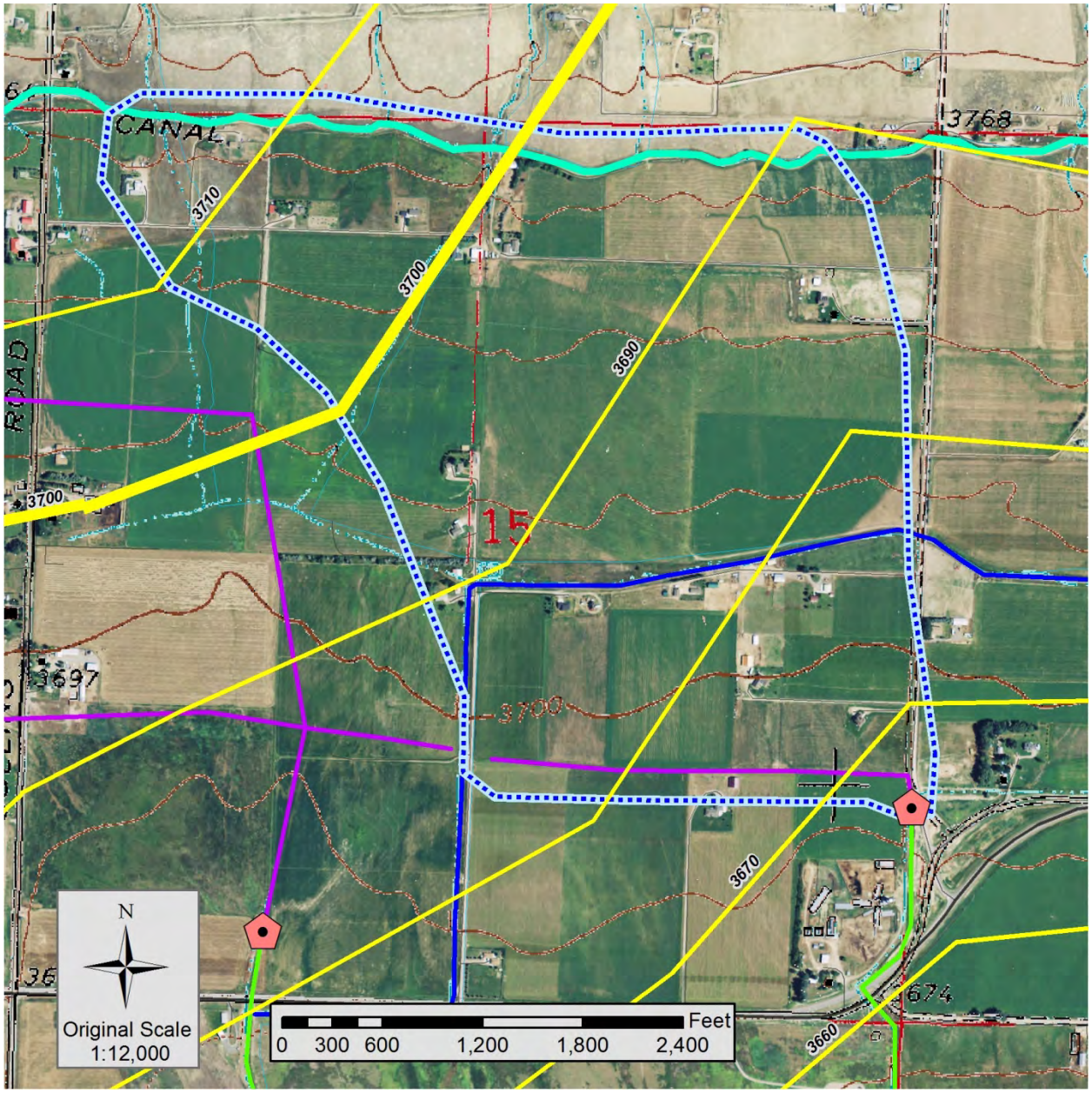


Figure 6-8 – Subwatershed Contributing area for D0-1 Drain.
Ground water flow contours at 10' interval, with flow to southeast towards Lake Helena.

Table 6-4 – D0-1 Drain Nitrogen and Phosphorus Loading

D0-1	Interval Days	Loading cfs	**Nitrogen lbs/day**	slope avg lbs/day	total lbs interval	**Phosphorus lbs/day**	slope avg lbs/day	total lbs interval
7/10/2013*		1.26	15.61			0.22		
9/5/2013	57	1.91	23.65	19.63	1118.76	0.41	0.31	17.91
9/24/2013	19	0.92	11.37	17.51	332.69	0.20	0.31	5.83
10/10/2013	16	0.61	8.35	9.86	157.76	0.10	0.15	2.44
10/25/2013	15	0.58	8.02	8.19	122.79	0.13	0.12	1.76
11/13/2013	19	0.58	10.35	9.19	174.56	0.13	0.13	2.51
12/12/2013	29	0.40	6.97	8.66	251.14	0.13	0.13	3.79
1/16/2014	35	0.22	3.73	5.35	187.19	0.030	0.080	2.80
2/20/2014	35	0.11	0.97	2.35	82.19	0.021	0.026	0.89
3/20/2014	28	0.05	0.66	0.81	22.78	0.007	0.014	0.39
4/14/2014	25	0.04	0.67	0.67	16.66	0.006	0.007	0.17
5/1/2014	17	0.01	0.20	0.44	7.41	0.002	0.004	0.07
5/21/2014	20	0.13	2.28	1.24	24.76	0.018	0.010	0.21
6/10/2014	20	0.84	12.50	7.39	147.84	0.14	0.08	1.63
7/10/2014	30	1.26	15.61	14.06	421.67	0.22	0.18	5.43
Total Days	365			**Total Pounds N**	**3068**		**Total Pounds P**	**45.83**
				Total Tons N	**1.53**		**Total Tons P**	**0.023**

* Data from 7-10-2014 used for 2013 to allow estimate of full year

6.2.2 D1 Ditch System

The D1 Ditch is a small ditch with a primary water source from one underground tile drain system, the D1-1 drain. The ditch discharges directly into a tributary into the northwest corner of Lake Helena. The area near the D-1 Ditch is depicted in Figure 6-9. Photographs of the drain discharge points are presented in Figure 6-10. Return flows from a surface water distribution lateral enters the main ditch just downstream of the drain discharge points, which dominates flow from that point. The D1-2 drain was observed during the field reconnaissance program, with a strong flow discharging from a relatively small PVC pipe. This drain was not installed as part of the HVID system, and appears to have been installed by a local landowner. Since construction information is not available, the recharge source and area for the drain is unknown.

Ground water in this area is interpreted to flow generally south to southeast, following topography, towards Lake Helena. The primary drain source is developed as a watering hole for cattle at the discharge point. Results from the reconnaissance water quality sampling for the drain indicate nitrate plus nitrate as nitrogen at 2.83 mg/L in D1-1 and 0.77 mg/L in D1-2 (Table 6-5). The reconnaissance sample data shows distinctly different chemistry between the two drains. The D1-1 Drain was selected as a primary sampling point for the project. The drain was sampled a total of 20 time during the program. The nutrient assessment water quality data is listed in Table 6-6, with time sequence graphs in Figure 6-11. The difference in chemistry data between the D1-2 drain, compared to the D1-1 drain, suggests a different water source for the drain. Given the water temperature, high dissolved solids and chloride, with low nitrate, the water source for drain D1-2 is suspected to be a local spring from depth in the Tertiary strata.

Table 6-5 – Laboratory Results from Reconnaissance Sampling, D1 Ditch

Analyses		**D1-1**	**D1-2**	
Field Parameters				
	pH	7.63	7.62	S.U.
	Conductivity	476	1351	µs/cm
	Temperature	6.9	10.5	°C
	Dissolved Oxygen	13.48	9.46	mg/L
Laboratory Results				
	Total Dissolved Solids, TDS @ 180°C	509	1320	mg/L
	Alkalinity, total as $CaCO_3$	260	330	mg/L
	Chloride	18	57	mg/L
	Bromide	<0.05	<0.05	mg/L
	Nitrogen, Nitrate + Nitrite as N	2.83	0.77	mg/L
	Phosphorus, total as P	0.028	0.209	mg/L

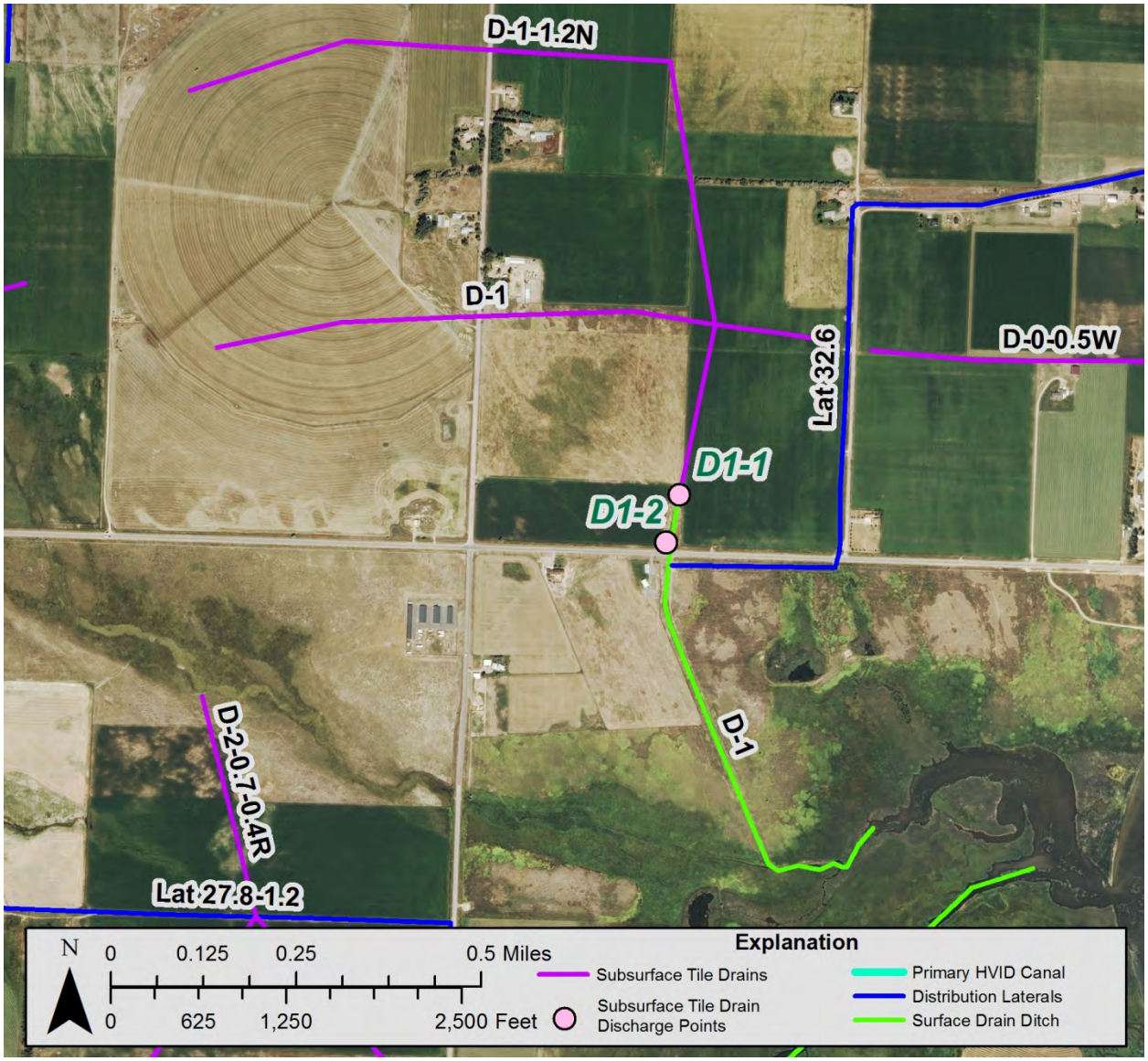


Figure 6-9 – D1 Ditch and Surrounding Features.

D1 Ditch with Drain discharge from D1-1 behind fence.

Drain D1-1 outfall

Drain D1-1 outfall, note flow outward in organic matter

D1 ditch looking north from Lincoln Road. Drain D1-2 visible in lower left

Drain D1-2 outfall with flowing water in lower right, near storm water pipes

Drain D1-2 outfall with flowing water

Figure 6-10– Photographs of Drain D1-1 and D1-2 Outlets.

Table 6-6 Laboratory Results from Sampling, D1-1 Drain

	Field Parameters				Laboratory Results						
D1-1	pH	Temp	specific conductivity	Dissolved Oxygen	Total Dissolved Solids, TDS @ 180°C	Alkalinity Total as $CaCO_3$	Cl	Br	SO_4	NO_3+ NO_2 as N	Phosphorus, Total as P
	S.U.	°C	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
5/9/13	7.63	6.9	476	13.48	509	260	18	0.02		2.83	0.028
6/20/13	7.64	9.3	584	11.27	533	320	22	0.08		5.04	0.045
7/10/13	7.6	9.9	565	11.88	520	320	20	0.08		4.62	0.034
7/26/13	7.66	11.6	586	10.72	505	330	19	0.08		4.11	0.038
8/6/13	7.68	12.6	611	9.85	490	340	18	0.06	90	3.51	0.046
8/23/13	7.72	12.1	629	8.85	532	340	21	0.18	110	3.77	0.036
9/5/13	7.69	12.1	603	10.09	519	320	20	0.09		3.81	0.032
9/24/13	7.81	12.2	699	10.44	488	320	19	0.13	99	3.7	0.033
10/10/13	7.9	11.5	599	6.98	488	330	19	0.035	100	3.61	0.024
10/25/13	7.91	10.9	599	5.69	504	330	19	0.09	100	3.42	0.037
11/13/13	7.93	10	684	5.69	517	330	20	0.08		3.51	0.034
11/13/13			Duplicate Sample		513	330	20	0.08		3.88	0.034
12/12/13	7.94	8.4	557	8.77	509	330	20	0.12	110	3.16	0.022
1/16/14	8.06	6.7	529	10.32	449	330	19	0.12	110	2.95	0.021
2/20/14	8.15	5.6	505	10.52	507	320	19	0.13	110	2.91	0.029
3/20/14	8.11	5.1	510	8.02	525	320	21	0.047	120	2.4	0.031
4/14/14	8.2	5.2	517	6.98	520	320	22	0.04	120	3.03	0.03
5/1/14	8.32	5.9	501	6.51	488	290	19	0.04	110	3	0.035
5/21/14	8.3	7.1	505	5.55	463	280	18	0.1	96	3.72	0.025
6/10/14	8.11	8.7	534	6.11	491	290	17	0.1	89	4.2	0.029
Max	8.32	12.6	699	13.48	533	340	22	0.18	120	5.04	0.046
Min	7.60	5.1	476	5.55	449	260	17	0.020	89	2.40	0.021
Average	7.91	9.1	574	8.67	503.5	317.5	19.5	0.085	104.9	3.56	0.032
Median	7.91	9.6	575	8.81	508.0	320.0	19.0	0.080	110.0	3.56	0.033
Std Dev	0.24	2.6	65.8	2.42	21.7	21.0	1.3	0.039	10.1	0.64	0.007

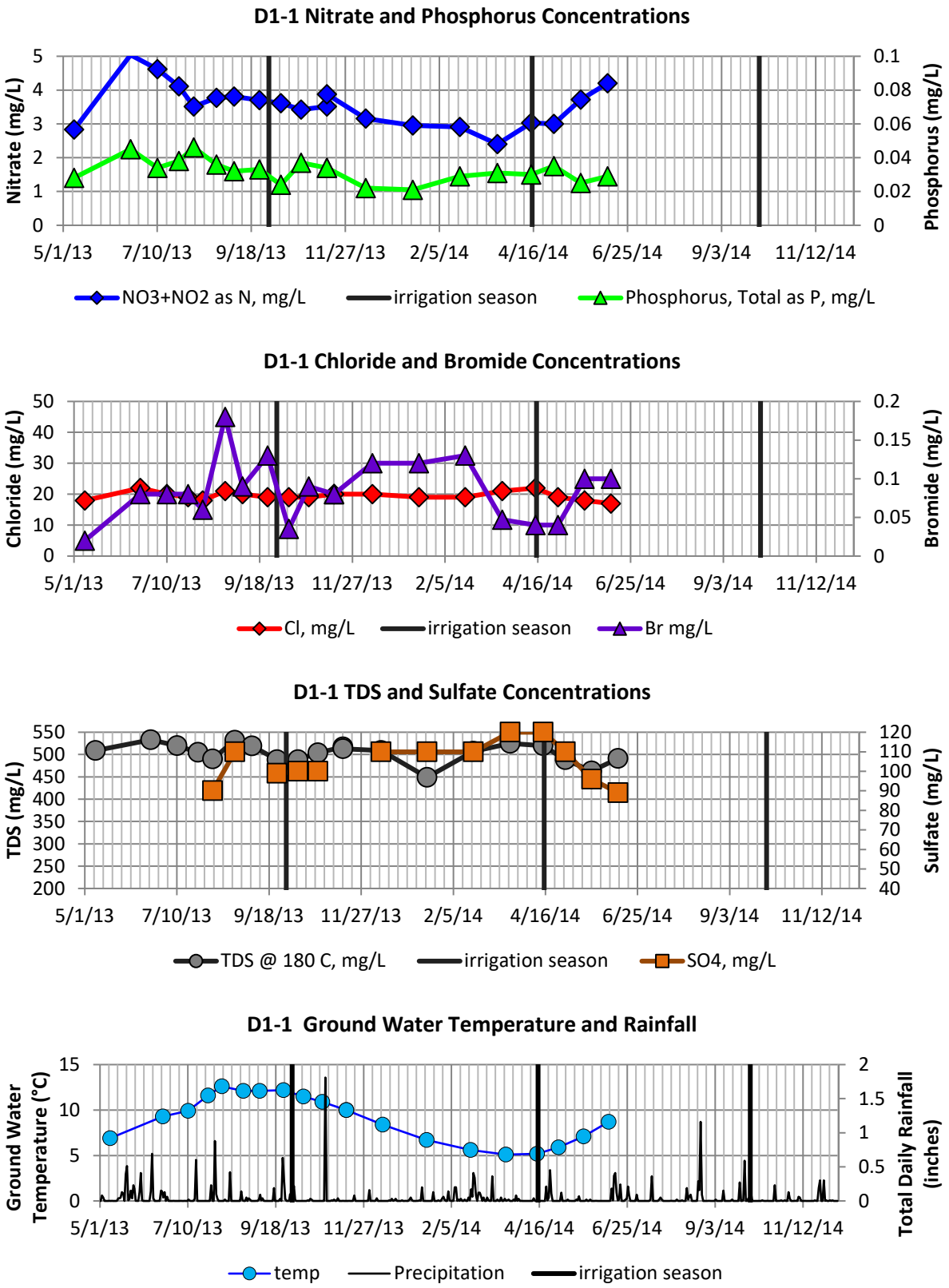


Figure 6-11 –Water Quality Nutrient Results for D1-1 Drain.

Irrigation season runs for April 15 – October 1, and represents the period when irrigation waters change the local hydrology.

D1-1 Drain System Hydrology and Discussion

The D1-1 drain discharged continuously during the monitoring period for this study, with measured flow rates ranging from 0.47 cfs up to 1.39 cfs (Table 6-7). Flow from the drain increased during summer to maximum discharge in late summer, with the lowest flows occurring in late winter/early spring and the beginning of irrigation season (Figure 6-12). The system appears to receive primary recharge during the irrigation season, with flows depleting local storage through the winter after irrigation season ends. The maximum measured discharge rate occurred in September 2013, interpreted as a response to the late summer precipitation providing additional recharge to the system.

Combining the nutrient data with flow discharge rates allows for calculation of estimates of nutrient mass loading rates. The loading rates for the D1-1 drain reflect the flow discharge rates for the tile drain (Figure 6-12). Loading to the system occurs primarily during the summer irrigation season. Loading rates decrease during the winter as discharge decreases.

The yearly loading rate for the D0-1 drain was calculated using the data presented in Table 6-8. In order to maintain a consistent time interval for all of the drains included in this study, sample data from September 2013 to June 2014 was used. In order to complete the year, data from June 2014 was used as an estimate for June 2013. The data allows for estimates of the total amount of nitrogen and phosphorus discharged from the drain during the study year. For this drain, this corresponds to a total of 6,053 pounds (3.03 tons) of nitrogen and 50.20 pounds (0.025 tons) of phosphorus discharged from June 2013 to June 2014 (Table 6-8).

The local watershed contributing to the water collected from the D0-1 drain is depicted in Figure 6-13, which also shows the configuration of the local water table. For purposes of this assessment, this includes the area upgradient from the drain, estimated from the water table map, up to and including the primary HVID Canal and irrigation distribution laterals which both potentially serve to recharge local ground water. Land use in this area is primarily irrigated agriculture with a limited number of houses. Potential nutrient sources include agricultural fertilizers and manure waste, and discharge from septic system drainfields.

Table 6-7 – D1-1 Drain Discharge & Loading Rates

Sample Date	Flow Rate ft^3/s	**Nitrogen** lbs/day	**Phosphorus** lbs/day
9/5/13	1.39	28.65	0.241
9/24/13	1.29	25.73	0.229
10/10/13	1.24	24.21	0.161
10/25/13	0.99	18.20	0.197
11/13/13	0.99	18.68	0.181
11/13/13	0.99	20.64	0.181
12/12/13	*0.79**	13.13	0.090
1/16/14	0.60	9.54	0.068
2/20/14	0.47	7.33	0.073
3/20/14	0.53	6.88	0.089
4/14/14	0.58	9.48	0.094
5/1/14	0.53	8.58	0.100
5/21/14	0.78	15.65	0.105
6/10/14	0.87	19.71	0.136
Max	1.39	28.65	0.241
Min	0.47	6.88	0.068
Average	0.86	16.17	0.139
Median	0.83	16.92	0.121
Stnd Dev	0.30	7.21	0.059

* Rate not measured in field, estimated as average between bounding measurements

The flows in the D1-1 drain can be seen to increase after the May 1, 2014 sampling event (Figure 6-12). Since irrigation season starts on April 15, this represents a minimum of a 15 day lag between the onset of irrigation and recovery of water from the tile drains. The response of the system to recharge is also seen from the October 28, 2013 rainfall event, which results in stable flows with increased loading in the subsequent sampling event (November 13, 2013). This infers that the rain event resulted in flushing of nutrients stored within the unsaturated zone at the end of irrigation season. Nitrate values in the drain range from 2.40 to 5.04 which, when compared to irrigation waters consistently below 1.0 mg/L (see Section 5.0), infers that nitrogen is from an upgradient, anthropogenic source. The detected nitrogen concentrations appear to increase at the beginning of irrigation season, and then stabilize and slowly decrease over time. This suggests that fertilizer application at the beginning of irrigation season dominates the system, with unsaturated zone storage and release controls the system through most of the year, with nitrate added to the system when infiltration occurs from recharge source (e.g. irrigation waters or precipitation). Since dissolved oxygen is consistently present exceeding 50 percent saturation, it is assumed that all nitrogen species are converted to nitrate within the ground water system. The variability of the bromide concentrations relative to chloride result in this assessment method being inconclusive for this system.

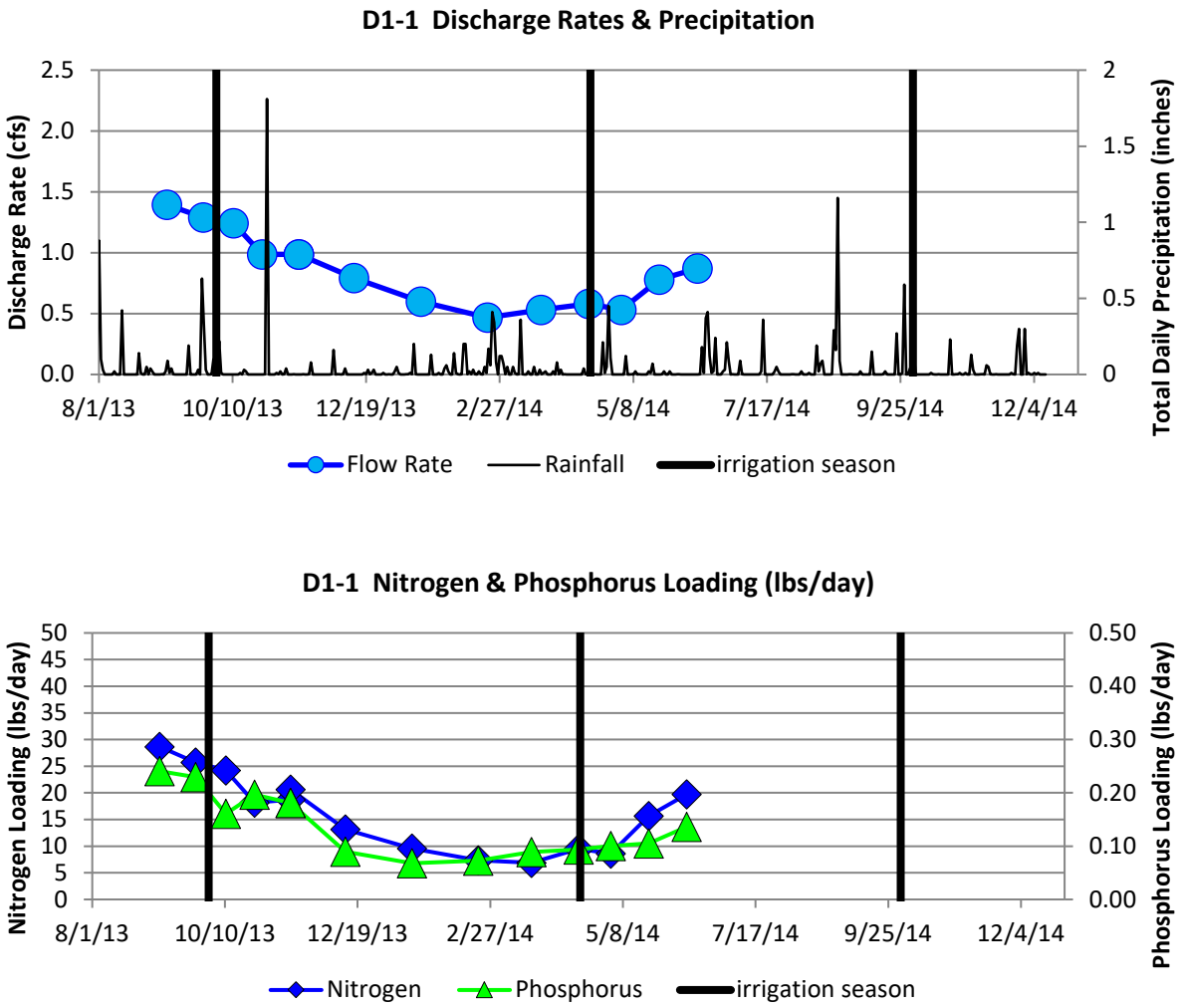


Figure 6-12 – Discharge Rates and Nitrogen and Phophorus Loading from D1-1 Drain.

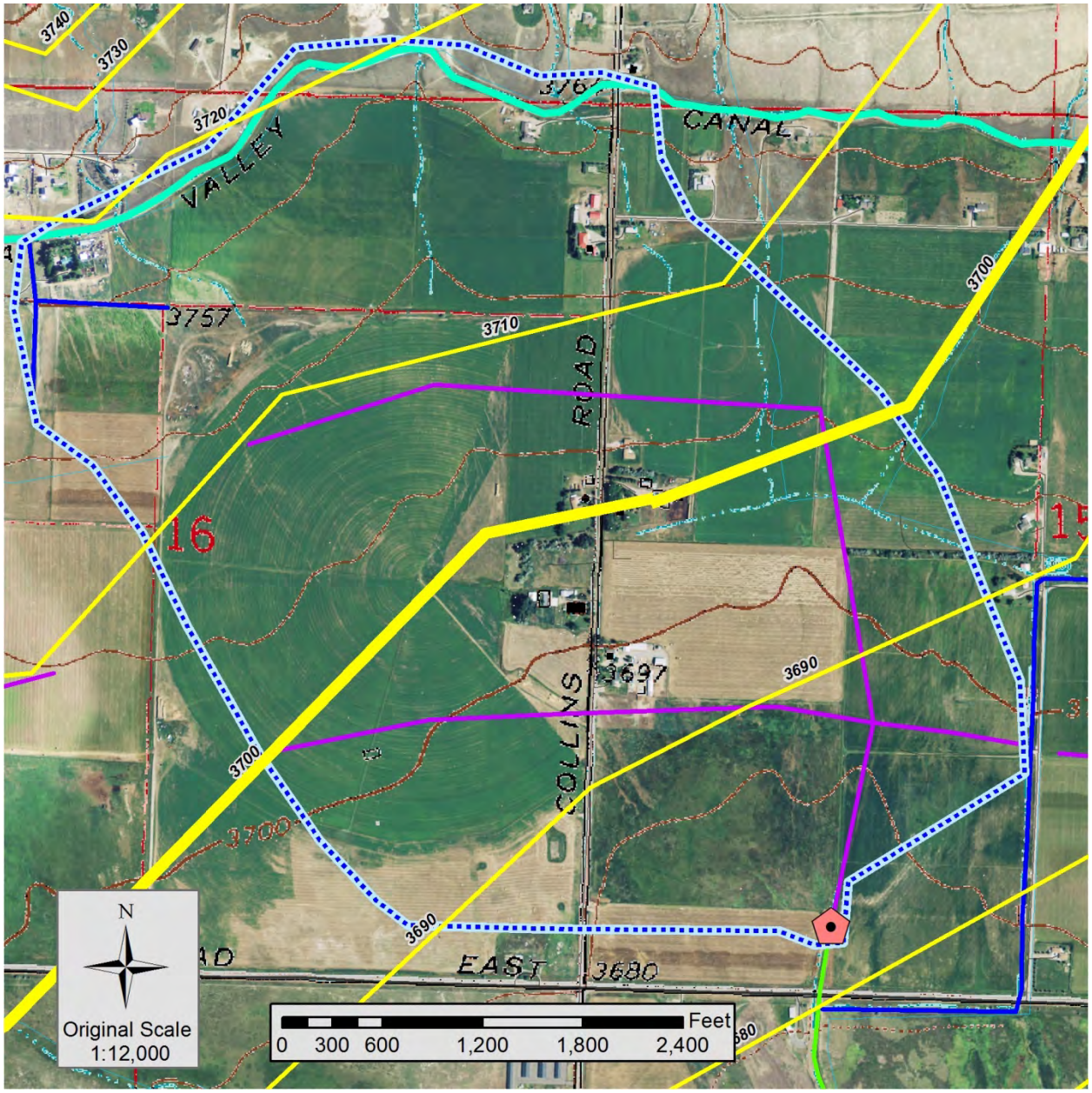


Figure 6-13 –Subwatershed Contributing Area for D1-1 Drain.
Ground water flow contours at 10' interval, with flow to southeast towards Lake Helena.

Table 6-8 – D1-1 Drain Nitrogen and Phosphorus Loading

D1-1	Interval Days	Loading cfs	**Nitrogen lbs/day**	slope avg lbs/day	total lbs interval	**Phosphorus lbs/day**	slope avg lbs/day	total lbs interval
6/10/2014*		0.87	19.71			0.14		
9/5/2013	87	1.39	28.65	24.18	2103.79	0.24	0.19	16.39
9/24/2013	19	1.29	25.73	27.19	516.61	0.23	0.24	4.47
10/10/2013	16	1.24	24.21	24.97	399.46	0.16	0.20	3.12
10/25/2013	15	0.99	18.20	21.20	318.03	0.20	0.18	2.68
11/13/2013	19	0.99	20.64	19.42	369.00	0.18	0.19	3.59
12/12/2013	29	0.79	13.51	17.08	495.32	0.094	0.14	3.99
1/16/2014	35	0.60	9.54	11.53	403.41	0.068	0.081	2.83
2/20/2014	35	0.47	7.33	8.43	295.16	0.073	0.070	2.47
3/20/2014	28	0.53	6.88	7.10	198.88	0.089	0.081	2.27
4/14/2014	25	0.58	9.48	8.18	204.44	0.094	0.091	2.28
5/1/2014	17	0.53	8.58	9.03	153.47	0.10	0.10	1.65
5/21/2014	20	0.78	15.65	12.11	242.27	0.11	0.10	2.05
6/10/2014	20	0.87	19.71	17.68	353.59	0.14	0.12	2.41
Total Days	365			**Total Pounds N**	**6053**		**Total Pounds P**	**50.20**
				Total Tons N	**3.03**		**Total Tons P**	**0.025**

* Data from 6-10-2014 used for 2013 to allow estimate of full year

6.2.3 North Lake Helena Drain Systems

A total of four tile drains were installed along the northern shore of Lake Helena, referred to in the original HVID planning documents as the D4 and D5 Drain systems. The systems each comprise two tile drains, with one discharging to a surface position just north of Lake Helena where a short ditch transmits water to the lake, and the other discharging directly into Lake Helena. Access issues prevented field inspection and sampling of these drains. The watershed areas upgradient from the drains, and the drain locations and identification criterion, are depicted in Figure 6-14.

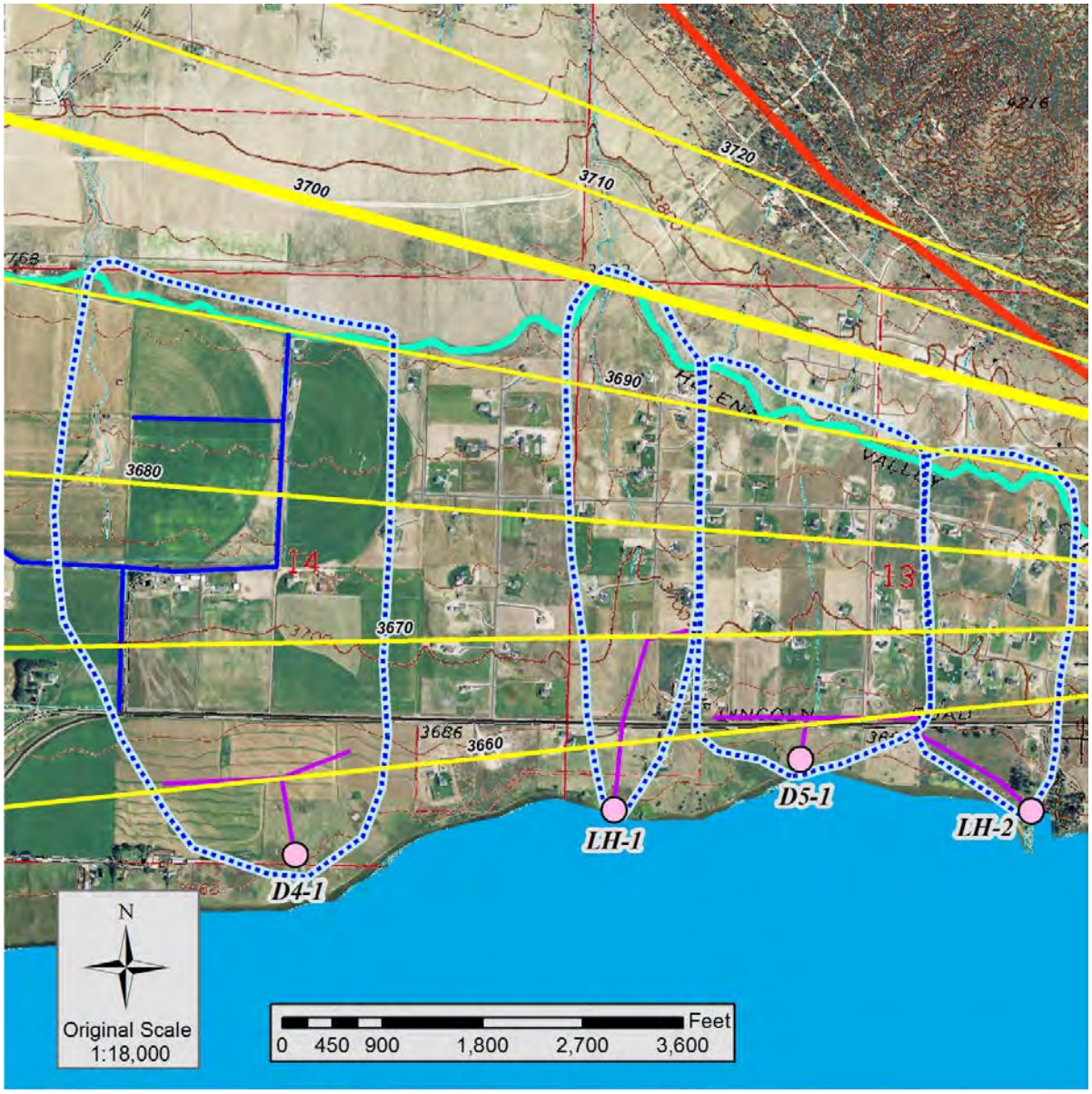


Figure 6-14–Subwatershed Contributing Area for Drains North of Lake Helena.
Ground water flow contours at 10' interval, with flow to south towards Lake Helena.

6.2.3.1 D4 Ditch System

The D4 Ditch system includes two small ditches with limited drainage and recharge areas. The area near the D4 Ditches is depicted in Figure 6-15, with the individual outlets shown in high resolution aerial photographs in Figure 6-16. Ground water in this area is interpreted to flow south, following topography, towards Lake Helena (Figure 6-14). The drain LH-1 from D4A does not have any visual evidence from the aerial photograph (Figure 6-16), therefore the location is approximate. Land use above the D4-1 drain is primarily irrigated agricultural, with a limited number of houses. Land use above the LH-1 drain is primarily residential on large lots, with limited agricultural areas.

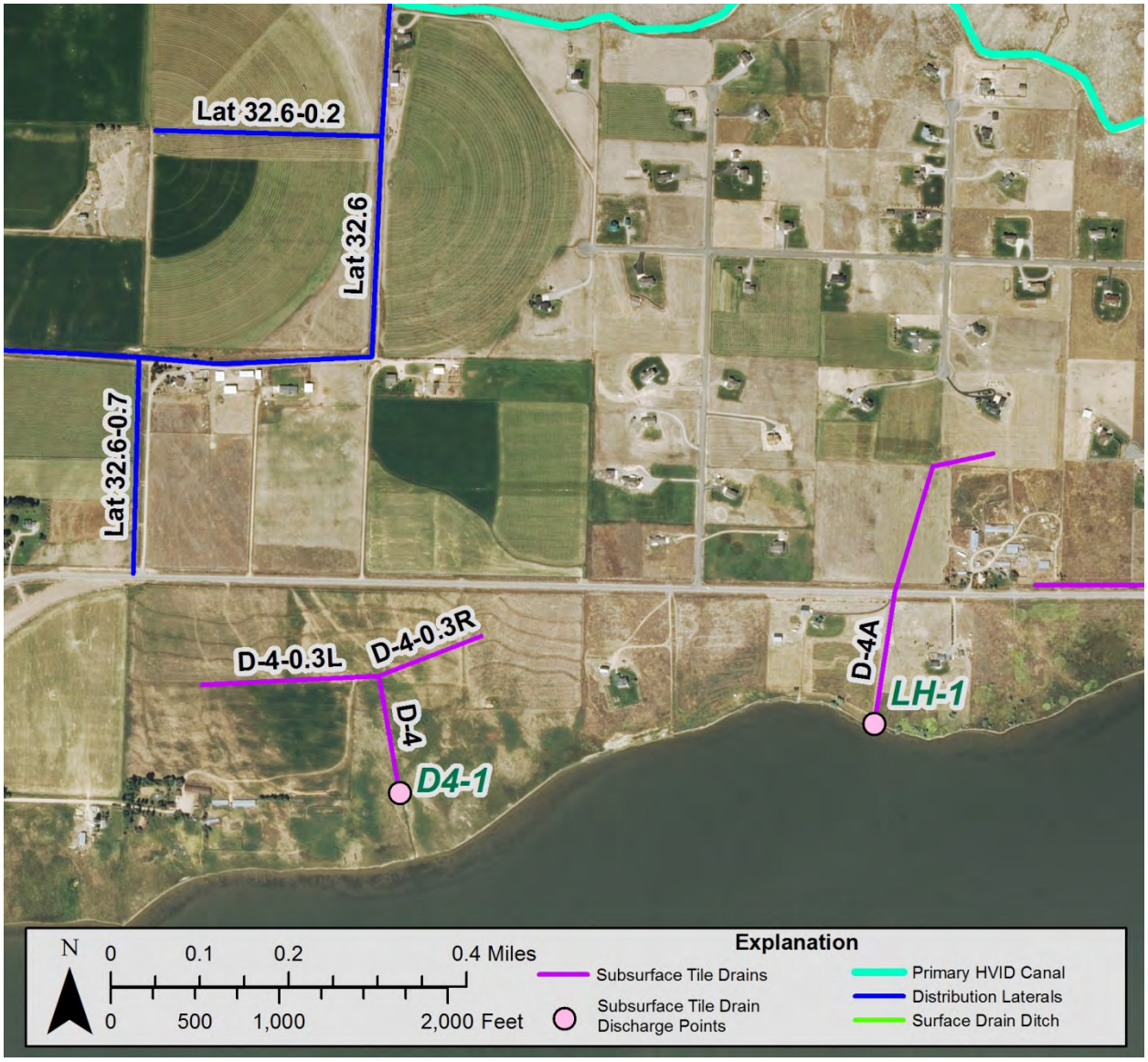


Figure 6-15 –D4 Ditch Components and Surrounding Features.

Figure 6-16a– Drain D4-1 Discharge Point from Aerial Photograph.

Figure 6-16b– Drain LH-1 Discharge Point from Aerial Photograph.
Location of discharge pipe is uncertain, with no visible evidence for this drain.

6.2.3.2 D5 Ditch System

The D5 Ditches include two small ditches with limited drainage and recharge areas, which both discharge directly into Lake Helena. The area near the D5 Ditches is depicted in Figure 6-17, with the individual outlets shown in high resolution aerial photographs in Figure 6-18. Ground water in this area is interpreted to flow south, following topography, towards Lake Helena (Figure 6-14). Land use above both drains is primarily residential on large lots, with limited agricultural areas. The drain LH-2 discharges into a lagoon from Lake Helena, surrounded by private land.

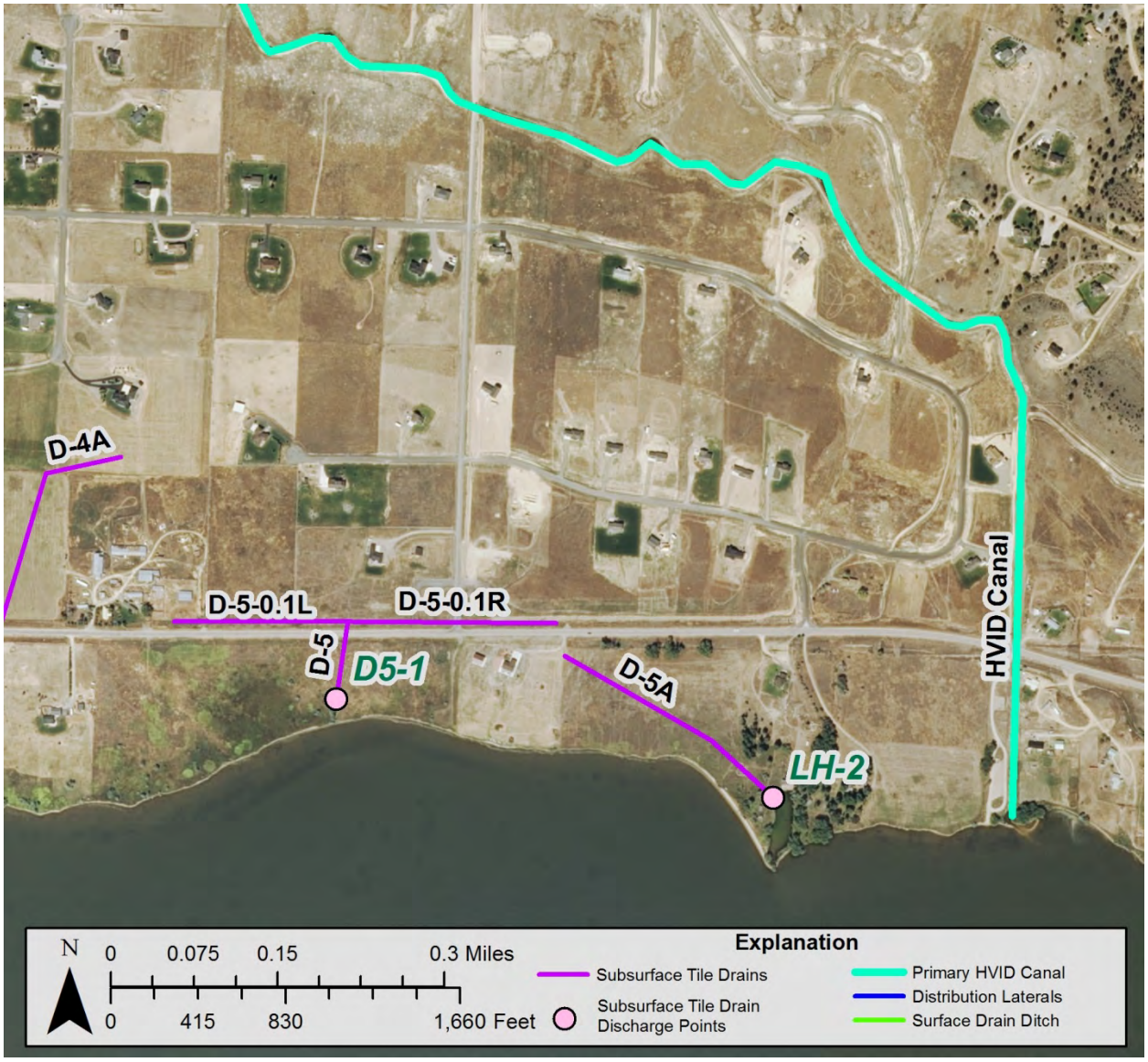


Figure 6-17 –D5 Ditch Components and Surrounding features.

Figure 6-18a – Drain D5-1 Discharge Point from Aerial Photograph.

Figure 6-18b – Drain LH-2 Discharge Point from Aerial Photograph.

6.2.3.3 Loading from D4 and D5 Drain Systems

The areas potentially contributing to flows discharged from both the D4 and D5 drain systems are depicted in Figure 6-14. Since there is no data on these drains, data from the D0-1 and D0-2 drains are used to approximate the loading from each of these drains into Lake Helena. The D4-1 drain area is predominantly agriculture, with only a limited number of houses with septic systems. The contributing areas for the other three drains are dominated by residential houses on 5 acre lots, which potentially have both septic systems and use agricultural fertilizers for lawn maintenance.

Loading estimates for the drains in these systems are summarized in Table 6-9. The estimates compare total loading to similar drains, then are proportional relative to the area that potentially contributes to each drain. The D4-1 drain was compared to D1-1 since both areas are predominantly agricultural. The D5-1, LH-1 and LH-2 drains were compared to D0-1 since the contributing areas have more residential houses present.

Table 6-9 – Estimates of D4 and D5 Drain System Nitrogen and Phosphorus Loading

	Drain Subwatershed		**Loading Estimates**				**Comments**
	Houses/	Area	Total N		Total P		
	septic systems	Acres	Pounds	Tons	Pounds	Tons	
D0-1	12	325	3068	1.53	45.83	0.023	Mixed agriculture and residential
D1-1	5	500	6053	3.03	50.20	0.025	Predominantly agriculture area
D4-1	3	310	**3753**	**1.88**	**31.12**	**0.016**	D1-1 Loading, proportional to D1-1 area
LH-1	9	110	**1038**	**0.52**	**15.51**	**0.008**	D0-1 Loading, proportional to D0-1 area
D5-1	15	150	**1416**	**0.71**	**21.15**	**0.011**	D0-1 Loading, proportional to D0-1 area
LH-2	16	90	**850**	**0.42**	**12.69**	**0.006**	D0-1 Loading, proportional to D0-1 area

6.3 Lower Silver Creek Subwatershed and D2 Ditch

The Lower Silver Creek subwatershed represents the area where Silver Creek enters the Helena Valley and loses flow as recharge to the ground water system. The transition from a predominantly bedrock aquifer system to a high permeability alluvial aquifer, the Helena Valley Aquifer, can be seen where the ground water contours show the gradient becoming much less steep, as depicted in Figure 6-19. The D-2 Ditch, the largest in the HVID System, comprises 3 main regions based on return flow ditches bringing irrigation return flows back to Lake Helena (Figure 6-20). Of the 3 regions, two represent the Lower Silver Creek Subwatershed, with the third in the Lower Tenmile Creek Subwatershed. The main D2 Ditch was installed into the former Silver Creek drainage channel to the discharge point into Lake Helena. Each of the three D2 drainage systems are discussed separately in the following sections.

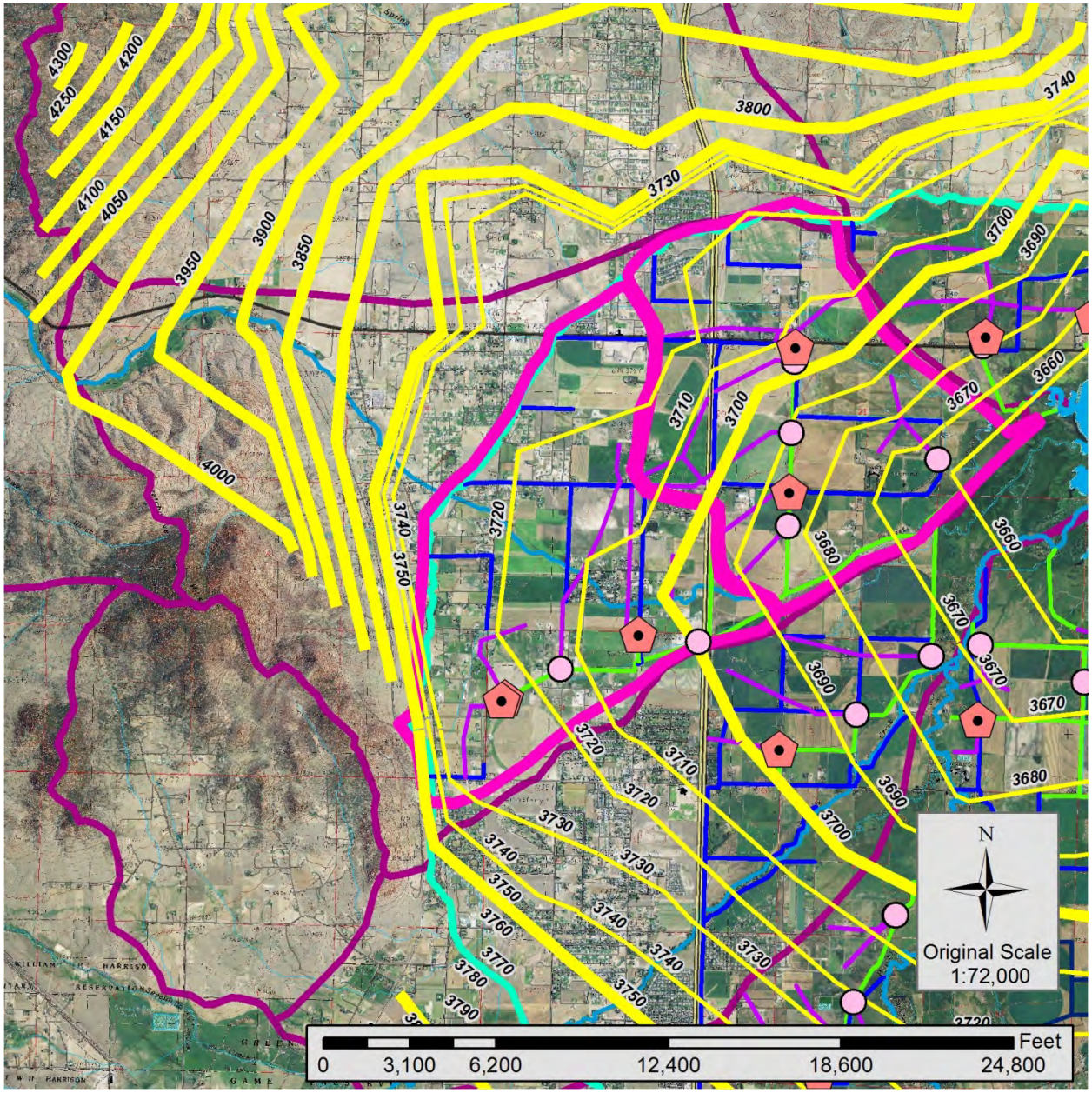


Figure 6-19– Lower Silver Creek Subwatershed

Tile drain discharge points are noted, with ground water potentiometric surface.

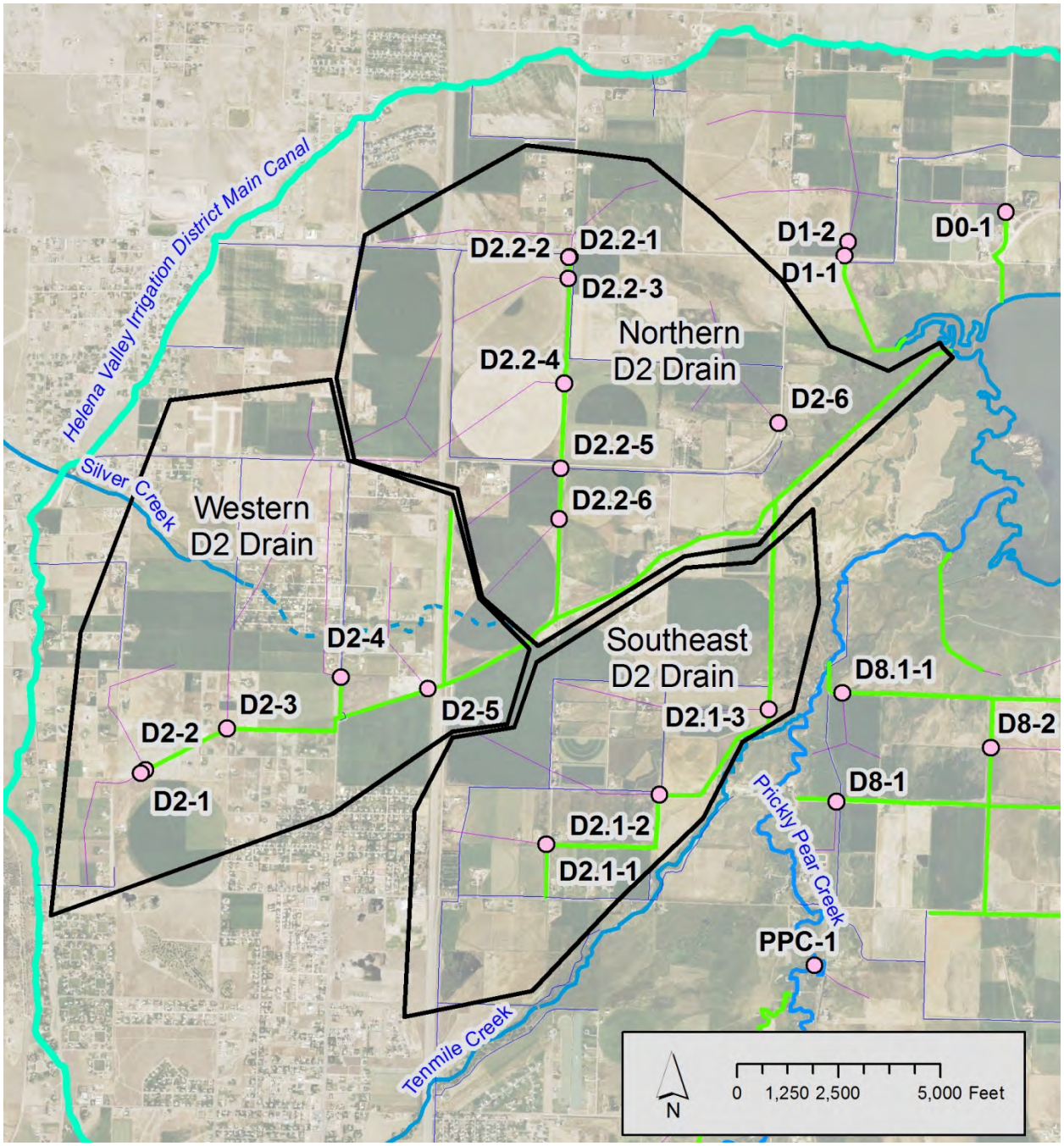


Figure 6-20 – Layout of D2 Ditch System.

Note drain system in two subwatersheds, with discharge from Lower Tenmile watershed into main D2 Ditch.

6.3.1 Western D2 Ditch System

The D2 ditch starts in the western part of the valley, as depicted in Figure 6-21. The actual ditch and drain system, with names for components, is depicted in Figure 6-22. Flows into this portion of this ditch reflect tile drain discharge and any intercepted ground water, with no return flows from surface water distribution laterals. Ground water in this area is interpreted to flow generally east to northeast, following topography, towards Lake Helena. There are five tile drains through this reach, with water observed flowing from three of them during the site reconnaissance. Results from the reconnaissance water quality sampling, listed in Table 6-10, show nitrate plus nitrate nitrogen ranging from 1.39 to 3.06 mg/L. Drains D2-1, D2-2 and D2-4 were all selected for the detailed sampling program.

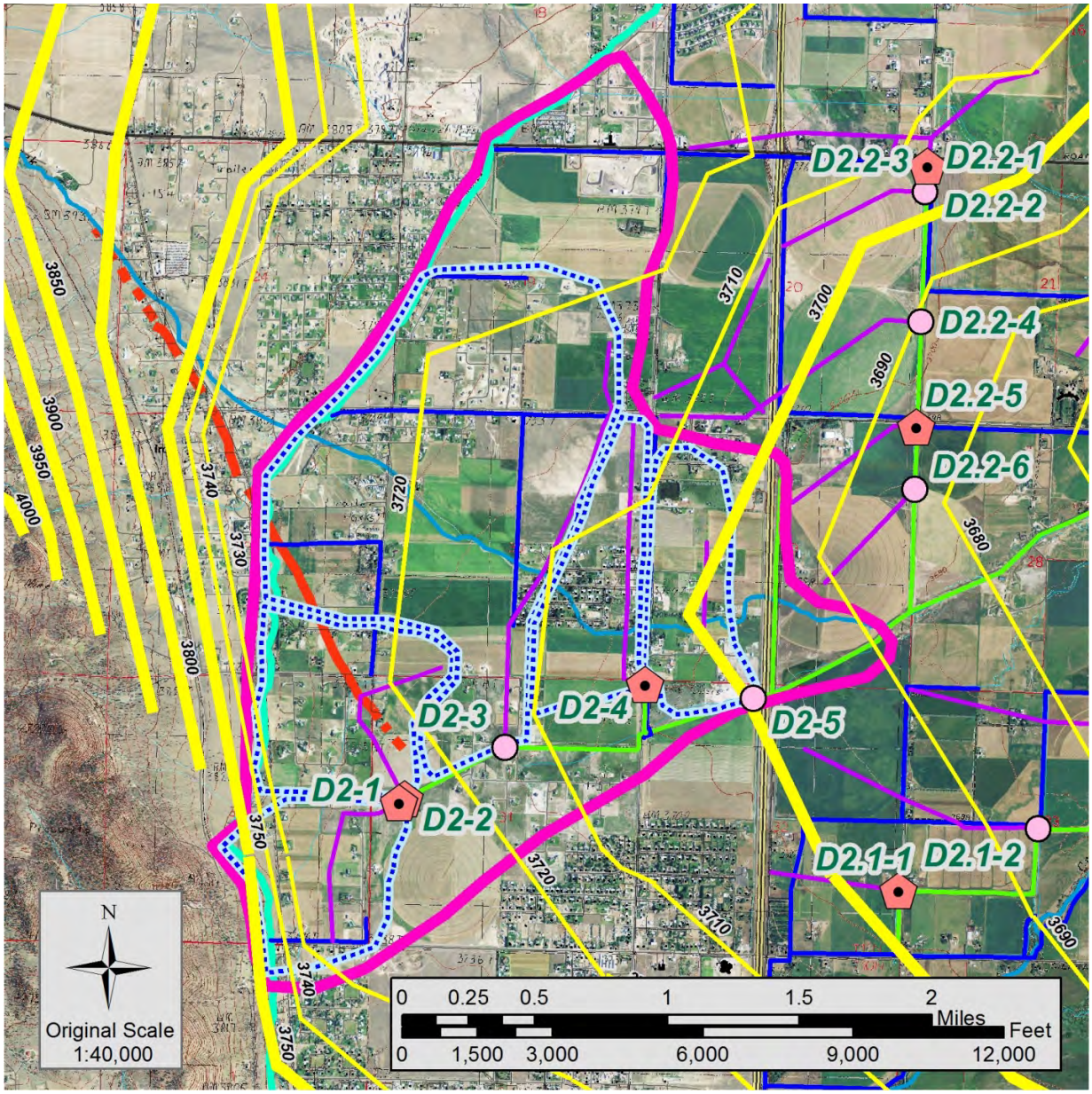


Figure 6-21– Western D2 Ditch SubwatershedArea

Tile drain discharge points are noted, with ground water potentiometric surface. See text for explanation.

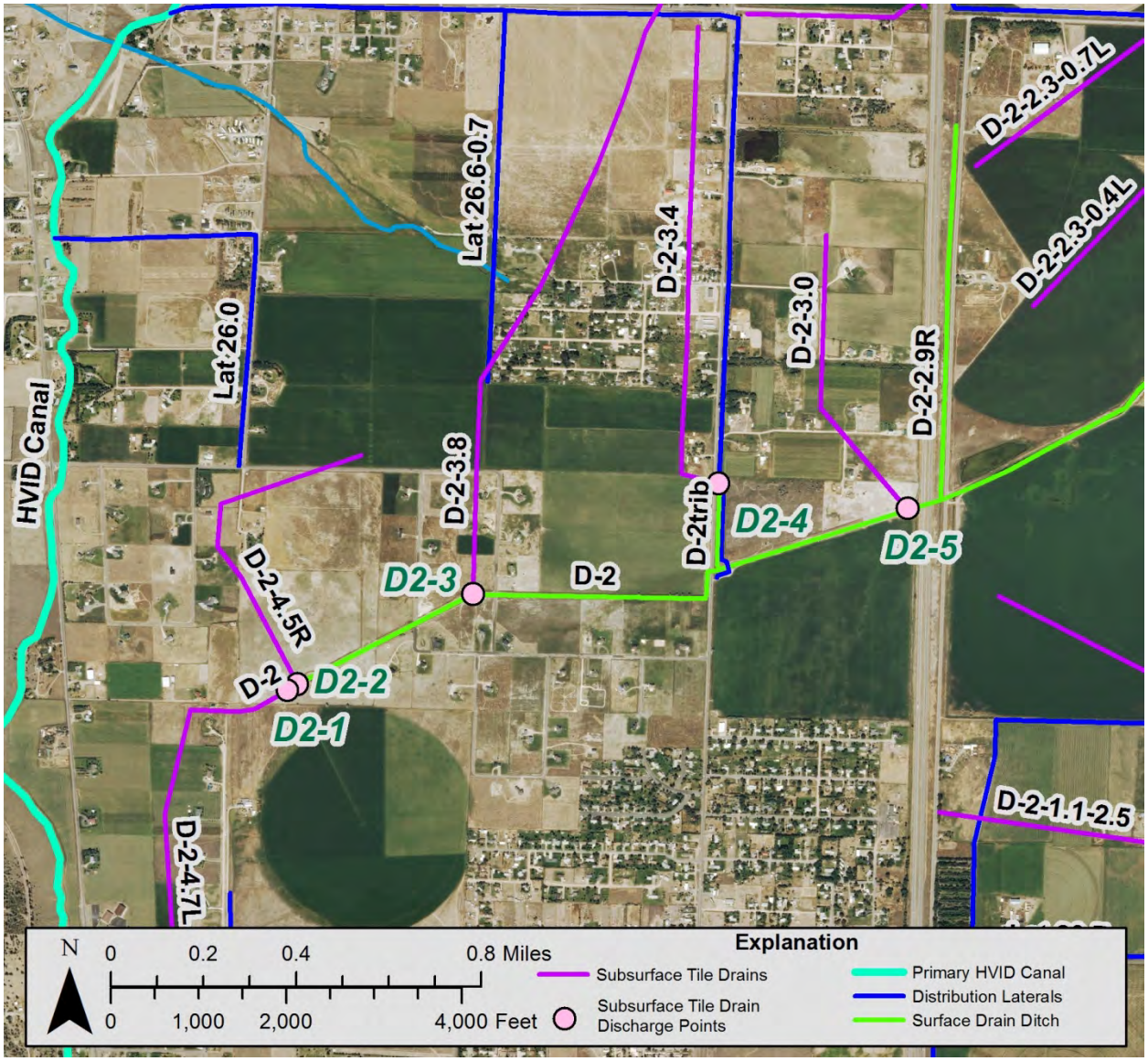


Figure 6-22 – Western D2 Ditch and Surrounding features.

Table 6-10 Laboratory Results from Reconnaissance Sampling, Western D2 Ditch

Analyses		D2-2	D2-4	D2-5	
Field Parameters					
	pH	7.54	7.54	7.53	S.U.
	Conductivity	418	418	407	µs/cm
	Temperature	7.3	7.3	9.5	°C
	Dissolved Oxygen	12.02	12.02	9.85	mg/L
Laboratory Results					
	Total Dissolved Solids, TDS @ 180°C	356	369	341	mg/L
	Alkalinity, total as $CaCO_3$	270	270	250	mg/L
	Chloride	17	18	17	mg/L
	Bromide	<0.05	<0.05	0.31	mg/L
	Nitrogen, Nitrate + Nitrite as N	3.06	2.91	1.39	mg/L
	Phosphorus, total as P	0.015	0.023	0.007	mg/L

6.3.1.1 D2-1 and D2-2 Drain Systems

The D2-1 and D2-2 drains are located at the western end of the main D2 ditch, and represent the initial flows into the system. At this location, there are no discharges from irrigation distribution laterals, so all flow is considered to come from the drains. The general layout of the two drain systems is depicted in Figure 6-21. These drains are located near the edge of the Helena Valley Aquifer, against the granite bedrock of the Scratchgravel Hills. Ground water in this area flows generally east, with the main Helena Valley Irrigation Canal located upgradient from the drains. Ground water recharge may occur from the Scratchgravel Hills bedrock in the subsurface, and from the irrigation canal when in use. Photographs of the drain outlets into the D2 Ditch are presented in Figure 6-23.

The D2-1 Drain was dry during the reconnaissance program, but flows increased during the summer, with the drain sampled a total of 16 times during the study. The data results from the sampling of the D2-1 Drain are summarized in Table 6-21. Time series graphs of the data results are presented in Figure 6-24. From the sampling, nitrate values ranged from 1.06 mg/L up to 2.91 mg/L, with the highest detected concentrations present after the 2013 irrigation season. Phosphate values ranged from 0.021 mg/L up to 0.040 mg/L.

The D2-2 Drain had continuous but low flows, with the drain sampled 19 times during the study. Samples were initially collected using a peristaltic pump; however, the flows from the drain into the ditch could be distinguished from standing water by clearing vegetation, and observing the deflection of sediment from the drain current. The data results from the sampling are summarized in Table 6-12, with time series graphs presented in Figure 6-25. From the samping, the nitrate values ranged from 1.50 mg/L up to 3.42 mg/L with no real trend in concentrations visible. Phosphate values ranged from 0.013 mg/L up to 0.030 mg/L.

View east of Drains D2-1 and D2-2. Large pipes are flooding storm drains from adjacent fields

View west of Drain D2-2 outlet, between storm drain discharge pipes

Figure 6-23 – Photographs of Drain D2-1 and D2-2 outlets.

Drain D2-1 Outlet, no flow visible

Drain D2-2 Outlet, limited flow present

Drain D2-2 Outlet

Flow at outlet of D2-2 Drain

Flow from D2-1 outlet in mid summer

Outlet of D2-2 Drain, mid-summer

Figure 6-23 (continued) – Photographs of Drain D2-1 and D2-2 outlets.

Table 6-11 Laboratory Results from Sampling, D2-1 Drain

	Field Parameters				Laboratory Data Results						
D2-1	pH	Temp	specific conductivity	Dissolved Oxygen	Total Dissolved Solids, TDS @ 180°C	Alkalinity Total as $CaCO_3$	Cl	Br	SO_4	NO_3+ NO_2 as N	Phosphorus, Total as P
	S.U.	°C	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
5/3/13			*No flow*								
6/21/13	7.72	9.5	436	12.61	379	300	16	0.041		1.51	0.029
7/10/13	7.64	10.4	456	11.79	407	300	15	0.036		1.42	0.04
7/26/13	7.62	11.7	470	11.36	417	320	14	0.05		1.22	0.032
8/6/13	7.62	12	480	10.11	392	310	14	0.049	46	1.06	0.032
8/23/13	7.64	12.5	488	10.38	393	300	17	0.14	57	1.29	0.029
9/5/13	7.48	12.7	506	10.29	402	310	17	0.05		1.36	0.03
9/24/13	7.81	13	489	9.59	381	300	15	< 0.02	48	1.45	0.03
10/9/13	7.51	12.5	499	10.21	388	320	21	0.03	58	2.91	0.021
10/24/13	7.87	12	490	8.8	388	310	15	0.06	47	1.55	0.038
11/14/13	7.97	11.1	473	4.46	383	310	15	0.037		1.7	0.038
12/2/13	8.08	10.2	461	10.15	395	300	19	0.06	58	1.89	0.025
1/16/14	7.91	7.6	422	11.9	381	290	16	0.09	47	1.89	< 0.001
2/20/14	8.46	6	404	11.2	407	290	16	0.023	46	1.94	0.032
3/20/14	8.35	5.5	396	12.73	383	280	18	0.02	49	2	0.039
4/14/14			*No flow*								
5/1/14			*No flow*								
5/21/14	8.16	7.7	426	5.43	371	270	14	< 0.01	44	1.87	0.027
6/11/14	8.17	8.8	457	5.1	411	290	14	0.09	46	1.29	0.032
Max	8.46	13.0	506	12.73	417	320	21	0.140	58	2.91	0.040
Min	7.48	5.5	396	4.46	371	270	14	< 0.01	44	1.06	0.021
Average	7.88	10.20	459.6	9.76	392.4	300.0	16.0	0.055	49.6	1.65	0.032
Median	7.84	10.75	465.5	10.25	390.0	300.0	15.5	0.050	47.0	1.53	0.032
Std Dev	0.30	2.44	33.92	2.59	13.14	13.66	2.00	0.032	5.32	0.44	0.005

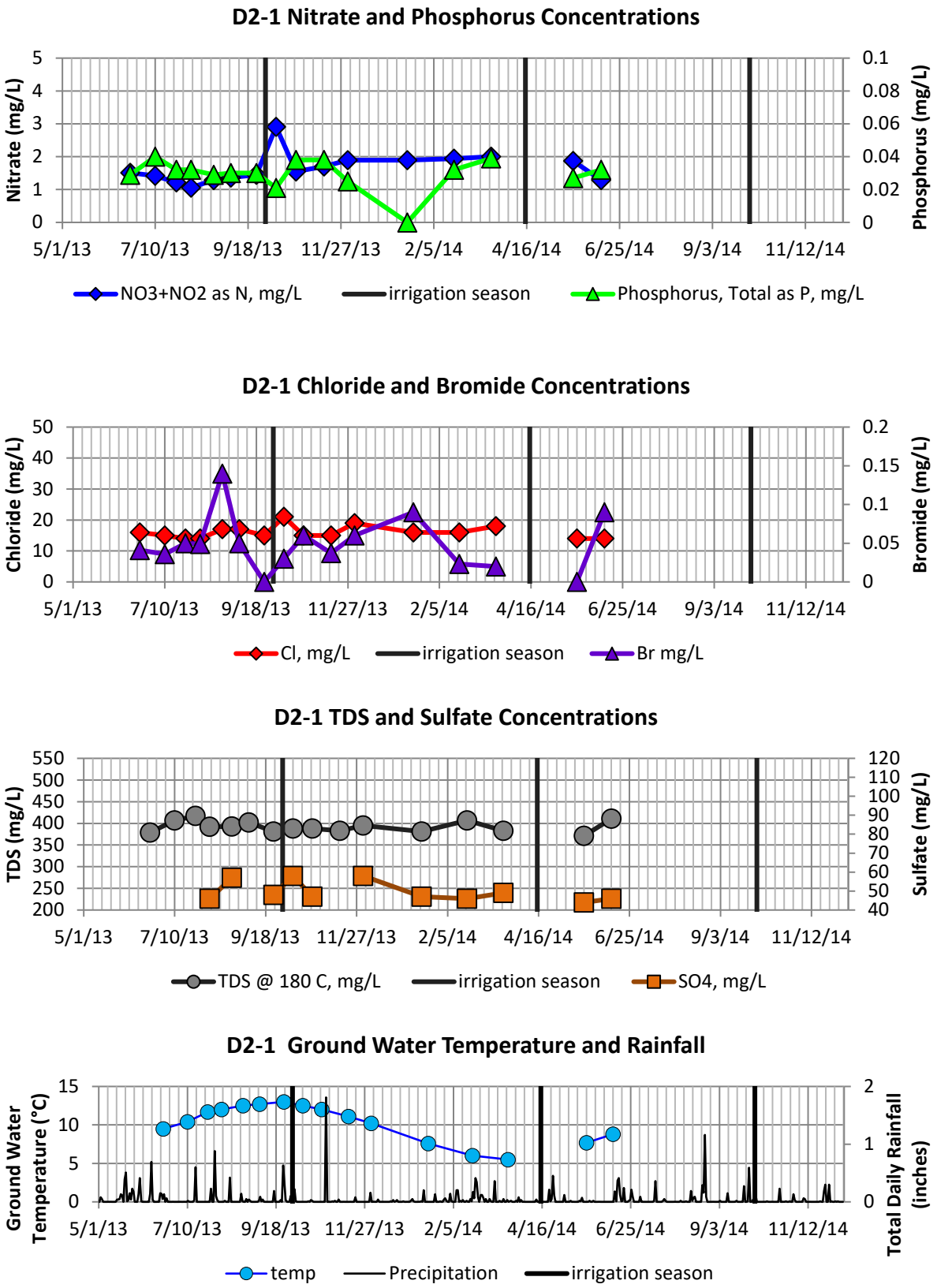


Figure 6-24 – Water quality nutrient results for D2-1 Drain.

Table 6-12 Laboratory Results from Sampling, D2-2 Drain

	Field Parameters				Laboratory Data Results						
D2-2	pH S.U.	Temp °C	specific conductivity µs/cm	Dissolved Oxygen mg/L	Total Dissolved Solids, TDS @ 180°C mg/L	Alkalinity Total as $CaCO_3$ mg/L	Cl mg/L	Br mg/L	SO_4 mg/L	NO_3+ NO_2 as N mg/L	Phosphorus , Total as P mg/L
5/3/13	7.73	7.6	411	11.07	356	270	17	0.037		3.06	0.015
6/21/13	7.78	10	432	10.71	382	260	22	0.09		2.66	0.021
7/10/13	7.61	10	473	9.26	432	280	22	0.049		3.42	0.021
7/26/13	7.66	12.7	560	8.24	467	330	21	0.07		2.19	0.028
8/6/13	7.67	11.6	513	8.56	395	310	16	0.045	50	1.56	0.027
8/23/13	7.69	12.4	522	8.21	411	300	22	0.08	65	2.95	0.022
9/5/13	7.61	12.5	522	7.71	416	300	22	0.08		3.01	0.02
9/24/13	7.80	14.2	569	5.68	428	320	21	0.07	58	1.75	0.028
10/9/13	7.65	12.2	520	7.36	400	310	15	< 0.02	48	1.5	0.03
10/24/13	7.85	11.5	497	6.56	400	290	19	0.06	54	2.69	0.023
10/24/13			duplicate	sample	402	290	19	0.06	54	2.65	0.02
11/14/13	7.99	10.6	470	4.57	391	290	17	0.05		2.5	0.023
12/2/13	7.99	9.6	453	8.15	394	290	21	0.08	65	2.58	0.015
1/16/14	7.86	7.3	419	9.32	362	280	17	0.1	49	2.64	0.017
2/20/14	8.19	6	405	9.92	402	270	18	0.037	49	1.6	0.02
3/20/14	8.12	5.8	405	9.9	385	280	18	< 0.01	54	2.6	0.017
4/14/14	8.33	6.1	410	9.12	389	280	19	0.21	52	3.29	0.018
5/1/14	8.23	6.6	416	10.77	373	260	16	0.03	46	2.98	0.022
5/21/14	8.10	7.3	427	6.07	377	260	16	< 0.01	27	3.13	0.013
6/11/14	8.19	8.5	440	4.58	387	260	16	0.04	44	3.12	0.017
Max	8.33	14.2	569	11.07	467	330	22	0.210	65	3.42	0.030
Min	7.61	5.8	405	4.57	356	260	15	< 0.01	27	1.50	0.013
Average	7.90	9.61	466.5	8.20	397.5	286.5	18.7	0.070	51.1	2.59	0.021
Median	7.85	10.00	453.0	8.24	394.5	285.0	18.5	0.060	51.0	2.66	0.021
Std Dev	0.24	2.66	54.62	1.99	25.31	20.59	2.43	0.041	9.35	0.59	0.005

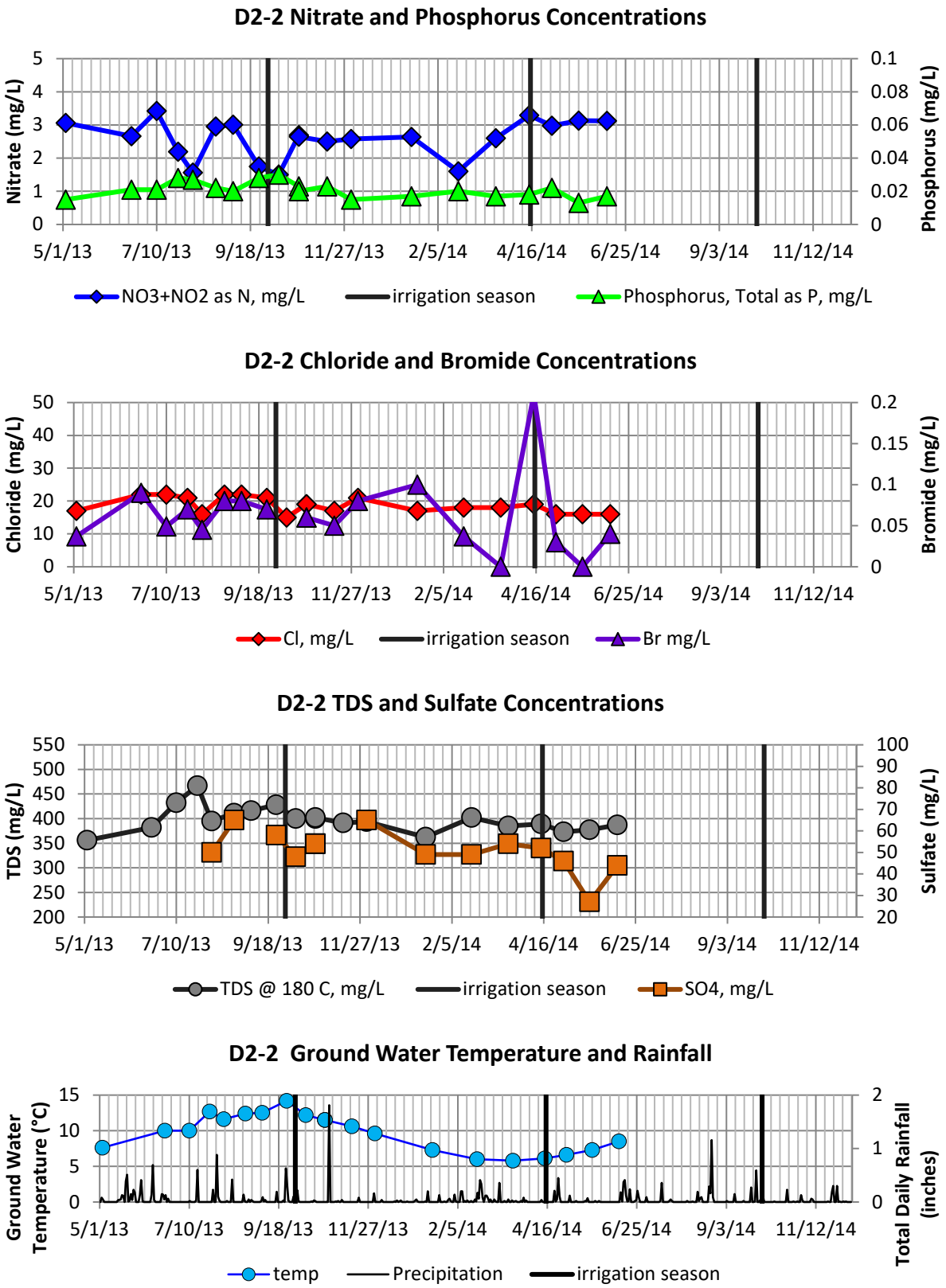


Figure 6-25 –Water quality nutrient results for D2-2 Drain.

Hydrology of D2-1 and D2-2 Area

The D2-1 and D2-2 drains are discussed together since both drain similar areas, show a similar response to recharge events, and are located adjacent to each other at the start of the D2 drain. The D2-1 drain showed a strong increase in flow from a late summer rain event, when flows increased from 0.86 cfs up to 2.68 cfs; however, during winter, the flows decreased until stopping in early spring (Table 6-13). In response to the same late summer event, the D2-2 drain increased flow from 0.53 cfs to 1.04 cfs, with flows diminishing in early spring to a low of 0.05 cfs (Table 6-14). The measured discharge rates for the drains, compared with precipitation events, are depicted in Figure 6-26. While discharge flows from D2-1 shows a more direct response to recharge events (precipitation, irrigation waters), the flows from D2-2 were more stable and consistent through the monitoring period.

Combining the nutrient data with flow discharge rates allows for calculation of estimates of nutrient mass loading rates. The loading rates for both the D2-1 and D2-2 drains reflect the flow discharge rates for the tile drains (Figure 6-26), with more mass loading from D2-1 when it flows. Loading to the system occurs primarily during the summer irrigation season. Loading rates decrease during the winter as discharge decreases.

The yearly loading rate for the D2-1 and D2-2 drains was calculated using the data presented in Tables 6-15 and 6-16. In order to maintain a consistent time interval for all of the drains included in this study, sample data from September 2013 to June 2014 was used. In order to complete the year, data from June 2014 was used as an estimate for June 2013. The data allows for estimates of the total amount of nitrogen and phosphorus discharged from the drain during the study year. For the D2-1 drain, this corresponds to a total of 1,860 pounds (0.93 tons) of nitrogen and 32.96 pounds (0.016 tons) of phosphorus discharged from June 2013 to June 2014 (Table 6-15). For the D2-2 drain, this corresponds to a total of 1,480 pounds (0.74 tons) of nitrogen and 13.10 pounds (0.007 tons) of phosphorus discharged from June 2013 to June 2014 (Table 6-16).

The local watershed contributing to the water collected from the D2-1 and D2-2 drains is depicted in Figure 6-27, which also shows the configuration of the local water table. For purposes of this assessment, this includes the area upgradient from the drain, estimated from the water table map, up to and including the primary HVID Canal and irrigation distribution laterals which both potentially serve to recharge local ground water. Land use in the area for both drains is primarily mixed residential with irrigated agriculture, comprised of large residential lots with both cropped lands and animal grazing Potential nutrient sources include agricultural fertilizers and manure waste, and discharge from septic system drainfields.

There was no flow in the D2-1 drain at the start of irrigation season (April 15), with no flow again on May 1. Flow was measured on May 21, indicating that there is a minimum of a 15 day time lag between the start of irrigation season and the onset of flows in the D2-1 drain. Flow from the D2-2 drain was stable and consistent through the start of irrigation season. Flow in both drains appears to steadily increase through the summer irrigation season, with flows slowly diminishing afterwards. The fall flows are attributed to increased storage of irrigation waters in the soils draining and supporting flows as the water table decreases through the winter. The correlation of precipitation to increased flows infers that the rain event resulted in flushing of nutrients stored within the unsaturated zone at the end of irrigation season.

Table 6-13 – D2-1 Drain Discharge & Loading Rates

Sample Date	Flow Rate ft^3/s	**Nitrogen** lbs/day	**Phosphorus** lbs/day
9/5/13	0.86	6.29	0.139
9/24/13	2.68	20.98	0.434
10/9/13	1.33	20.93	0.151
10/24/13	1.11	9.27	0.227
11/14/13	0.54	4.97	0.111
12/02/13	*0.37**	5.84	0.030
1/16/14	0.19	1.98	0.000
2/20/14	0.03	0.29	0.005
3/20/14	0.01	0.11	0.002
4/14/14		*No flow*	
5/1/14		*No flow*	
5/21/14	0.72	7.21	0.104
6/11/14	0.57	3.97	0.098
Max	2.68	20.98	0.104
Min	0.01	0.11	0.000
Average	0.76	7.44	0.118
Median	0.57	5.84	0.104
Stnd Dev	0.76	7.25	0.127

* Rate not measured in field, estimated as average between bounding measurements

Table 6-14 – D2-2 Drain Discharge & Loading Rates

Sample Date	Flow Rate ft^3/s	**Nitrogen** lbs/day	**Phosphorus** lbs/day
9/5/13	0.53	8.68	0.058
9/24/13	1.04	9.79	0.157
10/9/13	0.83	6.71	0.134
10/24/13	0.41	5.97	0.051
10/24/13	*dup*	5.88	0.044
11/14/13	0.38	5.10	0.047
12/02/13	*0.27**	4.25	0.022
1/16/14	0.16	2.24	0.014
2/20/14	0.11	0.94	0.012
3/20/14	0.05	0.67	0.004
4/14/14	0.13	2.31	0.013
5/1/14	0.17	2.73	0.020
5/21/14	0.15	2.53	0.011
6/11/14	0.14	2.36	0.013
Max	1.04	9.79	0.157
Min	0.05	0.67	0.004
Average	0.34	4.30	0.043
Median	0.22	3.49	0.021
Stnd Dev	0.29	2.82	0.047

* Rate not measured in field, estimated as average between bounding measurements

Nitrate values in the drains range from 1.06 to 3.42 which, when compared to irrigation waters consistently below 1.0 mg/L (see Section 5.0), infers that nitrogen is from upgradient, anthropogenic sources. Dissolved oxygen concentrations are reduced in the autumn samples, indicating that nitrification is occurring. The detected nitrogen concentrations appear to be generally stable during the year, with single event concentrations present both above and below the general averages. The stability of the nitrate results suggests that septic systems are a primary source of nitrate to this system. Increased concentrations occur from seasonal fertilizer applications, with a delay resulting from unsaturated zone storage before infiltrating waters mobilize the nitrogen into the saturated zone. Decreases in nitrate concentration are attributed to precipitation recharge to the system. Since dissolved oxygen is consistently present exceeding 50 percent saturation, it is assumed that all nitrogen species are converted to nitrate within the ground water system. The variability of the bromide concentrations relative to chloride result in this assessment method being inconclusive for this system.

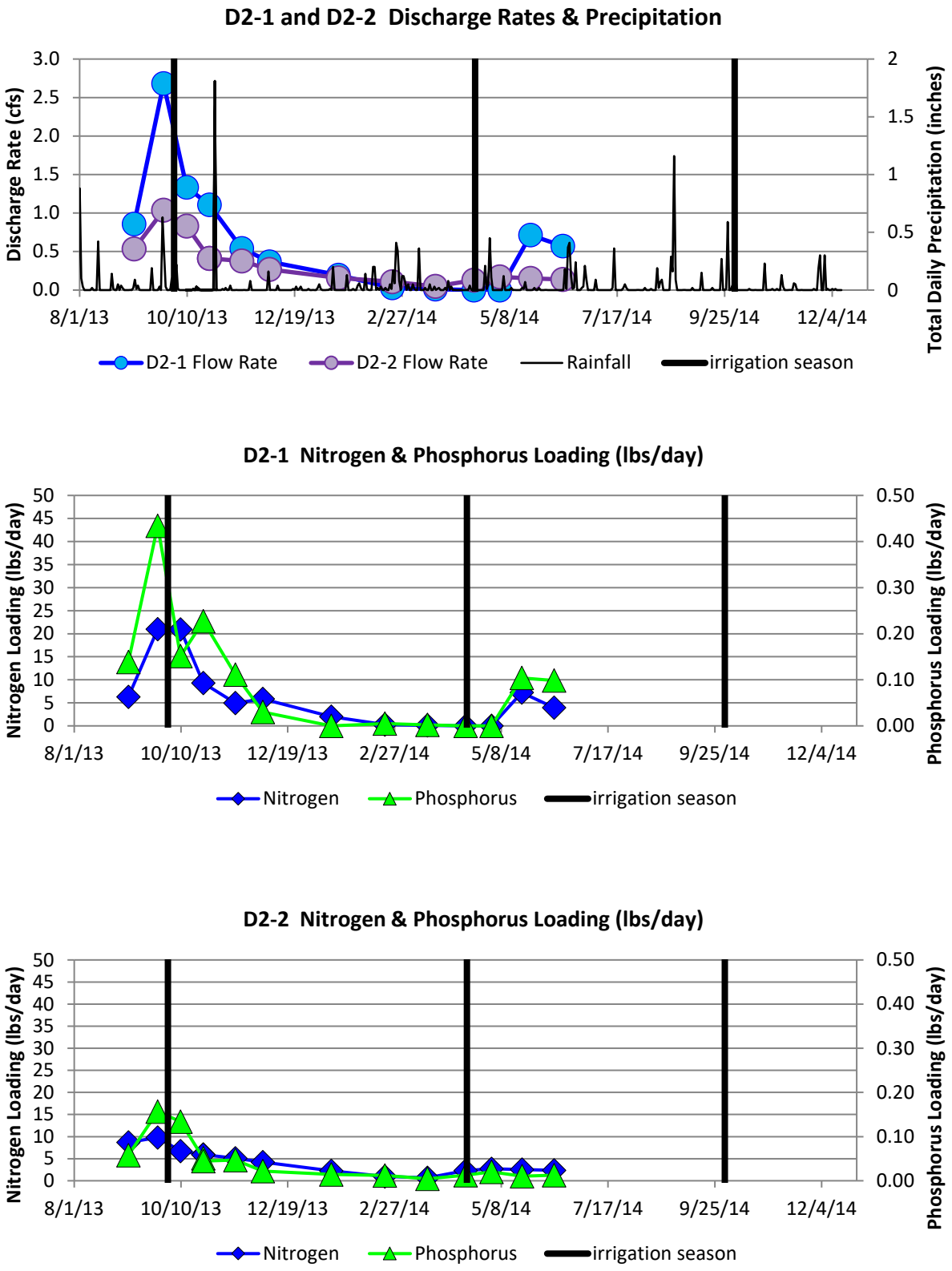


Figure 6-26 –Discharge Rates and Nitrogen and Phophorus Loading from D2-1 and D2-2 Drains.

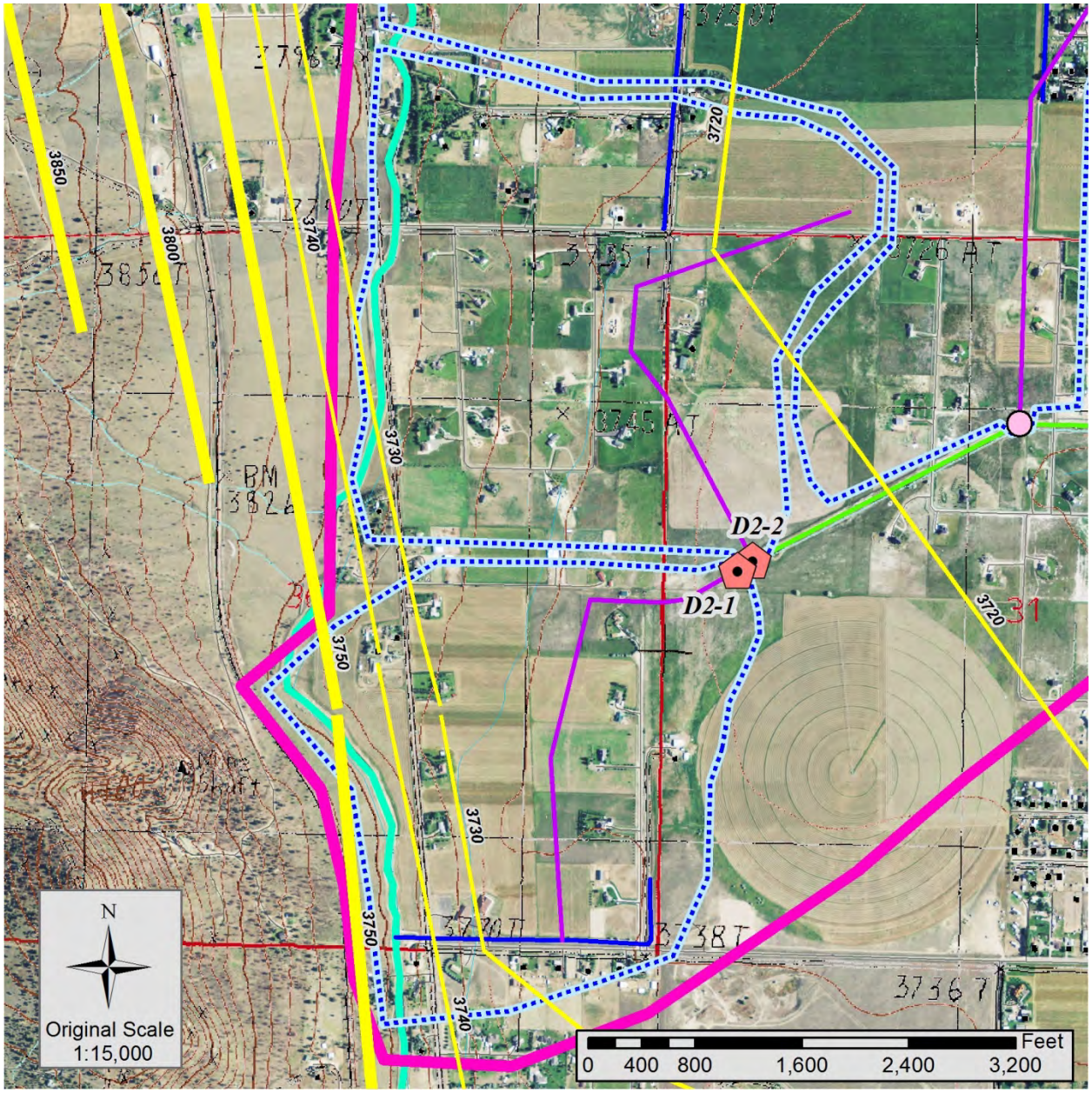


Figure 6-27 – Subwatershed contributing area for D2-1 and D2-2 Drains.
Ground water flow contours at 10' interval, with flow to the east.

Table 6-15 – D2-1 Drain Nitrogen and Phosphorus Loading

D2-1	Interval Days	Loading cfs	**Nitrogen lbs/day**	slope avg lbs/day	total lbs interval	**Phosphorus lbs/day**	slope avg lbs/day	total lbs interval
6/10/2013*		0.57	3.97			0.10		
9/5/2013	87	0.86	6.29	5.13	445.92	0.14	0.12	10.31
9/24/2013	19	2.68	20.98	13.63	259.02	0.43	0.29	5.44
10/10/2013	16	1.33	20.93	20.96	335.28	0.15	0.29	4.68
10/25/2013	15	1.11	9.27	15.10	226.48	0.23	0.19	2.84
11/13/2013	19	0.54	4.97	7.12	135.30	0.11	0.17	3.21
12/12/2013	29	0.37	3.75	4.36	126.58	0.05	0.08	2.33
1/16/2014	35	0.19	1.98	2.87	100.33	0.000	0.025	0.87
2/20/2014	35	0.03	0.29	1.13	39.71	0.005	0.002	0.08
3/20/2014	28	0.01	0.11	0.20	5.64	0.002	0.003	0.10
4/14/2014	25	0	0	0.06	1.40	0	0.00	0.03
5/1/2014	17	0	0	0.00	0.00	0	0.00	0.00
5/21/2014	20	0.72	7.21	3.61	72.12	0.10	0.05	1.04
6/10/2014	20	0.57	3.97	5.59	111.78	0.10	0.10	2.03
Total Days	365			**Total Pounds N**	**1860**		**Total Pounds P**	**32.96**
				Total Tons N	**0.93**		**Total Tons P**	**0.016**

* Data from 6-10-2014 used for 2013 to allow estimate of full year

Table 6-16 – D2-2 Drain Nitrogen and Phosphorus Loading

D2-2	Interval Days	Loading cfs	**Nitrogen lbs/day**	slope avg lbs/day	total lbs interval	**Phosphorus lbs/day**	slope avg lbs/day	total lbs interval
6/10/2013*		0.14	2.36			0.01		
9/5/2013	87	0.53	**8.68**	5.52	480.27	**0.06**	0.035	3.07
9/24/2013	19	1.04	**9.79**	9.24	175.50	**0.16**	0.107	2.04
10/10/2013	16	0.83	**6.71**	8.25	132.02	**0.13**	0.145	2.33
10/25/2013	15	0.41	**5.97**	6.34	95.14	**0.05**	0.093	1.39
11/13/2013	19	0.38	**5.10**	5.54	105.19	**0.05**	0.049	0.93
12/12/2013	29	0.27	**3.73**	4.41	127.97	**0.022**	0.034	0.99
1/16/2014	35	0.16	**2.24**	2.98	104.42	**0.014**	0.018	0.63
2/20/2014	35	0.11	**0.94**	1.59	55.73	**0.012**	0.013	0.46
3/20/2014	28	0.05	**0.67**	0.81	22.62	**0.004**	0.008	0.23
4/14/2014	25	0.13	**2.31**	1.49	37.24	**0.013**	0.009	0.21
5/1/2014	17	0.17	**2.73**	2.52	42.83	**0.020**	0.016	0.28
5/21/2014	20	0.15	**2.53**	2.63	52.65	**0.011**	0.015	0.31
6/10/2014	20	0.14	**2.36**	2.44	48.88	**0.013**	0.012	0.23
Total Days	365			**Total Pounds**	**1480**		**Total Pounds**	**13.10**
				Total Tons	**0.74**		**Total Tons**	**0.007**

* Data from 6-10-2014 used for 2013 to allow estimate of full year

6.3.1.2 D2-3 Drain System

The D2-3 drain is located approximately 2,250 feet east of and downstream from the D2-1 and D2-2 drains in the upper D2 Ditch system. Photographs of the discharge point of the pipe are presented in Figure 6-28. According to design documents obtained from the HVID, the drain trends in a north south direction, and is approximately 1.5 miles long (Figure 6-29). During the reconnaissance sampling program, no flows were observed from the drain, and sediment was present inside the lower portion of the pipe. The sediment is interpreted to result from the summer filling of the D2 drain since an outflow current would inhibit sedimentation. At this time, it is unknown if the drain flows as irrigation season progresses. The drain crosses the drainage path of Silver Creek, where coarse-grained deposits from the stream channel may provide a permeable conduit for ground water proximal to the creek. It is also possible that the drain was disturbed during the construction of the subdivision along the Silver Creek path several decades ago. While the reason has not been established, ***this drain is considered as non-functional at this time, with no discharge loading***.

Outlet for Drain D2-3 near stormwater outlet

Outlet for Drain D2-3. Note sediment filling pipe. No flow from pipe was observed at this time.

Figure 6-28– Photographs of Drain D2-3 Outlet.
No flow observed in ditch at this time. Additional discharge pipes are for storm water.

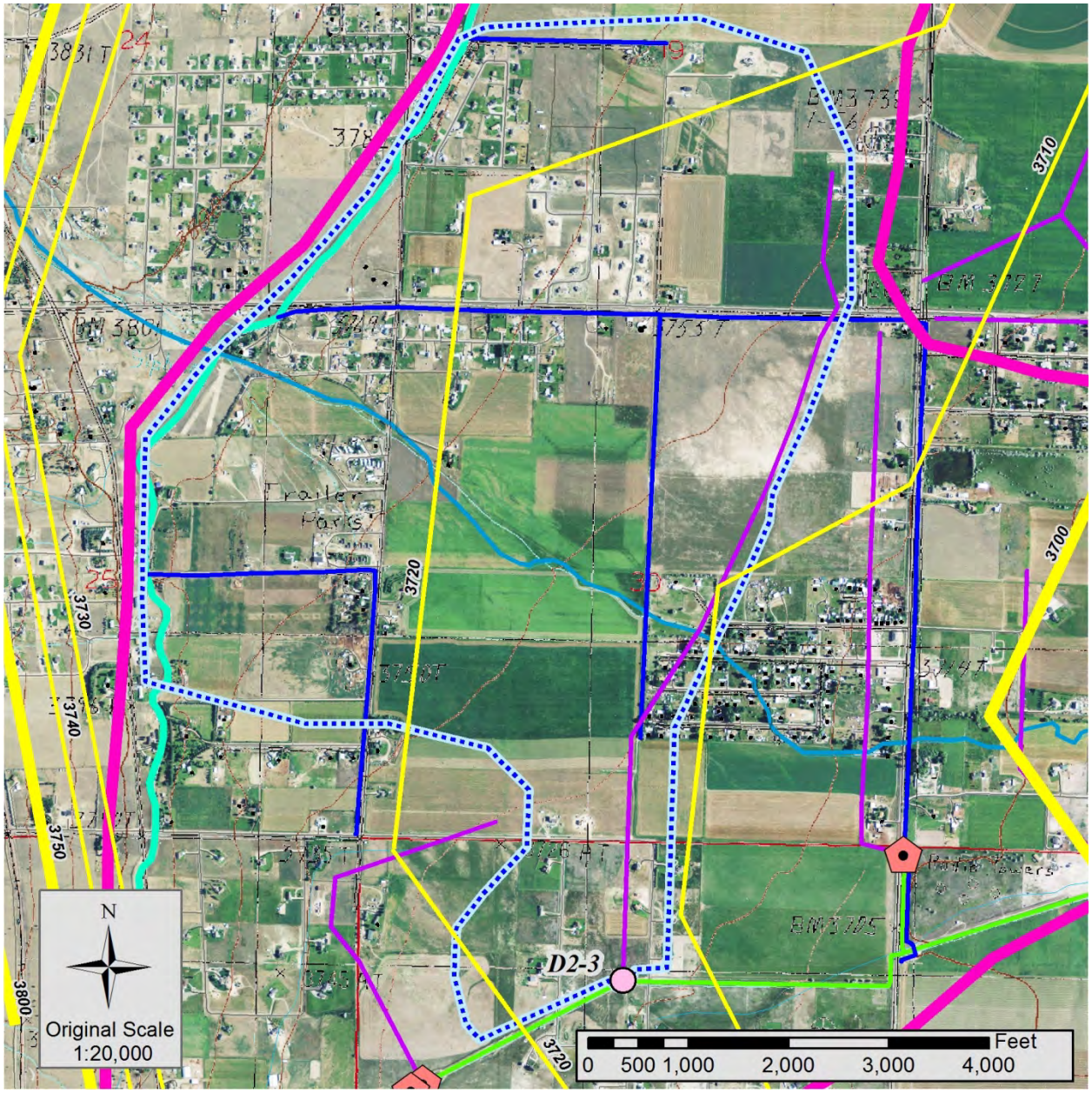


Figure 6-29 – Subwatershed Contributing Area for D2-3 Drain.
Ground water flow contours at 10' interval, with flow to the east. Drain does not appear to be functioning at this time

6.3.1.3 D2-4 Drain System

The D2-4 Drain is located on a small tributary ditch north of the main D2 ditch, where the first irrigation distribution lateral overflows into the ditch (Figure 6-22). The general layout of the drain system is depicted in Figure 6-21. The drain is located more than 1.75 miles east of the Helena Valley Aquifer boundary, across the channel of Silver Creek, which recharges the Helena Valley Aquifer where it enters the valley. Ground water in this area flows generally east, with the main Helena Valley Irrigation Canal located upgradient from the drains. Ground water recharge may occur from stream loss from Silver Creek into the alluvium, the Scratchgravel Hills bedrock in the subsurface, and from the irrigation canal when in use. Photographs of the drain outlets into the D2-4 Drain are presented in Figure 6-30.

The D2-4 Drain was sampled a total of 22 times during the study, and was observed as dry during three additional sampling events. The data results from the sampling of the D2-4 Drain are summarized in Table 6-17. Time series graphs of the data results are presented in Figure 6-31. From the sampling, nitrate values ranged from 1.68 mg/L up to 3.33 mg/L, with the highest detected concentrations present during low flows after the irrigation season. Phosphate values ranged from 0.014 mg/L up to 0.026 mg/L.

Figure 6-30 Photographs of Drain D2-4 outlet

Table 6-17 Laboratory Results from Sampling, D2-4 Drain

	Field Parameters				Laboratory Data Results						
D2-4	pH	Temp	specific conductivity	Dissolved Oxygen	Total Dissolved Solids, TDS @ 180°C	Alkalinity Total as $CaCO_3$	Cl	Br	SO_4	NO_3+ NO_2 as N	Phosphorus, Total as P
	S.U.	°C	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
5/3/13	7.54	7.3	418	12.02	369	270	18	0.036		2.91	0.023
5/3/13			duplicate	sample	362	270	18	0.049		2.89	0.023
6/20/13	7.57	8.5	416	10.33	366	260	20	0.08		2.55	0.018
6/28/13	7.60	8.8	408	10.06	364	250	17	0.09		2.21	0.019
7/10/13	7.59	9.1	434	10.51	393	260	19	0.049		2.7	0.026
7/26/13	7.59	9.9	420	9.2	375	260	18	0.06		2.25	0.019
8/6/13	7.61	11.1	417	7.77	336	250	17	0.05	52	1.96	0.021
8/23/13	7.68	11.6	422	7.42	347	240	18	0.11	60	1.81	0.022
9/5/13	7.59	12	436	7.65	338	250	28	0.07		1.93	0.02
9/24/13	7.68	12.1	446	7.65	328	250	17	0.047	55	1.9	0.022
9/24/13			duplicate	sample	331	250	17	0.06	56	1.89	0.024
10/9/13	7.70	11.7	470	9.16	373	370	18	0.045	58	3.26	0.014
10/24/13	7.82	11.4	460	6.29	371	260	18	0.06	55	3.06	0.021
11/14/13	7.97	10.9	449	4.37	350	260	18	0.06		3.24	0.025
12/2/13	8.10	10.2	440	7.97	368	260	23	0.08	69	3.24	0.017
1/16/14				dry							
2/20/14				dry							
3/20/14	8.25	6.4	362	10.28	373	250	18	0.03	62	2.5	0.023
4/14/14				dry							
5/1/14	8.13	6.9	405	11.15	354	240	16	0.02	54	2.96	0.025
5/21/14	8.13	7.3	406	5.47	352	240	16	0.05	55	2.59	0.018
6/11/14	8.18	8.4	398	5.97	346	230	14	0.04	49	1.68	0.02
7/10/14	8.31	9.1	430	5.77	368	230	16	0.06	53	2.42	0.017
8/8/14	7.81	10.6	450	7.82	367	240	16	< 0.01	52	2.25	0.018
8/28/14	8.25	10.8	477	6.71	395	260	16	< 0.01	57	1.86	0.021
9/30/14	8.49	11.4	444	8.26	348	240	16	0.06	47	1.94	0.023
11/24/14	8.75	10.5	443	10.69	371	240	16	0.09	47	3.33	0.023
Max	8.75	12.1	477	12.02	395	370	28	0.11	69	3.33	0.026
Min	7.54	6.4	362	4.37	328	230	14	< 0.01	47	1.68	0.014
Average	7.92	9.8	429.6	8.30	360.2	255.4	17.8	0.059	55.1	2.47	0.021
Median	7.82	10.4	432.0	7.90	365.0	250.0	17.5	0.060	55.0	2.46	0.021
Std Dev	0.35	1.77	26.05	2.06	17.53	26.86	2.78	0.021	5.60	0.54	0.003

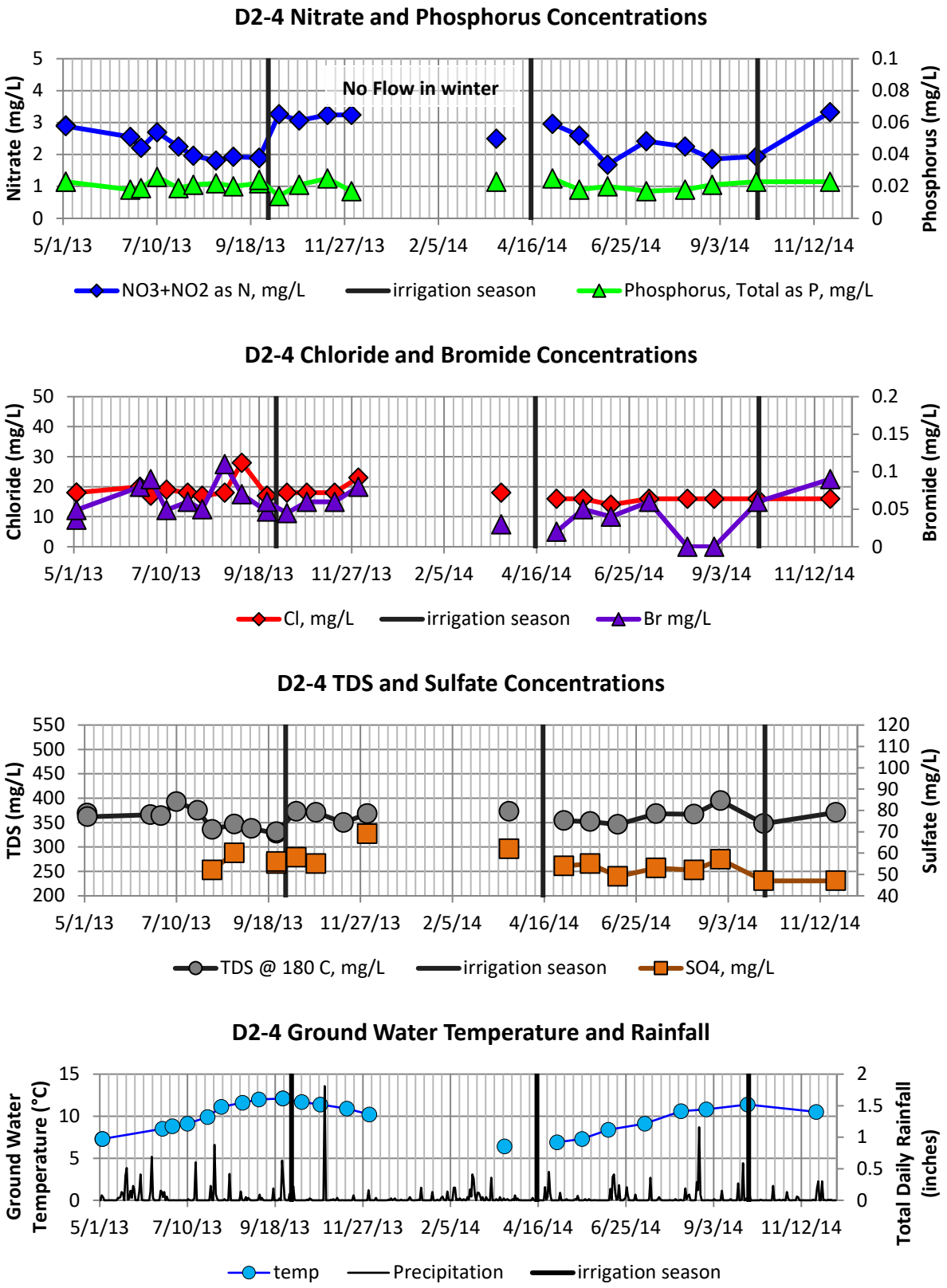


Figure 6-31 –Water Quality Nutrient Results for D2-4 Drain.

D2-4 Drain System Hydrology and Discussion

The D2-4 drain flows showed a strong response to summer irrigation seasons during the monitoring period for this study, with measured flow rates ranging from no flow up to 1.82 cfs (Table 6-18). Flow from the drain increased relatively quickly during summer to near maximum discharge in early June, with the flows remaining relatively stable through irrigation season (Figure 6-32). The system appears to receive primary recharge during the irrigation season, with flows depleting local storage through winter. The maximum measured discharge rate occurred in August.

Combining the nutrient data with flow discharge rates allows for calculation of estimates of nutrient mass loading rates. The loading rates for the D2-4 drain reflect the flow discharge rates for the tile drain (Figure 6-32). Loading to the system occurs primarily during the summer irrigation season. Loading rates decrease during the winter as discharge decreases.

The yearly loading rate for the D2-4 drain was calculated using the data presented in Table 6-19. In order to maintain a consistent time interval for all of the drains included in this study, sample data from September 2013 through September 2014 was used. In order to complete the year, data from August 2014 was used as an estimate for August 2013. The data allows for estimates of the total amount of nitrogen and phosphorus discharged from the drain during the study year. For this drain, this corresponds to a total of 2,994 pounds (1.50 tons) of nitrogen and 26.49 pounds (0.013 tons) of phosphorus discharged from September 2013 to September 2014 (Table 6-19).

The local watershed contributing to the ground water collected from the D2-4 drain is depicted in Figure 6-33, which also shows the configuration of the local water table. For purposes of this assessment, this includes the area upgradient from the drain, estimated from the water table map, including a subdivision and irrigated agriculture fields. Potential nutrient sources include agricultural fertilizers and manure waste, and discharge from septic system drainfields.

Table 6-18 – D2-4 Drain Discharge & Loading Rates

Sample Date	Flow Rate ft^3/s	**Nitrogen** lbs/day	**Phosphorus** lbs/day
9/5/13	1.69	17.63	0.183
9/24/13	1.72	17.61	0.222
10/9/13	0.48	8.45	0.036
10/24/13	0.36	5.93	0.041
11/14/13	0.22	3.91	0.030
12/2/13	*0.11**	1.78	0.009
1/16/14	Dry	0	0
2/20/14	Dry	0	0
3/20/14	0.042	0.57	0.005
4/14/14	Dry	0	0
5/1/14	0.37	5.91	0.050
5/21/14	0.95	13.27	0.092
6/11/14	1.66	15.04	0.179
7/10/14	1.47	19.19	0.135
8/8/14	1.82	22.09	0.177
8/28/14	1.34	13.44	0.152
9/30/14	1.52	15.91	0.189
11/24/14	0.09	1.62	0.011
Max	1.82	22.09	0.222
Min	0	0	0
Average	0.82	9.47	0.090
Median	0.48	8.45	0.050
Stnd Dev	0.74	7.75	0.083

* Rate not measured in field, estimated as average between bounding measurements

The flows in the D2-4 drain can be seen to increase with the May 1, 2014 sampling event (Figure 6-32). Since irrigation season starts on April 15, this represents an approximate 15 day lag between the onset of irrigation and recovery of water from the tile drains. Nitrate values in the drain range from 1.68 to 3.33 which, when compared to irrigation waters consistently below 1.0 mg/L (see Section 5.0), infers that nitrogen is from an upgradient, anthropogenic source. The detected nitrogen concentrations appear to increase after irrigation season ends, suggesting that the nutrient source is relatively constant, assuming irrigation waters provide dilution. Since dissolved oxygen is consistently present near or exceeding 50 percent saturation, it is assumed that all nitrogen species are converted to nitrate within the ground water system. The variability of the bromide concentrations relative to chloride result in this assessment method being inconclusive for this system.

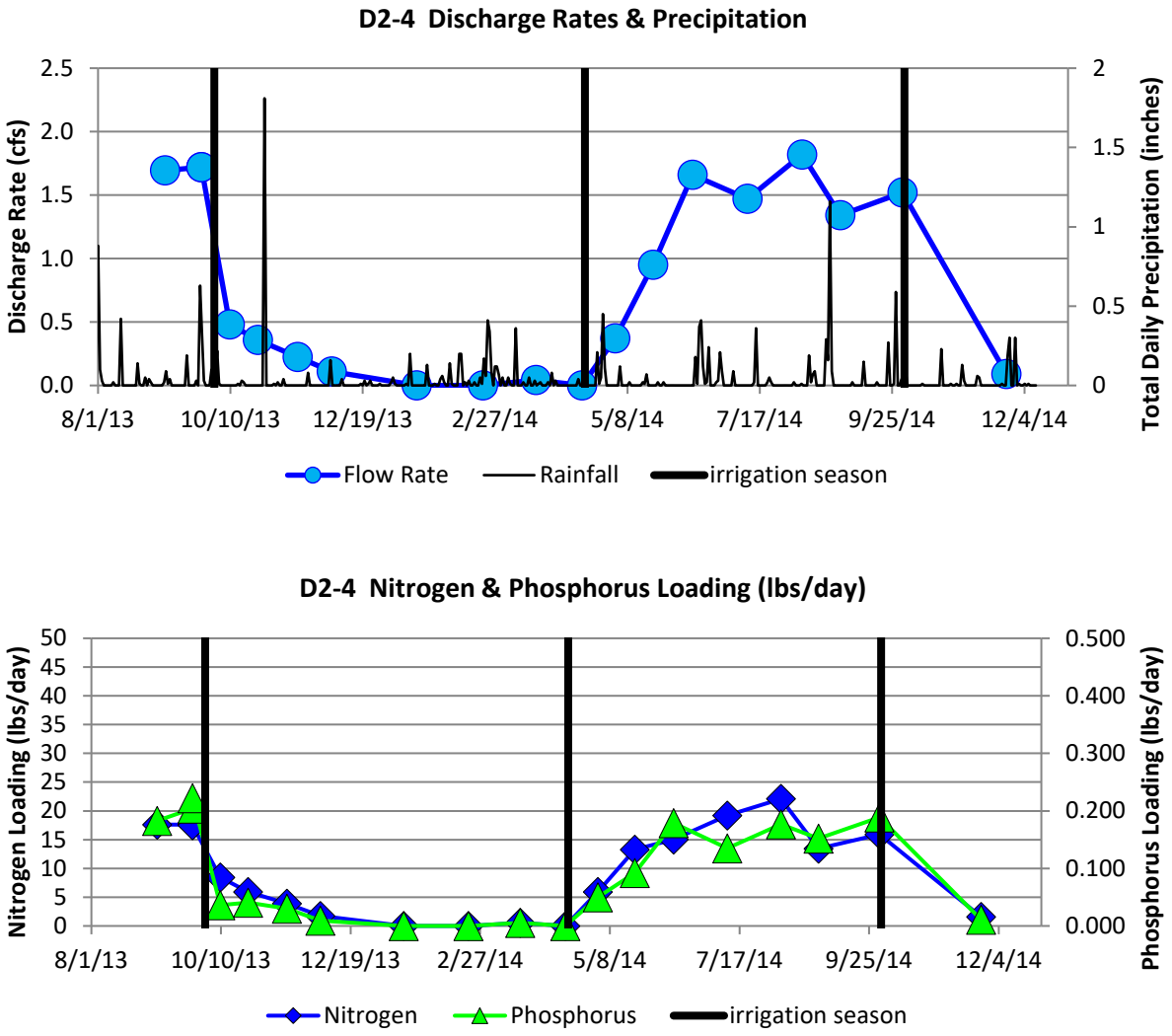


Figure 6-32 – Discharge Rates and Nitrogen and Phophorus Loading from D2-4 Drain.

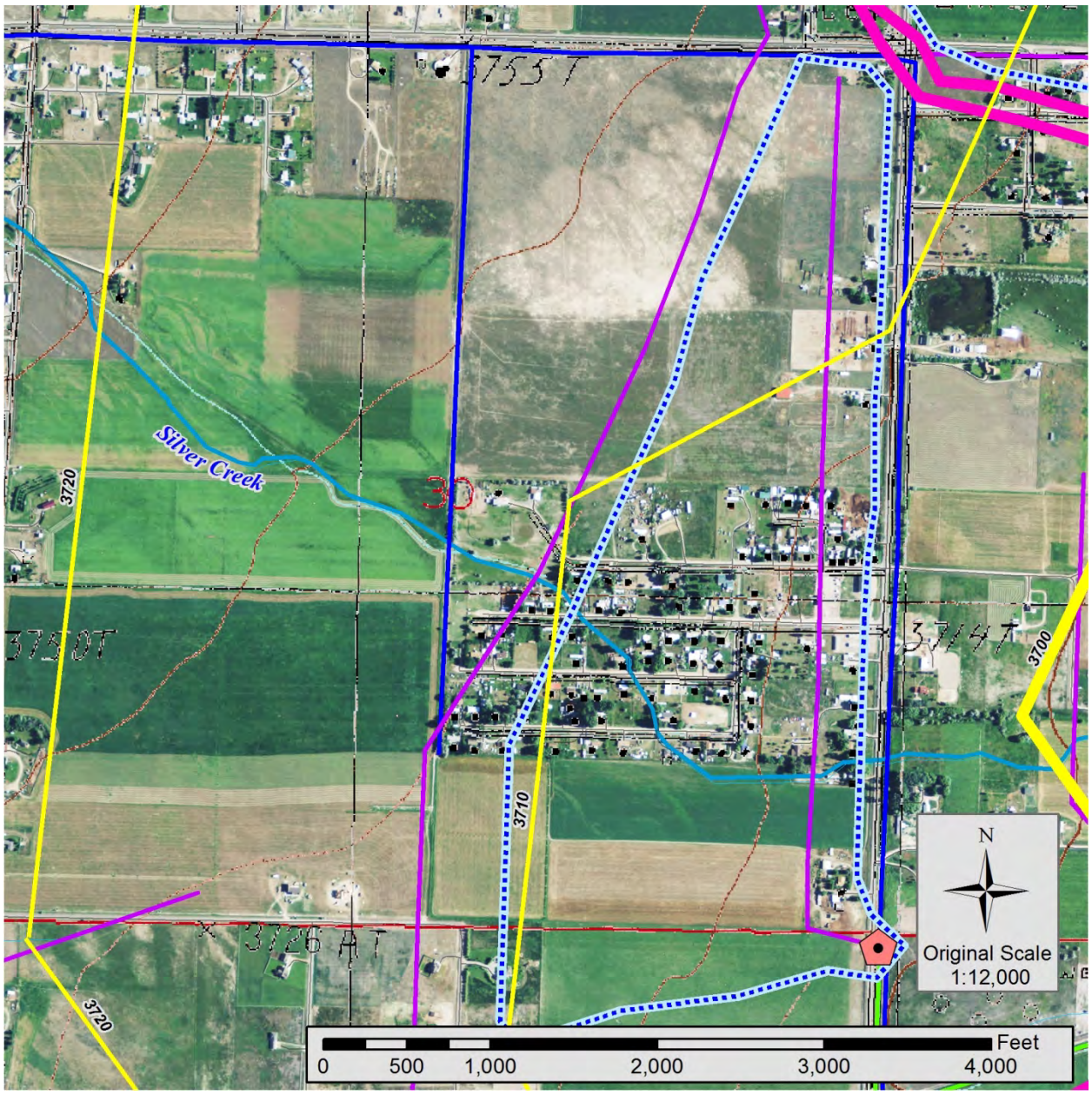


Figure 6-33 – Subwatershed Contributing Area for D2-4 Drain.
Ground water flow contours at 10' interval, with flow to the east.

Table 6-19 – D2-4 Drain Nitrogen and Phosphorus Loading

D2-4	Interval Days	Loading cfs	**Nitrogen lbs/day**	slope avg lbs/day	total lbs interval	**Phosphorus lbs/day**	slope avg lbs/day	total lbs interval
8/28/2014		1.34	**13.44**			**0.15**		
9/5/2013	8	1.69	**17.63**	15.53	124.26	**0.18**	0.17	1.34
9/24/2013	19	1.72	**17.52**	17.57	333.86	**0.22**	0.20	3.85
10/10/2013	16	0.48	**8.45**	12.98	207.73	**0.04**	0.13	2.07
10/25/2013	15	0.36	**5.93**	7.19	107.84	**0.04**	0.038	0.58
11/13/2013	19	0.22	**3.91**	4.92	93.51	**0.03**	0.035	0.67
12/12/2013	29	0.11	**1.96**	2.94	85.12	**0.01**	0.020	0.59
1/16/2014	35		**0**	0.98	34.24	**0**	0.005	0.18
2/20/2014	35		**0**	0.00	0.00	**0**	0.000	0.00
3/20/2014	28	0.04	**0.57**	0.28	7.95	**0.01**	0.003	0.07
4/14/2014	25		**0**	0.28	7.10	**0**	0.003	0.07
5/1/2014	17	0.37	**5.91**	2.95	50.21	**0.05**	0.025	0.42
5/21/2014	20	0.95	**13.27**	9.59	191.79	**0.09**	0.071	1.42
6/10/2014	20	1.66	**15.04**	14.16	283.14	**0.18**	0.14	2.71
7/10/2014	30	1.47	**19.19**	17.11	513.45	**0.13**	0.16	4.71
8/8/2014	29	1.82	**22.09**	20.64	598.53	**0.18**	0.16	4.52
8/28/2014	20	1.34	**13.44**	17.77	355.30	**0.15**	0.16	3.29
	365			**Total Pounds**	**2994**		**Total Pounds**	**26.49**
				Total Tons	**1.50**		**Total Tons**	**0.013**

6.3.1.4 D2-5 Drain System

The D2-5 drain is located at the downgradient point of the Western D2 Drain system, before major tributary ditches discharge flows back into the D2 Drain (Figure 6-22). Photographs of the discharge point of the pipe are presented in Figure 6-34. During the reconnaissance sampling program, nitrate was detected at 1.39 mg/L, and total phosphorus was 0.007 mg/L. Land use in the watershed area contributing to the drain includes multiple houses, with a limited amount of irrigated agricultural lands (Figure 6-35).

Discharge loading from the D2-5 Drain was estimated by comparing the reconnaissance sampling results with the results for the D2-2 Drain. The ratio of D2-5 data to D2-2 data for both nitrate and total phosphorus was multiplied by the loading rates from the D2-2 drain to get estimates for the D2-5 Drain. This results in an estimated **672 pounds (0.34 tons) of total nitrogen** and **12.36 pounds (0.006 tons) of total phosphorus** discharged from the drain

View of D2-5 outlet into D2 Ditch. View looking upgradient, to the west.

Drain D2-5 outlet. Note plant growing in pipe at discharge point

Figure 6-34 – Photographs of Drain D2-5 outlet.

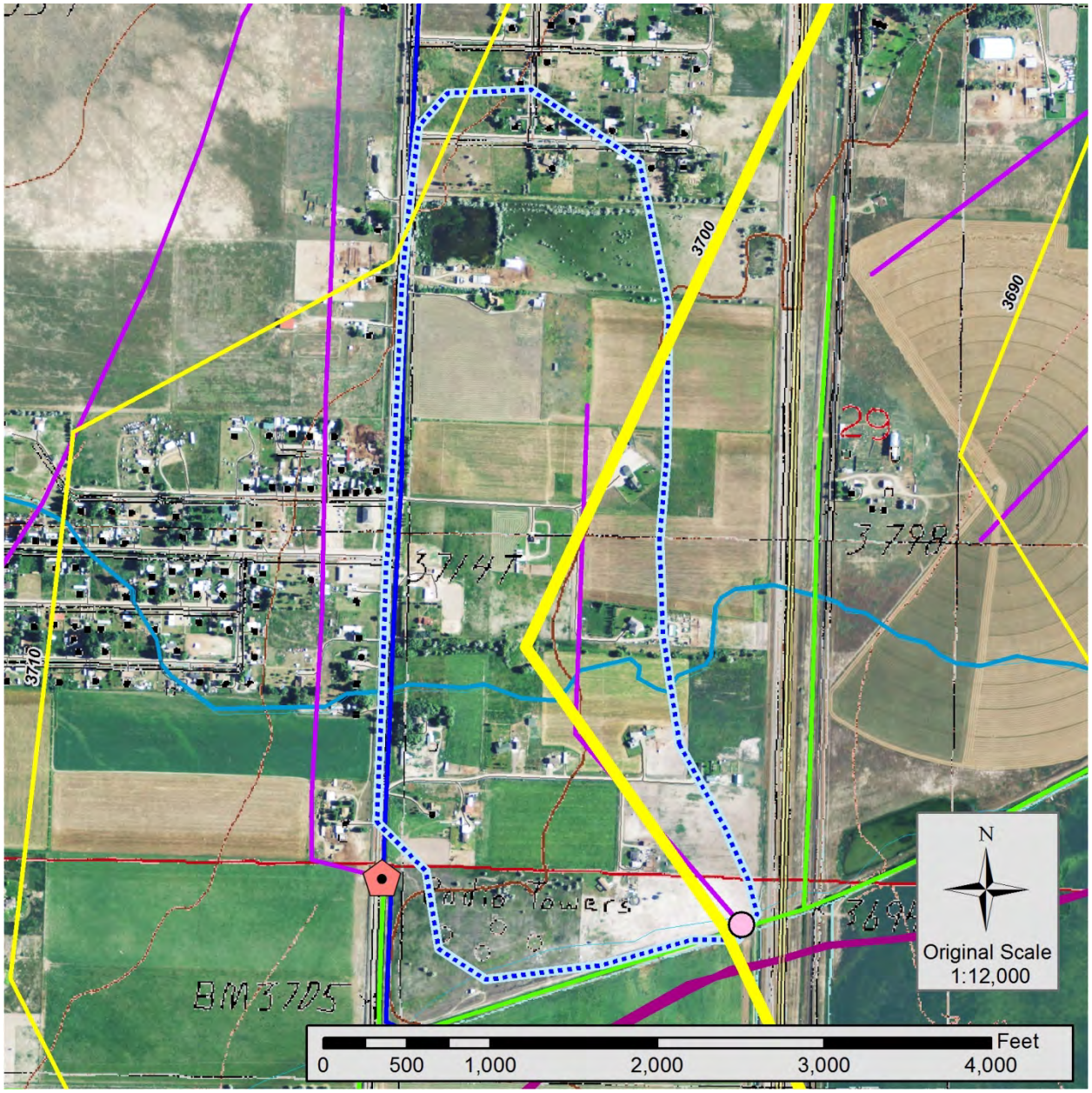


Figure 6-35 – Subwatershed Contributing Area for D2-5 Drain.
Ground water flow contours at 10' interval, with flow to the east.

6.3.2 Northern D2 Ditch System (Ditch D2-2.3 and Drains)

The D2-2.3 ditch starts in the northeastern part of the valley, flowing south before discharging into the main D2 ditch (Figure 6-36). A total of seven ground water drains discharge in this area, with six on the D2-2.3 ditch, and one (D2-6) into an unnamed tributary which flows into Lake Helena. The layout of the irrigation system network is depicted in Figure 6-37. Flows in the upper part of the D2-2.3 ditch do not include any return flows from surface water distribution laterals, while flows in the lower half are dominated by return flows from Lateral 27.8. Ground water in this area is interpreted to flow generally east to southeast, following topography, towards Lake Helena (Figure 6-36). The results from the reconnaissance water quality samples indicate nitrate concentrations ranging from 1.24 to 3.52 mg/L from the four drains with flow (Table 6-20).

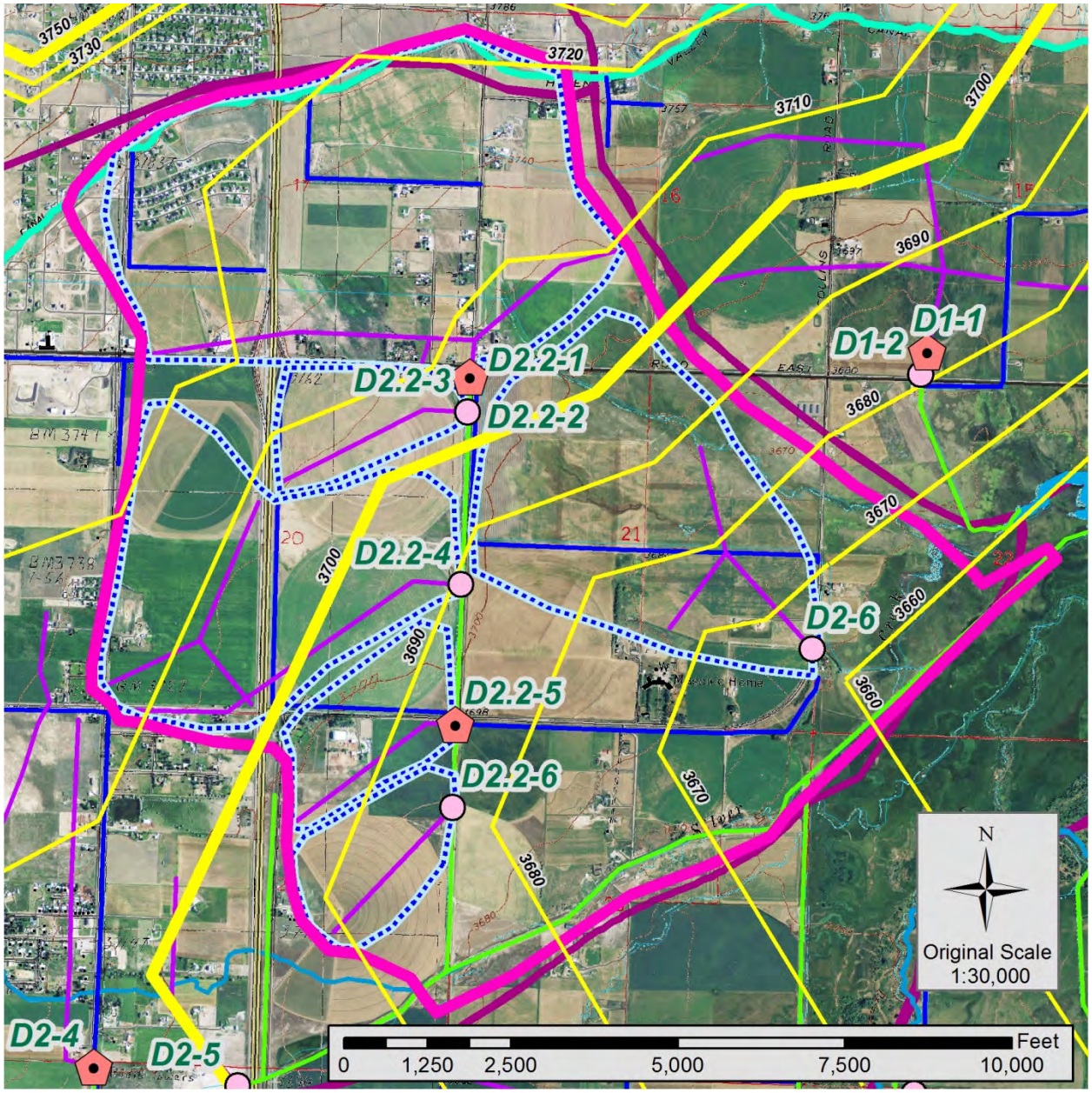


Figure 6-36– Northern D2 Ditch SubwatershedArea

Tile drain discharge points are noted, with ground water potentiometric surface. See text for explanation.

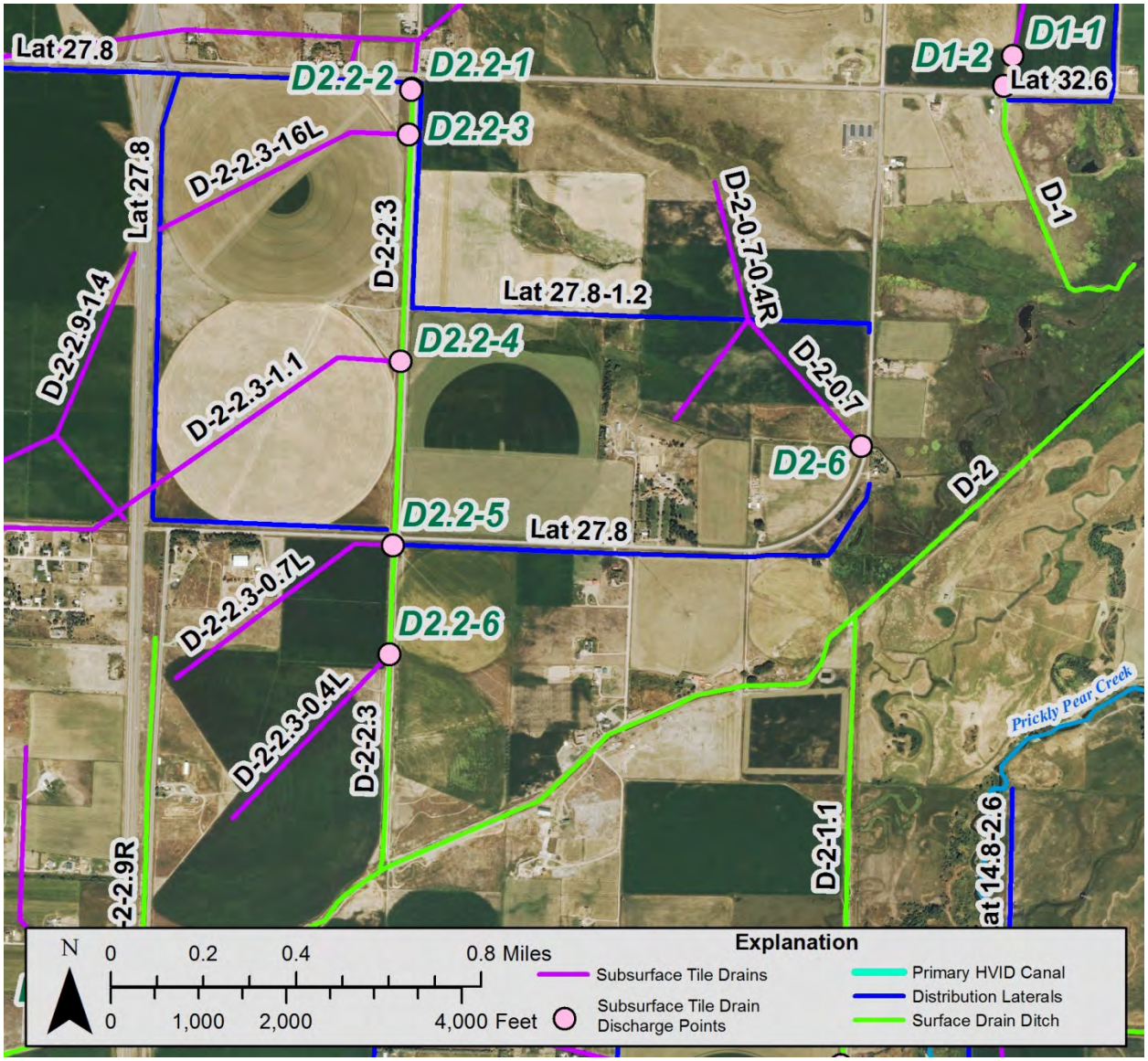


Figure 6-37 – D2-2.3 Ditch, Lower D2 Ditch and Surrounding Features.

Table 6-20 Laboratory Results from Reconnaissance Sampling, Lower D2 and D2-2.3 Ditch

Analyses	D2.2-1	D2.2-3	D2.2-5	D2-6	
Field Parameters					
pH	7.77	7.53	7.63	7.51	S.U.
Conductivity	371	364	427	159	µs/cm
Temperature	8.7	7.0	6.9	6.9	°C
Dissolved Oxygen	12.12	14.03	11.99	10.68	mg/L
Laboratory Results					
Total Dissolved Solids, TDS @ 180°C	321	328	368	513	mg/L
Alkalinity, total as $CaCO_3$	230	250	280	330	mg/L
Chloride	15	15	20	23	mg/L
Bromide	<0.05	<0.05	<0.05	0.45	mg/L
Nitrogen, Nitrate + Nitrite as N	1.76	1.94	3.52	1.24	mg/L
Phosphorus, total as P	0.022	0.024	0.017	0.028	mg/L

6.3.2.1 D2.2-1 and D2.2-2 Drain Systems

The D2.2-1 drain is located at the northern end of the D2-2.3 ditch, and provides the initial flows into the ditch. The D2.2-2 drain is an overflow storm drain that was misidentified as a tile drain outlet. The general layout of the drains is depicted in Figure 6-36. The D2.2-1 drain is located along the northern edge of the Helena Valley aquifer. Ground water in this area flows generally to the southeast, towards Lake Helena. Ground water recharge may occurs from irrigation canals, and from the upgradient area where recharge occurs from infiltration of local precipitation. Photographs of the drain outlets and the ditch are presented in Figure 6-37.

The D2.2-1 drain was sampled a total of 25 times during this program, and flows were observed during all sampling events. The data from the sampling of the drain is summarized in Table 6-21. Time series graphs of the data are presented in Figure 6-38. The sampling results show nitrate detected in values ranging from 1.76 mg/L up to 3.19 mg/L. Total phosphorus values ranged from 0.009 mg/L up to 0.033 mg/L. There does not appear to be any distinct seasonal trends to detected concentrations.

Flow downgradient from Drain D2.2-1 outlet in D2-2.3 Ditch.

Drain D2.2-1 outlet,with all flow in ditch from this drain. The outlet for Drain D2.2-2 was misidentified, as this is an overflow storm drain outlet. No flows were observed from this outlet during the sampling program.

Figure 6-38 – Photographs of Drain D2.2-1 and overflow storm drain (D2.2-2) outlets.

Table 6-21 Laboratory Results from Sampling, D2.2-1 Drain

	Field Parameters				Laboratory Data Results						
D2.2-1	pH S.U.	Temp °C	specific conductivity µs/cm	Dissolved Oxygen mg/L	Total Dissolved Solids, TDS @ 180°C mg/L	Alkalinity Total as $CaCO_3$ mg/L	Cl mg/L	Br mg/L	SO_4 mg/L	NO_3+ NO_2 as N mg/L	Phosphorus, Total as P mg/L
5/3/13	7.77	8.7	371	12.12	321	230	15	0.05		1.76	0.022
6/20/13	7.60	9.8	483	10.71	425	300	20	0.07		2.5	0.023
6/28/13	7.62	9.6	478	11.56	426	300	19	0.08		2.56	0.025
7/10/13	7.67	9.7	490	11.59	444	300	20	0.06		2.63	0.023
7/26/13	7.72	10.8	500	10.41	428	310	20	0.08		2.77	0.023
8/6/13	7.68	11.4	536	10	432	320	19	0.06	70	2.62	0.026
8/23/13	7.74	11.5	537	6.95	436	320	21	0.1	75	2.76	0.024
9/5/13	7.74	11.8	539	8.94	430	310	21	0.11		2.98	0.033
9/24/13	7.82	12	529	10.01	425	300	21	0.09	69	2.78	0.026
10/10/13	7.87	11.5	537	6.75	382	310	20	0.045	72	2.95	0.018
10/25/13	7.87	11	532	6.37	433	310	20	0.07	73	2.73	0.024
11/13/13	8.03	10.3	521	6.9	448	310	20	0.07		3.09	0.022
12/12/13	8.11	9.3	507	7.73	448	310	20	0.07	74	2.94	0.015
1/16/14	8.15	7.9	487	6.96	435	310	20	0.11	73	3.04	0.009
2/20/14	8.24	6.9	471	9.07	443	300	21	0.11	71	3.19	0.018
3/20/14	8.23	6.4	462	9.43	440	300	21	0.05	76	2.7	0.018
4/14/14	8.27	6.5	461	6.5	433	300	21	0.04	75	3.12	0.021
5/1/14	8.34	6.8	466	5.41	430	280	18	0.04	69	2.8	0.023
5/21/14	8.30	7.4	454	5.88	401	270	17	0.08	61	2.72	0.016
5/21/14			dup		399	270	17	0.08	61	2.83	0.018
6/10/14	8.05	8.4	462	10.13	417	270	16	0.12	56	2.45	0.021
7/10/14	8.11	9.9	484	6.33	414	260	17	0.04	60	2.35	0.023
8/8/14	8.23	11	500	9.23	412	280	17	< 0.01	56	2.5	0.025
8/28/14	8.36	11.5	514	5.91	427	280	18	< 0.01	60	2.03	0.023
9/30/14	8.34	11.3	507	5.72	408	280	19	0.06	60	2.46	0.028
11/24/14	8.57	10	506	7.77	439	280	18	0.08	65	2.89	0.025
Max	8.57	12.0	539	12.12	448	320	21	0.12	76	3.19	0.033
Min	7.60	6.4	371	5.41	321	230	15	< 0.01	56	1.76	0.009
Average	8.02	9.66	493.4	8.34	422.15	292.7	19.1	0.074	67.2	2.70	0.022
Median	8.05	9.90	500.0	7.77	429.0	300.0	20.0	0.07	69.0	2.75	0.023
Std Dev	0.28	1.81	37.39	2.09	26.06	21.17	1.74	0.024	6.88	0.33	0.005

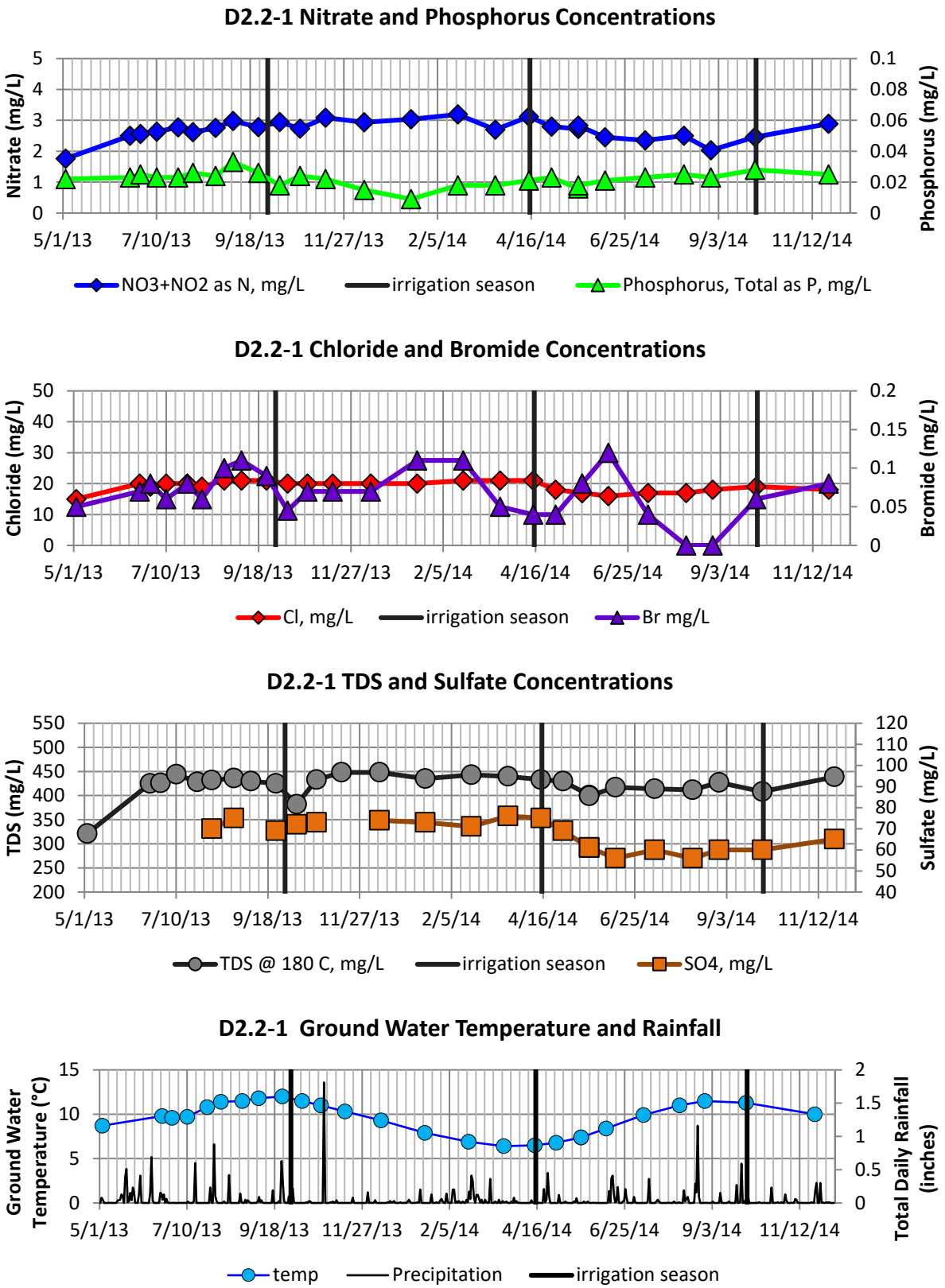


Figure 6-39 –Water Quality Nutrient Results for D2.2-1 Drain.

D2.2-1 Drain System Hydrology and Discussion

The D2.2-1 drain flowed continuously during this study, and showed a strong but muted response to summer irrigation season. During the monitoring period for this study, measured flow rates range from 0.20 cfs up to 1.47 cfs (Table 6-22). Flow from the drain steadily increased during summer to the maximum measured discharge in August (Figure 6-40). The system appears to receive primary recharge during the irrigation season, with flows depleting local storage through winter. The delayed response of the system to irrigation flows is interpreted to occur from a lower permeability system than other areas, where irrigation waters are stored within the system, and then released after irrigation season, only to be recharged from the next irrigation season.

Combining the nutrient data with flow discharge rates allows for calculation of estimates of nutrient mass loading rates. The loading rates for the D2.2-1 drain generally reflect the flow discharge rates for the tile drain, with the exception of phosphorus (Figure 6-40). Loading to the system occurs primarily during end of the summer irrigation season through fall and into the winter months. Loading rates decrease during the late winter and spring as discharge decreases.

The yearly loading rate for the D2.2-1 drain was calculated using the data presented in Table 6-23. In order to maintain a consistent time interval for all of the drains included in this study, sample data from September 2013 through September 2014 was used. In order to complete the year, data from August 2014 was used as an estimate for August 2013. The data allows for estimates of the total amount of nitrogen and phosphorus discharged from the drain during the study year. For this drain, this corresponds to a total of 5,555 pounds (2.78 tons) of nitrogen and 41.81 pounds (0.021 tons) of phosphorus discharged from September 2013 to September 2014 (Table 6-23).

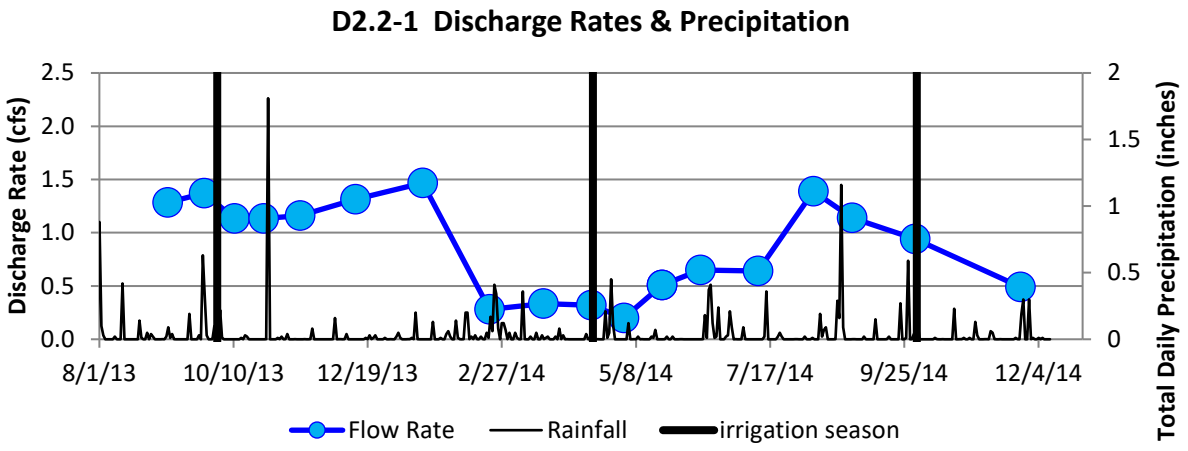
The local watershed contributing to the ground water collected from the D2.2-1 drain is depicted in Figure 6-41, which also shows the configuration of the local water table. For purposes of this assessment, this includes the area upgradient from the drain, estimated from the water table map, includes a series of large lot residential homes, a subdivision and irrigated agriculture fields. Potential nutrient sources include agricultural fertilizers and manure waste, and discharge from septic system drainfields.

Table 6-22 – D2.2-1 Drain Discharge & Loading

Sample Date	Flow Rate ft^3/s	**Nitrogen** lbs/day	**Phosphorus** lbs/day
9/5/13	1.28	20.65	0.229
9/24/13	1.37	20.55	0.192
10/10/13	1.13	18.04	0.110
10/25/13	1.13	16.70	0.147
11/13/13	1.16	19.34	0.138
12/12/13	*1.31**	20.84	0.106
1/16/14	1.47	24.06	0.071
2/20/14	0.28	4.80	0.027
3/20/14	0.33	4.85	0.032
4/14/14	0.32	5.39	0.036
5/1/14	0.20	3.02	0.025
5/21/14	0.51	7.48	0.044
5/21/14	Dup	7.78	0.050
6/10/14	0.65	8.59	0.074
7/10/14	0.64	8.11	0.079
8/8/14	1.39	18.74	0.187
8/28/14	1.14	12.48	0.141
9/30/14	0.94	12.47	0.142
11/24/14	0.49	7.64	0.066
Max	1.47	24.06	0.229
Min	0.20	3.02	0.025
Average	0.86	12.71	0.100
Median	0.94	12.47	0.079
Stnd Dev	0.44	6.80	0.062

* Rate not measured in field, estimated as average between bounding measurements

The flows in the D2.2-1 drain can be seen to increase with the May 21, 2014 sampling event, with peak summer flows measured on August 8, 2014 (Figure 6-40). The greatest measured flow occurring in January 2014, and is attributed to precipitation recharge supplementing the local ground water system. Since irrigation season starts on April 15, this represents an approximate 35 day lag between the onset of irrigation and recovery of water from the tile drains. Nitrate values in the drain range from 1.76 to 3.19 mg/L which, when compared to irrigation waters consistently below 1.0 mg/L (see Section 5.0), infers that nitrogen is from an upgradient, anthropogenic source. The detected nitrogen concentrations appear to increase after irrigation season ends, suggesting that the nutrient source is relatively constant, assuming irrigation waters provide dilution. Since dissolved oxygen is consistently present near or exceeding 50 percent saturation, it is assumed that all nitrogen species are converted to nitrate within the ground water system. The variability of the bromide concentrations relative to chloride result in this assessment method being inconclusive for this system.



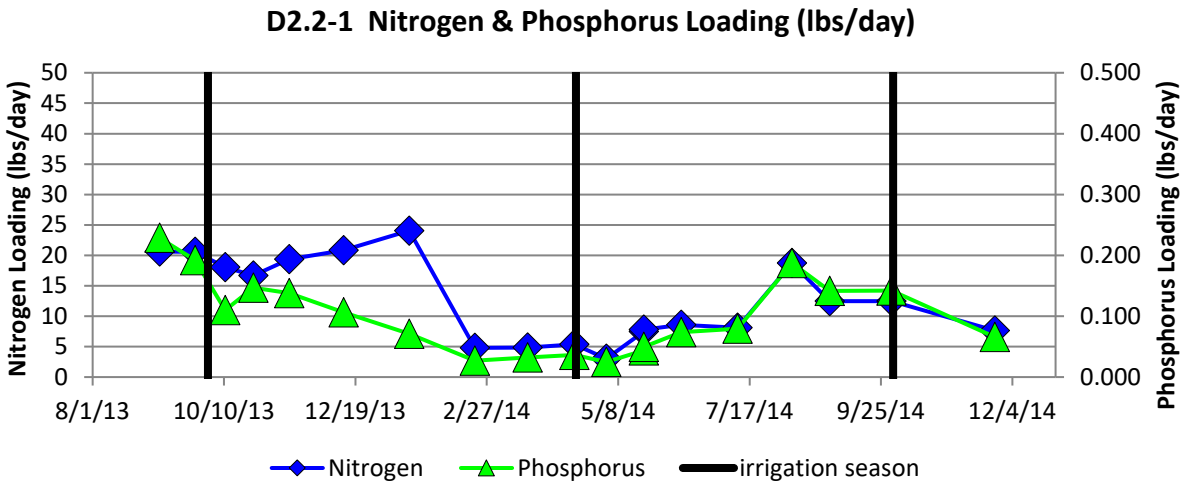


Figure 6-40 – Discharge Rates and Nitrogen and Phophorus Loading from D2.2-1 Drain.

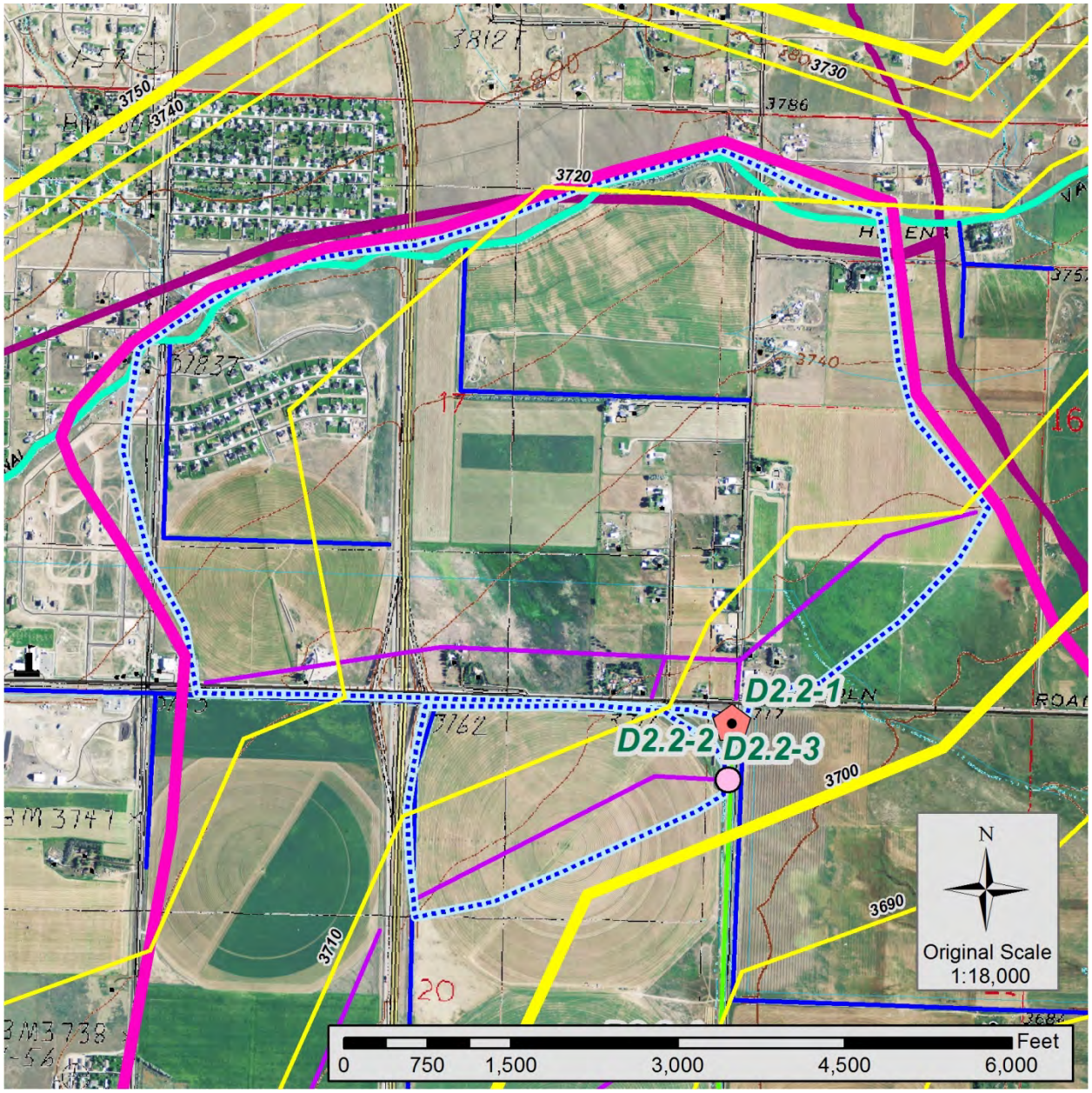


Figure 6-41 – Subwatershed contributing area for D2.2-1 Drain.
Ground water flow contours at 10' interval, with flow to the southeast.

Table 6-23 – D2.2-1 Drain Nitrogen and Phosphorus Loading

D2.2-1	Interval Days	Loading cfs	**Nitrogen lbs/day**	slope avg lbs/day	total lbs interval	**Phosphorus lbs/day**	slope avg lbs/day	total lbs interval
8/28/2013		1.14	**12.48**			**0.14**		
9/5/2013	8	1.28	**20.65**	14.38	819.62	**0.23**	0.15	8.78
9/24/2013	19	1.37	**20.55**	20.60	391.34	**0.19**	0.21	4.00
10/10/2013	16	1.13	**18.04**	19.29	308.72	**0.11**	0.15	2.42
10/25/2013	15	1.13	**16.70**	17.37	260.55	**0.15**	0.13	1.93
11/13/2013	19	1.16	**19.34**	18.02	342.39	**0.14**	0.14	2.70
12/12/2013	29	1.31	**20.84**	20.09	582.64	**0.11**	0.12	3.54
1/16/2014	35	1.47	**24.06**	22.45	785.75	**0.07**	0.09	3.11
2/20/2014	35	0.28	**4.80**	14.43	505.15	**0.03**	0.05	1.72
3/20/2014	28	0.33	**4.85**	4.83	135.21	**0.03**	0.03	0.83
4/14/2014	25	0.32	**5.39**	5.12	127.99	**0.04**	0.03	0.86
5/1/2014	17	0.20	**3.02**	4.20	71.45	**0.02**	0.03	0.52
5/21/2014	20	0.51	**7.78**	5.40	108.05	**0.05**	0.04	0.74
6/10/2014	20	0.65	**8.59**	8.19	163.74	**0.07**	0.06	1.23
7/10/2014	30	0.64	**8.11**	8.35	250.53	**0.08**	0.08	2.30
8/8/2014	29	1.39	**18.74**	13.43	389.36	**0.19**	0.13	3.86
8/28/2014	20	1.14	**12.48**	15.61	312.20	**0.14**	0.16	3.28
	365			**Total Pounds**	**5555**		**Total Pounds**	**41.81**
				Total Tons	**2.78**		**Total Tons**	**0.021**

6.3.2.2 D2.2-3 Drain System

The D2.2-3 Drain is located just south of the D2.2-1 drain, and provides drainage to a small irrigated field (Figure 6-41). Photographs of the discharge point of the pipe are presented in Figure 6-42. During the reconnaissance sampling program, nitrate was detected at 1.94 mg/L, and total phosphorus was 0.024 mg/L. Land use in the watershed area contributing to the drain represents predominantly irrigated agricultural lands (Figure 6-41).

Discharge loading from the D2.2-3 Drain was estimated by comparing the reconnaissance sampling results with the results for the D2.2-5 Drain. The ratio of D2.2-5 data to D2.2-3 data for both nitrate and total phosphorus was multiplied by the loading rates from the D2.2-5 drain to get estimates for the D2.2-3 Drain. This results in an estimated **584 pounds (0.29 tons) of total nitrogen** and **10.39 pounds (0.005 tons) of total phosphorus** discharged from the drain

Drain D2.2-3 Outlet

Drain 2.2-3 outlet and view north in Ditch D2-2.3.

Figure 6-42 – Photographs of Drain D2.2-3 outlet.

6.3.2.3 D2.2-4 Drain System

The D2.2-4 Drain is located south of the D2.2-3 ditch, and provides drainage to several irrigated agricultural fields. Photographs of the discharge point of the pipe are presented in Figure 6-43. There was no flow observed during the reconnaissance sampling program, so no samples were taken. The actual location on the drains in the upgradient area are not known, and they may not serve the design purpose at this time. Land use in the watershed area contributing to the drain represents predominantly irrigated agricultural lands, with one farm located along the upgradient boundary. (Figure 6-44).

Discharge loading from the D2.2-4 Drain was estimated by comparing the reconnaissance sampling results with the results for the D2.2-3 Drain. Assuming the same loading rates per watershed contribution area, the D2.2-3 data multiplied by the ratio of areas between the two drain system to estimate loading rates from the D2.2-4 drain. Due to the much larger contributing watershed area, this results in an estimated **2.532 pounds (1.27 tons) of total nitrogen** and **45.03 pounds (0.023 tons) of total phosphorus** discharged from the drain

Drain D2.2-4 discharge point into ditch from view north along Glass Drive. Observed flow in D2-23 Ditch from upgradient drains.

Drain D2.2-4 discharge point into ditch. No flow was observed from pipe.

Figure 6-43 – Photographs of Drain D2.2-4 outlet.

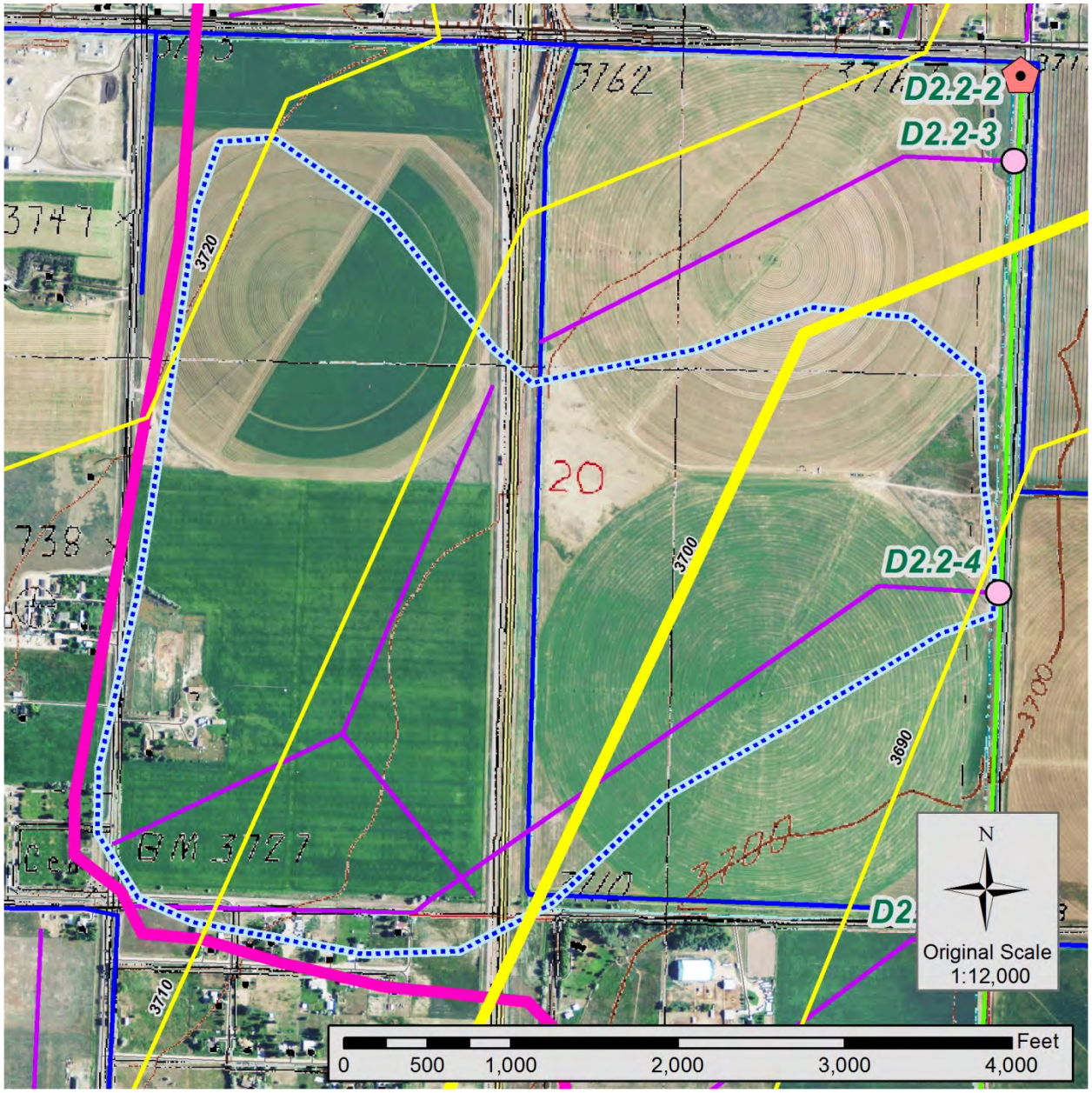


Figure 6-44 – Subwatershed Contributing Area for D2.2-4 Drain.
Ground water flow contours at 10' interval, with flow to the southeast.

6.3.2.4 D2.2-5 Drain System

The D2.2-5 drain is located in the middle of the D2-2.3 ditch, and provides relatively constant discharge flows into the ditch. The general layout of the drain is depicted in Figure 6-36. Ground water in this area flows generally to the southeast, towards Lake Helena. Ground water recharge may occurs from irrigation canals, and from the upgradient area where recharge occurs from infiltration of local precipitation. Photographs of the drain outlet and the ditch are presented in Figure 6-45.

The D2.2-1 drain was sampled a total of 18 times during this program, and flows were observed during all sampling events. The data from the sampling of the drain is summarized in Table 6-24. Time series graphs of the data are presented in Figure 6-46. The sampling results show nitrate detected in values ranging from 2.59 mg/L up to 4.9 mg/L, with the highest concentrations during the low flow winter months. Total phosphorus values ranged from 0.011 mg/L up to 0.045 mg/L. There does not appear to be any distinct seasonal trends to detected phosphorus concentrations.

Drain D2.2-5 Discharge into D2-2.3 Ditch visible in lower left.

Drain D2.2-5 Discharge into D2-2.3 Ditch

Figure 6-45 – Photographs of Drain D2.2-5 outlet.

Table 6-24 Laboratory Results from Sampling, D2.2-5 Drain

	Field Parameters				Laboratory Data Results						
D2.2-5	pH	Temp	specific conductivity	Dissolved Oxygen	Total Dissolved Solids, TDS @ 180°C	Alkalinity Total as $CaCO_3$	Cl	Br	SO_4	NO_3+ NO_2 as N	Phosphorus, Total as P
	S.U.	°C	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
6/20/13	7.36	8.8	468	9.38	400	290	24	0.09		3.13	0.017
7/10/13	7.35	9.6	454	8.89	410	290	23	0.06		2.73	0.02
7/10/13			duplicate	sample	411	290	22	0.06		2.72	0.018
7/26/13	7.51	10.2	468	9.38	388	290	22	0.08		2.93	0.021
8/6/13	7.54	11	471	7.97	381	290	20	0.06	57	2.59	0.02
8/23/13	7.55	11.8	519	5.14	406	300	22	0.1	68	2.76	0.02
9/5/13	7.50	12.1	517	7.25	405	300	21	0.19		2.82	0.023
9/24/13	7.60	12.4	514	8.54	397	290	21	0.07	60	2.8	0.023
10/10/13	7.72	11.5	542	5.3	421	320	23	0.043	68	3.36	0.045
10/25/13	7.79	10.7	535	6.19	433	320	24	0.07	68	3.82	0.018
11/13/13	7.82	9.9	532	6.03	446	320	25	0.09		3.99	0.02
12/12/13	7.92	8.6	476	7.11	446	310	26	0.08	70	3.9	0.016
1/16/14	7.99	7	500	8.34	444	310	27	0.12	70	4.5	0.011
2/20/14	8.02	5.9	389	7.53	467	310	25	0.12	71	4.5	0.02
3/20/14	8.05	5.5	329	7.59	454	310	26	0.05	73	3.7	0.022
4/14/14	8.11	5.7	320	7.14	450	310	25	< 0.01	72	4.9	0.025
5/1/14	8.25	6.4	430	5.87	387	270	19	0.03	55	3.11	0.027
5/21/14	8.12	7.2	415	5.76	380	250	18	0.1	55	2.91	0.016
6/10/14	7.96	8.2	447	7.56	399	270	17	0.08	52	2.8	0.022
Max	8.25	12.4	542	9.38	467	320	27	0.19	73	4.90	0.045
Min	7.35	5.5	320	5.14	380	250	17	0.03	52	2.59	0.011
Average	7.79	9.0	462.6	7.28	417.1	296.9	22.63	0.083	64.5	3.37	0.021
Median	7.81	9.2	469.5	7.39	410	300	23	0.08	68	3.11	0.02
St Dev	0.28	2.33	66.02	1.34	27.29	18.87	2.81	0.036	7.53	0.71	0.007

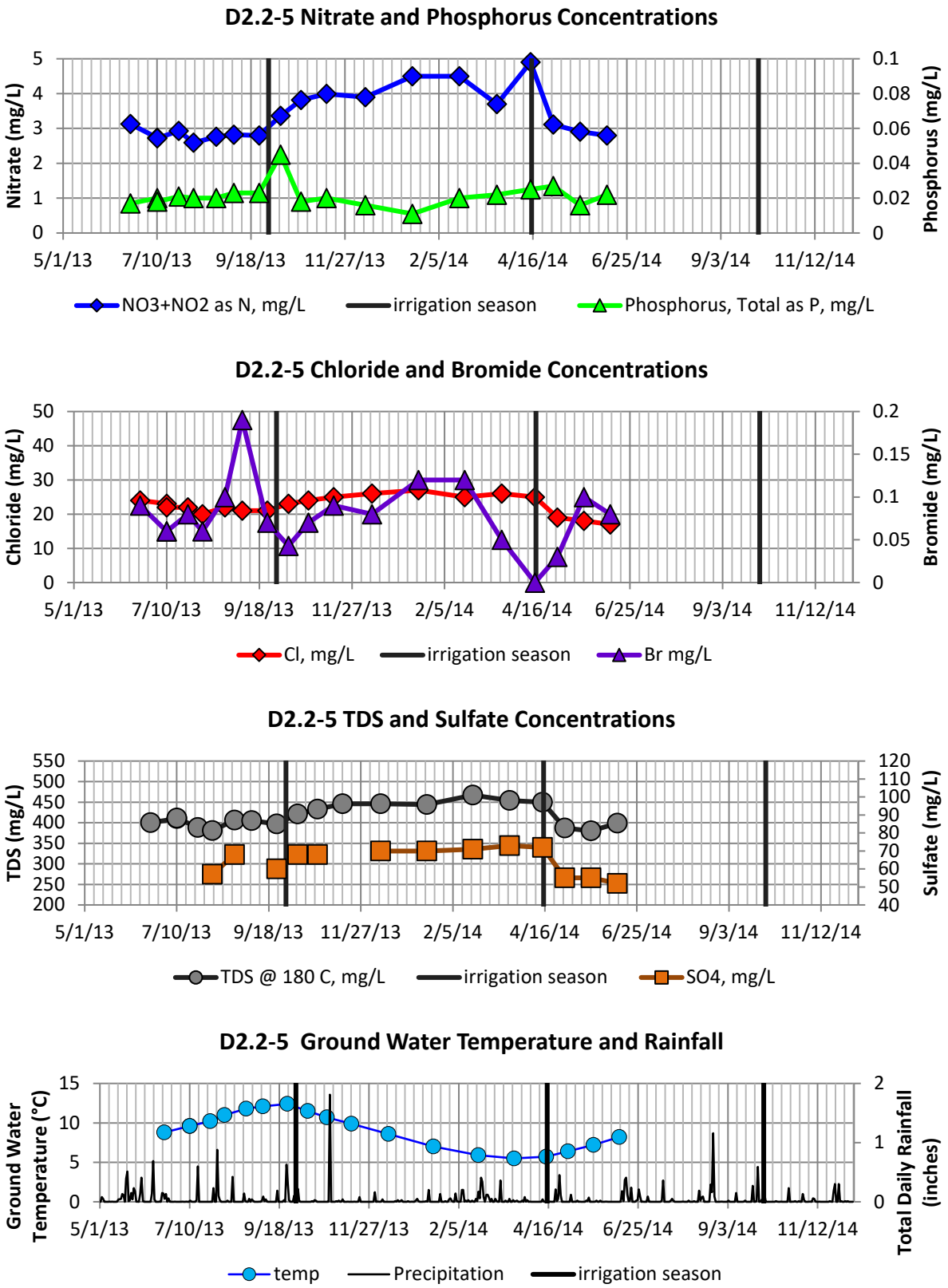


Figure 6-46 – Water Quality Nutrient Results for D2.2-5 Drain.

D2.2-5 Drain System Hydrology and Discussion

The D2.2-5 drain flowed continuously during this study, but with a relatively slow discharge rate compared to other drains in the study. The flows showed a response to summer irrigation season with flow steadily increasing from the start of irrigation. During the monitoring period for this study, measured flow rates range from 0.028 cfs up to 0.31 cfs (Table 6-25). Flow from the drain steadily increased during summer to the maximum measured discharge in late September (Figure 6-47). The system appears to receive primary recharge during the irrigation season, with flows depleting local storage through winter. The location of the drain near a distribution lateral provides recharge during irrigation season. The relatively quick increase in flow rates from the start of irrigation season shows a connection between irrigation waters and ground water levels.

Combining the nutrient data with flow discharge rates allows for calculation of estimates of nutrient mass loading rates. The loading rates for the D2.2-5 drain reflect the flow discharge rates for the tile drain (Figure 6-47). Loading to the system occurs primarily through the summer irrigation season. Loading rates decrease during the fall and into winter and spring as discharge decreases.

The yearly loading rate for the D2.2-5 drain was calculated using the data presented in Table 6-26. In order to maintain a consistent time interval for all of the drains included in this study, sample data from June 2013 through June 2014 was used. In order to complete the year, data from June 2014 was used as an estimate for June 2013. The data allows for estimates of the total amount of nitrogen and phosphorus discharged from the drain during the study year. For this drain, this corresponds to a total of 1,060 pounds (0.53 tons) of nitrogen and 7.36 pounds (0.004 tons) of phosphorus discharged from June 2013 to June 2014 (Table 6-26).

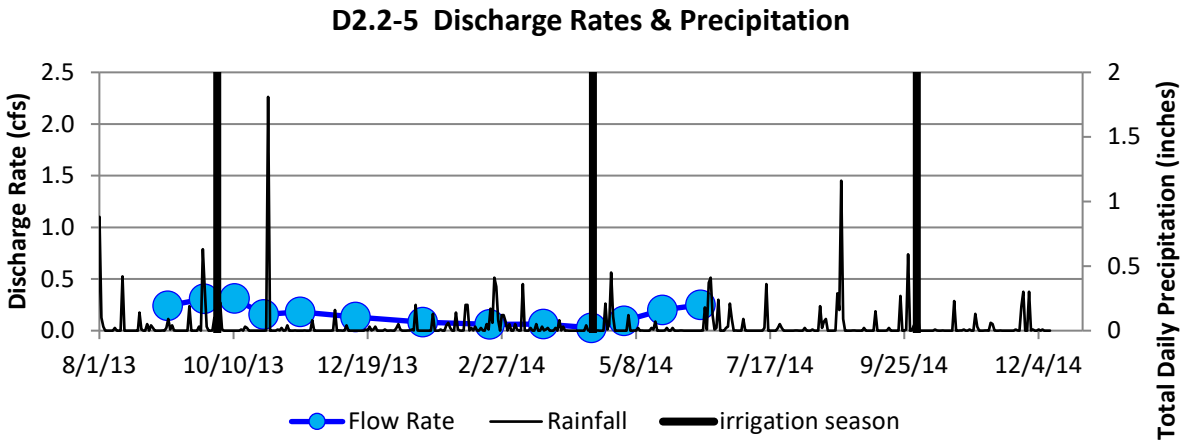
The local watershed contributing to the ground water collected from the D2.2-5 drain is depicted in Figure 6-48, which also shows the configuration of the local water table. For purposes of this assessment, this includes the area upgradient from the drain, estimated from the water table map, includes a single farm and irrigated agriculture fields. Potential nutrient sources include agricultural fertilizers and manure waste, and discharge from the septic system drainfield.

Table 6-25 – D2.2-5 Drain Discharge & Loading Rates

Sample Date	Flow Rate	**Nitrogen**	**Phosphorus**
	ft^3/s	lbs/day	lbs/day
9/5/13	0.24	3.66	0.030
9/24/13	0.31	4.65	0.038
10/10/13	0.31	5.66	0.076
10/25/13	0.16	3.21	0.015
11/13/13	0.18	3.88	0.019
12/12/13	*0.13**	2.09	0.011
1/16/14	0.083	2.02	0.005
2/20/14	0.059	1.44	0.006
3/20/14	0.065	1.29	0.008
4/14/14	0.028	0.74	0.004
5/1/14	0.095	1.59	0.014
5/21/14	0.20	3.14	0.017
6/10/14	0.25	3.78	0.030
Max	0.31	5.66	0.076
Min	0.028	0.74	0.004
Average	0.16	2.86	0.021
Median	0.16	3.14	0.015
Stnd Dev	0.095	1.46	0.020

* Rate not measured in field, estimated as average between bounding measurements

The flows in the D2.2-5 drain can be seen to increase with the May 1, 2014 sampling event, with peak summer flows measured in September and October 2013 at the end of irrigation season (Figure 6-47). Since irrigation season starts on April 15, the response of the system is considered less than 15 days as the water table rises (and flows increase accordingly). Nitrate values in the drain range from 2.59 to 4.9 mg/L which, when compared to irrigation waters consistently below 1.0 mg/L (see Section 5.0), infers that nitrogen is from an upgradient, anthropogenic source. The detected nitrogen concentrations appear to increase after irrigation season ends, suggesting that the nutrient source is relatively constant, assuming irrigation waters provide dilution. Since dissolved oxygen is consistently present near or exceeding 50 percent saturation, it is assumed that all nitrogen species are converted to nitrate within the ground water system. The variability of the bromide concentrations relative to chloride result in this assessment method being inconclusive for this system.



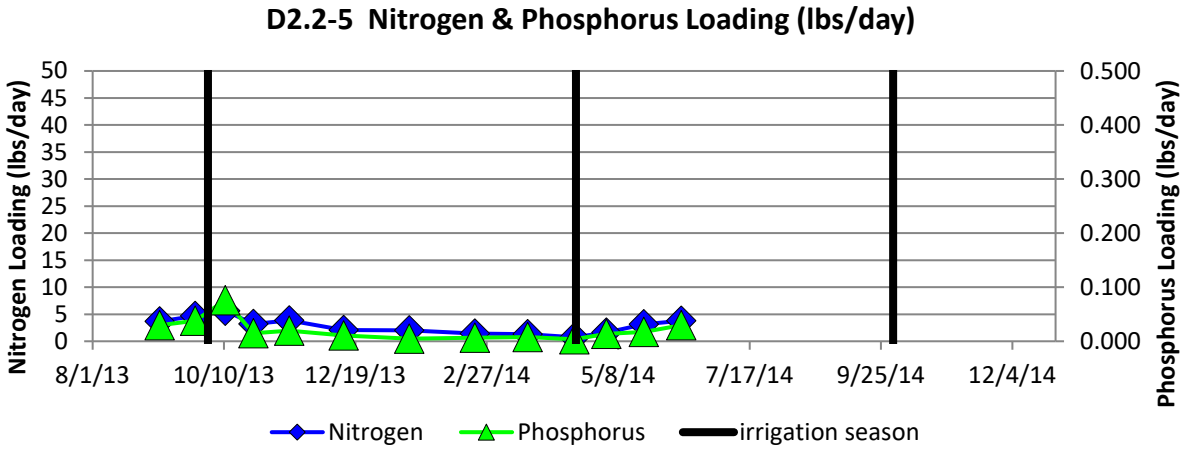


Figure 6-47 – Discharge Rates and Nitrogen and Phophorus Loading from D2.2-5 Drain.

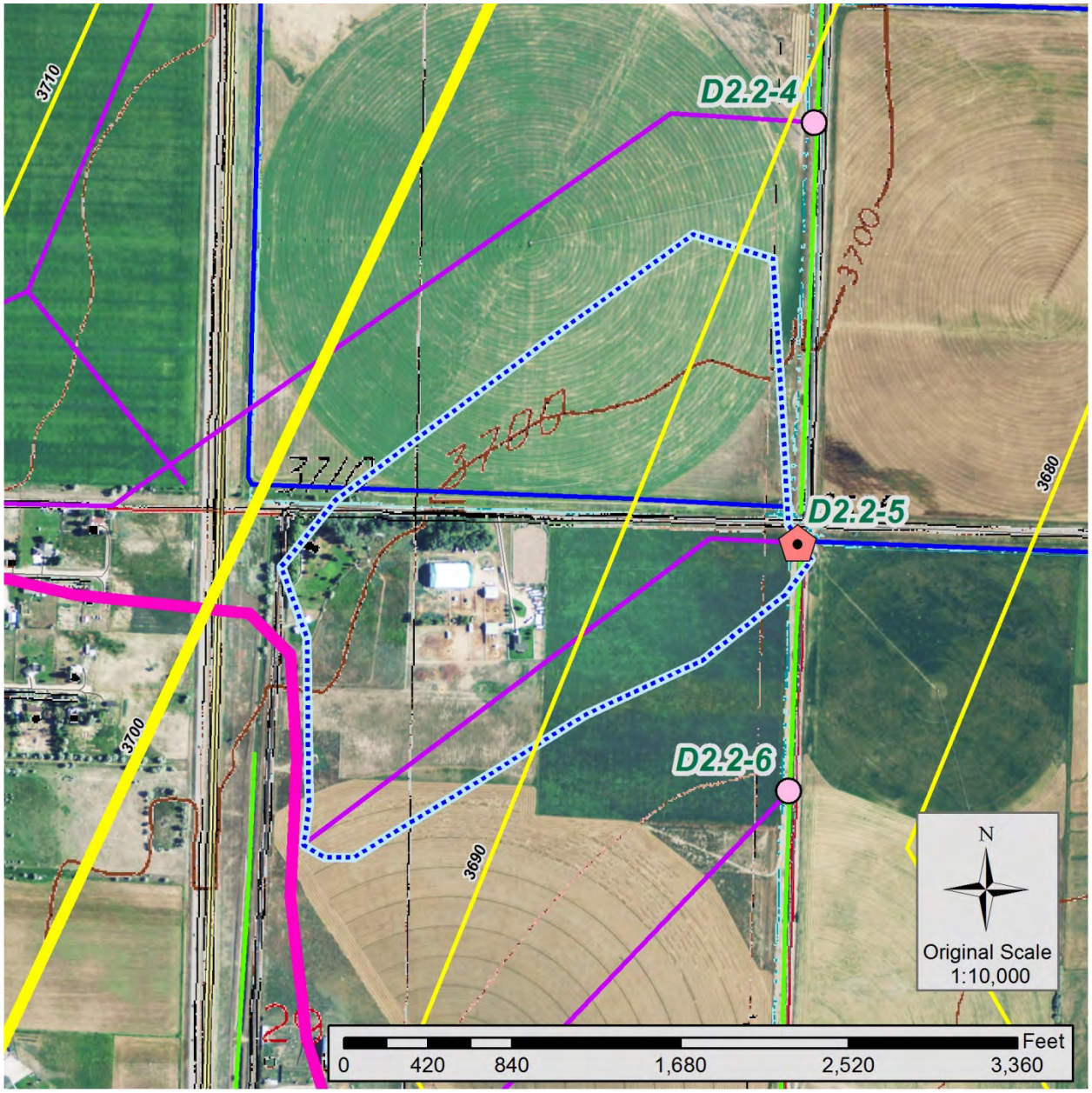


Figure 6-48 – Subwatershed contributing area for D2.2-5 Drain.
Ground water flow contours at 10' interval, with flow to the southeast.

Table 6-26 – D2.2-1 Drain Nitrogen and Phosphorus Loading

D2.2-5	Interval Days	Loading cfs	**Nitrogen lbs/day**	slope avg lbs/day	total lbs interval	**Phosphorus lbs/day**	slope avg lbs/day	total lbs interval
6/10/2013		0.25	**3.78**			**0.03**		
9/5/2013	87	0.24	**3.66**	3.72	323.57	**0.03**	0.03	2.59
9/24/2013	19	0.31	**4.65**	4.16	79.02	**0.04**	0.03	0.65
10/10/2013	16	0.31	**5.66**	5.16	82.51	**0.08**	0.06	0.91
10/25/2013	15	0.16	**3.21**	4.43	66.51	**0.02**	0.05	0.68
11/13/2013	19	0.18	**3.88**	3.55	67.37	**0.02**	0.02	0.33
12/12/2013	29	0.13	**2.77**	3.33	96.53	**0.01**	0.02	0.45
1/16/2014	35	0.08	**2.02**	2.40	83.92	**0.00**	0.01	0.29
2/20/2014	35	0.06	**1.44**	1.73	60.65	**0.01**	0.01	0.20
3/20/2014	28	0.06	**1.29**	1.37	38.27	**0.01**	0.01	0.20
4/14/2014	25	0.03	**0.74**	1.01	25.36	**0.00**	0.01	0.14
5/1/2014	17	0.10	**1.59**	1.17	19.84	**0.01**	0.01	0.15
5/21/2014	20	0.20	**3.14**	2.37	47.33	**0.02**	0.02	0.31
6/10/2014	20	0.25	**3.78**	3.46	69.15	**0.03**	0.02	0.47
	365			**Total Pounds**	**1060**		**Total Pounds**	**7.36**
				Total Tons	**0.53**		**Total Tons**	**0.004**

6.3.2.5 D2.2-6 Drain System

The D2.2-6 Drain is located on the southern part of the D2.2-3 ditch, and provides drainage to several irrigated agricultural fields. Photographs of the discharge point of the pipe are presented in Figure 6-49. There discharge end was submerged during the reconnaissance sampling program, and no flow was observed so no samples were taken. Land use in the watershed area contributing to the drain represents predominantly irrigated agricultural lands, with one farm located along the upgradient boundary. (Figure 6-44).

Discharge loading from the D2.2-6 Drain was estimated by comparing the loading rates with the D2.2-5 drain. Assuming the same loading rates per watershed contribution area, the D2.2-6 data multiplied by the ratio of areas between the two drain system to estimate loading rates from the D2.2-4 drain. This results in an estimated **964 pounds (0.48 tons) of total nitrogen** and **6.69 pounds (0.003 tons) of total phosphorus** discharged from the drain

Discharge point

Discharge point

Discharge point

View north, upgradient, from discharge point

Figure 6-49 – Photographs of Drain D2.2-6 outlet.

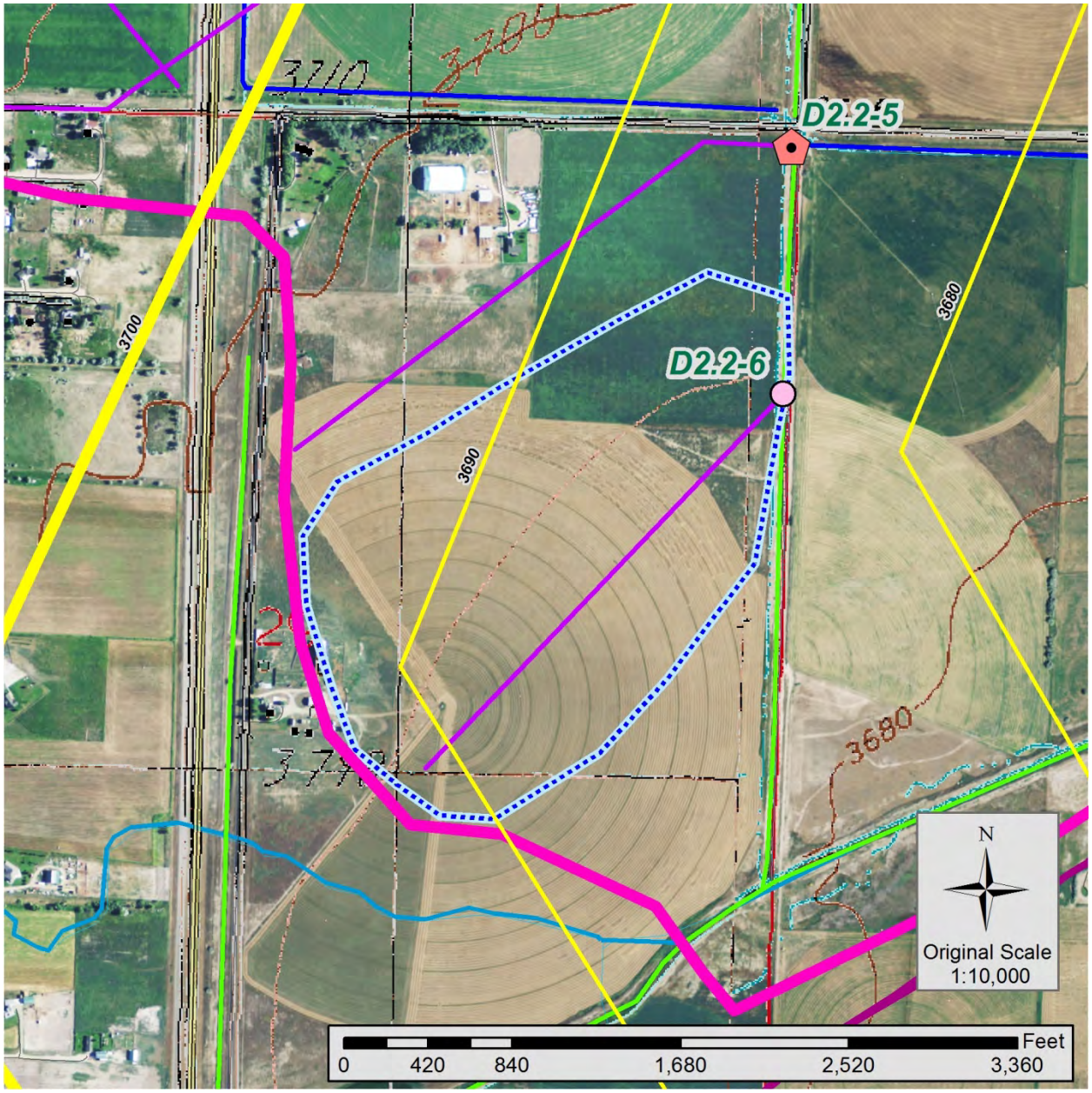


Figure 6-50 – Subwatershed contributing area for D2.2-6 Drain.
Ground water flow contours at 10' interval, with flow to the east.

6.3.2.6 D2-6 Drain System

The D2-6 Drain is located near Lake Helena, discharging near the terminus of the main D2 drain into Lake Helena (Figure 6-37). Photographs of the discharge point of the pipe are presented in Figure 6-51. Results from the reconnaissance sampling program show nitrate at 1.24 mg/L and total phosphate at 0.028 mg/L. Land use in the watershed area contributing to the drain represents predominantly agricultural lands, some irrigated, with several residential areas present (Figure 6-52).

Discharge loading from the D2-6 Drain was estimated by comparing the loading rates with the D2.2-5 drain. Since much of the area in the contributing area for the D2-6 drain appears undeveloped, the loading from the D2-6 drain was estimated by comparing the ratio of reconnaissance sampling results between the two drains. For the D2-6 drain, this results in an estimated **373 pounds (0.19 tons) of total nitrogen** and **12.12 pounds (0.006 tons) of total phosphorus** discharged from the drain

Discharge point for Drain D2-6

Figure 6-51 – Photographs of Drain D2-6 outlet.

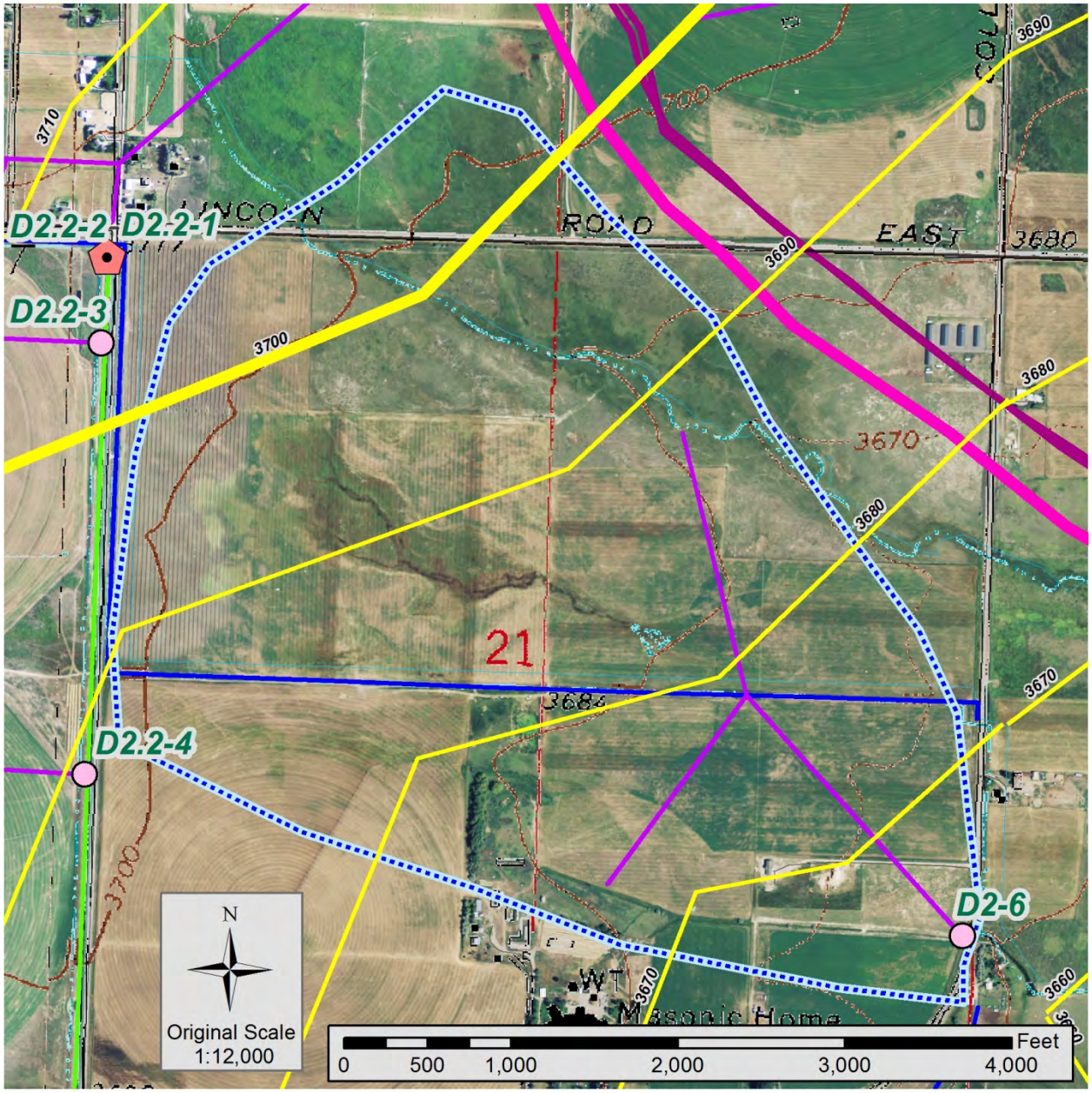


Figure 6-52 – Subwatershed contributing area for D2-6 Drain.
Ground water flow contours at 10' interval, with flow to the southeast.

6.4 Lower Tenmile Creek Subwatershed and Southeast D2 Ditch System (Ditch D2-1.1)

The Lower Tenmile Creek subwatershed represents the area where Tenmile Creek enters the Helena Valley and loses flow as recharge to the ground water system. Previous studies have shown that Tenmile Creek discharges to ground water that generally flows north of the stream within the valley (Swierc, 2013). The outline of the Lower Tenmile Creek subwatershed is depicted in Figure 6-53. The D-2-1.1 Ditch, part of the D2 Ditch System, drains ground water in the lower part of the subwatershed, near Lake Helena. The components of this ditch system are depicted in Figure 6-53. There are three tile drains through this reach, with water observed flowing from three of them during the site reconnaissance. Results from the reconnaissance water quality sampling, listed in Table 6-27, show nitrate plus nitrate nitrogen ranging from 0.69 to 2.49 mg/L.

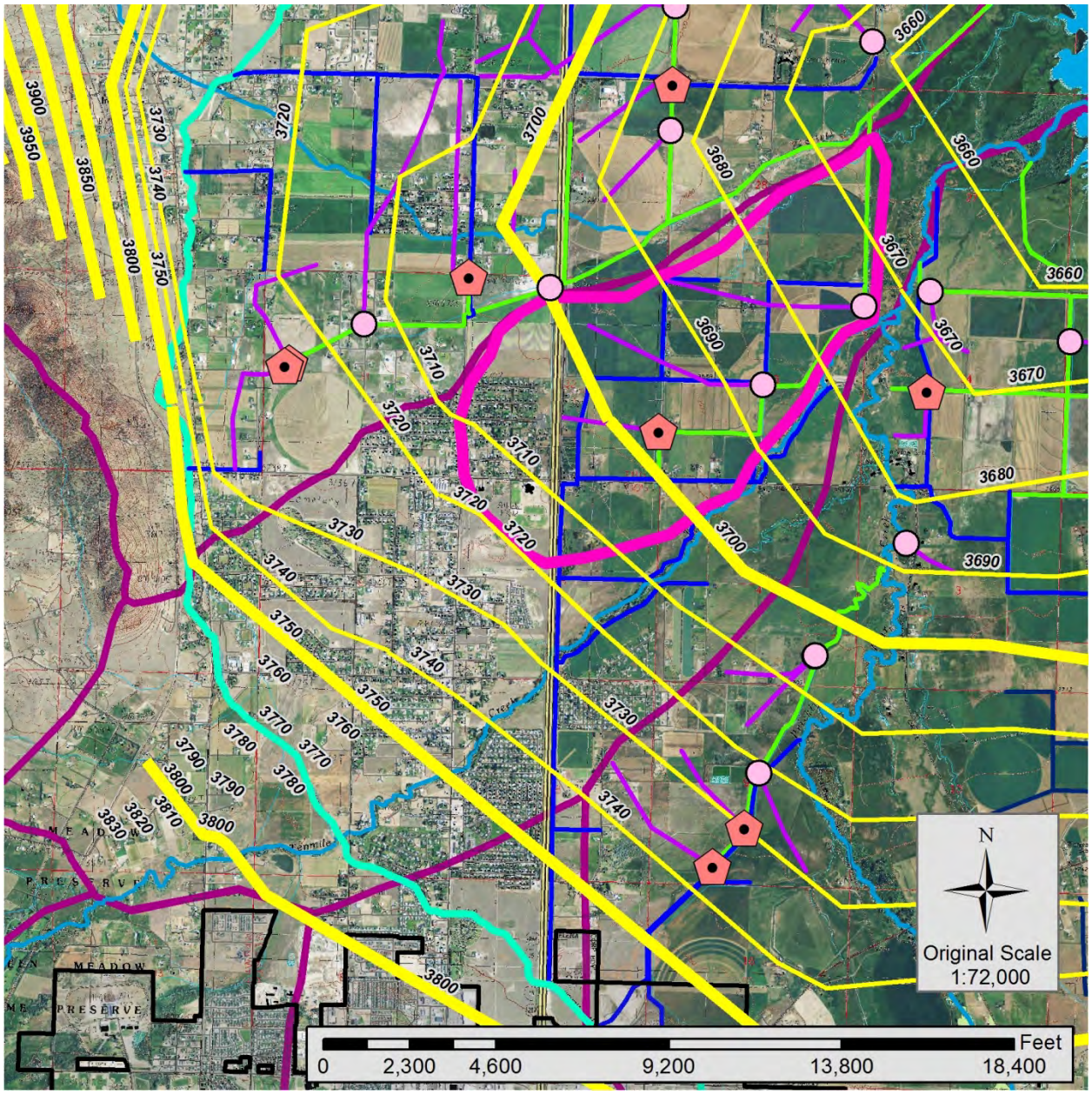


Figure 6-53– Lower Tenmile Creek Subwatershed

Tile drain discharge points are noted, with ground water potentiometric surface.

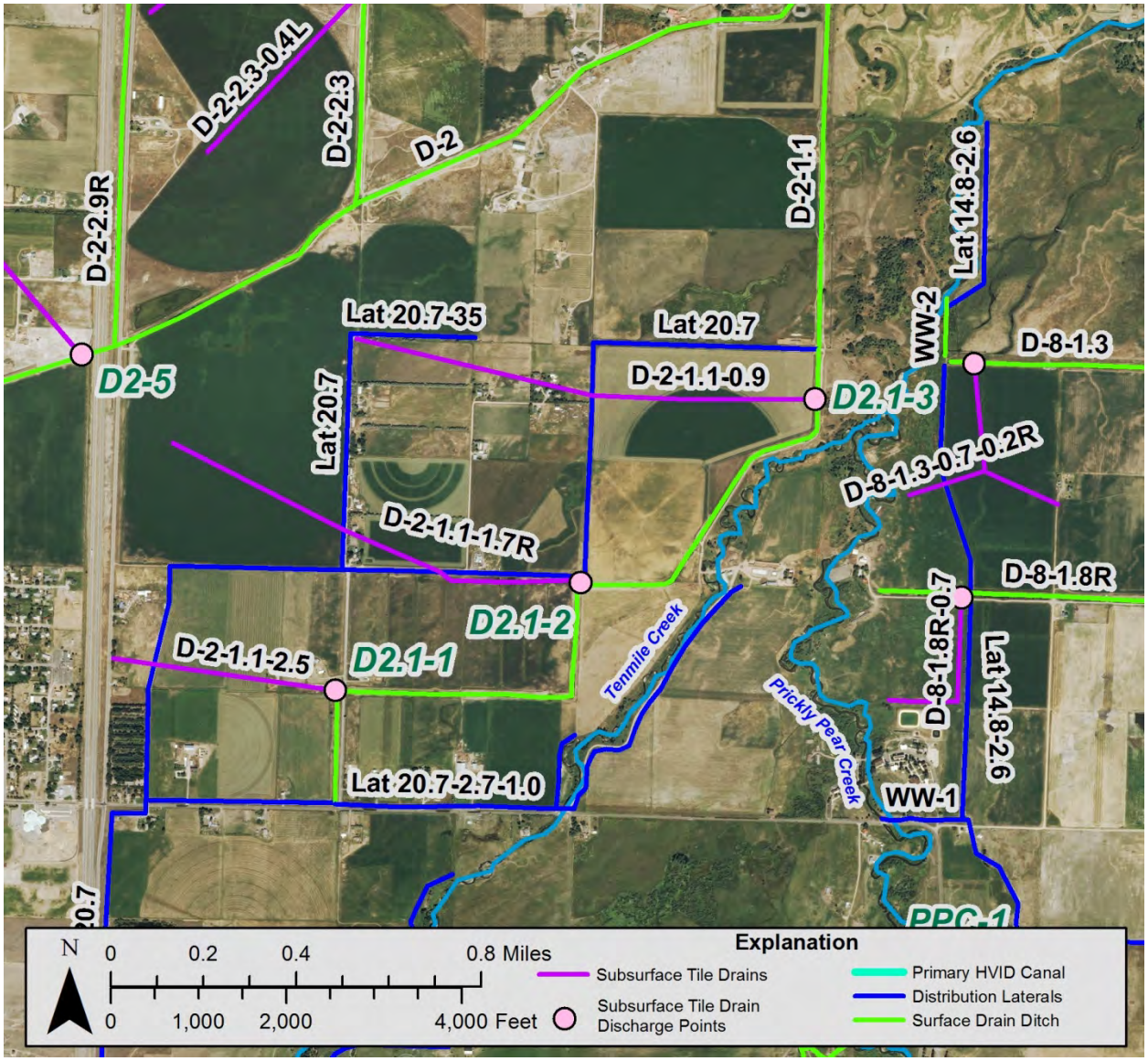


Figure 6-54 – D2-1.1 Ditch, Lower D2 Ditch and Surrounding features.

Table 6-27 Laboratory Results from Reconnaissance Sampling, D2-1.1 Ditch

Analyses	D2.1-1	D2.1-2	D2.1-3	
Field Parameters				
pH	7.24	7.18	7.22	S.U.
Conductivity	315	362	276	µs/cm
Temperature	7.7	7.7	6.9	°C
Dissolved Oxygen	11.31	5.33	9.52	mg/L
Laboratory Results				
Total Dissolved Solids, TDS @ 180°C	269	262	268	mg/L
Alkalinity, total as $CaCO_3$	170	170	170	mg/L
Chloride	19	15	12	mg/L
Bromide	<0.05	<0.05	<0.05	mg/L
Nitrogen, Nitrate + Nitrite as N	2.49	1.39	0.69	mg/L
Phosphorus, total as P	0.027	0.017	0.016	mg/L

6.4.1 D2.1-1 Drain System

The D2.1-1 drain is located south of the main D2 ditch, near the start of the D2.1 Ditch. At this location, there is a small amount of flow in the upper part of the ditch where the D2.1-1 drain enters. The general layout of the drain system is depicted in Figure 6-54. The drains are located within the central valley and the Helena Valley Aquifer. Ground water in this area flows generally northeast. Ground water recharge occurs from direct infiltration of precipitation, stream loss from Tenmile Creek, and from the irrigation canals when in use. Photographs of the D2.1-1 drain outlet are presented in Figure 6-55. The D2.1-1 Drain flowed through the duration of this study, but flows increased during the summer showing a response to irrigation seasons. The drain was sampled a total of 25 times during the study. The data results from the sampling of the D2.1-1 Drain are summarized in Table 6-28. Time series graphs of the data results are presented in Figure 6-56. From the sampling, nitrate values ranged from 1.50 mg/L up to 3.29 mg/L, and phosphate values ranged from 0.019 mg/L up to 0.035 mg/L.

Discharge from drain to ditch

View south upgradient from drain outlet

View east from drain outlet

Discharge from drain to ditch

Figure 6-55– Photographs of Drain D2.1-1 Outlet.

Table 6-28 Laboratory Results from Sampling, D2.1-1 Drain

	Field Parameters				Laboratory Data Results						
D2.1-1	pH	Temp	specific conductivity	Dissolved Oxygen	Total Dissolved Solids, TDS @ 180°C	Alkalinity Total as $CaCO_3$	Cl	Br	SO_4	NO_3+ NO_2 as N	Phosphorus, Total as P
	S.U.	°C	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
5/2/13	7.24	7.7	314	11.31	269	170	19	0.05		2.49	0.027
6/21/13	7.30	9.4	358	9.3	313	190	23	0.07		2.92	0.035
6/28/13	7.25	9.7	371	9.46	333	200	21	0.042		2.92	0.03
7/10/13	7.35	10.2	373	9.01	336	190	23	0.043		3.29	0.032
7/26/13	7.27	10.8	377	8.75	326	200	21	0.06		3.07	0.027
8/6/13	7.33	14.1	399	8.24	294	210	17	0.044	44	1.5	0.033
8/6/13			duplicate	sample	296	210	17	0.036	44	1.5	0.033
8/23/13	7.39	12.8	407	6.3	327	200	21	0.1	58	2.82	0.029
9/5/13	7.32	12.5	407	7.33	314	210	21	0.06		2.75	0.028
9/24/13	7.38	12.5	404	7.92	324	200	21	0.05	52	2.73	0.029
10/9/13	7.34	12.2	403	8.17	321	200	21	< 0.02	52	2.87	0.024
10/24/13	7.51	11.7	397	4.77	327	200	21	0.06	51	2.75	0.031
11/14/13	7.70	11	387	5.54	326	200	22	0.05		2.94	0.029
12/2/13	7.84	10.3	377	6.44	326	190	22	0.08	52	3.07	0.021
1/16/14	7.74	8.4	352	8.52	301	190	21	0.1	49	2.72	0.019
2/20/14	8.10	7.5	339	10.38	330	180	21	0.1	49	2.4	0.027
3/20/14	8.02	7	334	8.39	313	180	22	0.04	53	2.5	0.027
4/14/14	8.20	7.1	332	7.6	311	180	22	0.02	51	2.96	0.026
5/1/14	7.98	7.4	331	10.09	299	170	19	0.04	46	2.8	0.033
5/21/14	7.95	8	331	4.83	290	170	18	< 0.01	45	2.64	0.024
6/11/14	8.01	8.8	346	4.73	303	170	18	0.04	43	2.7	0.027
7/10/14	8.01	9.8	378	5.17	323	180	20	0.07	44	2.73	0.029
8/8/14	7.82	11.2	391	7.44	334	180	20	< 0.01	43	3.13	0.029
8/28/14	8.07	11.6	403	5.06	338	190	20	0.07	45	2.23	0.024
10/1/14	8.53	11.5	387	6.0	308	180	21	0.03	44	2.59	0.028
11/24/14	8.62	10.3	379	11.54	327	190	19	0.16	46	2.99	0.035
Max	8.62	14.1	407	11.54	338	210	23	0.16	58	3.29	0.035
Min	7.24	7.0	314	4.73	269	170	17	< 0.01	43	1.5	0.019
Average	7.73	10.3	371.1	7.69	315.7	189.6	20.4	0.06	47.9	2.69	0.028
Median	7.74	10.3	377	7.92	322	190	21	0.05	46	2.75	0.029
St Dev	0.41	2.12	28.73	2.05	16.8	12.8	1.65	0.031	4.3	0.42	0.004

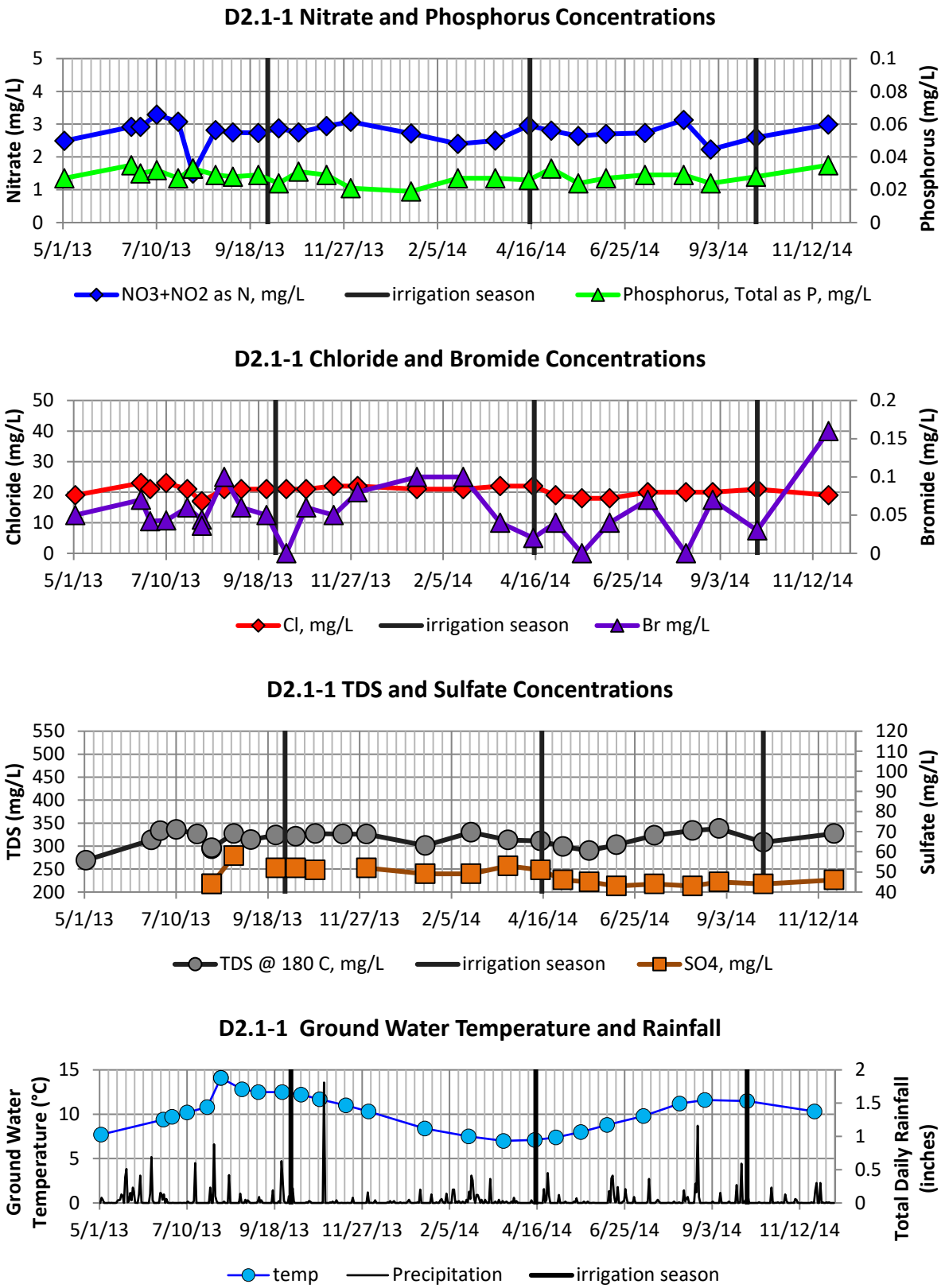


Figure 6-56 –Water Quality Nutrient Results for D2.1-1 Drain.

D2.1-1 Drain System Hydrology and Discussion

The D2.1-1 drain flowed continuously during this study, showing a strong response to summer irrigation season with flow increasing from the start of irrigation. During the monitoring period for this study, measured flow rates range from 0.51 cfs up to 2.64 cfs (Table 6-29). Flow from the drain increased during early summer to the maximum measured discharge in late May, with generally steady flows through the summer, and then steadily decreasing (Figure 6-57). The system appears to receive primary recharge during spring runoff and irrigation season, with flows depleting local storage through winter. The relatively quick increase in flow rates from the start of irrigation season shows a connection between irrigation waters and ground water levels.

Combining the nutrient data with flow discharge rates allows for calculation of estimates of nutrient mass loading rates. The loading rates for the D2.1-1 drain reflect the flow discharge rates for the tile drain (Figure 6-57). Loading to the system occurs primarily through the summer irrigation season. Loading rates decrease during the fall and into winter as discharge decreases.

The yearly loading rate for the D2.1-1 drain was calculated using the data presented in Table 6-30. In order to maintain a consistent time interval for all of the drains included in this study, sample data from August 2013 through August 2014 was used. In order to complete the year, data from late August 2014 was used as an estimate for late August 2013. The data allows for estimates of the total amount of nitrogen and phosphorus discharged from the drain during the study year. For this drain, this corresponds to a total of 8,153 pounds (4.08 tons) of nitrogen and 70.84 pounds (0.035 tons) of phosphorus discharged from August 2013 to August 2014 (Table 6-30).

The local watershed contributing to the ground water collected from the D2.1-1 drain is depicted in Figure 6-58, which also shows the configuration of the local water table. The upgradient boundary for this area is approximated, since there is no distinct boundary or recharge source such as the main HVID canal. For purposes of this assessment, this includes the area upgradient from the drain, estimated from the water table map, includes several subdivisions with numerous septic drainfields, a school using a septic drainfield and irrigated agriculture fields. Potential nutrient

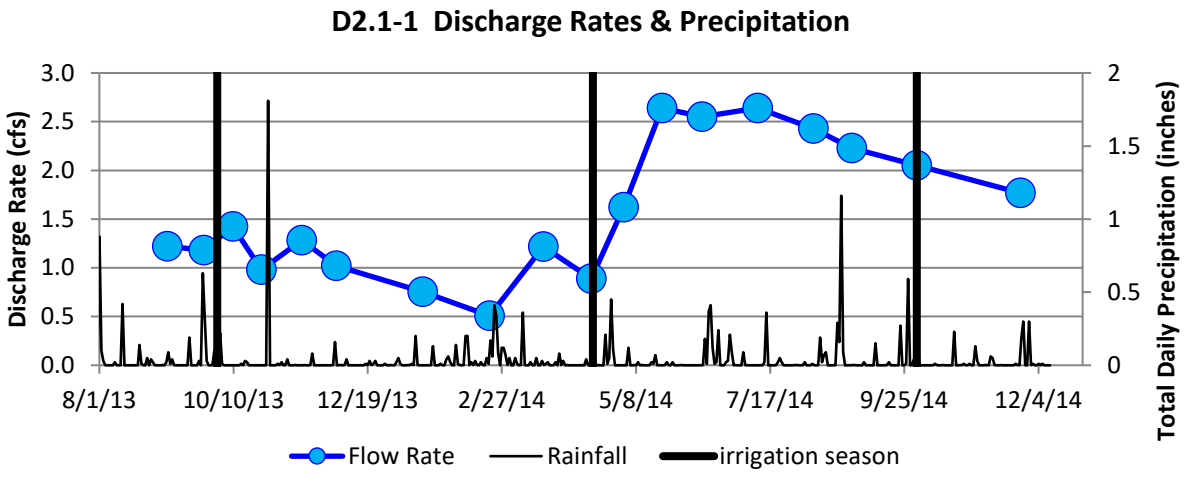
Table 6-29 – D2.1-1 Drain Discharge & Loading

Sample Date	Flow Rate ft^3/s	**Nitrogen** lbs/day	**Phosphorus** lbs/day
9/5/13	1.22	18.09	0.184
9/24/13	1.18	17.37	0.185
10/9/13	1.42	22.02	0.184
10/24/13	0.98	15.56	0.164
11/14/13	1.28	20.34	0.201
12/2/13	*1.02**	16.87	0.115
1/16/14	0.75	11.07	0.077
2/20/14	0.51	6.57	0.074
3/20/14	1.22	16.43	0.177
4/14/14	0.89	14.21	0.125
5/1/14	1.62	24.47	0.288
5/21/14	2.64	37.59	0.342
6/11/14	2.55	37.14	0.371
7/10/14	2.64	38.87	0.413
8/8/14	2.43	41.02	0.380
8/28/14	2.23	26.82	0.289
10/1/14	*2.05**	28.64	0.310
11/24/14	1.77	28.55	0.334
Max	2.64	41.02	0.413
Min	0.51	6.57	0.074
Average	1.58	23.37	0.234
Median	1.35	21.18	0.193
Stnd Dev	0.69	10.21	0.108

* Rate not measured in field, estimated as average between bounding measurements

sources include agricultural fertilizers and manure, and discharge from the septic system drainfields.

The flows in the D2.1-1 drain can be seen to increase with the May 1, 2014 sampling event, with peak summer flows measured in late May, generally continuing through the end of irrigation season (Figure 6-57). Since irrigation season starts on April 15, the response of the system is considered less than 15 days as the water table rises (and flows increase accordingly). Nitrate values in the drain range from 1.50 to 3.29 mg/L which, when compared to irrigation waters consistently below 1.0 mg/L (see Section xx), infers that nitrogen is from an upgradient, anthropogenic source. The detected nitrogen concentrations appear appear generally stable throughout the year, suggesting that the nutrient source is relatively constant. Since dissolved oxygen is consistently present near or exceeding 50 percent saturation, it is assumed that all nitrogen species are converted to nitrate within the ground water system. The variability of the bromide concentrations relative to chloride result in this assessment method being inconclusive for this system.



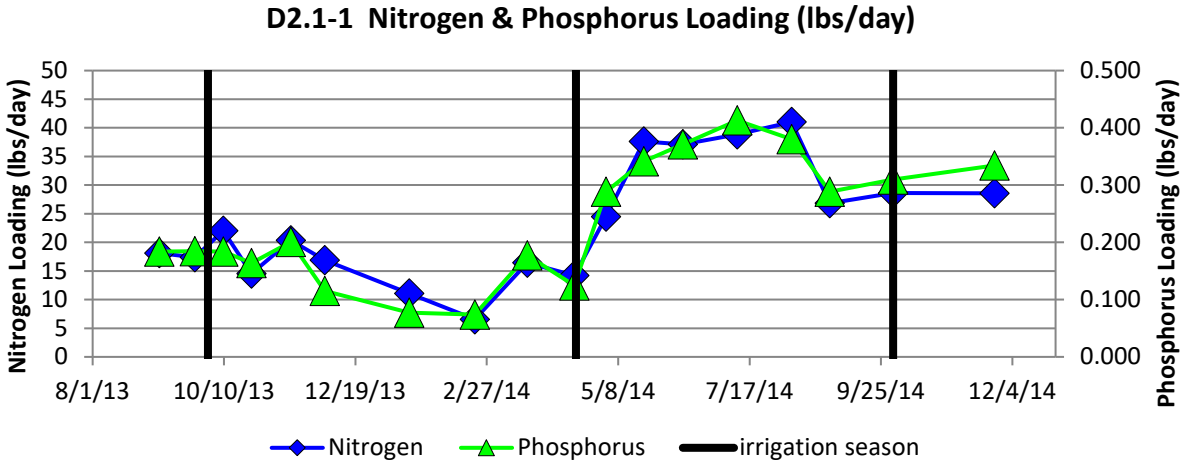


Figure 6-57 – Discharge Rates and Nitrogen and Phophorus Loading from D2.1-1 Drain.

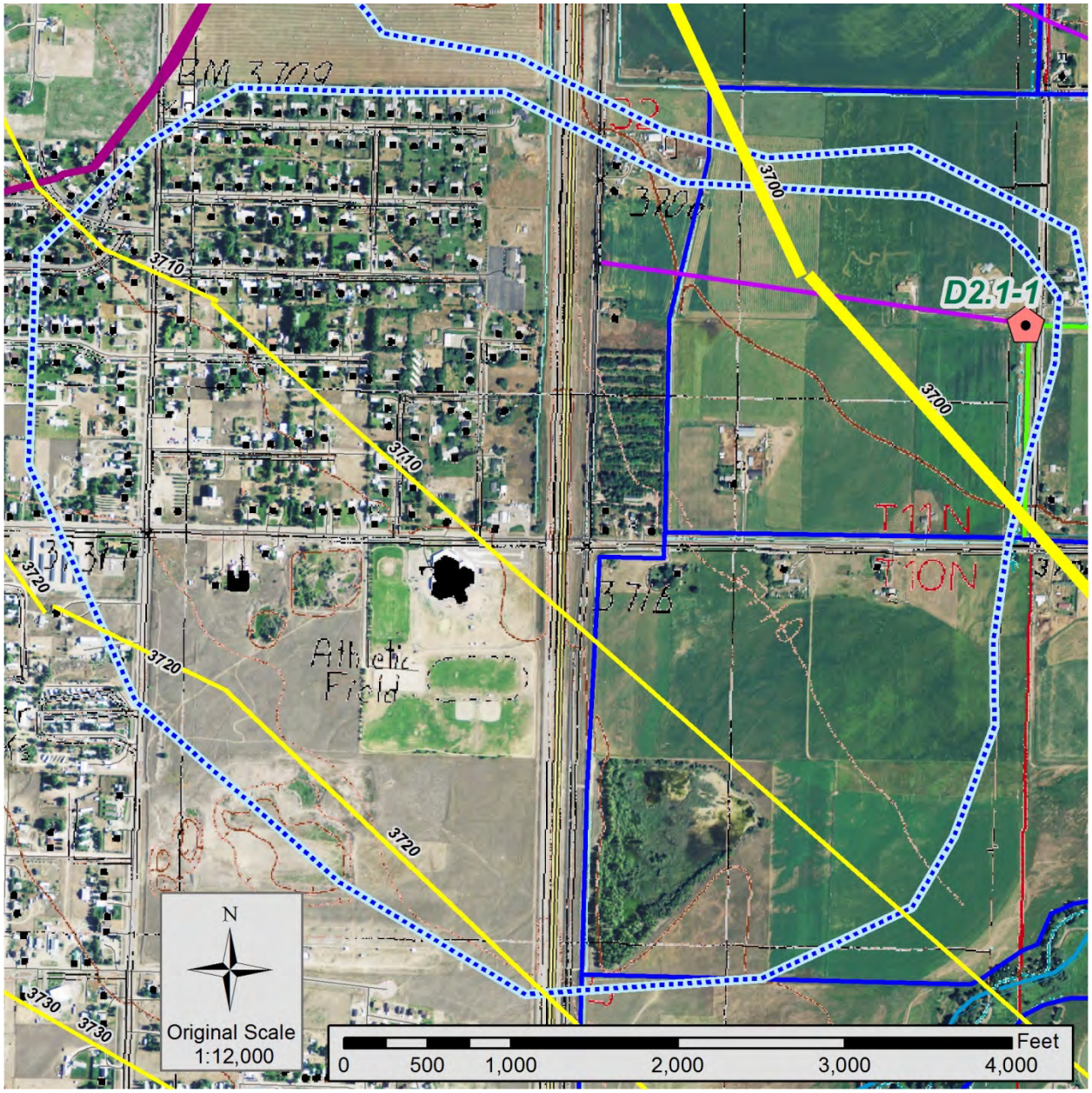


Figure 6-58 – Subwatershed Contributing Area for D2.1-1 Drain.
Ground water flow contours at 10' interval, with flow to the northeast.

Table 6-30– D2.1-1 Drain Nitrogen and Phosphorus Loading

D2.1-1	Interval Days	Loading cfs	**Nitrogen lbs/day**	slope avg lbs/day	total lbs interval	**Phosphorus lbs/day**	slope avg lbs/day	total lbs interval
8/28/2013		2.23	**26.82**			**0.29**		
9/5/2013	8	1.22	**18.09**	22.46	179.65	**0.18**	0.24	1.90
9/24/2013	19	1.18	**17.37**	17.73	336.90	**0.18**	0.18	3.50
10/10/2013	16	1.42	**22.02**	19.70	315.14	**0.18**	0.18	2.95
10/25/2013	15	0.98	**14.56**	18.29	274.33	**0.16**	0.17	2.61
11/13/2013	19	1.28	**20.34**	17.45	331.50	**0.20**	0.18	3.46
12/12/2013	29	1.02	**16.87**	18.60	539.48	**0.12**	0.16	4.58
1/16/2014	35	0.75	**11.07**	13.97	488.92	**0.08**	0.10	3.37
2/20/2014	35	0.51	**6.57**	8.82	308.72	**0.07**	0.08	2.65
3/20/2014	28	1.22	**16.43**	11.50	322.05	**0.18**	0.13	3.52
4/14/2014	25	0.89	**14.21**	15.32	383.04	**0.12**	0.15	3.78
5/1/2014	17	1.62	**24.47**	19.34	328.74	**0.29**	0.21	3.51
5/21/2014	20	2.64	**37.59**	31.03	620.59	**0.34**	0.32	6.30
6/10/2014	20	2.55	**37.14**	37.36	747.29	**0.37**	0.36	7.13
7/10/2014	30	2.64	**38.87**	38.01	1140.15	**0.41**	0.39	11.76
8/8/2014	29	2.43	**41.02**	39.95	1158.46	**0.04**	0.23	6.54
8/28/2014	20	2.23	**26.82**	33.92	678.40	**0.29**	0.16	3.27
	365			**Total Pounds**	**8153**		**Total Pounds**	**70.84**
				Total Tons	**4.08**		**Total Tons**	**0.035**

6.4.2 D2.1-2 Drain System

The D2.1-2 Drain is located at a midpoint on the D2.1 Ditch near distribution laterals (Figure 6-54). Photographs of the discharge point of the pipe are presented in Figure 6-59. Results from the reconnaissance sampling program show nitrate at 1.39 mg/L and total phosphate at 0.017 mg/L. Land use in the watershed area contributing to the drain represents predominantly agricultural lands, some irrigated, with several residences present (Figure 6-60).

Discharge loading from the D2.1-2 Drain was estimated by comparing the loading rates with the D2.1-1 drain. Since much of the contributing areas for the drains are similar, with recharge from local irrigation waters, the loading from the D2.1-2 drain was estimated by comparing the ratio of reconnaissance sampling results between the two drains. For the D2.1-2 drain, this results in an estimated **4551 pounds (2.28 tons) of total nitrogen** and **44.60 pounds (0.022 tons) of total phosphorus** discharged from the drain

Drain D2.1-2 outfall

View east of outfall and D2-1.1 ditch

Figure 6-59– Photographs of Drain D2.1-2 outlet.

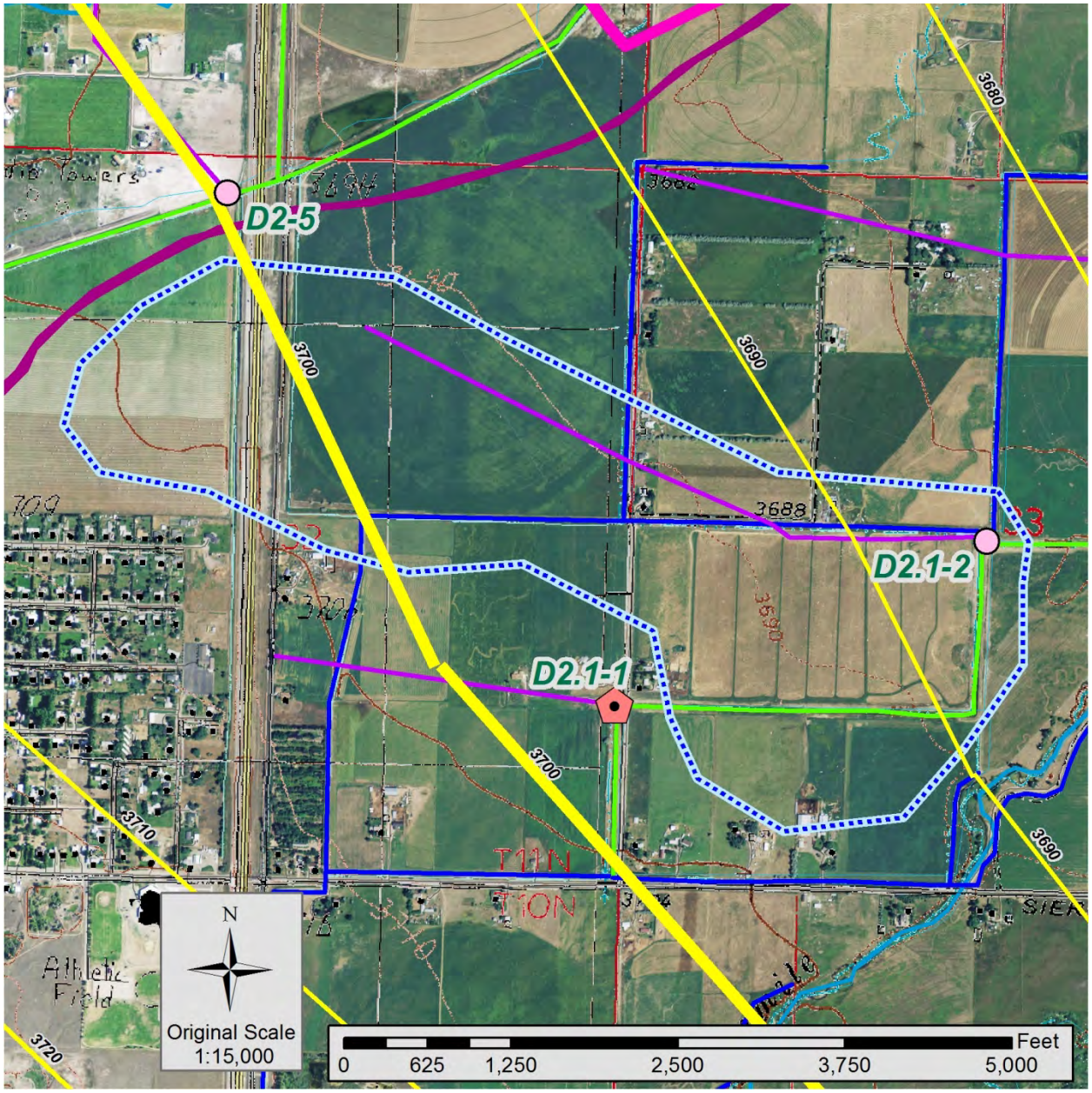


Figure 6-60 – Subwatershed contributing area for D2.1-2 Drain.
Ground water flow contours at 10' interval, with flow to the northeast.

6.4.3 D2.1-3 Drain System

The D2.1-3 Drain is located downgradient on the D2.1 Ditch near Tenmile Creek before the D2.1 ditch heads north to discharge into the Main D2 Ditch and Lake Helena (Figure 6-54). Photographs of the discharge point of the pipe are presented in Figure 6-61. Results from the reconnaissance sampling program show nitrate at 0.69 mg/L and total phosphate at 0.016 mg/L. Land use in the watershed area contributing to the drain represents predominantly agricultural lands, some irrigated, with several residences present (Figure 6-62).

Discharge loading from the D2.1-3 Drain was estimated by comparing the loading rates with the D2.1-1 drain. Since much of the contributing areas for the drains are similar, with recharge from local irrigation waters, the loading from the D2.1-3 drain was estimated by comparing the ratio of reconnaissance sampling results between the two drains. For the D2.1-3 drain, this results in an estimated **2259 pounds (1.13 tons) of total nitrogen** and **41.98 pounds (0.021 tons) of total phosphorus** discharged from the drain

Figure 6-61– Photographs of Drain D2.1-3 outlet. Note reconnaissance sample was collected from leak in pipe, visible in lower left photograph.

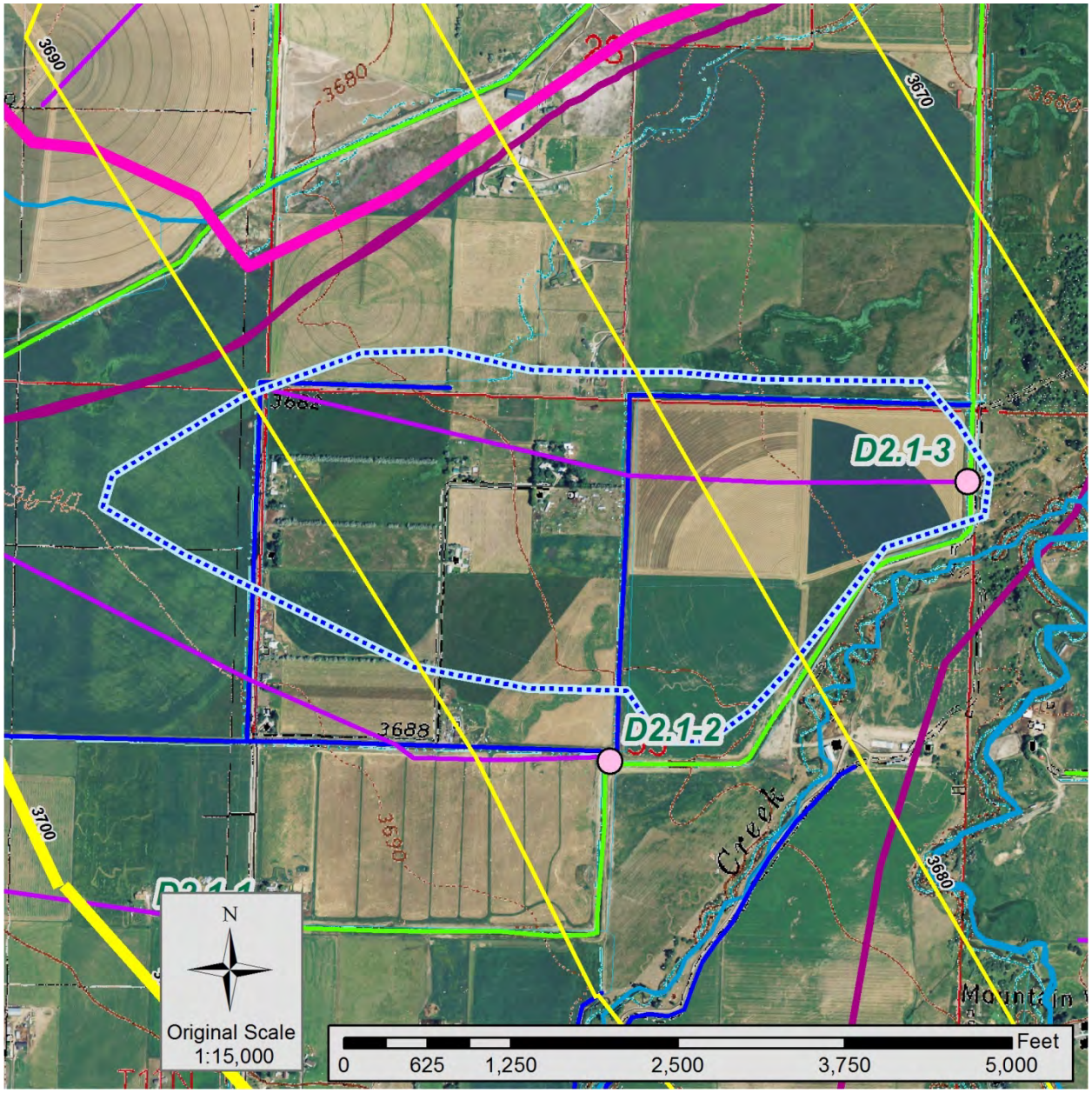


Figure 6-62 – Subwatershed contributing area for D2.1-3 Drain.
Ground water flow contours at 10' interval, with flow to the northeast.

6.5 Lower Prickly Pear Creek Subwatershed

The Lower Prickly Pear Creek subwatershed represents the area where Prickly Pear Creek enters the Helena Valley and loses flow as recharge to the ground water system. Previous studies have shown that Prickly Pear Creek discharges to ground water that generally flows north of the stream within the valley (Swierc, 2013). The outline of the Lower Prickly Pear Creek subwatershed in the Helena Valley is depicted in Figure 6-63, with the major tile drain systems identified. The D-3 Ditch drains ground water in the southwestern part of the subwatershed, just inside the main Helena Valley Irrigation Canal and downgradient from the Grizzly Gulch subwatershed. The D-8 Ditch system drains ground water east of the confluence between Tenmile and Prickly Pear Creeks, providing a conduit for collected water directly into Lake Helena using the D-8 Ditch.

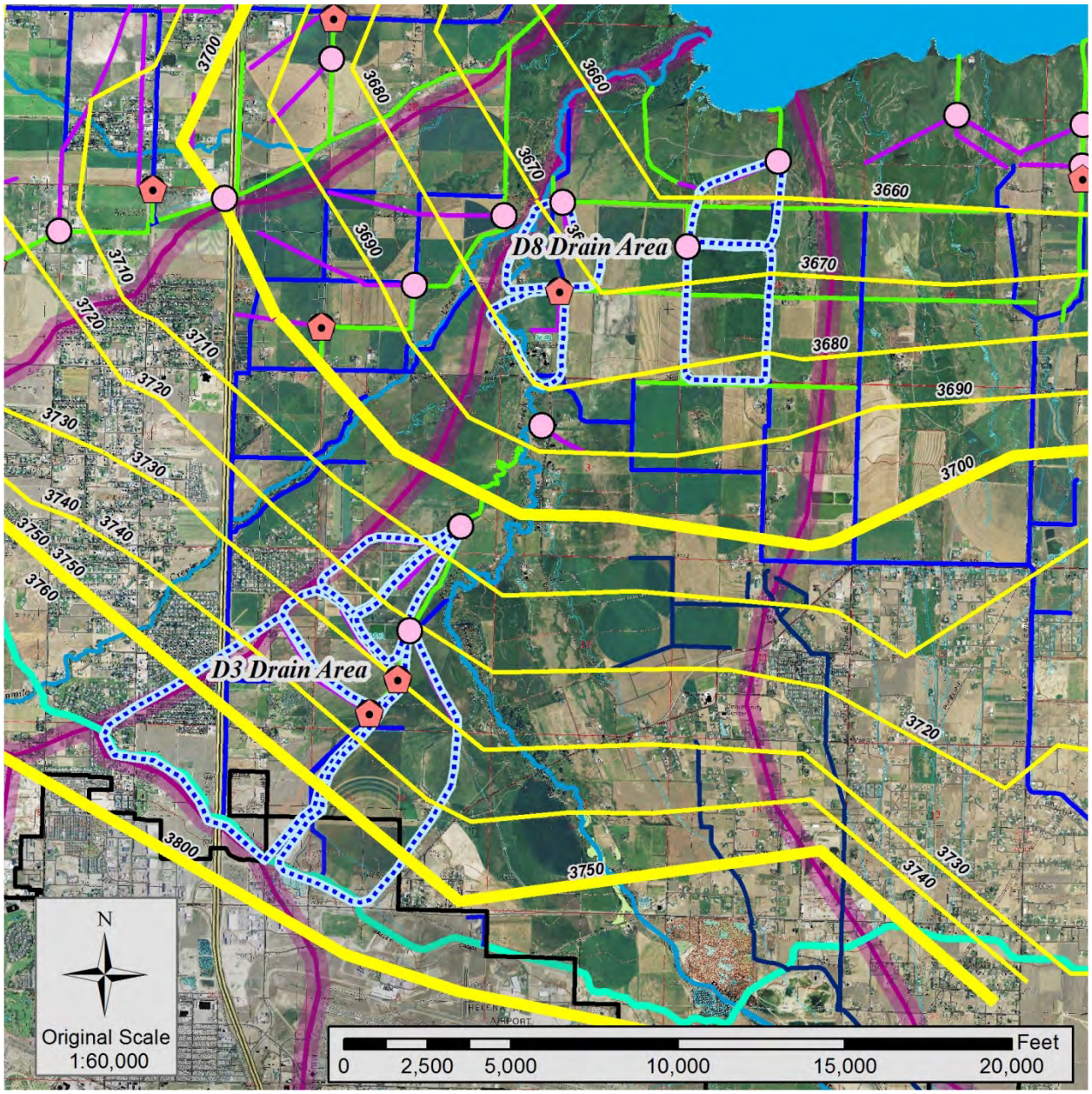


Figure 6-63 – Lower Prickly Pear Creek Subwatershed in the Helena Valley

Tile drain discharge points are noted, with ground water potentiometric surface.

6.5.1 D3 Ditch System

The D3 Ditch discharges into Prickly Pear Creek and receives discharge from five underground tile drains as depicted in Figure 6-64. The two downgradient underground drains (D3-4) discharge at the same location, and the specific locations of their drainage areas are approximated. Ground water is interpreted to flow generally east to northeast, following topography. Several wastewater treatment ponds are located adjacent to the ditch, and the upper part of the ditch flows parallel to the effluent discharge canal from the Helena Wastewater Treatment Plant. The results from the reconnaissance water quality sampling, listed in Table 6-31, show nitrate plus nitrite nitrogen ranging from 0.16 mg/L up to 2.92 mg/L. The main discharge canal from the Helena Wastewater Treatment plant runs parallel to the D3 ditch before discharging into Prickly Pear Creek.

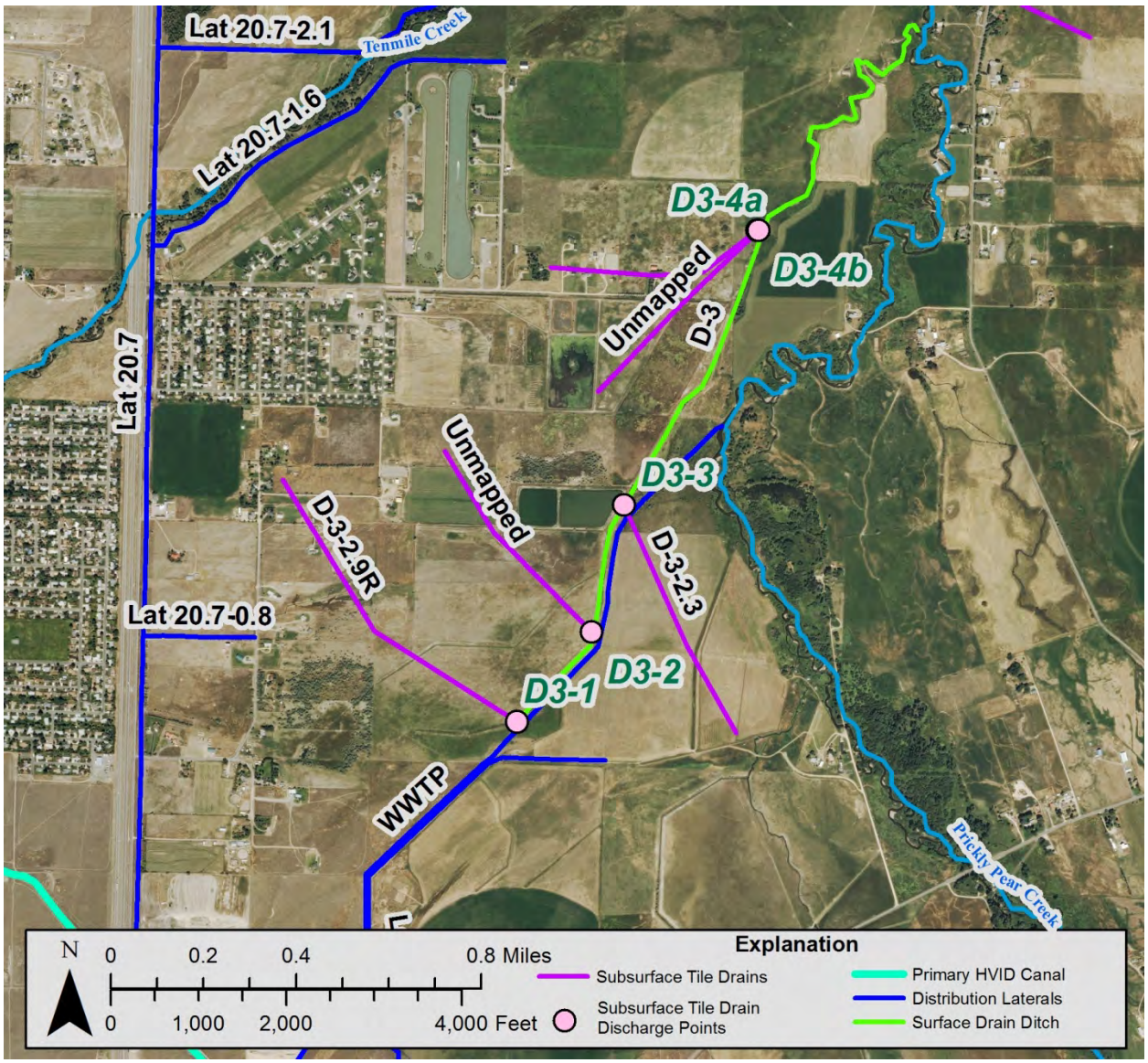


Figure 6-64 – D3 Ditch and Surrounding Features.

Table 6-31 Laboratory Results from Reconnaissance Sampling, D-3 Ditch

Analyses		D3-1	D3-2	D3-3	D3-4a	D3-4b	
Field Parameters							
	pH	7.57	7.55	7.61	7.36	7.46	S.U.
	Conductivity	458	429	379			µs/cm
	Temperature	8.6	8.5	7.8	7.7	8.0	°C
	Dissolved Oxygen	7.72	8.59	9.92	5.18	9.51	mg/L
Laboratory Results							
	Total Dissolved Solids, TDS @ 180°C	403	377	351	517	433	mg/L
	Alkalinity, total as $CaCO_3$	250	230	210	350	250	mg/L
	Chloride	38	33	23	51	40	mg/L
	Bromide	0.46	0.74	0.40	0.28	0.24	mg/L
	Nitrogen, Nitrate + Nitrite as N	2.43	2.51	0.89	0.16	2.92	mg/L
	Phosphorus, total as P	0.013	0.010	0.024	0.139	0.051	mg/L

6.5.1.1 D3-1 Drain System

The D3-1 drain is located at the upgradient points where the D3 ditch starts. The general layout of the drain system is depicted in Figure 6-64. The drain is located within the central valley and the Helena Valley Aquifer. Ground water in this area flows generally northeast. Ground water recharge occurs from direct infiltration of precipitation, from Helena Storm water retention ponds and from the irrigation canals when in use. The discharge pipe for the D3-1 drain is not visible; however, the discharge flow is visible as a waterspout within the base of the D3 ditch. Photographs of the D3-1 drain outlet are presented in Figure 6-65. The D3-1 Drain flowed through the duration of this study, but flows increased during the summer showing a response to irrigation seasons. The drain was sampled a total of 13 times during the study, but was discontinued as a focused study site due to redundancy with the D3-2 Drain. The data results from the sampling of the D3-1 Drain are summarized in Table 6-32. Time series graphs of the data results are presented in Figure 6-66. From the sampling, nitrate values ranged from 1.32 mg/L up to 2.68 mg/L, and phosphate values ranged from 0.007 mg/L up to 0.047 mg/L.

Drain D3-1 at start of D3 Ditch

Drain D3-1 upwelling, view downstream

Drain D3-1 pool, view downstream

Upwelling waters from Drain D3-1

Figure 6-65 – Photographs of Drain D3-1 outlet
Outlet pipe is not visible, with water noted surfacing from a single location.

Table 6-32 Laboratory Results from Sampling, D3-1 Drain

	Field Parameters				Laboratory Data Results						
D3-1	pH	Temp	specific conductivity	Dissolved Oxygen	Total Dissolved Solids, TDS @ 180°C	Alkalinity Total as $CaCO_3$	Cl	Br	SO_4	NO_3+ NO_2 as N	Phosphorus, Total as P
	S.U.	°C	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
6/6/13	7.57	8.6	458	7.72	403	250	38	0.11		2.43	0.013
6/27/13	7.52	9.2	468	7.39	411	250	38	0.1		2.37	0.016
7/11/13	7.58	9.6	476	6.97	412	250	40	0.23		1.32	0.017
7/26/13	7.45	10.2	480	7.09	418	260	38	0.07		2.42	0.014
8/6/13	7.48	10.6	487	7.48	439	260	38	0.08	64	2.27	0.019
8/23/13	7.70	11.0	471	5.78	413	250	38	0.14	70	2.5	0.047
9/5/13	7.69	11.2	503	6.45	410	250	38	0.16		2.62	0.024
9/24/13	7.55	11.4	494	6.48	398	250	37	0.09	64	2.52	0.02
10/9/13	7.70	11.2	501	6.27	402	260	38	0.11	65	2.62	0.012
10/24/13	7.43	10.8	499	6.54	403	260	39	0.1	64	2.63	0.017
11/13/13	7.45	10.2	491	6.38	404	260	39	0.11		2.58	0.018
12/13/13	7.89	9.2	479	4.89	406	260	39	0.09	64	2.56	0.01
1/17/14	7.88	8.0	463	5.65	427	260	39	0.13	63	2.68	0.007
Max	7.89	11.4	503	7.72	439	260	40	0.23	70	2.68	0.047
Min	7.43	8.0	458	4.89	398	250	37	0.07	63	1.32	0.007
Average	7.61	10.1	482.3	6.55	711.2	255.4	38.4	0.12	64.9	2.42	0.018
Median	7.57	10.2	480	6.48	410	260	38	0.11	64	2.52	0.017
St Dev	0.16	1.09	14.84	0.80	11.35	5.19	0.77	0.04	2.34	0.35	0.010

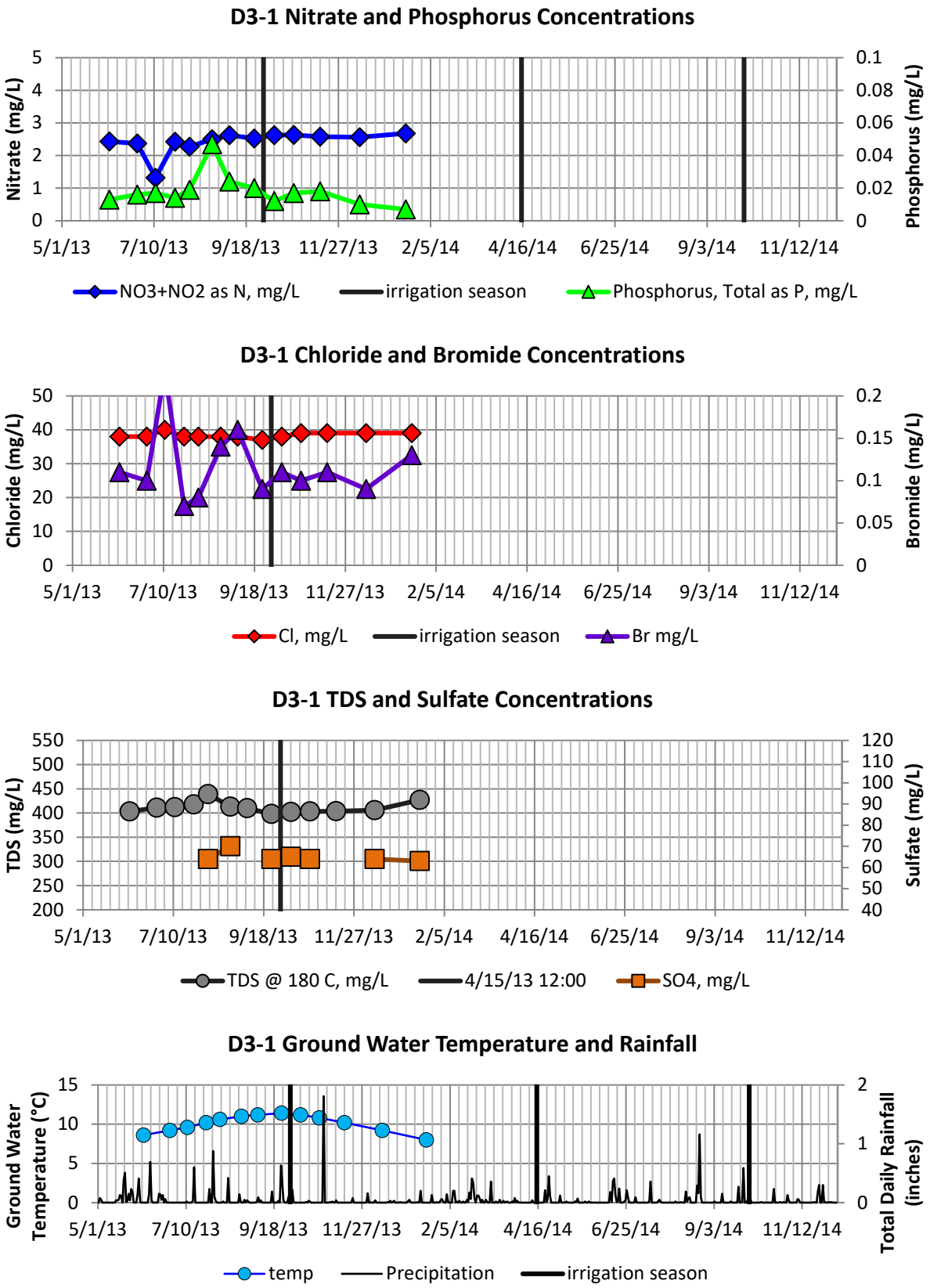


Figure 6-66 –Water Quality Nutrient Results for D3-1 Drain.

D3-1 Drain System Hydrology and Discussion

The D3-1 drain flowed continuously during this study, but monitoring was limited in 2014. Due to budget issues, the drain was removed from primary monitoring due to the proximity to D3-2, and similarity of data between the two drains. During the monitoring period for this study, measured flow rates range from 1.20 cfs up to 1.73 cfs (Table 6-33). Flow from the drain was greatest when flow measuring started in September, then decreased during the fall and early winter (Figure 6-67). The system appears to receive primary recharge during spring runoff and irrigation season, with flows depleting local storage through winter. The relatively quick increase in flow rates from the start of irrigation season shows a connection between irrigation waters and ground water levels.

Combining the nutrient data with flow discharge rates allows for calculation of estimates of nutrient mass loading rates. The loading rates for the D3-1 drain reflect the flow discharge rates for the tile drain (Figure 6-67).

Table 6-33 – D3-1 Drain Discharge & Loading

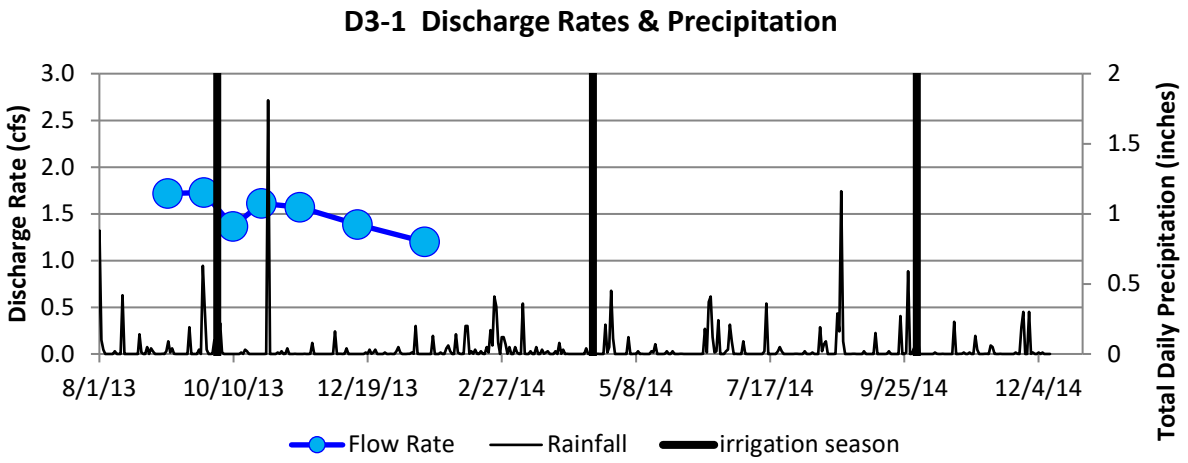
Sample Date	Flow Rate ft^3/s	**Nitrogen** lbs/day	**Phosphorus** lbs/day
9/5/13	1.72	24.29	0.223
9/24/13	1.73	23.48	0.186
10/9/13	1.36	19.27	0.088
10/24/13	1.61	22.86	0.148
11/13/13	1.57	21.85	0.152
12/13/13	*1.39**	19.13	0.075
1/17/14	1.20	17.35	0.045
Max	1.73	24.29	0.223
Min	1.20	17.35	0.045
Average	1.51	21.17	0.131
Median	1.57	21.85	0.148
Stnd Dev	0.20	2.61	0.064

* Rate not measured in field, estimated as average between bounding measurements

The yearly loading rate for the D3-1 drain was calculated using the data presented in Table 6-34. In order to maintain a consistent time interval for all of the drains included in this study, sample data from January 2013 through January 2014 was used. In order to complete the year, data from late January 2014 was used as an estimate for late January 2013. The data allows for estimates of the total amount of nitrogen and phosphorus discharged from the drain during the study year. For this drain, this corresponds to a total of 5,595 pounds (2.80 tons) of nitrogen and 41.91 pounds (0.021 tons) of phosphorus discharged from January 2013 to January 2014 (Table 6-34).

The local watershed contributing to the ground water collected from the D3-1 drain is depicted in Figure 66-68, which also shows the configuration of the local water table. The upgradient boundary for this area is approximated as the main HVID canal. For purposes of this assessment, the area upgradient from the drain, includes several septic drainfields and irrigated agriculture fields. Potential nutrient sources include agricultural fertilizers and manure, and discharge from the septic system drainfields.

The flows in the D3-1 drain can be seen to decrease after the end of irrigation season (Figure 6-67). Nitrate values in the drain range from 1.32 to 2.68 mg/L which, when compared to irrigation waters consistently below 1.0 mg/L (see Section 5.0), infers that nitrogen is from an upgradient, anthropogenic source. The detected nitrogen concentrations appear appear generally stable, with one result lower than others (July 2013), suggesting that the nutrient source is relatively constant. Since dissolved oxygen is consistently present near or exceeding 50 percent saturation, it is assumed that all nitrogen species are converted to nitrate within the ground water system. The variability of the bromide concentrations relative to chloride result in this assessment method being inconclusive for this system.



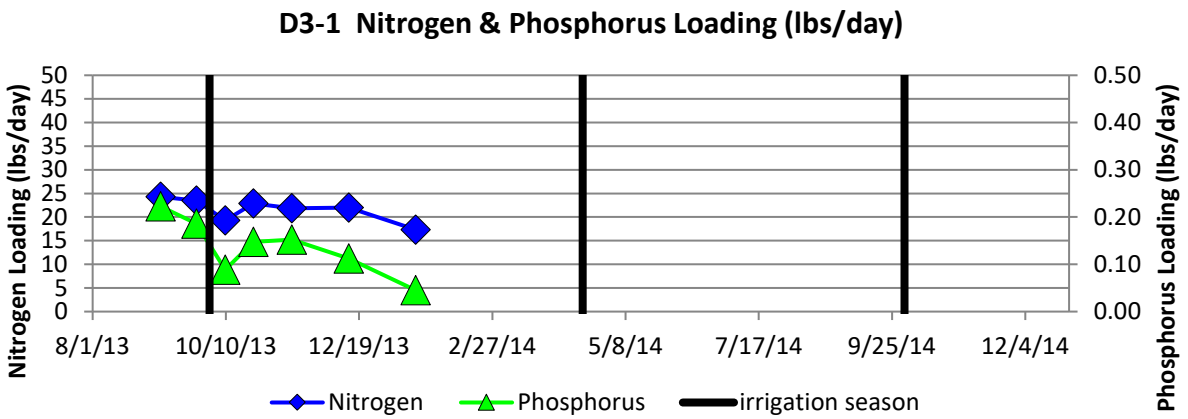


Figure 6-67 –Discharge Rates and Nitrogen and Phophorus Loading from D3-1 Drain.

Table 6-34– D3-1 Drain Nitrogen and Phosphorus Loading

D3-1	Interval Days	Loading cfs	**Nitrogen lbs/day**	slope avg lbs/day	total lbs interval	**Phosphorus lbs/day**	slope avg lbs/day	total lbs interval
1/17/2013		1.20	**17.35**			**0.05**		
9/5/2013	231	1.72	**24.29**	12.15	2805.76	**0.22**	0.11	25.70
9/24/2013	19	1.73	**23.48**	23.89	450.00	**0.19**	0.20	3.85
10/9/2013	15	1.36	**19.27**	21.37	324.77	**0.09**	0.14	2.09
10/24/2013	15	1.61	**22.86**	21.06	312.53	**0.15**	0.12	1.75
11/13/2013	20	1.57	**21.85**	22.35	448.80	**0.15**	0.15	3.01
12/13/2013	30	1.39	**19.13**	20.49	614.77	**0.07**	0.11	3.41
1/17/2014	35	1.20	**17.35**	18.24	638.82	**0.05**	0.06	2.10
	365			**Total Pounds**	**5595**		**Total Pounds**	**41.91**
				Total Tons	**2.80**		**Total Tons**	**0.021**

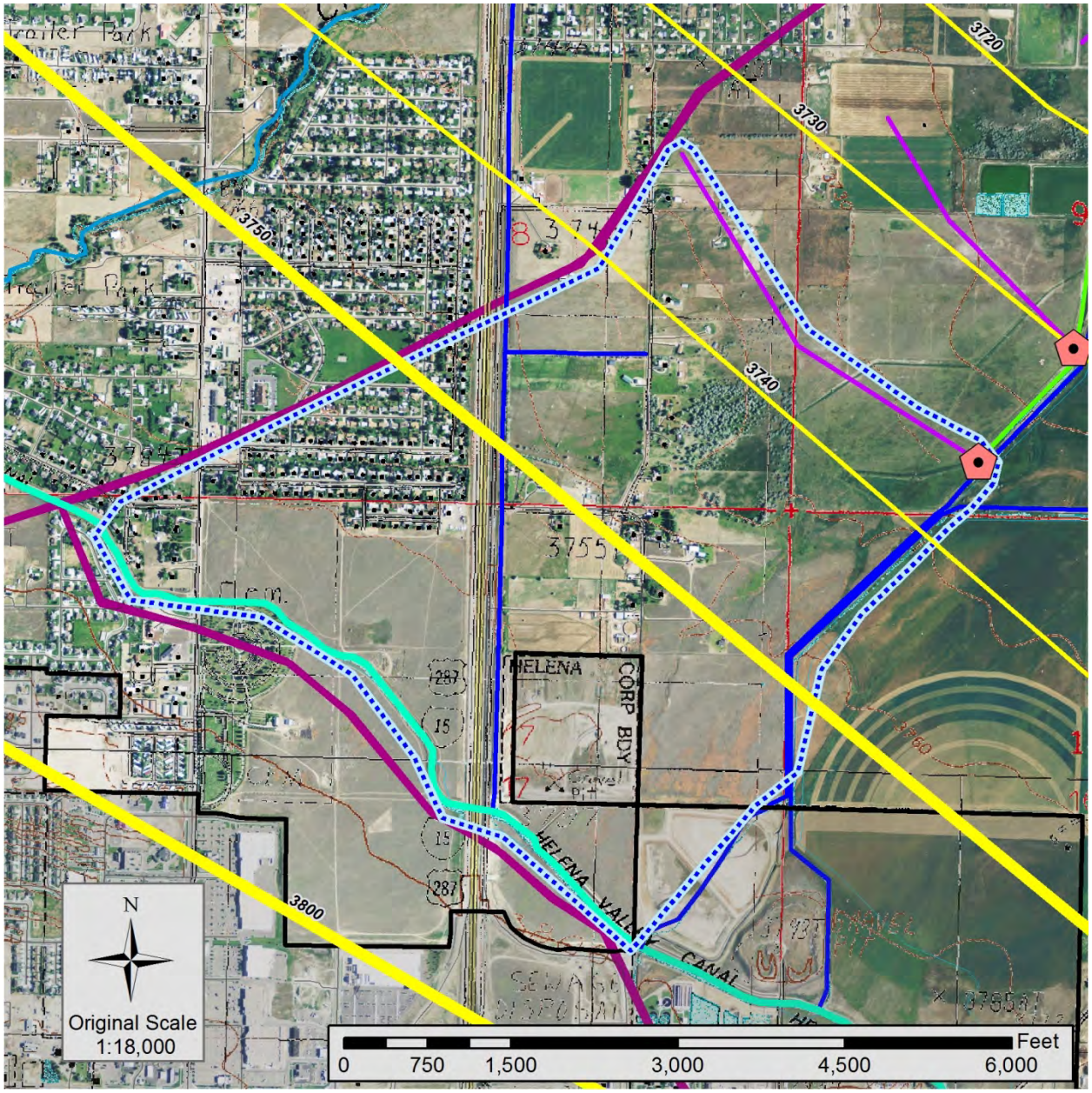


Figure 6-68 – Subwatershed contributing area for D3-1 Drain.
Ground water flow contours at 10' interval, with flow to the northeast.

6.5.1.2 D3-2 Drain System

The D3-2 drain is located approximately 1,300 feet downgradient from the D3-1 drain, where the D3 ditch starts. The general layout of the drain system is depicted in Figure 6-64. The drain is located within the central valley and the Helena Valley Aquifer. Ground water in this area flows generally northeast. Ground water recharge occurs from direct infiltration of precipitation and from the irrigation canals when in use. Photographs of the D3-2 drain outlet are presented in Figure 6-69. The D3-2 Drain flowed through the duration of this study, but flows increased during the summer showing a response to irrigation season. The drain was sampled a total of 22 times during the study, with several intervals missed due to weather conditions. The data results from the sampling of the D3-2 Drain are summarized in Table 6-35. Time series graphs of the data results are presented in Figure 6-70. From the sampling, nitrate values ranged from 1.46 mg/L up to 3.31 mg/L, and phosphate values ranged from 0.004 mg/L up to 0.017 mg/L.

View downstream, north, of D3-2 drain outlet into D-3 Ditch

D3-2 Drain outlet discharge

Figure 6-69 – Photographs of Drain D3-2 outlet

Table 6-35 Laboratory Results from Sampling, D3-2Drain

	Field Parameters				Laboratory Data Results						
D3-2	pH	Temp	specific conductivity	Dissolved Oxygen	Total Dissolved Solids, TDS @ 180°C	Alkalinity Total as $CaCO_3$	Cl	Br	SO_4	NO_3+ NO_2 as N	Phosphorus, Total as P
	S.U.	°C	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
6/6/13	7.55	8.5	429	8.59	377	230	33	0.09		2.51	0.01
6/27/13	7.55	9.1	451	8.49	406	230	37	0.09		2.53	0.014
7/11/13	7.59	9.5	472	8.15	413	240	43	0.21		1.46	0.015
7/26/13	7.59	10.4	472	7.37	412	240	41	0.06		2.6	0.012
8/6/13	7.52	10.7	468	7.16	409	240	41	0.07	68	2.53	0.014
8/23/13	7.69	11.3	503	6.69	421	240	43	0.12	75	2.74	0.015
9/5/13	7.67	11.4	506	7.36	412	240	41	0.11		2.87	0.016
9/24/13	7.64	11.7	505	7.26	412	240	42	0.08	71	2.84	0.015
10/9/13	7.70	11.5	497	7.48	409	240	38	0.09	70	2.84	0.009
10/24/13	7.73	11.2	489	7.74	403	240	37	0.08	69	2.67	0.014
11/13/13	7.62	10.6	480	6.75	395	240	36	0.08		3.24	0.014
12/13/13	7.87	9.7	465	4.94	406	240	35	0.08	69	2.77	0.008
1/17/14	7.86	8.5	447	6.23	415	240	33	0.12	68	2.71	0.004
3/27/14	8.49	7.2	427	6.79	388	230	31	0.06	65	2.3	0.014
4/15/14	8.40	7.3	476	5.78	397	230	32	< 0.01	70	2.69	0.017
5/2/14	8.32	7.5	430	8.71	388	220	31	0.04	64	2.5	0.017
5/21/14	8.10	7.9	438	4.94	390	220	31	< 0.01	64	2.48	0.012
6/11/14	8.16	8.5	453	5.94	408	220	33	0.18	64	2.4	0.013
7/10/14	8.16	9.3	483	4.62	418	210	38	0.09	70	2.47	0.009
8/28/14	8.22	11	587	6.96	506	230	59	< 0.01	87	3.08	0.015
9/30/14	8.48	11.1	552	5.87	461	230	52	0.04	76	3.31	0.016
11/24/14	8.46	10.2	501	7.25	442	230	39	0.08	68	3.18	0.017
Max	8.49	11.7	587	8.71	506	240	59	0.21	87	3.31	0.017
Min	7.52	7.2	427	4.62	377	210	31	< 0.01	64	1.46	0.004
Average	7.93	9.7	478.7	6.87	413.1	232.7	38.5	0.09	69.9	2.67	0.013
Median	7.80	10.0	474	7.06	409	235	37.5	0.08	69	2.68	0.014
St Dev	0.35	1.48	39.1	1.17	27.43	8.83	6.90	0.04	5.76	0.39	0.003

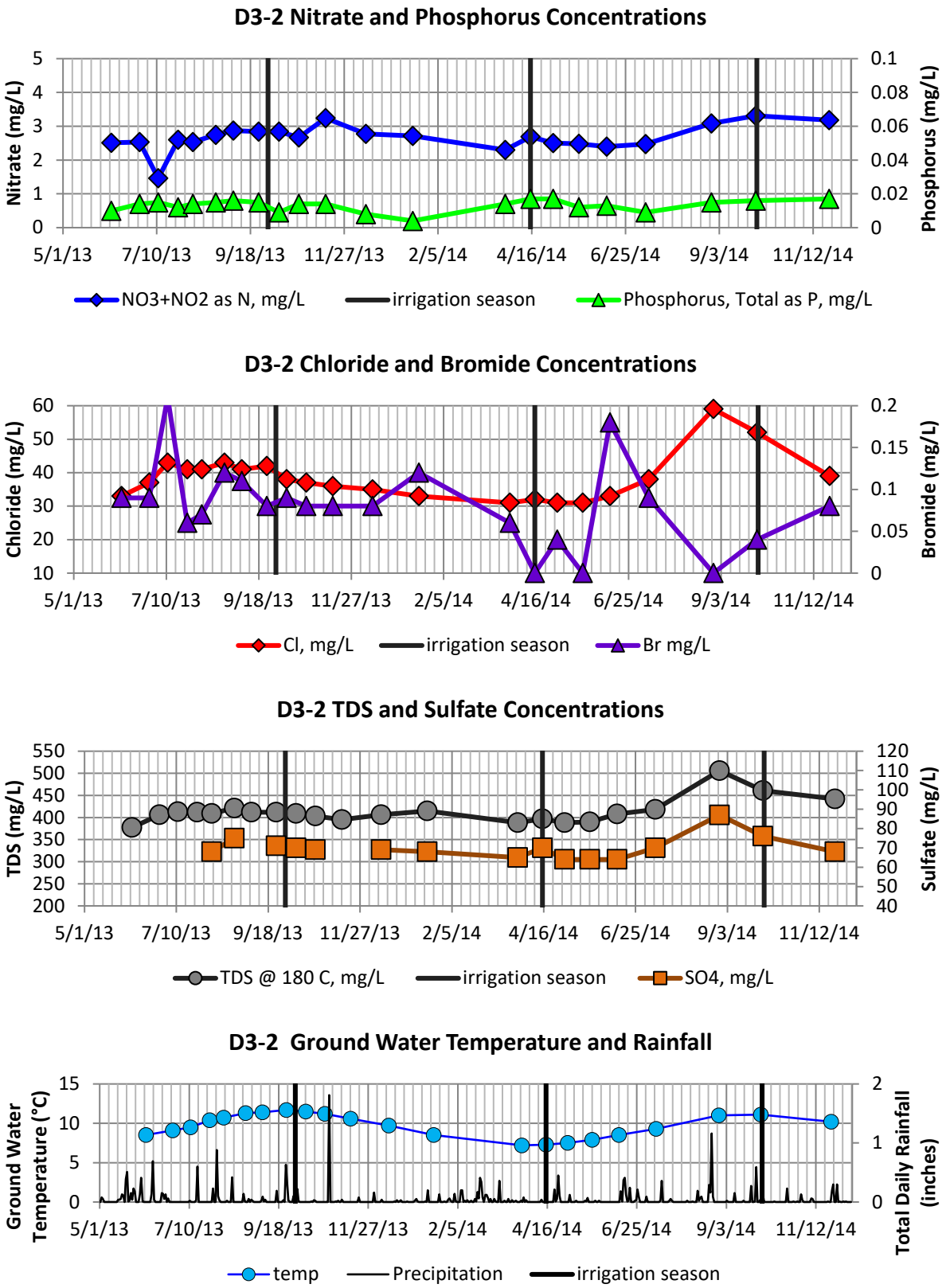


Figure 6-70–Water Quality Nutrient Results for D3-2 Drain.

D3-2 Drain System Hydrology and Discussion

The D3-2 drain flowed continuously during this study, showing a response to summer irrigation season, and an increase in flows during the last half of 2014 when maximum measured flows occurred. During the monitoring period for this study, measured flow rates range from 1.16 cfs up to 2.61 cfs (Table 6-36). The increase in flows during late summer 2014 and into the fall may be related to precipitation (Figure 6-71). The system appears to receive primary recharge during spring runoff and irrigation season, with flows depleting local storage through winter. The relatively quick increase in flow rates from the start of irrigation season shows a connection between irrigation waters and ground water levels.

Combining the nutrient data with flow discharge rates allows for calculation of estimates of nutrient mass loading rates. The loading rates for the D3-2 drain reflect the flow discharge rates for the tile drain (Figure 6-71). Loading to the system occurs throughout the year, with an anomalous increase in loading in late 2014. The cause of this increase is not known, and may be related to construction work in the contributing watershed upgradient from the drain.

Table 6-36 – 3-2 Drain Discharge & Loading

Sample Date	Flow Rate ft^3/s	**Nitrogen** lbs/day	**Phosphorus** lbs/day
9/5/13	1.60	24.80	0.138
9/24/13	1.53	23.38	0.123
10/9/13	1.62	24.85	0.079
10/24/13	1.36	19.65	0.103
11/13/13	1.57	27.37	0.118
12/13/13	*1.36**	21.58	0.110
1/17/14	1.16	16.88	0.025
3/27/14	1.31	16.25	0.099
4/15/14	1.57	22.78	0.144
5/2/14	1.98	26.70	0.182
5/21/14	1.94	25.95	0.126
6/11/14	1.99	25.76	0.140
7/10/14	2.01	26.78	0.098
8/28/14	2.32	38.54	0.188
9/30/14	2.31	41.24	0.199
11/24/14	2.61	44.77	0.239
Max	2.61	44.77	0.239
Min	1.16	16.25	0.025
Average	1.76	26.71	0.132
Median	1.61	25.31	0.125
Stnd Dev	0.42	8.14	0.052

* Rate not measured in field, estimated as average between bounding measurements

The yearly loading rate for the D3-2 drain was calculated using the data presented in Table 6-37. In order to maintain a consistent time interval for all of the drains included in this study, sample data from August 2013 through August 2014 was used. In order to complete the year, data from early September 2013 was used as an estimate for late August 2013 since the 2014 flows and loading appears anomalous. The data allows for estimates of the total amount of nitrogen and phosphorus discharged from the drain during the study year. For this drain, this corresponds to a total of 9,821 pounds (4.91 tons) of nitrogen and 44.30 pounds (0.022 tons) of phosphorus discharged from August 2013 to August 2014 (Table 6-37).

The local watershed contributing to the ground water collected from the D3-2 drain is depicted in Figure 6-72, which also shows the configuration of the local water table. The upgradient boundary for this area is estimated at the D3-1 drain. The area upgradient from the drain, estimated from the water table map, comprises predominantly agricultural lands, with one apparent household and associated septic drainfields. Potential nutrient sources include agricultural fertilizers and manure, and discharge from the septic system drainfields. Wastewater treatment ponds located adjacent to the drain, in a downgradient position, may impact the flows and water quality in the drain.

The flows in the D3-2 drain can be seen to increase with the May 1, 2014 sampling event, with peak summer flows measured in late summer, with the highest measured flow from November 2014 (Figure 6-71). Since irrigation season starts on April 15, the response of the system is considered less than 15 days as the water table rises (and flows increase accordingly). Nitrate values in the drain range from 1.46 to 3.31 mg/L which, when compared to irrigation waters consistently below 1.0 mg/L (see Section 5.0), infers that nitrogen is from an upgradient, anthropogenic source. The highest nitrate concentrations were detected at the end of the study. This suggests an additional source of nutrients, or local loading changed at this time. The exact cause for this is not known at this time. Since dissolved oxygen is consistently present near or exceeding 50 percent saturation, it is assumed that all nitrogen species are converted to nitrate within the ground water system. The variability of the bromide concentrations relative to chloride result in this assessment method being inconclusive for this system.

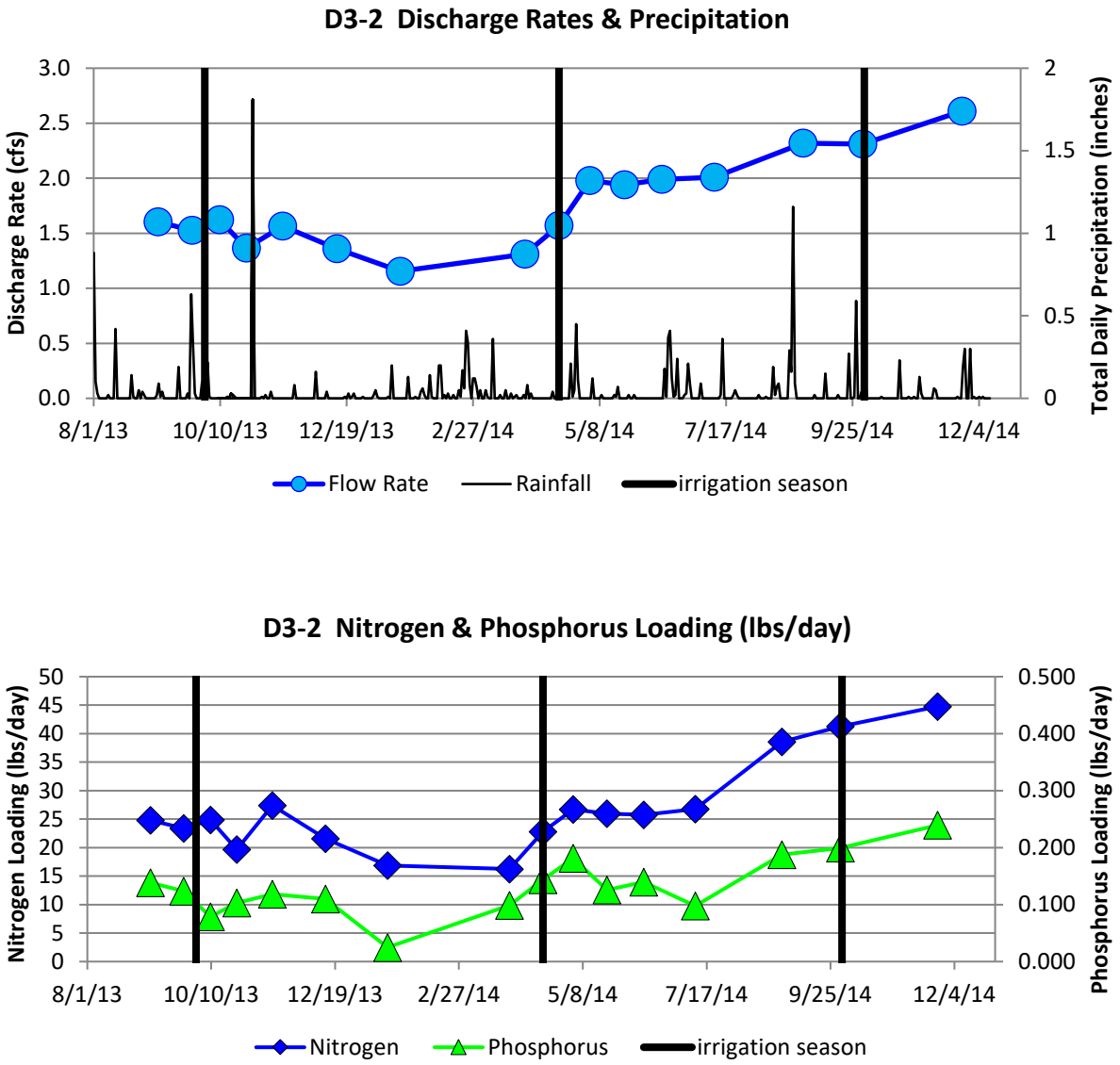


Figure 6-71 – Discharge Rates and Nitrogen and Phophorus Loading from D3-2 Drain.

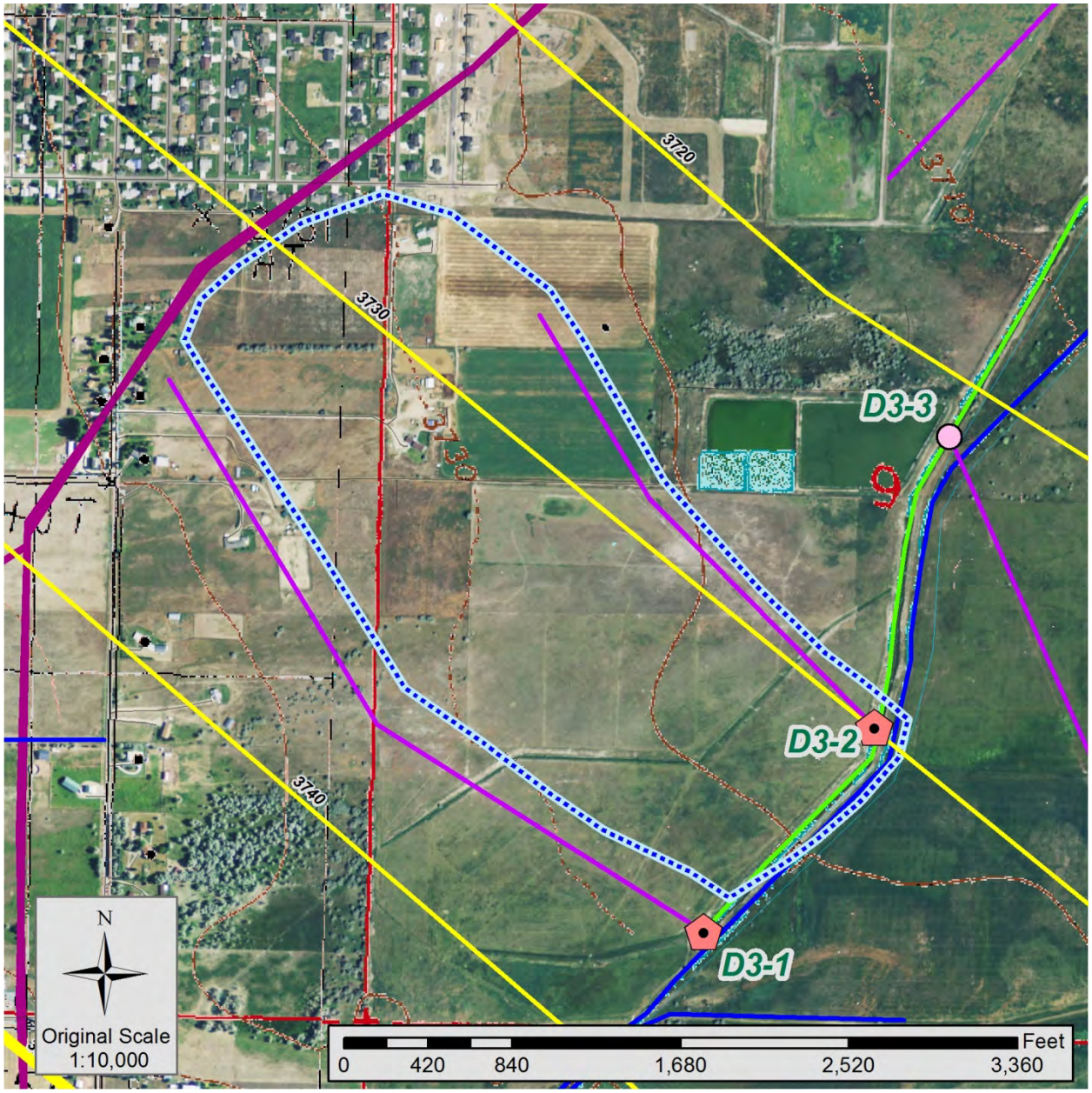


Figure 6-72 – Subwatershed contributing area for D3-2 Drain.
Ground water flow contours at 10' interval, with flow to the northeast.

Table 6-37 – D3-2 Drain Nitrogen and Phosphorus Loading

D3-2	Interval Days	Loading cfs	**Nitrogen lbs/day**	slope avg lbs/day	total lbs interval	**Phosphorus lbs/day**	slope avg lbs/day	total lbs interval
8/28/2013*		1.60	**24.80**			**0.14**		
9/5/2013	8	1.60	**24.80**	25.79	1470.07	**0.14**	0.12	6.72
9/24/2013	19	1.53	**23.38**	24.09	457.72	**0.12**	0.13	2.49
10/10/2013	16	1.62	**24.85**	24.11	385.83	**0.08**	0.10	1.62
10/25/2013	15	1.36	**19.65**	22.25	333.77	**0.10**	0.09	1.36
11/13/2013	19	1.57	**27.37**	23.51	446.72	**0.12**	0.11	2.10
12/12/2013	29	1.36	**20.33**	23.85	691.63	**0.06**	0.09	2.57
1/16/2014	35	1.16	**16.88**	18.61	651.20	**0.02**	0.04	1.46
3/20/2014	63	1.31	**16.25**	16.57	1043.73	**0.10**	0.06	3.90
4/14/2014	25	1.57	**22.78**	19.52	487.89	**0.14**	0.12	3.04
5/1/2014	17	1.98	**26.70**	24.74	420.57	**0.18**	0.16	2.77
5/21/2014	20	1.94	**25.95**	26.32	526.50	**0.13**	0.15	3.07
6/10/2014	20	1.99	**25.76**	25.86	517.11	**0.14**	0.13	2.65
7/10/2014	30	2.01	**26.78**	26.27	788.09	**0.10**	0.12	3.56
8/28/2014	49	2.32	**38.54**	32.66	1600.30	**0.19**	0.14	7.00
	365			**Total Pounds**	**9821**		**Total Pounds**	**44.30**
				Total Tons	**4.91**		**Total Tons**	**0.022**

* Data from 9/5/13 used for this interval

6.5.1.3 D3-3 Drain System

The D3-3 Drain is located downgradient and opposite from the D3-2 drain outlet, installed into the area east of the D3 Ditch (Figure 6-64). Photographs of the discharge point of the pipe are presented in Figure 6-73. Results from the reconnaissance sampling program show nitrate at 0.89 mg/L and total phosphate at 0.024 mg/L. Land use in the watershed area contributing to the drain represents predominantly agricultural lands, some irrigated, with several residences present (Figure 6-74).

Discharge loading from the D3-3 Drain was estimated by comparing the loading rates with the D3-1 drain. Since much of the contributing areas for the drains are similar, with recharge from local irrigation waters, the loading from the D3-3 drain was estimated by comparing the ratio of reconnaissance sampling results between the two drains. For the D3-3 drain, this results in an estimated **2049 pounds (1.02 tons) of total nitrogen** and **77.37 pounds (0.039 tons) of total phosphorus** discharged from the drain

View upstream in D3 Ditch with D3-3 outlet visible

Drain D3-3 outlet into ditch. Note clear water from drain before mixing with cloudy water in ditch.

Figure 6-73– Photographs of Drain D3-3 outlet

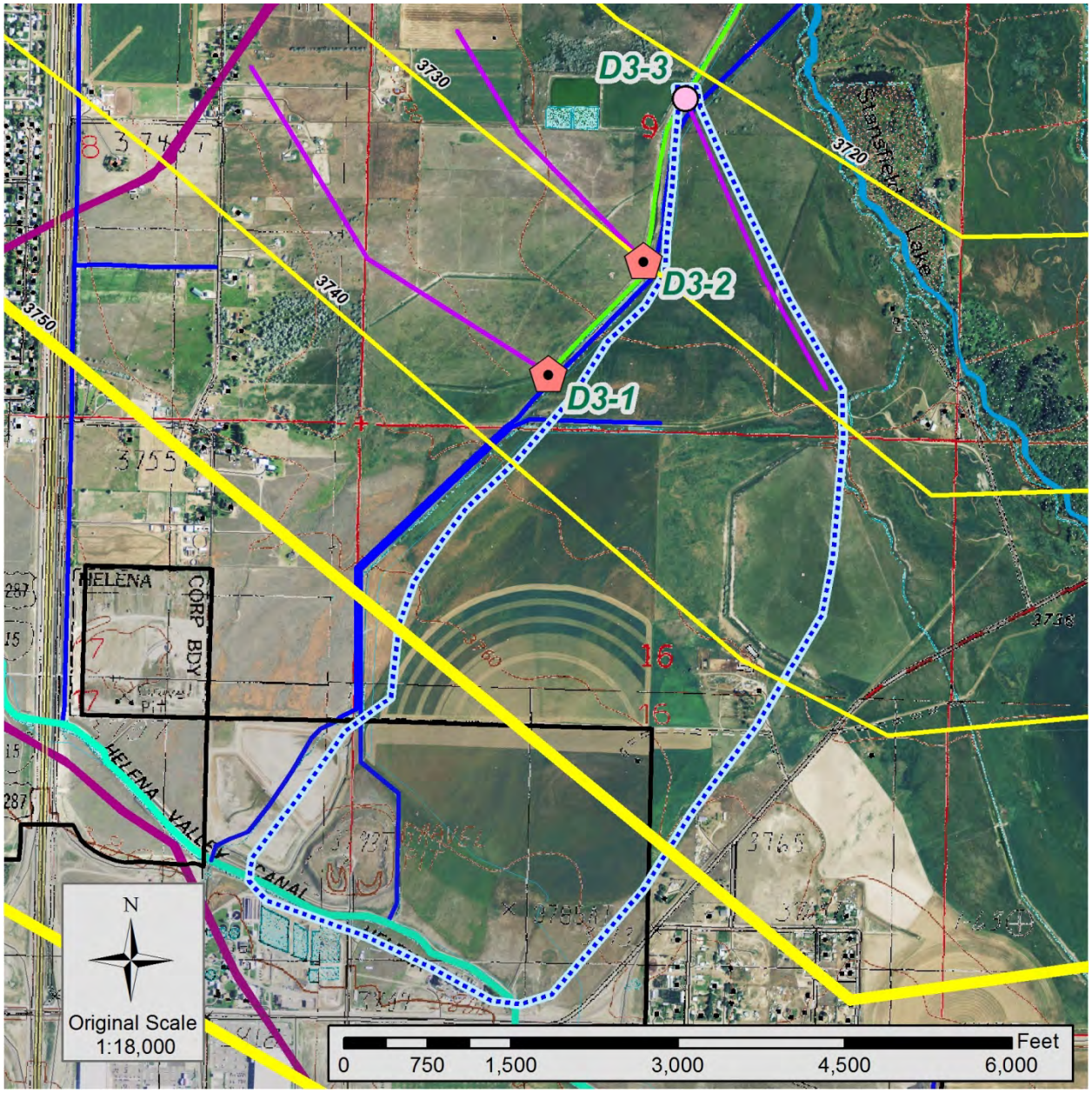


Figure 6-74 – Subwatershed Contributing Area for D3-3 Drain.
Ground water flow contours at 10' interval, with flow to the northeast.

6.5.1.4 D3-4 Drain System

The D3-4 Drains are located downgradient from other drains, installed into the area west of the D3 Ditch (Figure 6-64). These drains were not installed for the Helena Valley Irrigation Project, and are constructed of 7 inch (D3-4a) and 12 inch (D3-4b) diameter PVC at the discharge points. Photographs of the discharge points of the pipes are presented in Figure 6-75. Results from the reconnaissance sampling program for D3-4a show nitrate at 0.16 mg/L and total phosphate at 0.139 mg/L. While the water had dissolved oxygen present, this drain may have additional organic nitrogen present, based on previous sampling by the LCWQPD. Land use in the watershed area contributing to the drain represents predominantly agricultural lands, some irrigated, with several residences present, and several wastewater treatment lagoons (Figure 6-75). Results from the reconnaissance sampling program for D3-4b show nitrate at 2.92 mg/L and total phosphate at 0.051 mg/L. Land use in the watershed area contributing to the drain represents predominantly agricultural lands, some irrigated, with several residences present, and several wastewater treatment lagoons (Figure 6-75). Additional construction of new residences, and reconditioning of the wastewater treatment lagoons occurred concurrent with this study in 2014.

Discharge loading from the D3-4a Drain was estimated by comparing the loading rates with the D3-2 drain. Since much of the contributing areas for the drains are similar, with recharge from local irrigation waters, the loading from the D3-4a drain was estimated by comparing the ratio of the subwatershed contributing area between the two drains. For the D3-4a drain, this results in an estimated **6314 pounds (3.16 tons) of total nitrogen** and **28.48 pounds (0.014 tons) of total phosphorus** discharged from the drain. Discharge loading from the D3-4b Drain was estimated by comparing the loading rates with the D3-2 drain. Since much of the contributing areas for the drains are similar, with recharge from local irrigation waters, the loading from the D3-4b drain was estimated by comparing the ratio of the subwatershed contributing area between the two drains. For the D3-4b drain, this results in an estimated **5612 pounds (2.81 tons) of total nitrogen** and **25.31 pounds (0.013 tons) of total phosphorus** discharged from the drain

Discharge from outlet pipes for Drains D3-4. Drain D3-4a, to the left, is a 7-inch diameter pipe. Drain D3-4b, to the right, is a 12-inch diameter pipe.

View north of discharge canal from Drains D3-4a and D3-4b into D3 Ditch

Figure 6-75 – Photographs of Drain D3-4 Outlets and Discharge to D-3 ditch

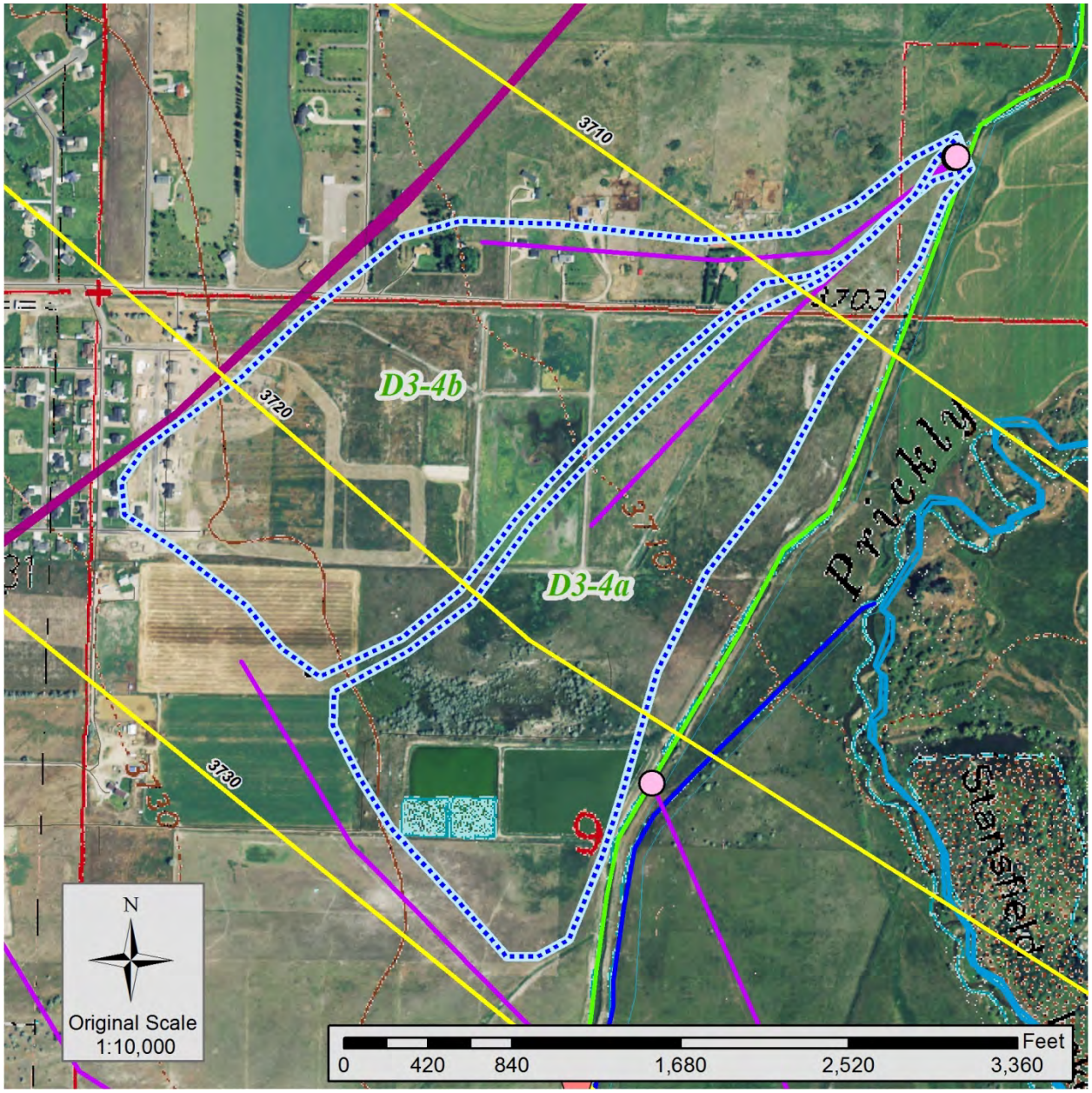


Figure 6-76 – Subwatershed contributing area for D3-4 Drains.
Ground water flow contours at 10' interval, with flow to the northeast.

6.5.2 D8 Ditch System

The D8 Ditch comprises three tributary lateral ditches, discharges directly into Lake Helena and receives discharge from four underground tile drains as depicted in Figure 6-77. Ground water is interpreted to flow generally north, following topography. However, the interaction of return flows from irrigation, stream loss in canal laterals, the ditches and underground drains likely modifies local ground water flow. A set of wastewater treatment ponds are located near Prickly Pear Creek and the western side of the ditch. The uppermost drain, D8-1, is located immediately downgradient from the wastewater treatment ponds. The results from the reconnaissance water quality sampling, listed in Table 6-38, show nitrate plus nitrite nitrogen ranging from 0.37 mg/L up to 0.68 mg/L.

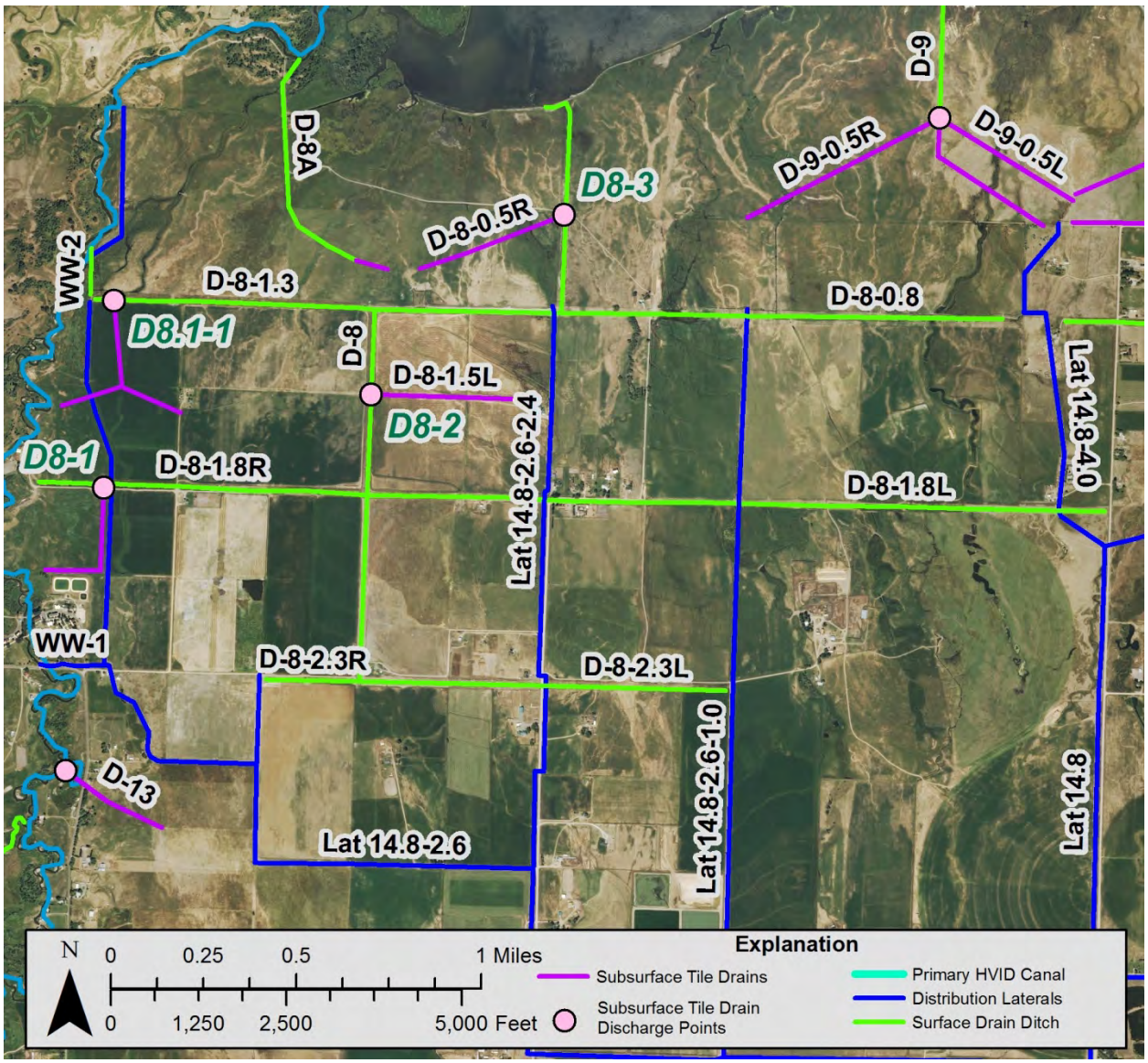


Figure 6-77 – D8 Ditch and Surrounding features.

Table 6-38 Laboratory Results from Reconnaissance Sampling, D-8 Ditch

Analyses		D8-1	D8-1.1	D8-2	
Field Parameters					
	pH	7.62	7.48	7.38	S.U.
	Conductivity	289	77	182	µs/cm
	Temperature	8.3	7.9	9.5	°C
	Dissolved Oxygen	3.96	8.16	6.11	mg/L
Laboratory Results					
	Total Dissolved Solids, TDS @ 180°C	256	252	298	mg/L
	Alkalinity, total as $CaCO_3$	170	160	170	mg/L
	Chloride	10	10	12	mg/L
	Bromide	<0.05	<0.05	<0.05	mg/L
	Nitrogen, Nitrate + Nitrite as N	0.55	0.68	0.37	mg/L
	Phosphorus, total as P	0.025	0.021	0.043	mg/L

6.5.2.1 D8-1 Drain System

The D8-1 drain is located adjacent to Prickly Pear Creek, and downgradient from wastewater treatment ponds at the Montana Law Enforcement Academy. The general layout of the drain system is depicted in Figure 6-77. The drain is located within the central valley and the Helena Valley Aquifer. Ground water in this area flows generally north. Ground water recharge occurs from direct infiltration of precipitation, and from the irrigation canals when in use. Note that there is a generally vertical upward gradient for deep ground water the lower Helena Valley, including this area. The discharge pipe for the D8-1 drain is routed into a watering hole for cattle by the landowner. Photographs of the D8-1 drain outlet are presented in Figure 6-65. The D8-1 Drain flowed through the duration of this study, but flows were generally slower than other drains, with little response to irrigation seasons. The drain was sampled a total of 13 times during the study, but was discontinued due to similar data results from all seasons. The data results from the sampling of the D8-1 Drain are summarized in Table 6-39. Time series graphs of the data results are presented in Figure 6-79. From the sampling, nitrate values ranged from 0.29 mg/L up to 0.62 mg/L, and phosphate values ranged from 0.014 mg/L up to 0.029 mg/L.

Fenced area around Drain D8-1 discharge point

Closeup of Drain D8-1 discharge pipe, partially submerged

Figure 6-78 – Photographs of Drain D8-1 Outlet

Table 6-39 Laboratory Results from Sampling, D8-1 Drain

	Field Parameters				Laboratory Data Results						
D8-1	pH	Temp	specific conductivity	Dissolved Oxygen	Total Dissolved Solids, TDS @ 180°C	Alkalinity Total as $CaCO_3$	Cl	Br	SO_4	NO_3+ NO_2 as N	Phosphorus, Total as P
	S.U.	°C	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
5/8/13	7.62	8.3	289	3.96	256	170	10	0.041		0.55	0.025
6/28/13	7.68	10.4	302	2.13	268	170	11	0.05		0.39	0.02
7/10/13	7.72	11	320	2.19	376	180	12	0.047		0.45	0.023
7/26/13	7.66	11.5	333	1.81	282	190	11	0.05		0.42	0.029
8/6/13	7.65	15.5	388	1.4	281	210	12	0.046	42	0.29	0.023
8/23/13	7.63	13.7	376	1.33	296	230	14	0.09	56	0.32	0.022
9/5/13	7.69	13.5	355	1.47	374	190	14	0.09		0.34	0.019
9/24/13	7.76	13.5	372	1.67	273	200	12	0.023	50	0.37	0.023
10/10/13	7.79	12.4	351	1.73	280	190	11	0.02	53	0.49	0.018
10/10/13			duplicate	sample	269	210	12	0.017	53	0.49	0.019
10/24/13	7.8	11.7	340	2.26	286	180	11	0.06	53	0.51	0.022
11/14/13	7.86	10.8	329	2.46	280	180	11	0.038		0.61	0.025
12/12/13	7.72	9.8	318	2.32	277	180	11	0.02	54	0.62	0.016
1/17/14	8.21	8.7	306	2.81	289	170	11	0.1	52	0.62	0.014
Max	8.21	15.5	388	3.96	376	230	14	0.1	56	0.62	0.029
Min	7.62	8.3	289	1.33	256	170	10	0.017	42	0.29	0.014
Average	7.75	11.6	336.8	2.12	291.9	189.3	11.6	0.049	51.6	0.46	0.021
Median	7.72	11.5	333	2.13	280.5	185	11	0.047	53	0.47	0.022
St Dev	0.15	2.09	30.41	0.71	36.52	17.74	1.15	0.027	4.24	0.11	0.004

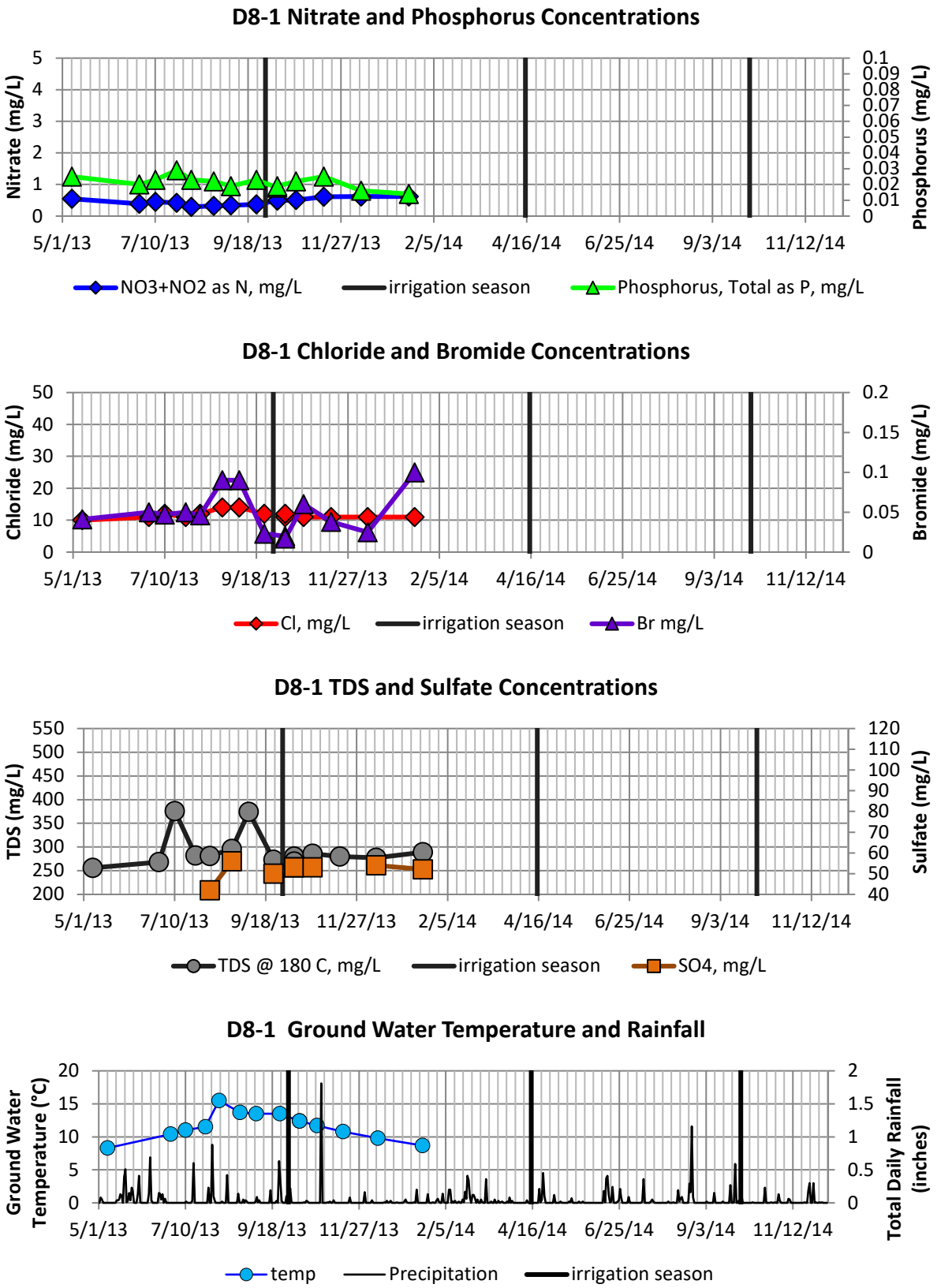


Figure 6-79–Water Quality Nutrient Results for D8-1 Drain.

D8-1 Drain System Hydrology and Discussion

The D8-1 drain flowed continuously during this study, but monitoring was limited in 2014. Due to budget issues, the drain was removed from primary monitoring due to the low concentrations detected during sampling coupled with access issues. During the monitoring period for this study, measured flow rates range from 0.52 cfs up to 0.87 cfs (Table 6-40). Flow from the drain was greatest when flow measuring started in September, then decreased during the fall and early winter (Figure 6-80). The system appears to receive primary recharge during spring runoff and irrigation season, with flows depleting local storage through winter.

Combining the nutrient data with flow discharge rates allows for calculation of estimates of nutrient mass loading rates. The loading rates for the D8-1 drain reflect the flow discharge rates for the tile drain (Figure 6-80).

Table 6-40 – D8-1 Drain Discharge & Loading

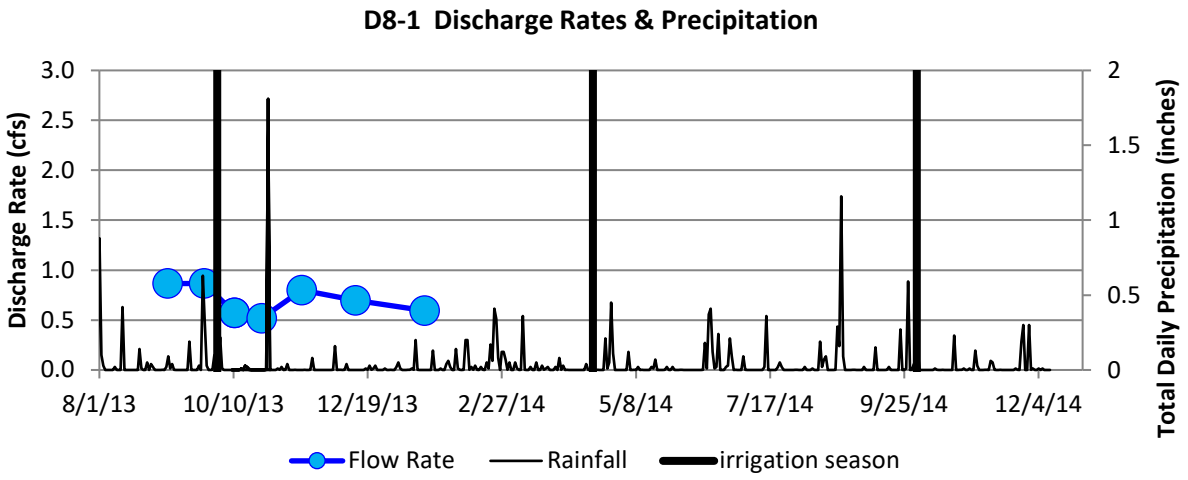
Sample Date	Flow Rate ft^3/s	**Nitrogen** lbs/day	**Phosphorus** lbs/day
9/5/13	0.87	1.59	0.089
9/24/13	0.87	1.73	0.107
10/10/13	0.57	1.51	0.056
10/24/13	0.52	1.42	0.061
11/14/13	0.80	2.63	0.108
12/12/13	*0.70**	2.33	0.060
1/17/14	0.59	1.98	0.045
Max	0.87	2.63	0.108
Min	0.52	1.42	0.045
Average	0.70	1.88	0.075
Median	0.70	1.73	0.061
Stnd Dev	0.14	0.45	0.026

* Rate not measured in field, estimated as average between bounding measurements

The yearly loading rate for the D8-1 drain was calculated using the data presented in Table 6-41. In order to maintain a consistent time interval for all of the drains included in this study, sample data from January 2013 through January 2014 was used. In order to complete the year, data from late January 2014 was used as an estimate for late January 2013. The data allows for estimates of the total amount of nitrogen and phosphorus discharged from the drain during the study year. For this drain, this corresponds to a total of 680 pounds (0.34 tons) of nitrogen and 25.41pounds (0.013 tons) of phosphorus discharged from January 2013 to January 2014 (Table 6-41).

The local watershed contributing to the ground water collected from the D3-1 drain is depicted in Figure 6-81, which also shows the configuration of the local water table. The upgradient boundary for this area is approximated as Prickly Pear Creek and several irrigation distribution laterals. For purposes of this assessment, the area upgradient from the drain, includes the wastewater treatment ponds for the Montana Law Enforcement Academy, and irrigated agriculture fields. Potential nutrient sources include agricultural fertilizers and manure, and discharge/leakage from the wastewater treatment ponds.

The flows in the D8-1 drain can be seen to slightly decrease after the end of irrigation season (Figure 6-80). Nitrate values in the drain range from 0.29 to 0.62 mg/L which, when compared to irrigation waters consistently below 1.0 mg/L (see Section 5.0), infers that nitrate may be natural. The waters consistently had a low dissolved oxygen content; however, total nitrogen samples indicated all the nitrogen was from nitrate. Based on this data, there appears to be no impact from the wastewater lagoons, and any released nitrogen appears to be attenuated by the natural system. The variability of the bromide concentrations relative to chloride result in this assessment method being inconclusive for this system.



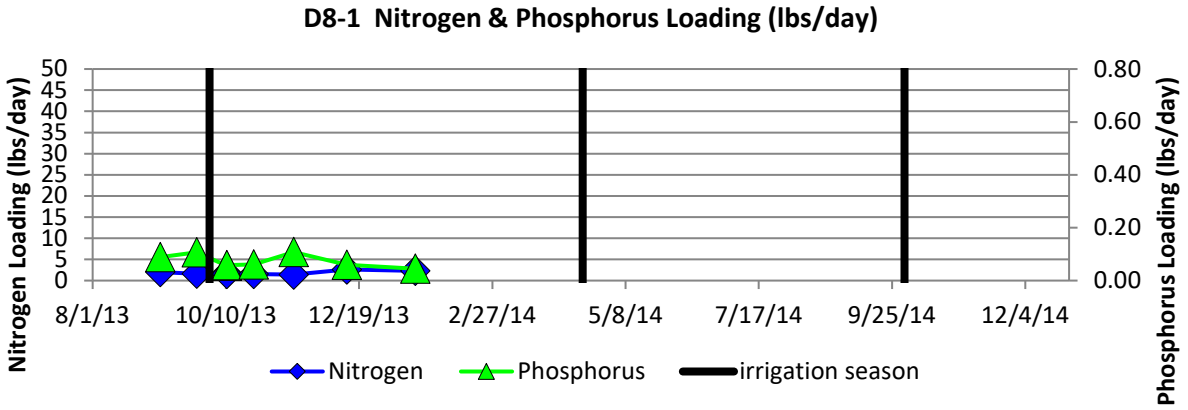


Figure 6-80 – Discharge Rates and Nitrogen and Phophorus Loading from D8-1 Drain.

Table 6-41– D8-1 Drain Nitrogen and Phosphorus Loading

D8-1	Interval Days	Loading cfs	**Nitrogen lbs/day**	slope avg lbs/day	total lbs interval	**Phosphorus lbs/day**	slope avg lbs/day	total lbs interval
1/16/2013*		0.59	**1.98**			**0.04**		
9/5/2013	232	0.87	**1.59**	1.79	414.35	**0.09**	0.07	15.49
9/24/2013	19	0.87	**1.73**	1.66	31.49	**0.11**	0.10	1.86
10/10/2013	16	0.57	**1.51**	1.62	25.94	**0.06**	0.08	1.30
10/25/2013	15	0.52	**1.42**	1.47	22.04	**0.06**	0.06	0.88
11/13/2013	19	0.80	**2.63**	2.03	38.49	**0.11**	0.08	1.61
12/12/2013	29	0.7	**2.33**	2.48	71.85	**0.06**	0.08	2.43
1/16/2014	35	0.59	**1.98**	2.16	75.46	**0.04**	0.05	1.84
	365			**Total Pounds**	**680**		**Total Pounds**	**25.41**
				Total Tons	**0.34**		**Total Tons**	**0.013**

*****data for 2014 used to simulate year

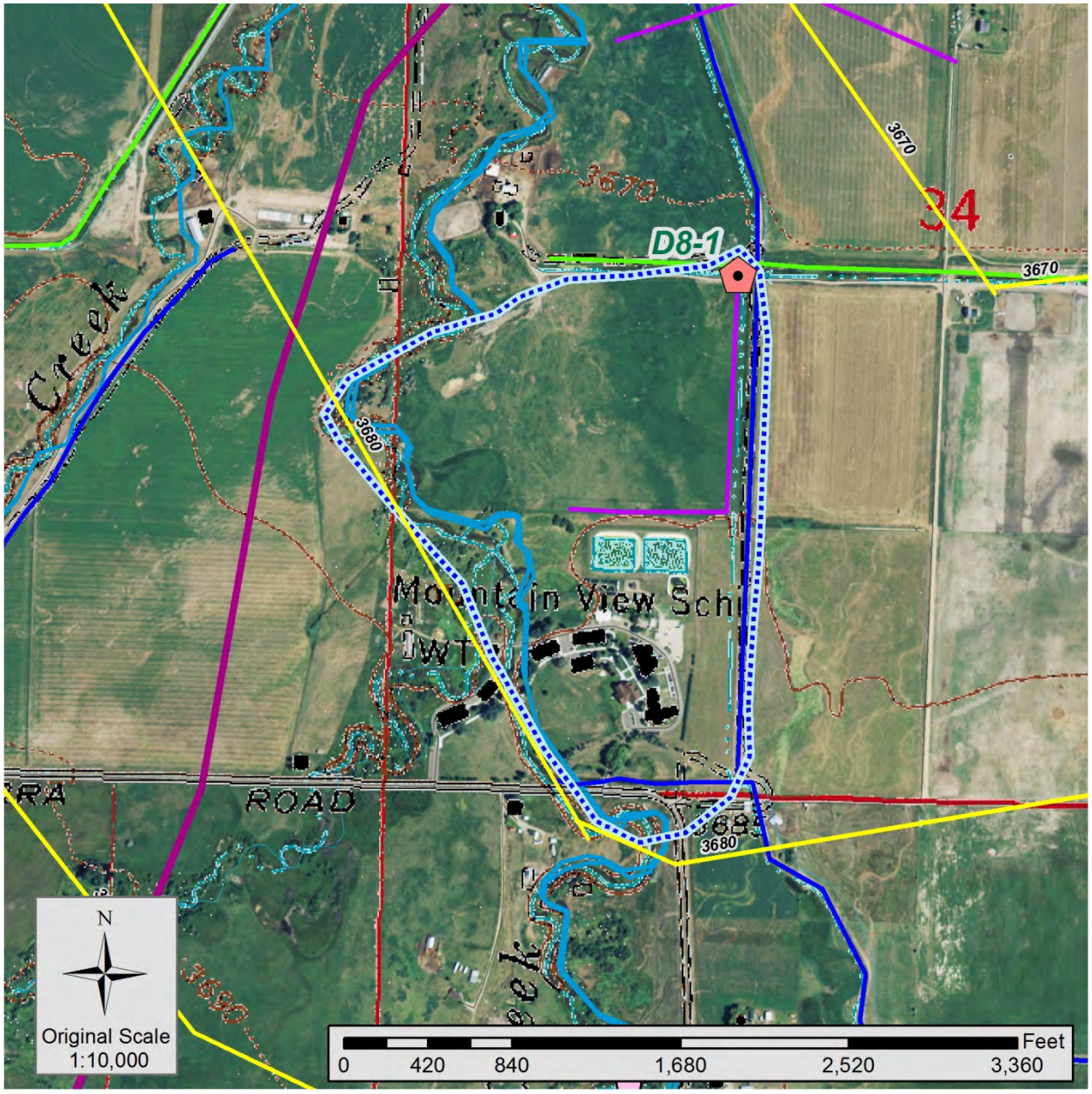


Figure 6-81 – Subwatershed contributing area for D8-1 Drain.
Ground water flow contours at 10' interval, with flow to the northeast.

6.5.2.2 D8.1-1 Drain System

The D8.1-1 Drain is located north of the D8-1 drain outlet, near Prickly Pear Creek, providing drainage into a tributary ditch the main D8 Ditch system (Figure 6-77). Photographs of the discharge point of the pipe are presented in Figure 6-82. Results from the reconnaissance sampling program show nitrate at 0.68 mg/L and total phosphate at 0.021 mg/L. Land use in the watershed area contributing to the drain represents predominantly agricultural lands, some irrigated, with one residence present (Figure 6-83).

Discharge loading from the D8.1-1 Drain was estimated by comparing the loading rates with the D8-1 drain. Since much of the contributing areas for the drains are similar, with recharge from local irrigation waters, the loading from the D8.1-1 drain was estimated by comparing the area contributing water between the two drains. For the D8.1-1 drain, this results in an estimated **831 pounds (0.42 tons) of total nitrogen** and **31.06 pounds (0.016 tons) of total phosphorus** discharged from the drain

View west of Drain D8-1.1 discharge

View east of Drain D8-1.1 discharge

Figure 6-82 – Photographs of Drain D8.1-1 outlet

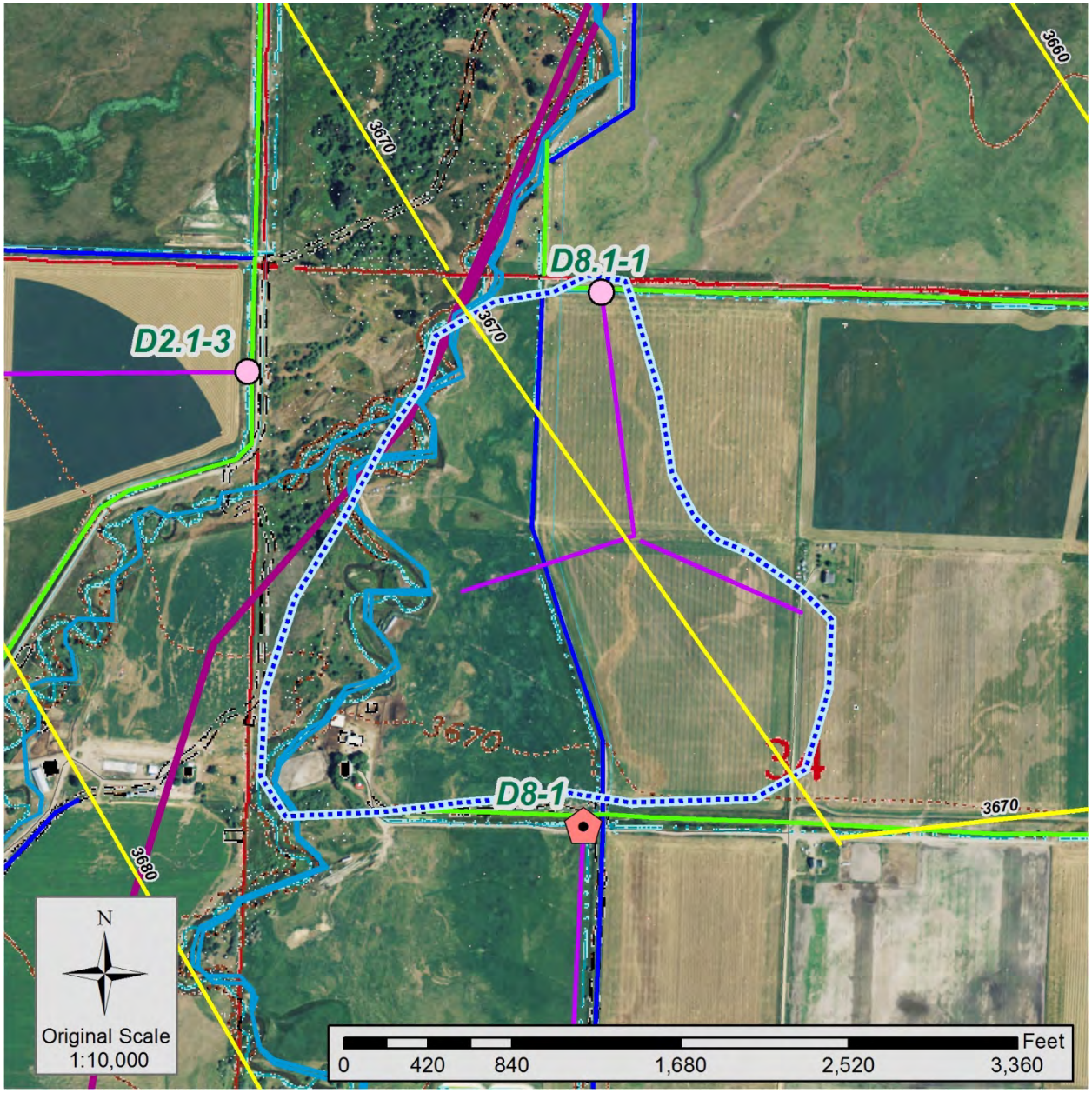


Figure 6-83 – Subwatershed contributing area for D8.1-1 Drain.
Ground water flow contours at 10' interval, with flow to the northeast.

6.5.3.5 D8-2 Drain System

The D8-2 Drain is located east of the D8-1 drain outlet, providing drainage into the main D8 Ditch system (Figure 6-77). Photographs of the discharge point of the pipe are presented in Figure 6-84. Results from the reconnaissance sampling program show nitrate at 0.37 mg/L and total phosphate at 0.043 mg/L. Land use in the watershed area contributing to the drain represents predominantly agricultural lands, some irrigated, with several residences present (Figure 6-85).

Discharge loading from the D8-2 Drain was estimated by comparing the loading rates with the D8-1 drain. Since much of the contributing areas for the drains are similar, with recharge from local irrigation waters, the loading from the D8-2 drain was estimated by comparing the area contributing water between the two drains. For the D8-2 drain, this results in an estimated **1662 pounds (0.83 tons) of total nitrogen** and **62.11 pounds (0.031 tons) of total phosphorus** discharged from the drain

View south of Drain D8-2 discharge point

Closeup of discharge from Drain D8-2. Grate over end is partially filled with debris, resulting in observed flow pattern

Figure 6-84 – Photographs of Drain D8-2 outlet

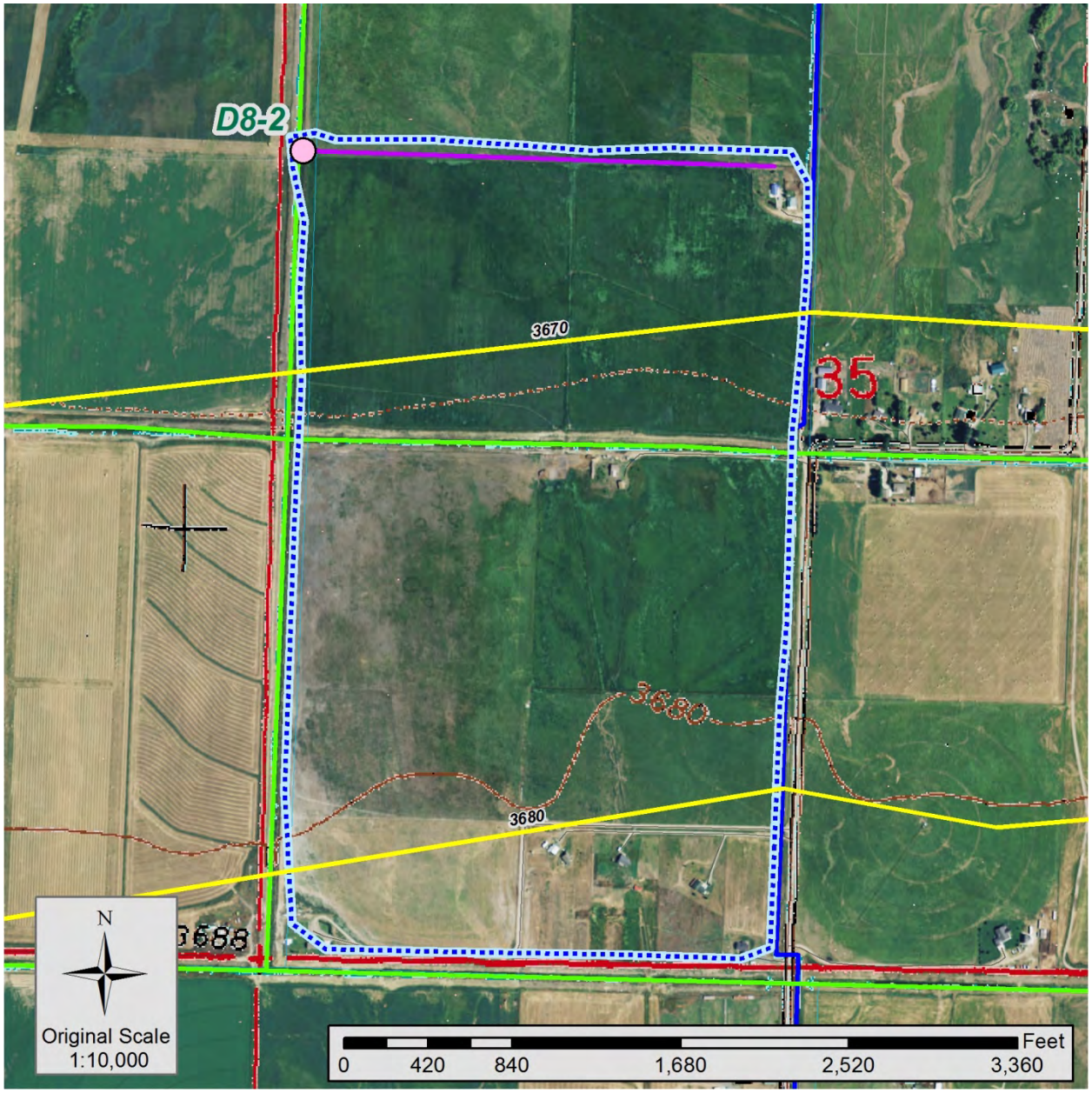


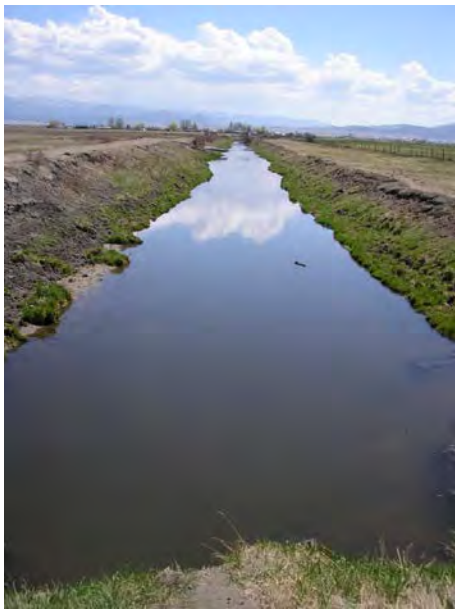
Figure 6-85 – Subwatershed contributing area for D8-2 Drain.
Ground water flow contours at 10' interval, with flow to the north.

6.5.2.3 D8-3 Drain System

The D8-3 Drain is located at a downgradient position providing drainage into the main D8 Ditch system near Lake Helena (Figure 6-77). During the reconnaissance sampling, the discharge point was observed submerged in water in the D8 Ditch. Photographs of the discharge point of the pipe are presented in Figure 6-86. Samples were not collected from this drain during the reconnaissance sampling program. Land use in the watershed area contributing to the drain represents predominantly agricultural lands, some irrigated, with one residence present (Figure 6-87).

Discharge loading from the D8-3 Drain was estimated by comparing the loading rates with the D8-1 drain. Since much of the contributing areas for the drains are similar, with recharge from local irrigation waters, the loading from the D8-3 drain was estimated by comparing the area contributing water between the two drains. For the D8-3 drain, this results in an estimated **907 pounds (0.45 tons) of total nitrogen** and **33.88 pounds (0.017 tons) of total phosphorus** discharged from the drain

Closeup view of submerged discharge point for Drain D8-3.



View south of D-8 Ditch, with submerged D8-3 drain visible along western side of ditch.

Figure 6-86 – Photographs of Drain D8-3 outlet

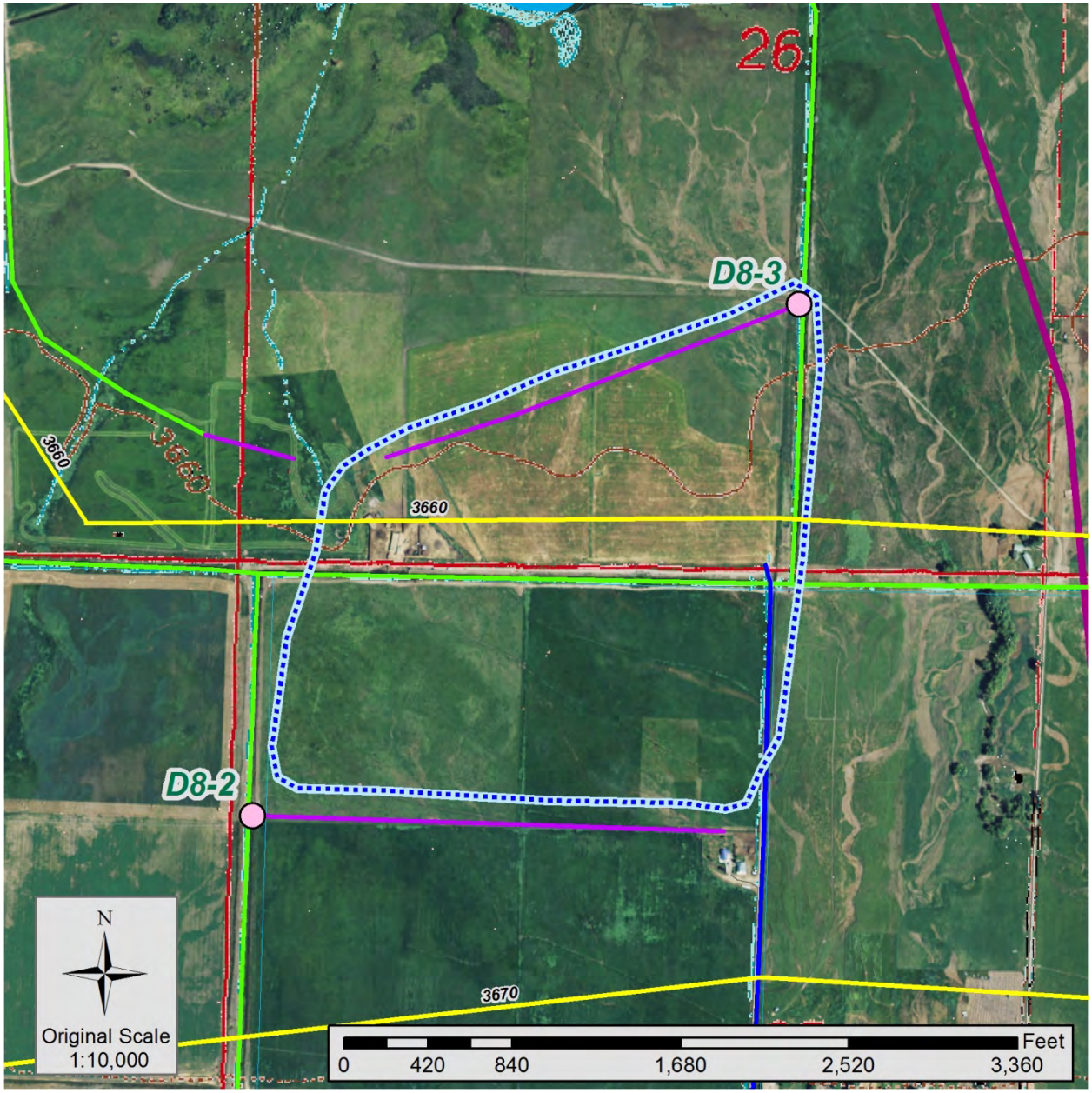


Figure 6-87 – Subwatershed Contributing Area for D8-3 Drain.
Ground water flow contours at 10' interval, with flow to the north.

6.6 East Helena Valley Subwatershed

The Lower East Helena Valley subwatershed represents the area east of Prickly Pear Creek where ground water is shallow, and flows in small streams north into Lake Helena. Ground water flows to the north, with an upward gradient in deep wells (Swierc, 2013). The outline of the Lower East Helena Valley subwatershed in the Helena Valley is depicted in Figure 6-88, with the major tile drain systems identified. The D-6 Ditch drains ground water in a small area along the southeast shore of Lake Helena. The D-7 and D-9 Ditches drain the area just south of Lake Helena.

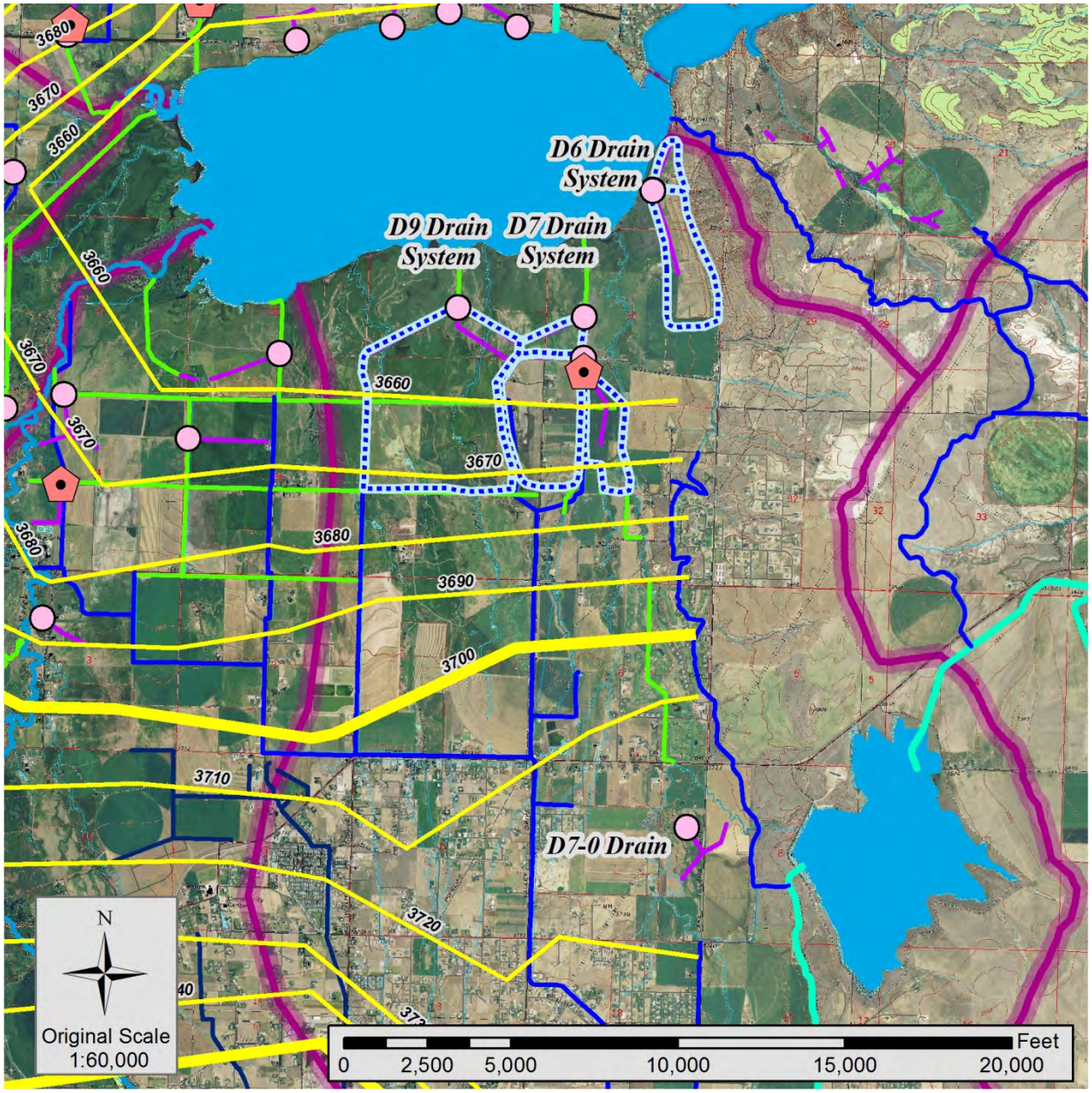


Figure 6-88 – Lower East Helena Valley Subwatershed in the Helena Valley

Tile drain discharge points are noted, with ground water potentiometric surface.

6.6.1 D6 Ditch System

The D6 Ditch is a small ditch with a primary water source from two underground tile drains which discharge at the same location. The ditch discharges into the eastern side of Lake Helena. The area near the D6 Ditch is depicted in Figure 6-89. Shallow ground water in the area flows to the north towards the southern drain, and likely flows westward towards Lake Helena in the vicinity of the northern drain. Nitrate concentrations in the drains were 0.62 and 1.09 mg/L, with the water quality data listed in Table 6-42. The underground drains discharge into a pool area, shown in an aerial photograph in Figure 6-90, and with on-site photographs in Figure 6-91. Rising ground water from springs were noted in the base of the receiving pool in the ditch.

Discharge loading from the D6 Drains was estimated by comparing the loading rates with the D7-1 drain. Since much of the contributing areas for the drains are similar, with recharge from local irrigation waters, the loading from the D6 drains was estimated by comparing the area contributing water between the two drains, and the results of the reconnaissance sampling. For the D6-1 drain, this results in an estimated **1839 pounds (0.92 tons) of total nitrogen** and **169.58 pounds (0.085 tons) of total phosphorus** discharged from the drain. For the D6-2 drain, this results in an estimated **882 pounds (0.44 tons) of total nitrogen** and **33.51 pounds (0.017 tons) of total phosphorus**.

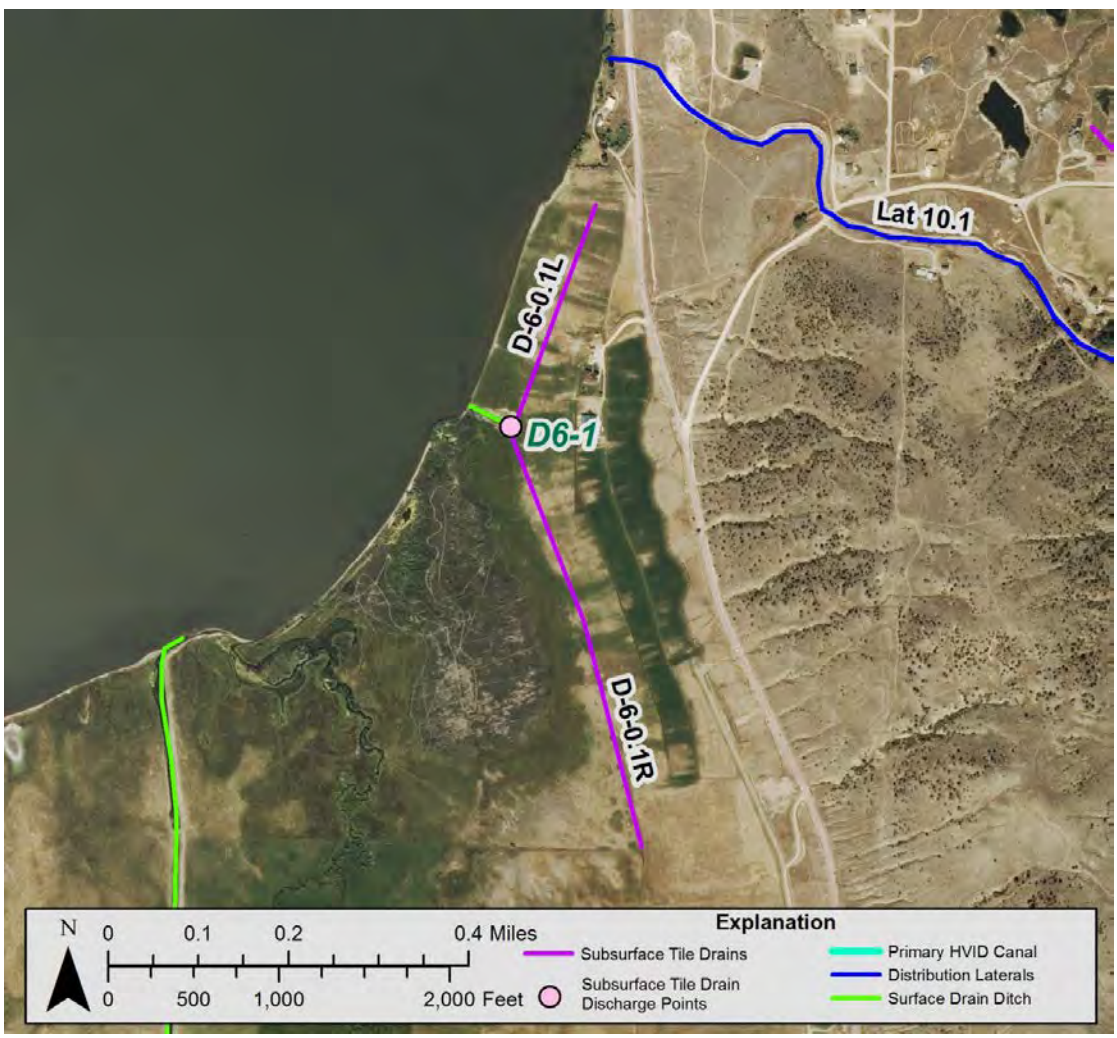


Figure 6-89 – D6 Ditch and Surrounding features.

Table 6-42 Laboratory Results from Reconnaissance Sampling, D-6 Ditch

Analyses		D6-1	D6-2	
Field Parameters				
	pH	7.60	7.48	S.U.
	Conductivity	389	380	µs/cm
	Temperature	9.4	10.7	°C
	Dissolved Oxygen	9.49	9.94	mg/L
Laboratory Results				
	Total Dissolved Solids, TDS @ 180°C	336	307	mg/L
	Alkalinity, total as $CaCO_3$	240	220	mg/L
	Chloride	14	14	mg/L
	Bromide	0.80	0.21	mg/L
	Nitrogen, Nitrate + Nitrite as N	0.62	1.09	mg/L
	Phosphorus, total as P	0.069	0.050	mg/L

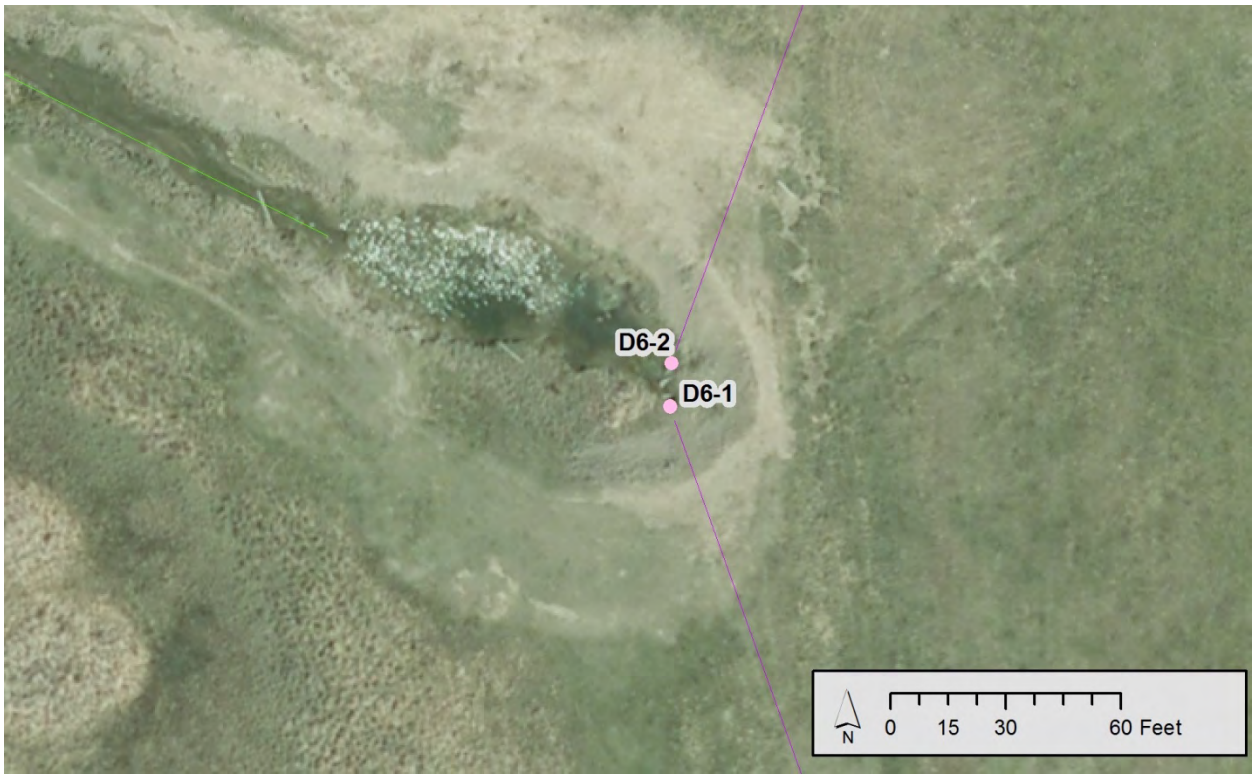


Figure 6-90 – Aerial Photograph of D6-1 and D6-2 Discharge Points and Receiving Pool

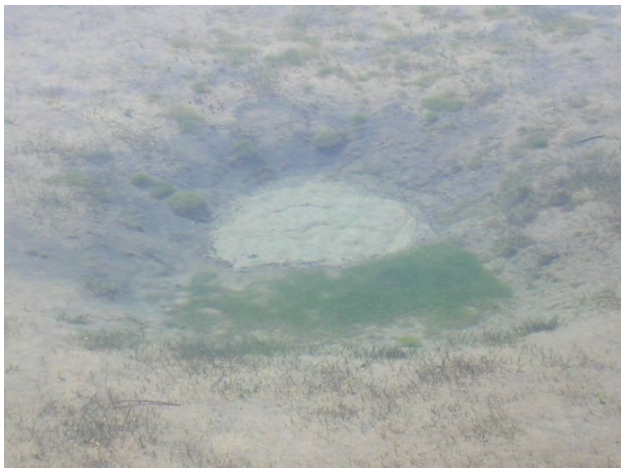
Drain D6-1, with north outlet (D6-2) in front, to left; and south outlet (D6-1) flowing towards camera.

View west along D6 Ditch into Lake Helena

View east of D6-1 Drain outlet into pool

Outlet for D6-2 Drain

Outlet pool for D6 Drains. Note springs in center of pool, characterized by color change from brown sediments to gray-green in spring outlets



Closeup view of spring outlet in D6 Ditch.

Figure 6-91 – Photographs of Drain D6-1 and D6-2 Outlets

6.6.2 D7 Ditch System

The D7 Ditch flows north into Lake Helena following a generally northward trend, parallel to the valley margin. The ditch system comprises two parts, and utilizes natural drainage features for flows. The southern part of the ditch crosses the Fox Ridge golf course with flows derived from natural shallow drainages. A single drain is present in the headwaters area; however, a review of detailed aerial photographs showed no evidence of historical flows from this drain. As a result, the drain is identified as D7-0, since it does not appear to contribute any significant flows to the ditch system. The southern part of the ditch system is depicted in Figure 6-92. The southernmost drain, D7-0, was not sampled since no evidence of flow was visible in the aerial photograph of the drain (Figure 6-93).

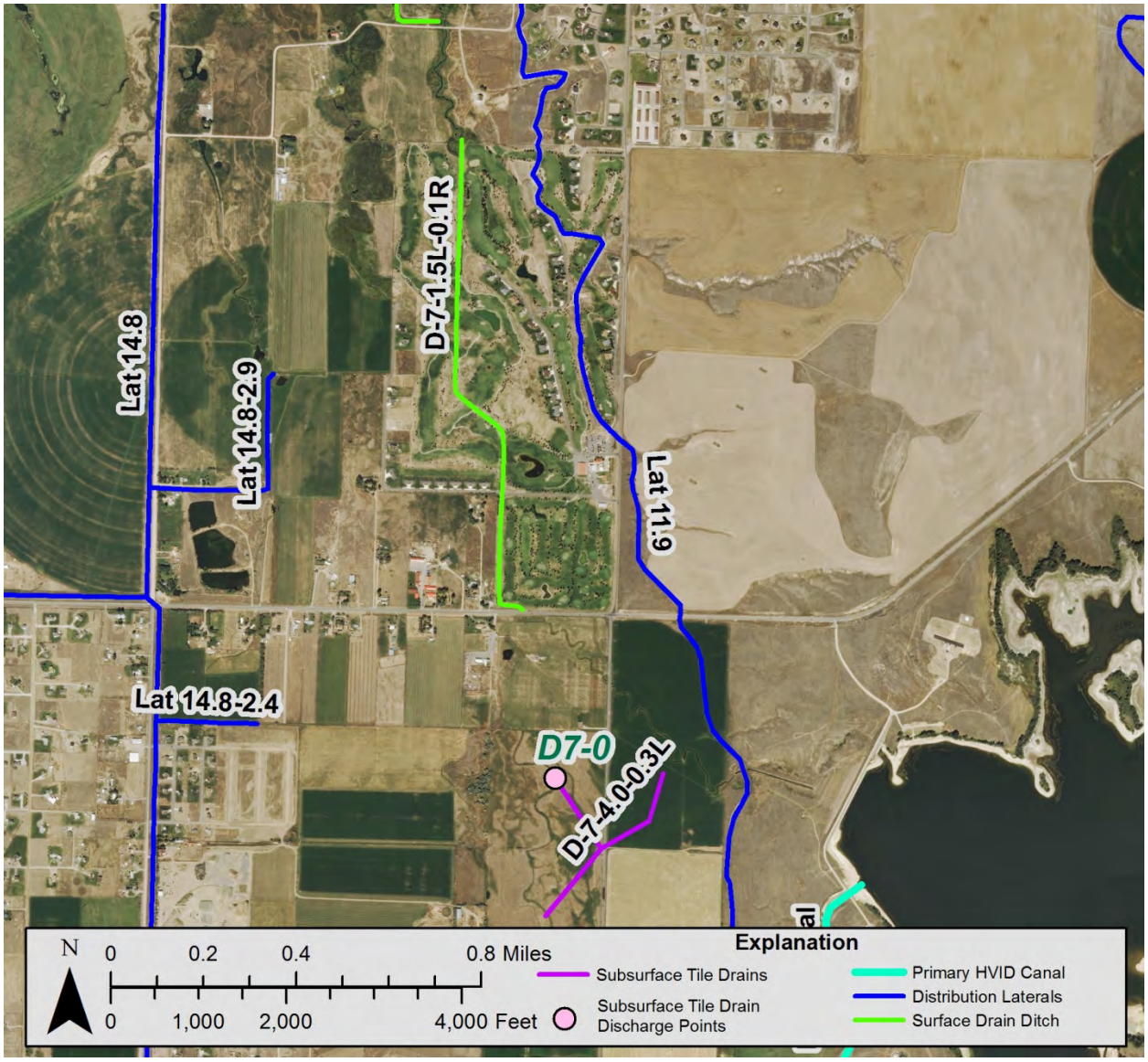


Figure 6-92 – Southern D-7 Ditch Components and Surrounding Features.

Figure 6-93 – Drain D7-0 Discharge Point from Aerial Photograph.

After passing through the Fox Ridge golf course, the D7 Ditch follows a more consistent northern path to discharge in Lake Helena, as depicted in Figure 6-94. Ground water in this area is considered likely to flow to the north, following topography towards Lake Helena. A total of three underground drains were mapped as discharging into the ditch; however, drain D7-2 was not located. Several concrete culverts and irrigation operation components were noted present in the expected discharge location of D7-2; however, the disposition of this drain is not certain at this time and it is assumed to be captured in the culvert, and pumped for irrigation water use. The results of the reconnaissance water samples from D7-1 and D7-3 are listed in Table 6-43. The data show detected nitrate concentrations in of 0.97 in D7-1 and 0.71 mg/L in D7-3.

Table 6-43 Laboratory Results from Reconnaissance Sampling, D-7 Ditch

Analyses	D7-1	D7-3	
Field Parameters			
pH	7.21	7.36	S.U.
Conductivity	310	250	µs/cm
Temperature	8.8	7.4	°C
Dissolved Oxygen	8.78	12.34	mg/L
Laboratory Results			
Total Dissolved Solids, TDS @ 180°C	265	224	mg/L
Alkalinity, total as $CaCO_3$	180	110	mg/L
Chloride	14	11	mg/L
Bromide	<0.05	<0.05	mg/L
Nitrogen, Nitrate + Nitrite as N	0.97	0.71	mg/L
Phosphorus, total as P	0.107	0.033	mg/L

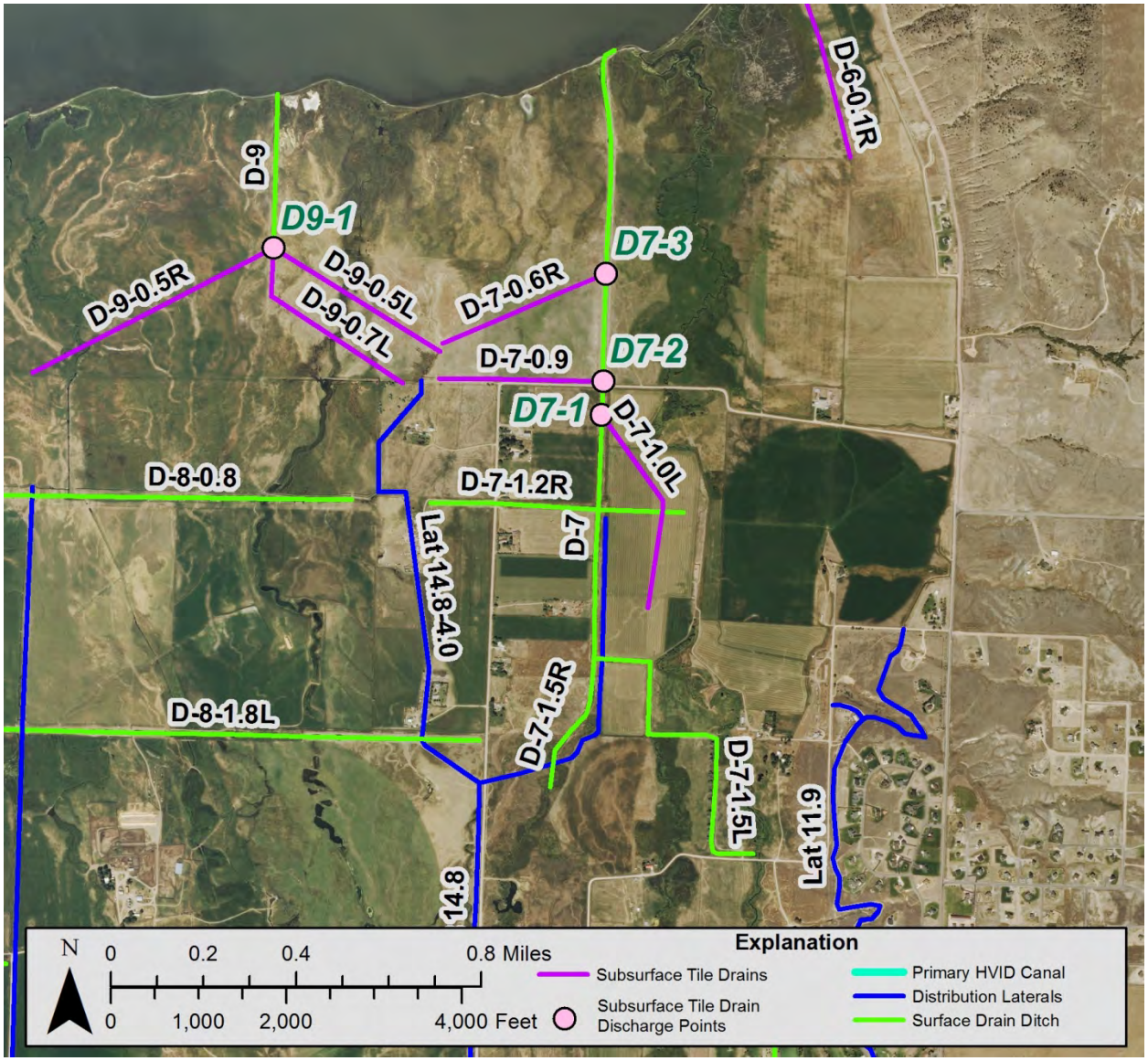


Figure 6-94 –Northern D-7 Ditch and Surrounding Features.

6.6.2.1 D7-1 Drain System

The D7-1 Drain is located approximately 4,000 feet from Lake Helena where the D7 Ditch runs north parallel to Merritt Creek. The general layout of the drain system is depicted in Figure 6-94. The drain is located near the eastern margin of the Helena Valley Aquifer, in an area where ground water is present at shallow depths. Ground water flows to the north in this area. Ground water recharge occurs from direct infiltration of precipitation, and from irrigation waters. Photographs of the D7-1 drain outlet are presented in Figure 6-95. The D7-1 drain flowed throughout the study, with flows increasing in summer in response to irrigation season. The drain was sampled a total of 19 times during the study. The data results from the sampling are summarized in Table 6-44. Time series graphs of the data results are presented in Figure 6-96. From the sampling, nitrate values ranged from 0.84 mg/L up to 1.39 mg/L, and phosphate values ranged from 0.096 mg/L up to 0.116 mg/L.

View south of Drain D7-1 discharge in D7 Ditch

View north of Drain D7-1 discharge

Figure 6-95 – Photographs of Drain D7-1 Outlet

Table 6-44 Laboratory Results from Sampling, D7-1 Drain

	Field Parameters				Laboratory Data Results						
D7-1	pH	Temp	specific conductivity	Dissolved Oxygen	Total Dissolved Solids, TDS @ 180°C	Alkalinity Total as $CaCO_3$	Cl	Br	SO_4	NO_3+ NO_2 as N	Phosphorus, Total as P
	S.U.	°C	µs/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
5/8/13	7.21	8.8	310	8.78	265	180	14	0.05		0.97	0.107
6/20/13	7.30	9.9	330	7.18	292	180	16	0.1		1.01	0.102
6/28/13	7.31	11.3	330	7.4	296	190	14	0.06		1.3	0.099
7/10/13	7.38	10.4	337	6.59	307	180	15	0.07		1.24	0.115
7/26/13	7.35	10.6	342	6.2	309	190	15	0.06		1.16	0.096
8/7/13	7.36	10.7	344	6.39	294	190	14	0.05	49	1.12	0.107
8/23/13	7.48	10.8	342	5.86	311	220	16	0.1	57	1.08	0.109
9/5/13	7.41	10.8	343	6.3	293	160	16	0.11		1.14	0.106
9/24/13	7.42	11	349	6	285	190	15	0.07	51	1.17	0.114
10/10/13	7.53	10.7	346	6.06	297	190	15	0.03	50	1.1	0.099
10/24/13	7.52	10.4	341	3.51	299	190	15	0.07	48	0.95	0.116
11/13/13	7.50	9.9	336	4.54	292	190	15	0.06		1.12	0.115
12/12/13	7.59	9.3	330	7.77	299	190	15	0.1	48	0.94	0.101
1/16/14	7.75	8.6	323	5.73	299	190	15	0.07	45	0.84	0.098
3/20/14	7.83	7.7	322	5.62	319	180	15	0.04	55	1.3	0.105
4/14/14	8.04	8	325	5.76	317	180	15	0.04	53	1.29	0.105
5/1/14	8.13	8.3	326	7.55	304	170	14	0.03	47	1.16	0.112
5/21/14	7.88	8.8	329	4.12	295	170	13	0.07	45	1.08	0.098
6/11/14	7.99	9.5	343	4.22	311	170	13	0.045	45	1.39	0.106
Max	8.13	11.3	349	8.78	319	220	16	0.11	57	1.39	0.116
Min	7.21	7.7	310	3.51	265	160	13	0.03	45	0.84	0.096
Average	7.58	9.76	334.1	6.08	299.2	184.2	14.7	0.065	49.4	1.12	0.106
Median	7.5	9.9	336	6.06	299	190	15	0.06	48.5	1.12	0.106
Std Dev	0.28	1.11	10.22	1.34	12.34	12.61	0.87	0.024	3.96	0.14	0.006

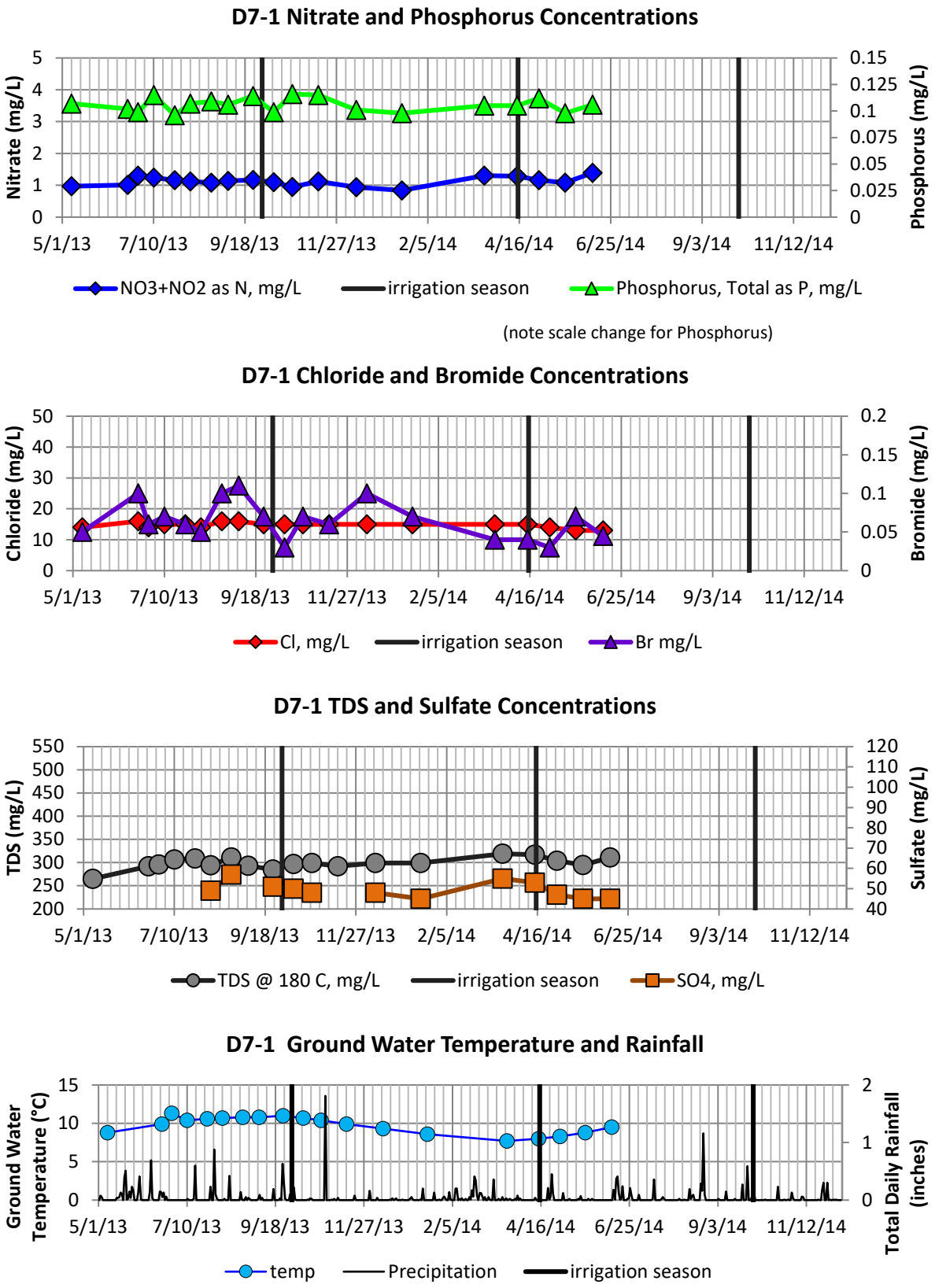


Figure 6-96 – Water Quality Nutrient Results for D7-1 Drain.

D7-1 Drain System Hydrology and Discussion

The D7-1 drain flowed continuously during this study, showing a response to summer irrigation season. During the monitoring period for this study, measured flow rates range from 0.60 cfs up to 1.22 cfs (Table 6-45). The increase in flows during late summer 2013 and into the fall may be related to precipitation (Figure 6-97). The system appears to receive primary recharge during spring runoff and irrigation season, with flows depleting local storage through winter. The relatively quick increase in flow rates from the start of irrigation season shows a connection between irrigation waters and ground water levels. Combining the nutrient data with flow discharge rates allows for calculation of estimates of nutrient mass loading rates. The loading rates for the D7-1 drain reflect the flow discharge rates for the tile drain (Figure 6-97). Loading to the system appears relatively consistent throughout the year.

Table 6-45 – D7-1 Drain Discharge & Loading

Sample Date	Flow Rate ft^3/s	**Nitrogen** lbs/day	**Phosphorus** lbs/day
9/5/13	1.03	6.34	0.590
9/24/13	1.22	7.72	0.752
10/10/13	1.13	6.70	0.603
10/25/13	0.82	4.19	0.512
11/13/13	0.96	5.79	0.594
12/12/13	*0.82**	4.14	0.445
1/16/14	0.68	3.07	0.358
3/20/14	0.88	6.14	0.496
4/14/14	0.90	6.26	0.510
5/1/14	0.60	3.75	0.362
5/21/14	0.79	4.60	0.418
6/10/14	1.15	8.62	0.658
Max	1.22	8.62	0.752
Min	0.60	3.07	0.362
Average	0.91	5.61	0.525
Median	0.89	5.96	0.511
Stnd Dev	0.19	1.68	0.120

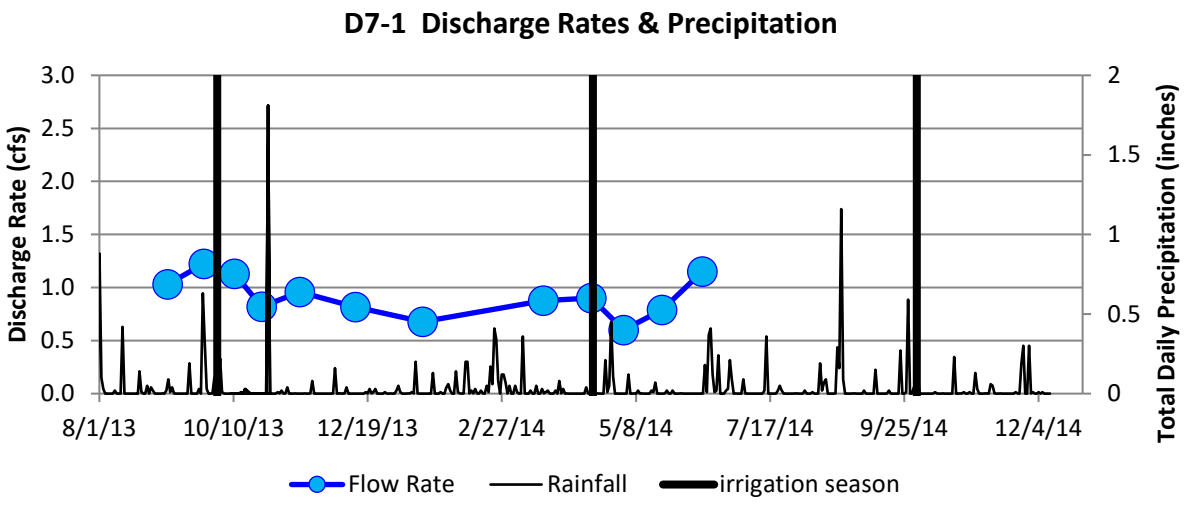
* Rate not measured in field, estimated as average between bounding measurements

The yearly loading rate for the D3-2 drain was calculated using the data presented in Table 6-46. In order to maintain a consistent time interval for all of the drains included in this study, sample data from September 2013 through September 2014 was used. In order to complete the year, data from early June 20143 was used as an estimate for late June 2013. The data allows for estimates of the total amount of nitrogen and phosphorus discharged from the drain during the study year. For this drain, this corresponds to a total of 2,092 pounds (1.05 tons) of nitrogen and 191.25 pounds (0.096 tons) of phosphorus discharged from June 2013 to June 2014 (Table 6-46).

The local watershed contributing to the ground water collected from the D3-2 drain is depicted in Figure 6-98, which also shows the configuration of the local water table. The upgradient boundary for this area is estimated where the D7 Ditch crosses the upgradient area from the drain. The area upgradient from the drain comprises predominantly agricultural lands, mostly irrigated. Potential nutrient sources include agricultural fertilizers and manure.

The flows in the D3-2 drain are relatively stable, but can be seen to increase with the May 1, 2014 sampling event, with peak summer flows measured in late summer 2013, however, the summer flows appear to be stable (Figure 6-97). Since irrigation season starts on April 15, the response of the system is considered less than 15 days as the water table rises (and flows increase accordingly). Nitrate values in the drain range from 0.84 to 1.39 mg/L which, when compared to irrigation waters consistently below 1.0 mg/L (see Section 5.0), infers that at least some of the nitrogen is from an upgradient, anthropogenic source. Since dissolved oxygen is consistently present near or exceeding 50 percent saturation, it is

assumed that all nitrogen species are converted to nitrate within the ground water system. The variability of the bromide concentrations relative to chloride result in this assessment method being inconclusive for this system. This drain had the highest phosphorus loading measured in this study, with a source from either fertilizers or natural. Ground water data from this area, and other parts of the Helena Valley near Tertiary strata indicated natural, elevated levels of phosphate (see Section 7.0 of this study)



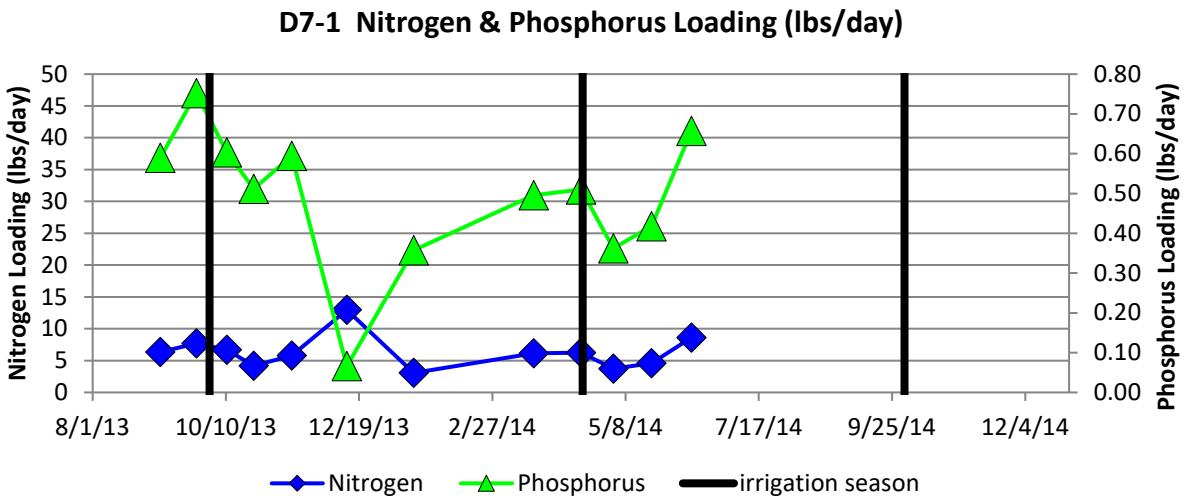


Figure 6-97 –Discharge Rates and Nitrogen and Phophorus Loading from D7-1 Drain.

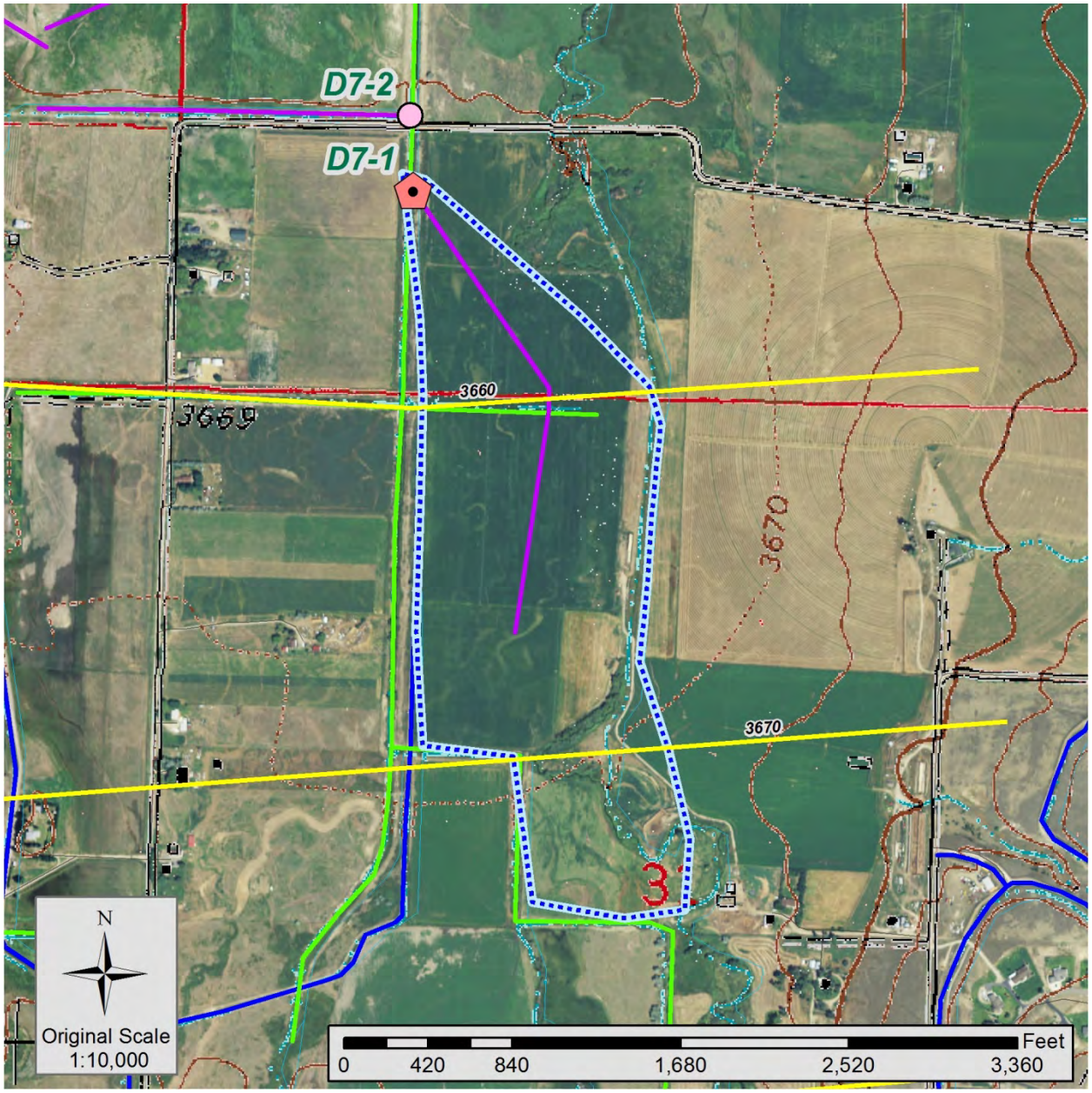


Figure 6-98 – Subwatershed contributing area for D7-1 Drain.
Ground water flow contours at 10' interval, with flow to the north.

Table 6-46 – D7-1 Drain Nitrogen and Phosphorus Loading

D7-1	Interval Days	Loading cfs	**Nitrogen lbs/day**	slope avg lbs/day	total lbs interval	**Phosphorus lbs/day**	slope avg lbs/day	total lbs interval
6/10/2013*		1.15	**8.62**			**0.66**		
9/5/2013	87	1.03	**6.34**	7.48	650.90	**0.59**	0.62	54.25
9/24/2013	19	1.22	**7.72**	7.03	133.60	**0.75**	0.67	12.75
10/10/2013	16	1.13	**6.70**	7.21	115.41	**0.60**	0.68	10.85
10/25/2013	15	0.82	**4.19**	5.45	81.71	**0.51**	0.56	8.36
11/13/2013	19	0.96	**5.79**	4.99	94.79	**0.59**	0.55	10.51
12/12/2013	29	0.82	**4.14**	4.97	143.99	**0.45**	0.52	15.07
1/16/2014	35	0.68	**3.07**	3.60	126.15	**0.36**	0.40	14.05
3/20/2014	63	0.88	**6.14**	4.60	289.91	**0.50**	0.43	26.88
4/14/2014	25	0.90	**6.26**	6.20	155.01	**0.51**	0.50	12.57
5/1/2014	17	0.60	**3.75**	5.01	85.14	**0.36**	0.44	7.41
5/21/2014	20	0.79	**4.60**	4.18	83.56	**0.42**	0.39	7.80
6/10/2014	20	1.15	**8.62**	6.61	132.24	**0.66**	0.54	10.75
	365			**Total Pounds**	**2092**		**Total Pounds**	**191.25**
				Total Tons	**1.05**		**Total Tons**	**0.096**

6.6.2.2 D7-2 Drain System

The D7-2 Drain is located just downgradient from the D7-1, drainage to the area west of the D7 Ditch (Figure 6-94). During the reconnaissance sampling, the discharge point was no observed with a concrete structure at the anticipated location. An aerial photographs of the discharge point of the pipe is presented in Figure 6-99. Since the drain was not located, samples were not collected from this drain during the reconnaissance sampling program. Land use in the watershed area contributing to the drain represents predominantly agricultural lands, some irrigated, with several residence present (Figure 6-100).

Discharge loading from the D7-2 Drain was estimated by comparing the loading rates with the D7-1 drain. Since much of the contributing areas for the drains differ, with recharge from local irrigation waters, the loading from the D7-2 drain was estimated by comparing the area contributing water between the two drains. For the D7-2 drain, this results in an estimated **4969 pounds (2.48 tons) of total nitrogen** and **454.22 pounds (0.227 tons) of total phosphorus** discharged from the drain.

Figure 6-99 – Approximate Drain D7-2 Discharge Point from Aerial Photograph.

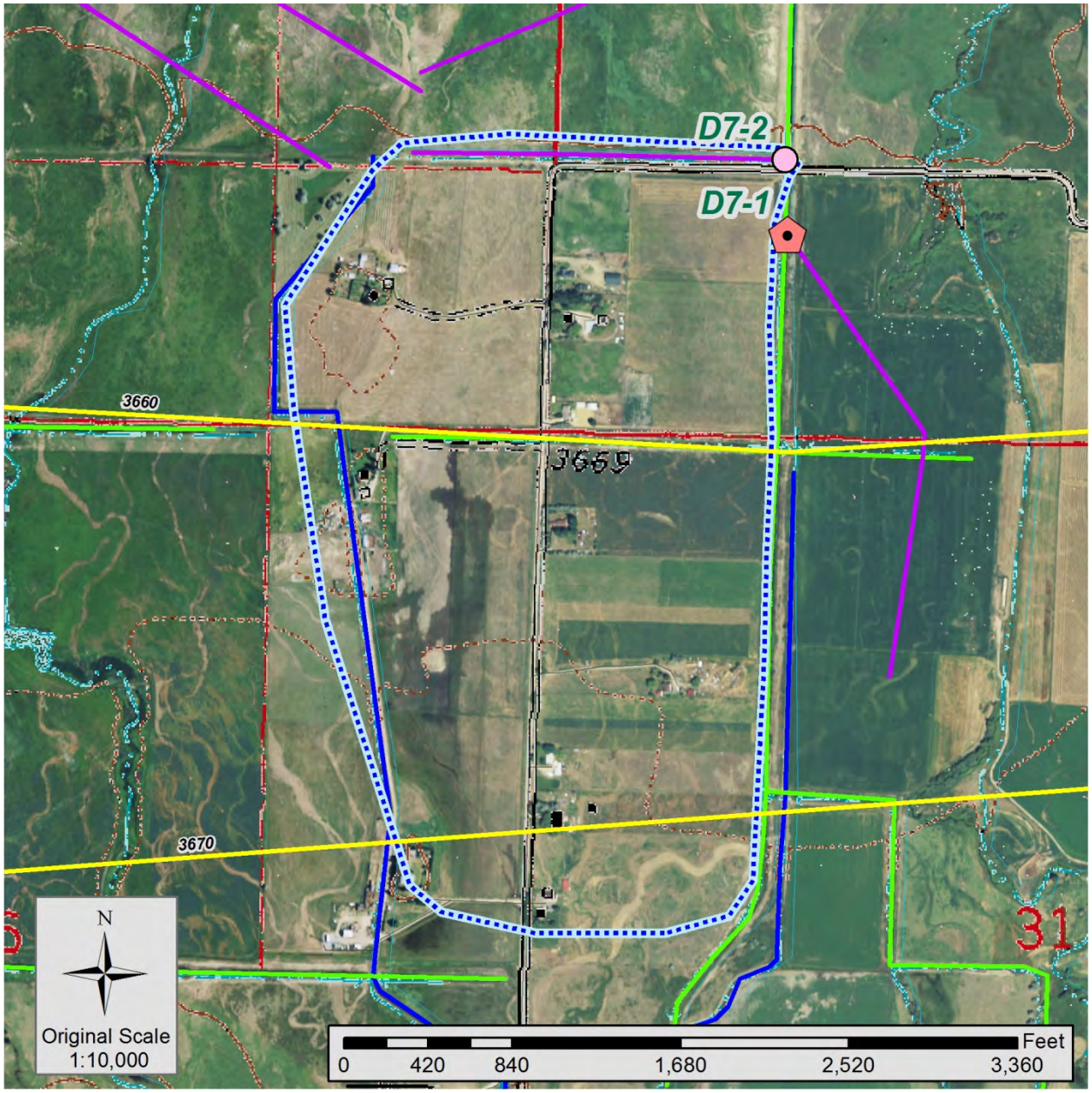


Figure 6-100 – Subwatershed contributing area for D7-2 Drain.
Ground water flow contours at 10' interval, with flow to the north.

6.6.2.3 D7-3 Drain System

The D7-3 Drain is located approximately 1,200 feet downgradient from the D7-2 Drain, and provides drainage to a small area west of the main D7 Ditch system near Lake Helena (Figure 6-94). During the reconnaissance sampling, the discharge point was observed with limited flow into the ditch. Photographs of the discharge point of the pipe are presented in Figure 6-101. The sampling results from the reconnaissance sampling program show nitrate at 0.71 mg/L and total phosphate at 0.033 mg/L. Land use in the watershed area contributing to the drain represents predominantly agricultural lands, with some irrigation (Figure 6-102).

Discharge loading from the D7-3 Drain was estimated by comparing the loading rates with the D7-1 drain. Since much of the contributing areas for the drains differ, with recharge from local irrigation waters, the loading from the D7-3 drain was estimated by comparing the area contributing water between the two drains. For the D7-3 drain, this results in an estimated **915 pounds (0.46 tons) of total nitrogen** and **83.67 pounds (0.042 tons) of total phosphorus** discharged from the drain

View north towards Lake Helena along D7 Ditch showing Drain D7-3 discharge point

Closeup of discharge from Drain D7-3

Figure 6-101 – Photographs of Drain D7-3 outlet

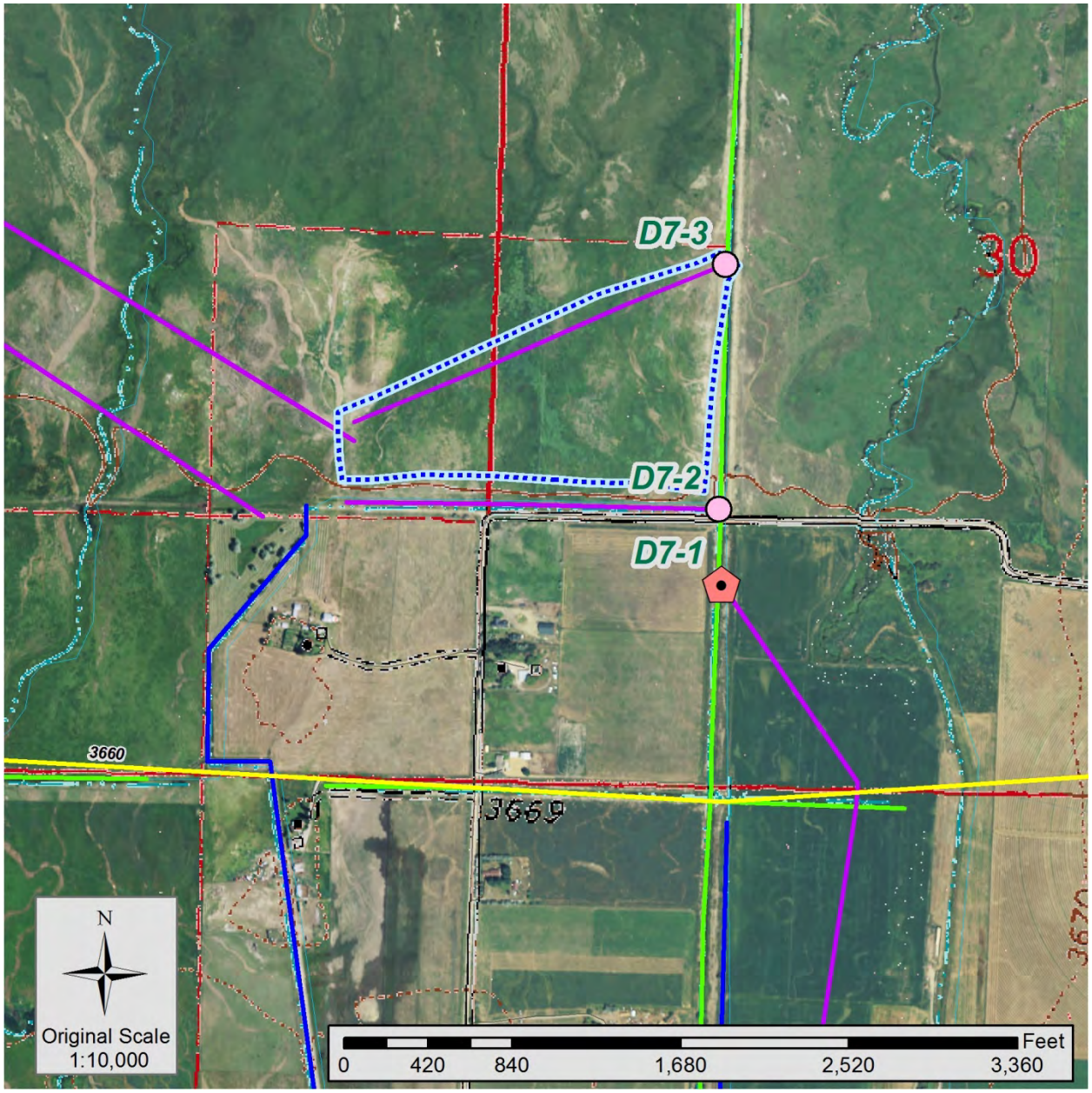


Figure 6-102 – Subwatershed contributing area for D7-3 Drain.
Ground water flow contours at 10' interval, with flow to the north.

6.6.3 D9 Ditch System

The D9 Ditch is a relatively small ditch with a limited drainage and recharge area, which flows north and discharges directly into Lake Helena. Three drains discharge into the ditch near the same position. The area near the D9 Ditch is depicted in Figure 6-103, with the individual outlets shown in high resolution aerial photographs in Figure 6-104. These drains were not sampled during the field reconnaissance due to access issues, and the undeveloped nature of the area near the underground drains. Land use in the watershed area contributing to the drain represents predominantly agricultural lands (Figure 6-105).

Discharge loading from the D9-1 Drain was estimated by comparing the loading rates with the D8-1 drain. Since much of the contributing areas for the drains differ, with recharge from local irrigation waters, the loading from the D9-1 drain was estimated by comparing the area contributing water between the two drains. For the D9-1 drain, this results in an estimated **3627 pounds (1.81 tons) of total nitrogen** and **135.52 pounds (0.068 tons) of total phosphorus** discharged from the drain

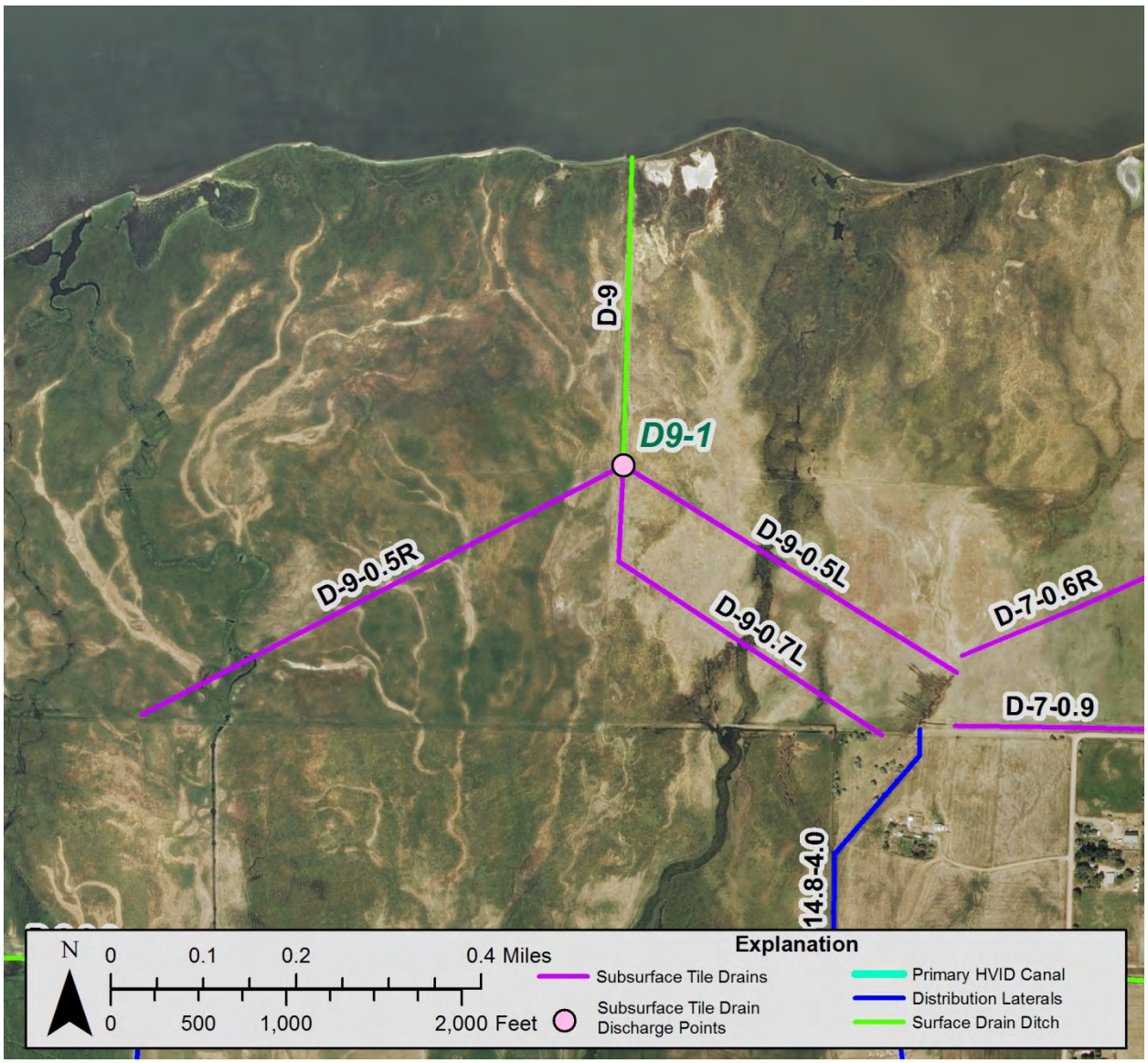


Figure 6-103 – D9 Ditch and Surrounding Features.

Figure 6-104 – Drain D9-1 Discharge Points from Aerial Photograph.

Discharge pipes for these drains are not visible, so terminus locations are approximated.

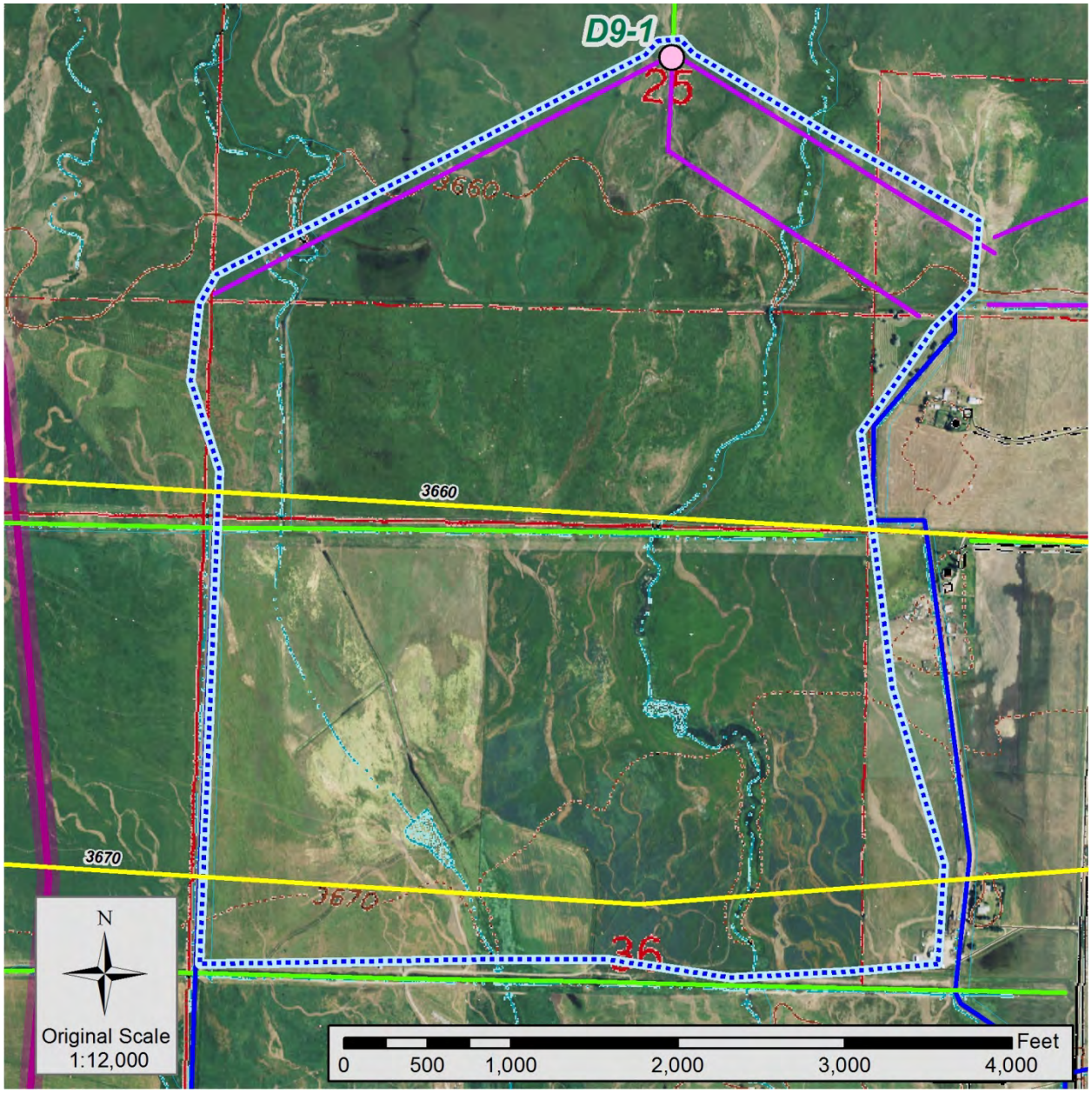


Figure 6-105 – Subwatershed Contributing Area for D9-1 Drain.
Ground water flow contours at 10' interval, with flow to the north.

6.7 Summary of Drain Loading

The tile drains represent an efficient mechanism to collect near-surface ground water, the receiving waters for nutrient loading from surficial sources. Table 6-47 provides a summary of the loading from all of the drains included with this study, with the exception of Drain D1-2 which was discovered during the reconnaissance sampling program. As potential loading sources, estimates were made of each source in the watershed contributing area for the drains. This included the number of houses as an estimate of the number of septic systems, and the area of irrigated lots as potential fertilizer sources; and the estimated number of acres of irrigated agriculture. From the data, several observations can be made for the different subwatersheds:

East North Hills - The D0 and D1 Drains discharge directly into Lake Helena, with much agriculture in watershed areas. Nitrate loading is higher for the D1-1 Drain area, which is larger than the contributing area for D0-1. Phosphorus loading is similar for both. For the D0-1 Drain, the greater phosphorus loading from a smaller contributing area is attributed to the greater number of houses and septic systems present. Given land use, agricultural fertilizers are considered the primary source of nutrients for these drains. Note there is no data for the D4 and D5 Drains, which may have a greater contribution from septic systems given landuse in their watershed contributing areas.

West North Hills – The D2.2-1 Drain receives recharge from the downgradient end of this subwatershed area. The contributing area includes irrigated agriculture as well as septic systems at varying densities. The presence of agricultural lands, and the much lower loading numbers for other Drains in the D2.2 Ditch system, suggests that agriculture is the primary source of nutrients.

Lower Silver Creek – The D2 drain dominates the Silver Creek subwatershed, with the actual D2 Drain constructed in the former main bed of Silver Creek as it approaches Lake Helena. The upgradient D2 Drains, and the downgradient D2.2 Drains both show similar loading numbers. Land use for the upgradient D2 Drains includes both houses and irrigated agriculture, with both representing nutrient sources to the system. Land use in the D2.2 Drains is primarily agricultural, with a limited number of septic systems.

Lower Tenmile Creek – The D2.1 Ditch collects water from this subwatershed, and discharges it into the D2 Drain. The D2.1 Ditch shows relatively high loading rates for the upgradient drain, with rates increasing downgradient. While land use is primarily agricultural, a large number of houses are present in the upgradient recharge area. The nutrient sources are attributed to primarily septic systems with some agricultural loading, given the number of houses in the upgradient areas.

Lower Prickly Pear Creek – the D8 Drains collect primarily irrigation return flows, with relatively low loading rates for this area. Primarily agricultural land use is attributed as the nutrient source. The lagoons from the Montana Law Enforcement Academy wastewater treatment system are not considered likely to be a significant source of nutrients to the system, based on data from Drain D8-1.

East Helena Valley – The D6 and D7 Ditches are installed in an area with a strong upward vertical gradient, in primarily agricultural lands. The D6 drains have low loading rates, with primarily agriculture as the nutrient source. The D7 ditch has primarily agricultural lands; however, a golf course is located further upgradient and may represent a source for high phosphate detected here. Note that agricultural lands include large areas used for cattle grazing, as manure may be a greater source than fertilizer use.

Table 6-47 Summary of Nutrient Loading Estimates for Individual Drains

	Estimated # Houses/ # Septic Systems	Avg Lot Size Acres	Avg Lawn Size Acres	Est. Irrig Ag Acres	Est Total Acres	Total Nitrogen lbs/yr	Total Nitrogen tons/yr	Total Phosphorus lbs/yr	Total Phosphorus tons/yr
D0-1	12	10	1	230	325	3068	1.53	45.83	0.023
D1-1	5	5	1	370	500	6053	3.03	50.2	0.025
D1-2	Drainshed/source unknown								
D2-1	6	10	1	40	200	1860	0.93	32.96	0.016
D2-2	20	5	1	15	260	1480	0.74	13.1	0.007
D2-3	65	1	1	240	980	--	--	--	--
D2-4	60	0.5	0.5	60	205	2994	1.5	26.49	0.013
D2-5	12	10	2	30	200	672	0.34	12.36	0.006
D2.2-1	18	5	1	200	650	5555	2.78	41.81	0.021
D2.2-2	--	--	--	--	--	--	--	--	--
D2.2-3	0	--	--	80	90	584	0.29	10.39	0.005
D2.2-4	1	--	--	300	390	2532	1.27	45.03	0.023
D2.2-5	1	--	4	60	110	1060	0.53	7.36	0.004
D2.2-6	1	--	--	80	100	964	0.48	6.69	0.003
D2-6	1	--	--	200	420	373	0.19	12.12	0.006
D2.1-1	50	0.5	0.5	200	580	8153	4.08	70.84	0.035
D2.1-2	2	--	--	180	320	4551	2.28	44.60	0.022
D2.1-3	3	--	--	200	280	2259	1.13	41.98	0.021
D3-1	70	0.5	0.5	90	620	5595	2.80	41.91	0.021
D3-2	1	--	--	30	140	9821	4.91	44.30	0.022
D3-3	1	--	--	350	470	2049	1.02	77.37	0.039
D3-4a	3	--	--	0	90	6314	3.16	28.48	0.014
D3-4b	0	--	--	0	80	5612	2.81	25.31	0.013
D4-1	3	20	1	140	310	3753	1.88	31.12	0.023
LH-1	9	10	1	0	110	1038	0.52	15.51	0.008
D5-1	15	5	1	0	150	1416	0.71	21.15	0.011
LH-2	16	2.5	0.5	0	90	850	0.42	12.69	0.006
D6-1	4	1	0.5	80	110	1839	0.92	169.58	0.085
D6-2	1	--	--	25	30	882	0.44	33.51	0.017
D7-1	0	--	--	60	80	2092	1.05	191.25	0.096
D7-2	8	2.5	1	50	190	4969	2.48	454.22	0.227
D7-3	0	--	--	0	35	915	0.46	83.67	0.042
D8-1	1	--	--	35	90	680	0.34	25.41	0.013
D8.1-1	1	--	--	70	110	831	0.42	31.06	0.016
D8-2	3	--	--	110	220	1662	0.83	62.11	0.031
D8-3	1	--	--	70	120	907	0.45	33.88	0.017
D9-1	--	--	--	0	480	3627	1.81	135.52	0.068
					TOTALS	**97009**	**48.52**	**1979.8**	**0.998**

7.0 Ground Water Assessment

The ground water sampling program incorporated sampling selected monitoring wells and private potable water wells for nutrients, and using this dataset to build upon existing water quality data for the study area. The objective of the ground water sampling, following this objectives of this study, were to obtain data to help differentiate between non-points sources of nutrient pollution to ground water. For this study, the primary sources represent agricultural fertilizers and manure, and from septic systems. The ground water assessment focuses on the upgradient areas from the Helena Valley Aquifer, in the general area outside of the main Helena Valley Irrigation Canal. The ground water assessment addresses each of the subwatershed areas separately, supplementing the information obtained from the drain sampling program. The well sampling program was implemented in several phases during the project. The sampling program was designed to supplement existing data collected during recent studies in the Helena are (Waren et al., 2013; Swierc, 2013; Bobst et al., 2014).

The sampling program design included utilization of the mass ratio of chloride to bromide as a tool to help differentiate between sources of nutrients to ground water. This approach had previously been incorporated into the sampling program for LCWQPD studies (Swierc, 2013). Unfortunately, the previous dataset for Bromide utilized a high detection limit of 0.5 mg/L, where the majority of sample results were reported as non-detect. For this study, the detection limit was lowered to 0.05 mg/L in collaboration with the project laboratory (Energy Laboratories, Inc.). In response to the variability in the bromide results from the initial drain samples (Section 6.0), the contract laboratory analyst agreed to review previous results to report detections below reporting levels, as well as the method detection limits determined for each set of analyses. This resulted in a much more complete dataset from previous LCWQPD monitoring, providing much more baseline data than previously existed. As a result, the ground water sampling program was re-focused to include confirmation samples collected under different climate conditions from previous samples, and for samples to be collected from areas with limited data. The entire ground water characterization dataset for this study, comprising nutrient data with chloride ***and*** bromide data, is listed in Table 7-1.

During the first year (2013), sampling focused on selected shallow monitoring wells, and private wells previously identified with existing data as having elevated nitrate levels. During the second year (2014), sampling focused on private potable water wells in areas with elevated nitrate to address data gaps due to limited data in these areas. The program included two focused sampling efforts. First, two wells were sampled twice in March before irrigation season, and again in May after the start of irrigation season, to look at the potential response from infiltration of natural precipitation and snowmelt in March 2014. Second, the samples were collected from relatively deep wells installed into Tertiary strata on the East Bench area, to assess natural background sources for halogens. The sample locations are depicted in Figure 7-1. A total of 64 ground water samples were collected specifically for this study during seven sample events.

Ground Water Assessment Technical Approach

The impact to ground water quality requires several steps to understand the fate and transport of nutrients that are released to the system. Nutrients released from the surface, or near the surface, enter the system through the unsaturated zone. Percolation through the unsaturated zone generally occurs as “piston-flow,” where infiltrating waters displace existing water in pores by pushing them vertically downward. Percolation only occurs when additional waters are added to the system. Water in pores near the surface is available to plants for growth. Water that percolates below the root zone is

Table 7-1 Monitoring Well and Potable Well Ground Water Assessment Dataset

MBMG GWIC Identification	Total Depth	Sample Date	Data Source	Solids, Total Dissolved TDS @ 180°C, mg/L	Bicarbonate as HCO_3	Cl	SO_4	Br	NO_3+NO_2 as N	N-Total	Phosphorus, Ortho-phosphate as P	Phosphorus, Total as P	Cl/Br ratio
	ft				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
East North Hills													
148259	350	27-Sep-13	This Study	295	150	17	60	0.120	1.41		0.026	0.016	142
148259	350	12-May-14	This Study	309	142	15	52	0.050	1.35			0.007	300
148259	350	12-May-14	This Study	313	141	15	52	0.050	1.35			0.007	300
148259	350	29-Aug-14	This Study	309	140	15	54	0.110	1.08			0.014	136
257064	51	19-Aug-10	MBMG		261	21	85	0.125	0.967	1.45	<0.1		170
257064	51	20-Oct-10	MBMG		234	21	89	0.118	1.21	1.4	<0.1		181
257064	51	18-Aug-11	HGWP	358	250	22	84	0.102	1.29	2.2	0.021	0.01	215
257064	51	14-Nov-11	HGWP	370	250	18	83	<0.5	1.3	1.5	0.012	0.029	
64774	420	14-Apr-10	MBMG		168	19	110	0.142	<0.5		<0.05		137
64774	420	18-Aug-10	MBMG		171	19	110	0.155	0.518	<1.0	<0.1		125
64774	420	6-Oct-10	MBMG		170	19	111	0.150	0.511	<1.0	<0.1		129
64798	85	7-Apr-10	MBMG		171	10	34	0.054	0.37		<0.05		193
64798	85	17-Aug-10	MBMG		189	10	34	0.064	0.158	<1.0	<0.1		163
64798	85	6-Oct-10	MBMG		180	10	33	< 0.05	0.135	<1.0	<0.1		
128054	390	6-Apr-10	MBMG		139	23	77	0.174	1.75		<0.05		132
128054	390	18-Aug-10	MBMG		155	22	72	0.168	1.76	2.47	<0.1		131
128054	390	6-Oct-10	MBMG		140	21	72	0.163	1.75	2.2	<0.1		131
144725	192	6-Apr-10	MBMG		105	32	122	0.216	<0.5		<0.05		149
144725	192	18-Aug-10	MBMG		187	31	121	0.212	0.49	<1.0	<0.1		147
144725	192	6-Oct-10	MBMG		178	31	118	0.197	0.484	<1.0	<0.1		158
144726	240	6-Apr-10	MBMG		179	35	73	0.227	1.49		<0.05		153
144726	240	16-Apr-10	MBMG		185	22	75	0.157	2.97		<0.05		138
144726	240	17-Aug-10	MBMG		188	20	72	0.148	1.97	2.58	<0.1		133
144726	240	5-Oct-10	MBMG		172	23	73	0.170	1.93	2.23	<0.1		138
145957	115	6-Apr-10	MBMG		213	24	111	0.672	0.639		<0.05		35
145957	115	17-Aug-10	MBMG		227	39	169	0.203	0.987	1.33	<0.1		194
145957	115	5-Oct-10	MBMG		212	26	121	0.155	0.73	1.22	<0.1		165
176010	259	6-Apr-10	MBMG		192	32	93	0.215	0.728		<0.05		149
176010	259	17-Aug-10	MBMG		207	34	87	0.213	0.778	<1.0	<0.1		158
176010	259	6-Oct-10	MBMG		185	34	87	0.211	0.77	<1.0	<0.1		160
178386	98	6-Apr-10	MBMG		172	26	109	0.187	<0.5		<0.05		138
178386	98	18-Aug-10	MBMG		197	39	134	0.248	0.676	1.64	<0.1		158
178386	98	6-Oct-10	MBMG		177	33	125	0.205	0.83	1.25	<0.1		159
West North Hills													
143645	174	30-Aug-13	This Study	255	170	25	56	0.140	1.89	1.91	0.025	0.019	179
180976	370	7-May-13	This Study	293	280	26	27	0.060	2.15	1.98	0.01	0.006	433
180976	370	22-Aug-13	This Study	440	290	94	43	0.140	4.16			0.006	671
180976	370	22-Aug-13	This Study	374	290	75	43	0.120	3.83			0.005	625
191532	100	18-Aug-11	HGWP	216	210	8	15	0.054	1.08	1.12	0.022	0.017	148
191532	100	14-Nov-11	HGWP	216	210	6	14	<0.5	0.95	1.11	0.013	0.038	
191532	100	21-Aug-13	This Study	220		16	19	0.130	1.22			0.052	123
206026	200	30-Aug-13	This Study	457	240	62	120	0.270	2.69	2.78	0.011	0.007	230
258294	350	12-Jun-14	This Study	241	240	3	10	< 0.01	0.42	0.53	0.055	0.073	
258401	255	20-Jun-14	This Study	262	240	3	28	< 0.01	0.51	0.63		0.011	
Sawbuck		2-May-12	HGWP	587	390	100	33	0.220	8.4	8.3	0.018	0.01	455
64730	170	14-Apr-10	MBMG		203	8	18	0.065	0.847		<0.05		115
64730	170	18-Aug-10	MBMG		197	7	17	0.073	0.837	1.76	<0.1		96
64730	170	5-Oct-10	MBMG		200	7	18	0.072	0.828	1.07	<0.1		98
138527	356	14-Apr-10	MBMG		332	10	44	0.076	<0.5		<0.05		133
138527	356	20-Aug-10	MBMG		319	10	45	0.119	0.221	<1.0	<0.1		83
138527	356	7-Oct-10	MBMG		326	9	43	0.083	0.182	<1.0	<0.1		111

MBMG GWIC Identification	Total Depth ft	Sample Date	Data Source	Solids, Total Dissolved TDS @ 180°C, mg/L	Bicarbonate as HCO_3 mg/L	Cl mg/L	SO_4 mg/L	Br mg/L	NO_3+NO_2 as N mg/L	N-Total mg/L	Phosphorus, Ortho-phosphate as P mg/L	Phosphorus, Total as P mg/L	Cl/Br ratio
West North Hills (continued)													
143645	174	21-Aug-10	MBMG		150	23	44	0.184	2.12	1.93	<0.1		125
143645	174	5-Oct-10	MBMG		154	24	46	0.171	2.09	1.95	<0.1		143
152551	170	16-Apr-10	MBMG		169	136	27	0.205	3.22		<0.05		662
152551	170	20-Aug-10	MBMG		167	133	27	0.231	3.65	3.49	<0.1		576
152551	170	30-Sep-10	MBMG		182	134	27	0.220	3.52	6.75	<0.1		608
180976	370	7-Apr-10	MBMG		262	84	32	0.110	3.79		<0.05		762
180976	370	7-Apr-10	MBMG		267	97	33	0.113	<0.5		<0.05		860
180976	370	21-Aug-10	MBMG		269	93	31	0.119	4.2	4.63	<0.1		784
180976	370	30-Sep-10	MBMG		285	84	31	0.108	3.74	3.92	<0.1		779
187438	120	7-Apr-10	MBMG		341	39	77	0.113	10.21		<0.05		345
187438	120	20-Aug-10	MBMG		332	40	66	0.117	4.16	4.47	<0.1		340
187438	120	5-Oct-10	MBMG		334	40	63	0.110	4.22	4.33	<0.1		367
191532	100	15-Apr-10	MBMG		198	8	19	0.067	0.968		<0.05		112
191532	100	19-Aug-10	MBMG		186	7	18	0.080	0.974	1.93	<0.1		90
191532	100	20-Oct-10	MBMG		203	8	19	0.074	0.981	<1.0	<0.1		101
194435	57	7-Apr-10	MBMG		210	3	24	< 0.05	0.565		<0.05		
194435	57	18-Aug-10	MBMG		200	2	24	0.053	0.495	<1.0	<0.1		46
194435	57	30-Sep-10	MBMG		217	2	24	0.052	0.469	<1.0	<0.1		47
198749	340	16-Apr-10	MBMG		242	9	30	0.073	5.2		<0.05		128
198749	340	21-Aug-10	MBMG		245	8	28	0.081	3.31	3.68	<0.1		99
198749	340	30-Sep-10	MBMG		246	8	28	0.078	4.03	3.9	<0.1		107
202175	98	14-Apr-10	MBMG		223	8	30	< 0.05	1.21		<0.05		
202175	98	18-Aug-10	MBMG		227	8	29	0.068	1.27	1.86	<0.1		114
202175	98	5-Oct-10	MBMG		227	8	29	< 0.05	1.27	1.4	<0.1		
206026	200	14-Apr-10	MBMG		207	118	220	0.296	4.08		<0.05		399
206026	200	20-Aug-10	MBMG		220	66	121	0.214	2.9	3.3	<0.1		308
206026	200	30-Sep-10	MBMG		241	98	166	0.262	4.18	5.65	<0.1		372
206393	177	14-Apr-10	MBMG		227	9	31	0.082	1.34		<0.05		113
206393	177	18-Aug-10	MBMG		217	9	30	0.092	1.42	2.17	<0.1		100
206393	177	5-Oct-10	MBMG		224	9	31	0.090	1.42	1.53	<0.1		104
243352	156	21-Aug-10	MBMG		189	27	52	0.188	2.25	2.51	<0.1		146
243352	156	5-Oct-10	MBMG		190	31	55	0.199	2.43	2.93	<0.1		158
Lower Silver Creek													
191534	100	18-Aug-11	HGWP	432	140	110	80	1.300	3.64	4.4	0.017	0.01	85
191534	100	14-Nov-11	HGWP	482	140	140	69	0.900	4.16	4.2	0.01	0.012	156
191534	100	21-May-13	This Study	488	130	150	85	0.710	4	3.96	0.024	0.009	211
191534	100	21-Aug-13	This Study	514		170	83	0.840	4.46			0.018	202
191537	43	17-Aug-11	HGWP	224	180	9	25	<0.5	0.16	0.25	0.227	0.026	
191537	43	6-Dec-11	HGWP	202	180	7	20	0.090	0.17	0.19	0.024	0.019	78
191537	43	21-Aug-13	This Study	220		15	46	0.080	0.14			0.024	188
191537	43	26-Nov-13	This Study	226		13	35	0.050	0.2			0.766	260
191555	29	17-Aug-11	HGWP	366	330	20	41	0.059	0.62	0.84	0.032	0.025	341
191555	29	15-Nov-11	HGWP	358	330	18	41	<0.5	0.85	1.21	0.024	0.024	
191555	29	1-Aug-13	This Study	422		32		0.100	1.36			0.021	320
191555	29	26-Nov-13	This Study	415		25	59	0.080	1.45			0.017	313
254216	15	5-Jan-12	HGWP	520	490	12	94	0.080	<0.01			0.389	150
254216	15	25-Apr-12	HGWP	566	500	11	110	0.070	<0.01		0.074	0.084	157
254216	15	27-Sep-12	HGWP	540	480	10	110	< 0.06	<0.01			0.079	
254237	23	5-Jan-12	HGWP	395	330	16	100	0.070	0.2			0.013	229
254237	23	25-Apr-12	HGWP	512	430	16	110	0.080	0.34	0.41	0.011	0.014	200
254237	23	27-Sep-12	HGWP	507	450	15	95	0.090	0.05	0.042		0.042	167
257063	58	17-Aug-11	HGWP	420	330	20	61	<0.5	1.64	2.1	0.024	0.179	

MBMG GWIC Identification	Total Depth	Sample Date	Data Source	Solids, Total Dissolved TDS @ 180°C, mg/L	Bicarbonate as HCO_3	Cl	SO_4	Br	NO_3+NO_2 as N	N-Total	Phosphorus, Ortho-phosphate as P	Phosphorus, Total as P	Cl/Br ratio
	ft				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Lower Silver Creek (continued)													
257063	58	15-Nov-11	HGWP	400	330	18	58	<0.5	1.52	2.1	0.02	0.033	
P-D2B-D2	15	29-Dec-11	HGWP	206	140	14	43	0.070	3.05			1.06	200
P-D2B-D2	15	26-Apr-12	HGWP	250	160	17	50	0.070	1.85	1.65	0.005	0.02	243
P-D2B-D2	15	26-Sep-12	HGWP	269	220	17	43	< 0.06	2.24			0.697	
278687	--	2-May-12	HGWP	361	260	16	51	<0.5	8.6	8.5	0.022	0.017	
278687	--	7-May-13	This Study	356	260	16	63	0.025	6.49	6.72	0.023	0.018	640
278687	--	21-Aug-13	This Study	352		17	74	0.090	6.1			0.019	189
278687	--	4-Mar-14	This Study	387	290	15	75	0.080	4.8			0.018	188
278687	--	26-Mar-14	This Study	384		15	70	0.060	4.6			0.019	250
278687	--	13-May-14	This Study	391		13	69	0.020	4.58			0.023	650
278687	--	2-Sep-14	This Study	399	280	13	68	0.030	4.61			0.015	433
Masonic Home Rd	--	29-Aug-14	This Study	313	240	14	40	0.080	2.62			0.013	175
65316	97	6-Apr-10	MBMG		388	16	100	0.083	1.36		<0.05		190
65316	97	12-Aug-10	MBMG		429	20	160	0.097	0.428	<1.0	<0.05		205
65316	97	7-Oct-10	MBMG		445	19	156	0.101	0.477	<1.0	<0.1		184
65536	200	16-Apr-10	MBMG		273	27	57	0.092	8.94		<0.05		297
65536	200	10-Aug-10	MBMG		256	31	64	0.100	10.82	11.7	<0.05		311
65536	200	6-Oct-10	MBMG		260	32	70	0.103	10.62	11.1	<0.1		306
147289	70	10-Aug-10	MBMG		197	11	40	0.058	0.296	1.53	<0.05		190
147289	70	6-Oct-10	MBMG		199	11	40	< 0.05	0.302	<1.0	<0.1		
147289	70	6-Oct-10	MBMG		199	11	40	< 0.05	0.302	<1.0	<0.1		
191534	100	22-Aug-02	MBMG		142	78	99	0.460	3.7		<0.05		169
191534	100	19-Aug-10	MBMG		119	106	86	0.538	3.76	4.88	<0.1		197
191534	100	20-Oct-10	MBMG		129	131	79	0.643	3.96	4.78	<0.1		204
191537	43	19-Aug-10	MBMG		165	10	33	0.066	0.178	<1.0	<0.1		149
191537	43	20-Oct-10	MBMG		162	9	33	< 0.05	0.16	<1.0	<0.1		
191555	29	15-Apr-10	MBMG		344	23	56	0.069	1.47		<0.05		337
191555	29	19-Aug-10	MBMG		351	28	77	0.093	1.89	2.74	<0.1		304
191555	29	20-Oct-10	MBMG		346	24	65	< 0.05	1.72	1.92	<0.1		
254703	144	16-Apr-10	MBMG		161	86	83	0.319	12.96		<0.05		271
254703	144	10-Aug-10	MBMG		152	86	80	0.322	13.53	14.6	<0.05		267
254703	144	6-Oct-10	MBMG		148	97	88	0.359	14.36	15.7	<0.1		270
257063	60	19-Aug-10	MBMG		305	16	65	0.074	1.21	1.82	<0.1		210
257063	60	20-Oct-10	MBMG		292	15	65	0.069	0.892	1.59	<0.1		222
Middle Silver Creek													
135317	300	6-Apr-10	MBMG		316	22	96	0.140	<0.5		<0.05		
135317	300	11-Aug-10	MBMG		350	30	119	0.160	1.18	1.57	<0.05		
135317	300	7-Oct-10	MBMG		360	30	115	0.157	1.13	1.06	<0.1		
227906	49	16-Apr-10	MBMG		385	14	130	0.098	0.569		<0.05		
227906	49	12-Aug-10	MBMG		349	14	125	0.100	<0.05	1.61	<0.05		
227906	49	7-Oct-10	MBMG		406	14	125	0.104	0.573	<1.0	<0.1		
Lower Tenmile Creek													
5756	66	31-May-12	HGWP	482	210	32	93	??	4.11	4.17	0.017	0.029	
5756	66	7-May-13	This Study	582	370	41	120	0.043	5.66	6.08	0.013	0.015	953
5756	66	22-Aug-13	This Study	526	500	29	100	0.110	3.68			0.012	264
5756	66	4-Mar-14	This Study	585	380	43	140	0.150	5.4			0.005	287
5756	66	26-Mar-14	This Study	580		41	130	0.050	4.7			0.011	820
5756	66	12-May-14	This Study	594		41	130	0.020	5.2			0.006	2050
5756	66	29-Aug-14	This Study	525	400	21	100	< 0.01	1.58			0.011	
191524	25	30-Aug-11	HGWP	376	310	18	47	0.046	1.28	1.34	0.027	0.02	391
191524	25	17-Nov-11	HGWP	318	290	16	43	0.046	1.29	1.38	0.026	0.025	350
191525	50	30-Aug-11	HGWP	360	310	19	42	<0.5	2.05	2.5	0.034	0.039	

MBMG GWIC Identification	Total Depth	Sample Date	Data Source		Solids, Total Dissolved TDS @ 180°C, mg/L	Bicarbonate as HCO_3	Cl	SO_4	Br	NO_3+NO_2 as N	N-Total	Phosphorus, Ortho-phosphate as P	Phosphorus, Total as P	Cl/Br ratio
	ft					mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Lower Tenmile Creek (continued)														
191525	50	17-Nov-11	HGWP		328	300	17	46	<0.5	2.33	2.6	0.028	0.031	
191525	50	15-May-13	This Study		295	240	20	51	<0.05	2.25	2.2	0.031	0.035	
191525	50	2-Aug-13	This Study		328	270	21		0.060	1.87			0.025	350
191525	50	26-Nov-13	This Study		329		21	54	0.050	1.87			0.021	420
P-T4	11	29-Dec-11	HGWP	#	296	140	18	100	0.040	0.22			0.246	450
P-T4	11	26-Apr-12	HGWP		166	110	8	19	< 0.07	0.13	0.29	0.021	0.061	
P-T4	11	27-Sep-12	HGWP		176	140	11	24	< 0.06	0.1			0.014	
P-T6	9	30-Dec-11	HGWP	#	274	200	14	45	< 0.04	0.43			0.576	
P-T6	9	26-Apr-12	HGWP		238	180	6	18	< 0.07	0.03	0.38	0.075	0.09	
P-T6	9	27-Sep-12	HGWP		197	160	8	23	< 0.06	<0.01			0.054	
Myrl Rd	--	29-May-12	HGWP		275	220	14	41	<0.5	2.15	2.47	0.022	0.019	
Sun Valley	--	29-May-12	HGWP		345	250	31	60	<0.5	5.25	5.16	0.022	0.019	
278709	--	30-Jul-13	This Study		262	190	16	47	0.043	2.61	2.68	0.035	0.024	372
278709	--	12-May-14	This Study		280		16	41	0.010	2.56			0.021	1600
278709	--	2-Sep-14	This Study		276	180	16	39	0.010	2.9			0.022	1600
61368	--	14-Apr-10	MBMG			177	14	45	0.062	2.94		<0.05		233
61368	--	11-Aug-10	MBMG			168	14	43	0.056	1.8	2.55	<0.05		248
61368	--	7-Oct-10	MBMG			179	14	41	< 0.05	1.91	2.19	<0.1		
62471	120	10-Aug-10	MBMG			519	19	184	0.068	0.253	0.789	<0.05		274
62471	120	6-Oct-10	MBMG			566	19	190	0.078	0.148	<1.0	<0.1		242
62523	50	24-May-05	MBMG			298	5	38	< 0.05	<0.5		<0.05		
62523	50	7-Apr-10	MBMG			299	6	41	0.051	<0.5		<0.05		108
62523	50	10-Aug-10	MBMG			286	5	40	< 0.05	0.149	<1.0	<0.05		
62523	50	6-Oct-10	MBMG			294	5	39	< 0.05	0.197	<1.0	<0.1		
65088	52	15-Apr-10	MBMG			271	16	64	0.059	1.58		<0.05		267
65088	52	12-Aug-10	MBMG			269	16	63	0.059	1.6	2.45	<0.05		263
65088	52	6-Oct-10	MBMG			263	15	62	< 0.05	1.64	1.74	<0.1		
Middle Tenmile Creek														
191539	19	17-Aug-11	HGWP		396	260	28	73	0.075	2.12	2.2	0.022	0.014	375
191539	19	15-Nov-11	HGWP		426	250	29	83	0.040	1.93	2	0.011	0.055	718
191539	19	1-May-13	This Study		485	300	43	110	0.086	2.89	3.11	0.014	0.019	501
191539	19	1-Aug-13	This Study		498		43		0.140	2.9			0.008	307
191539	19	27-Nov-13	This Study		522		48	120	0.140	1.76			0.009	343
P-T24	12	29-Dec-11	HGWP	#	188	95	10	9	< 0.04	<0.01			0.363	
P-T24	12	27-Apr-12	HGWP		196	130	13	32	< 0.07	0.2	0.26	0.15	0.274	
P-T24	12	26-Sep-12	HGWP		141	110	5	12	< 0.06	<0.01			0.041	
Grizzly Gulch														
61923	57	9-May-14	This Study		558		24	89	0.040	9.38			0.016	600
61923	57	29-Aug-14	This Study		571	380	28	92	0.100	7.3			0.017	280
191529	25	2-May-13	This Study		882	510	97	180	0.290	13.3	13.5	0.012	0.008	334
191529	25	21-Aug-13	This Study		826		96	190	0.500	13.2			0.031	192
191529	25	26-Nov-13	This Study		879		100	190	0.680	16			0.025	147
Lower Prickly Pear Creek														
191549	16	30-Aug-11	HGWP		180	140	7	18	<0.5	<0.01	0.15	0.039	0.036	
191549	16	16-Nov-11	HGWP		194	180	8	21	<0.5	<0.01	0.23	0.045	0.045	
191550	47	19-Aug-11	HGWP		246	160	12	48	0.494	0.68	0.72	0.035	0.028	24
191550	47	29-Nov-11	HGWP		232	180	10	49	0.108	0.71	1.26	0.031	0.055	93
191551	19	19-Aug-11	HGWP		312	250	15	50	0.042	1.18	1.37	0.038	0.027	361
191551	19	29-Nov-11	HGWP		234	160	15	42	0.048	1.71	1.76	0.037	0.073	313
191554	61	30-Aug-11	HGWP		242	170	7	36	0.044	1.48	1.54	0.042	0.046	160
191554	61	16-Nov-11	HGWP		214	170	7	37	0.067	1.45	1.53	0.041	0.039	104
193012	34	31-Aug-11	HGWP		268	180	12	51	0.042	0.27	0.36	0.022	0.016	284

MBMG GWIC Identification	Total Depth	Sample Date	Data Source	Solids, Total Dissolved TDS @ 180°C, mg/L	Bicarbonate as HCO_3	Cl	SO_4	Br	NO_3+NO_2 as N	N-Total	Phosphorus, Ortho-phosphate as P	Phosphorus, Total as P	Cl/Br ratio
	ft				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Lower Prickly Pear Creek (continued)													
193012	34	31-Aug-11	HGWP	270	180	12	51	0.045	0.27	0.33	0.022	0.016	270
193012	34	28-Nov-11	HGWP	238	180	13	52	0.050	0.24	0.4	0.03	0.018	262
193012	34	20-Aug-13	This Study	264		15	72	0.080	0.26			0.021	188
193012	34	26-Nov-13	This Study	249		14	54	0.060	0.26			0.016	233
P-P10	11	30-Dec-11	HGWP	124	15	5	23	< 0.04	0.04			1.24	
P-P10	11	26-Apr-12	HGWP	234	140	9	52	< 0.07	0.04	0.81	0.006	0.013	
P-P10	11	27-Sep-12	HGWP	226	95	10	62	< 0.06	0.01			0.008	
P-P12	16	30-Dec-11	HGWP	148	120	8	23	0.050	0.11			2.4	160
P-P12	16	24-Apr-12	HGWP	186	170	10	29	< 0.07	0.19	0.19	0.009	0.039	
P-P12	16	27-Sep-12	HGWP	177	160	8	23	< 0.06	0.01			0.01	
P-P5	10	30-Dec-11	HGWP	208	110	8	56	0.040	0.05			0.13	200
P-P5	10	25-Apr-12	HGWP	182	110	5	42	< 0.07	0.13	0.2	0.018	0.038	
P-P5	10	26-Sep-12	HGWP	232	140	6	56	< 0.06	0.33			0.03	
Rawhide	--	24-May-12	HGWP	188	120	5	37	<0.5	1.51	1.55	0.018	0.021	
191526	46	30-Aug-11	HGWP	266	190	6	44	<0.5	1.19	1.25	0.02	0.014	
191526	46	16-Nov-11	HGWP	240	180	6	44	0.047	1.16	1.37	0.022	0.015	128
191527	18	30-Aug-11	HGWP	450	280	16	110	0.057	0.53	1.05	0.014	0.009	279
191527	18	16-Nov-11	HGWP	398	280	15	100	0.075	0.58	1.04	0.016	0.014	200
191531	121	16-Aug-11	HGWP	702	210	75	250	0.643	4.23	4.6	0.028	0.025	117
191531	121	17-Nov-11	HGWP	682	210	68	250	0.716	4.25	5.2	0.026	0.024	95
191533	121	31-Aug-11	HGWP	442	190	31	110	0.198	1.73	1.78	0.02	0.013	157
191533	121	28-Nov-11	HGWP	414	190	33	110	0.278	1.69	1.95	0.021	0.009	119
191535	55	31-Aug-11	HGWP	1560	460	180	530	0.977	4.97	5.7	0.025	0.015	184
191535	55	28-Nov-11	HGWP	1550	460	170	570	1.200	5.32	7.3	0.042	0.014	142
191535	55	15-May-13	This Study	1650	430	180	650	0.990	6.24	6.04	0.045	0.018	182
191535	55	20-Aug-13	This Study	1560		180	640	1.300	6.07			0.022	138
191538	80	31-Aug-11	HGWP	246	180	13	35	0.047	0.3	0.32	0.012	0.005	279
191538	80	28-Nov-11	HGWP	212	180	13	37	0.060	0.32	0.51	0.018	0.011	217
191540	61	16-Aug-11	HGWP	628	270	82	160	0.506	7.2	7.6	0.031	0.027	162
191540	61	17-Nov-11	HGWP	606	260	81	160	0.600	5.18	5.7	0.029	0.026	135
191540	61	21-May-13	This Study	606	270	81	160	0.570	4.54	4.42	0.023	0.025	142
191540	61	21-Aug-13	This Study	596		83	160	0.700	5.1			0.022	119
East Helena Valley													
88214	25	19-Jul-11	HGWP	238	170	15	32	0.077	1.47	1.52	0.04	0.057	195
88214	25	29-Nov-11	HGWP	228	160	15	41	0.083	1.66	1.86	0.039	0.098	181
88213	104	20-Jul-11	HGWP	172	130	22	45	0.294	1.05	1.13	0.025	0.025	75
88213	104	29-Nov-11	HGWP	226	130	23	53	0.259	0.99	1.29	0.028	0.022	89
123550	78	19-Jul-11	HGWP	228	120	9	84	0.900	0.62	0.62	0.018	0.02	10
123550	78	29-Nov-11	HGWP	256	120	10	94	0.900	0.66	1.18	0.023	0.121	11
892201	21	20-Jul-11	HGWP	226	190	10	22	0.057	0.16			0.048	
191530	56	19-Aug-11	HGWP	608	110	130	190	1.500	5.7	6.2	0.022	0.014	87
191530	56	17-Nov-11	HGWP	572	110	110	180	0.800	5.6	6.2	0.017	0.011	138
191530	56	17-Nov-11	HGWP	574	110	110	190	0.352	5.81	6.2	0.017	0.014	313
191530	56	15-May-13	This Study	602	100	110	160	0.660	6.57	5.84	0.033	0.019	167
191530	56	2-Aug-13	This Study	587	120	110		0.600	5.9			0.012	183
191530	56	27-Nov-13	This Study	589		110	170	0.980	7.2			0.009	112
191536	70	18-Aug-11	HGWP	336	150	22	78	<0.5	9.7	10.6	0.031	0.022	
191536	70	29-Nov-11	HGWP	298	140	20	76	0.076	8.4	9.1	0.027	0.037	265
191536	70	15-May-13	This Study	323	130	21	78	<0.05	9.68	9.28	0.028	0.025	
191536	70	2-Aug-13	This Study	324	150	23		0.050	9.4		0.025	0.025	460
191536	70	27-Nov-13	This Study	333		22	85	0.070	9.7			0.022	314
191548	136	18-Aug-11	HGWP	304	170	18	79	0.114	1.27	1.45	0.025	0.017	158

MBMG GWIC Identification	Total Depth	Sample Date	Data Source	Solids, Total Dissolved TDS @ 180°C, mg/L	Bicarbonate as HCO_3	Cl	SO_4	Br	NO_3+NO_2 as N	N-Total	Phosphorus, Ortho-phosphate as P	Phosphorus, Total as P	Cl/Br ratio
	ft				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
East Helena Valley (continued)													
191548	136	6-Dec-11	HGWP	310	170	17	75	0.121	1.15	1.12	0.018	0.015	140
224230	80	18-Feb-14	This Study	291	250	10	35	0.010	0.75	0.36	<0.001	0.045	1000
202169	100	9-Apr-14	This Study	305		17	42	< 0.01	0.77	0.89		0.02	
202169	100	29-Aug-14	This Study	292	180	15	34	0.080	0.48			0.018	188
214268	400	18-Sep-12	HGWP	809	180	43	410	0.236	<0.01			0.007	182
214268	400	9-Apr-14	This Study	870		45	430	0.650					69
244157	245	18-Sep-12	HGWP	617	200	29	280	0.142	0.01			0.011	204
258900	600	18-Sep-12	HGWP	537	220	33	200	0.189	<0.01			0.004	175
247915	325	10-Apr-14	This Study	741		40	330	0.490	<0.01	<0.04		0.007	82
268597	720	10-Apr-14	This Study	571	303	52	120	0.440	<0.01	0.22		0.007	118
276039	540	10-Apr-14	This Study	852		42	440	0.440	<0.01	<0.04		0.009	95
248549	75	10-May-13	This Study	307	160	15	83	0.220	5.48	5.86	0.021	0.031	68
248549	75	29-Aug-13	This Study	327		17	89	0.290	5.14			0.021	59
248550	78	10-May-13	This Study	296	160	13	76	<0.05	5.28	5.82	0.032	0.029	
248550	78	29-Aug-13	This Study	321		17	83	0.060	5.42			0.027	283
Sevenmile Creek													
191557	80	31-Aug-11	HGWP	340	300	6	41	0.043	<0.01	0.09	0.032	0.064	140
191557	80	16-Nov-11	HGWP	302	310	6	46	0.046	<0.01	0.08	0.038	0.84	131
255141	17	4-Jan-12	HGWP	418	320	14	97	0.080	<0.01			0.018	175
255141	17	27-Apr-12	HGWP	452	330	15	100	0.080	<0.01	<0.05	0.018	0.026	188
255141	17	27-Sep-12	HGWP	465	330	19	110	< 0.06	0.1			0.032	
255143	14	4-Jan-12	HGWP	494	510	20	45	0.100	<0.01			0.206	200
255143	14	27-Apr-12	HGWP	504	500	21	51	0.070	<0.01	0.43	0.163	0.179	300
255143	14	27-Sep-12	HGWP	457	470	16	34	0.080	<0.01			0.162	200
65541	200	15-Apr-10	MBMG		229	8	46	0.065	0.516		<0.05		115
65541	200	11-Aug-10	MBMG		224	7	45	0.062	0.475	0.773	<0.05		117
65541	200	5-Oct-10	MBMG		240	7	45	0.072	0.463	<1.0	<0.1		99
123839	201	14-Apr-10	MBMG		343	21	90	0.108	0.799		<0.05		193
123839	201	11-Aug-10	MBMG		363	17	85	0.097	0.457	<1.0	<0.05		180
123839	201	5-Oct-10	MBMG		366	18	85	0.106	0.498	<1.0	<0.1		170
232194	740	15-Apr-10	MBMG		256	5	70	0.104	<0.5		<0.05		44
232194	740	11-Aug-10	MBMG		258	14	63	0.105	0.261	1.06	<0.05		135
232194	740	4-Oct-10	MBMG		260	14	69	0.111	0.286	<1.0	<0.1		129
254740	--	16-Apr-10	MBMG		264	36	217	0.274	9.47		<0.05		132
254740	--	9-Aug-10	MBMG		253	35	218	0.280	<0.05	0.362	<0.05		126
254740	--	4-Oct-10	MBMG		276	35	213	0.263	<0.05	<1.0	<0.1		132
706014	206	14-Apr-10	MBMG		200	3	82	0.051	1		<0.05		61
706014	206	10-Aug-10	MBMG		202	3	82	0.050	<0.05	<1.0	<0.05		62
706014	206	4-Oct-10	MBMG		201	3	84	< 0.05	0.062	<1.0	<0.1		
706039	205	15-Apr-10	MBMG		294	21	118	0.154	1.7		<0.05		135
706039	205	11-Aug-10	MBMG		297	20	118	0.163	<0.05	<1.0	<0.05		124
706039	205	5-Oct-10	MBMG		297	20	119	0.161	<0.05	<1.0	<0.1		125
Scratchgravel Hills													
62369	110	14-May-93	MBMG		205	8	58	0.053	1.97		<.05		149
62369	110	31-May-05	MBMG		419	18	75	< 0.05	9.45		<0.05		
62369	110	15-Apr-10	MBMG		205	8	60	0.077	5.07		<0.05		100
62369	110	9-Aug-10	MBMG		205	9	60	0.078	5.84	6.19	<0.05		115
62369	110	7-Oct-10	MBMG		211	7	58	0.088	4.97	5.71	<0.1		85
62369	110	28-Aug-13	This Study	365	220	16	70	0.070	8.56	9.2	0.023	0.02	229
62369	110	11-Apr-14	This Study	363		12	63	0.040	6			0.019	300
65615	125	15-Apr-10	MBMG		273	81	51	0.089	3.1		<0.05		910
65615	125	9-Aug-10	MBMG		265	76	49	0.088	3.17	3.75	<0.05		859

MBMG GWIC Identification	Total Depth	Sample Date	Data Source	Solids, Total Dissolved TDS @ 180°C, mg/L	Bicarbonate as HCO_3	Cl	SO_4	Br	NO_3+NO_2 as N	N-Total	Phosphorus, Ortho-phosphate as P	Phosphorus, Total as P	Cl/Br ratio
	ft				mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	
Scratchgravel Hills (continued)													
65615	125	5-Oct-10	MBMG		275	86	50	0.097	3.51	3.88	<0.1		882
65615	125	28-Aug-13	This Study	411	300	46	60	0.150	2.54	8.9	0.026	0.024	307
65618	167	14-Apr-10	MBMG		276	18	33	0.061	1.32		0.053		298
65618	167	10-Aug-10	MBMG		249	13	32	0.057	1.07	1.49	<0.05		231
65618	167	5-Oct-10	MBMG		255	11	32	0.069	0.962	1.13	<0.1		159
258347	280	5-Oct-10	MBMG		234	16	65	0.084	7.18	7.5	<0.1		194
257369	400	12-Jun-14	This Study	227	160	3	40	< 0.01	<0.01	<0.04	0.023	0.032	
706001	90	15-Apr-10	MBMG		225	10	59	0.080	6.14		<0.05		126
706001	90	9-Aug-10	MBMG		228	12	65	0.082	10.18	11	<0.05		152
706001	90	4-Oct-10	MBMG		241	12	61	0.085	7.81	7.7	<0.1		139
706055	180	14-Apr-10	MBMG		221	17	45	0.062	1.7		<0.05		280
706055	180	12-Aug-10	MBMG		277	21	44	0.059	2.29	2.86	<0.05		358
706055	180	5-Oct-10	MBMG		288	18	43	0.070	1.75	2.31	<0.1		254
706058	46	14-Apr-10	MBMG		286	7	44	0.055	3.51		<0.05		129
706058	46	9-Aug-10	MBMG		298	7	41	< 0.05	1.94	2.6	<0.05		
706058	46	6-Oct-10	MBMG		312	7	41	< 0.05	2.01	2.53	<0.1		

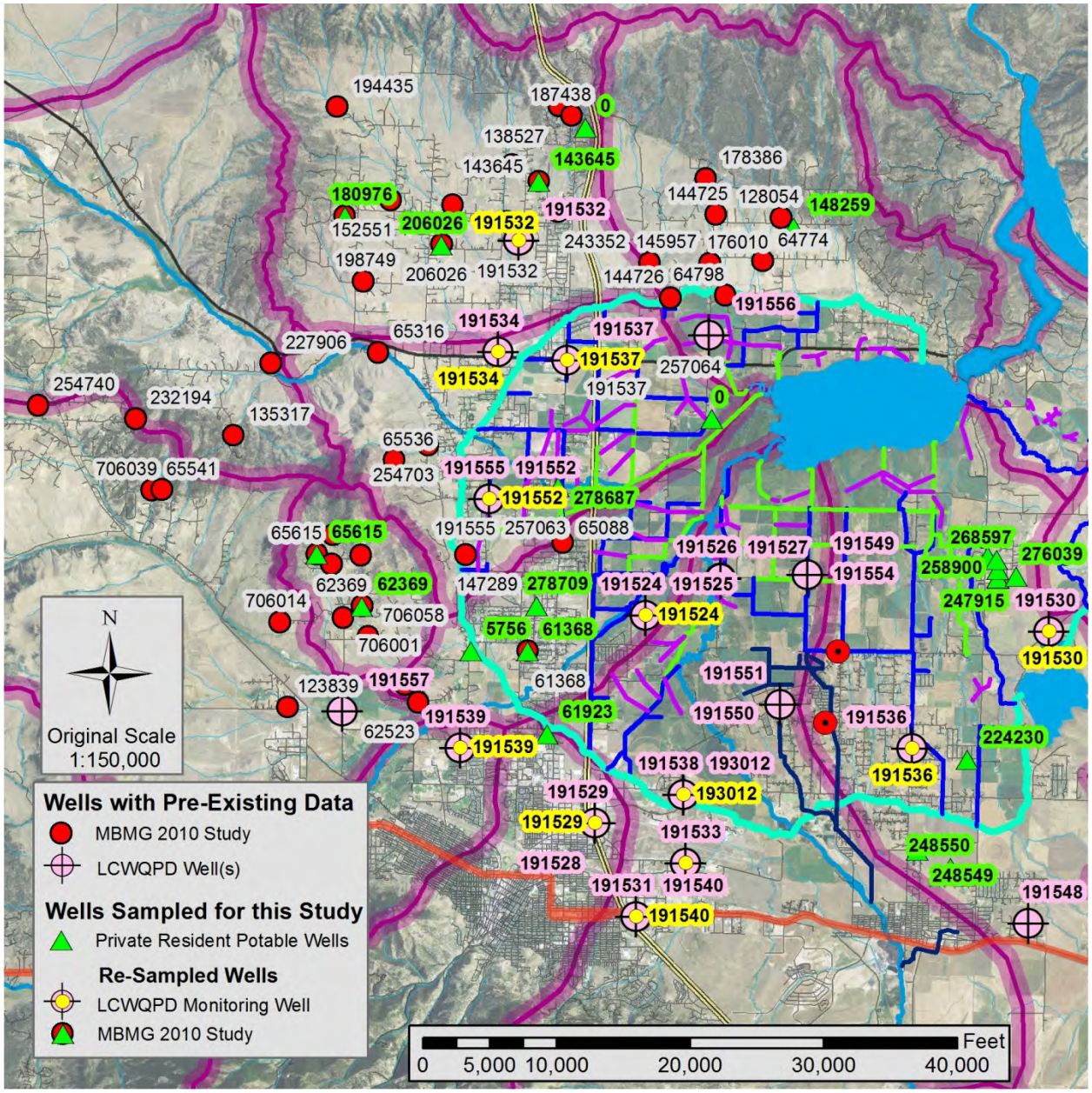


Figure 7-1. Ground Water Well Sampling Locations with MBMG-GWIC Identification Numbers

then stored in pores until further recharge induces further percolation. Pore waters residing within pores below the root zone represents storage within the system. The discharge from septic system drainfields represents a relatively constant loading source to the system. In contrast, agricultural fertilizers represent seasonal loading events, which enter the ground water system at variable rates reflecting irrigation water application rates and the occurrence of local precipitation events. This assessment reviews concentrations within the saturated zone as fate and transport within the unsaturated zone requires additional data outside the scope of work of this project.

Ground water flow models constructed for parts of the Helena Area provide information characterizing the hydrogeologic properties for the local aquifer. The earliest ground water model reviewed the

Helena Valley as a whole, completing a water balance for the area demonstrating that bedrock recharge in the subsurface represents an important component of recharge to the Helena Valley Aquifer (Briar & Madison, 1992). MBMG completed models for the North Hills (Waren et al., 2012) and Scratchgravel Hills (Bobst et al., 2013). As part of the site characterization effort for the East Helena Superfund site, a model was developed for the East Helena Valley and the area where Prickly Pear Creek enters the valley (Newfields, 2014). A review of the models indicate generally consistent properties for the Helena Valley Aquifer; however, the model for the East Helena area shows higher hydraulic conductivities than the other models.

Ground water flow rates were estimated using Darcy's Law for each of the subwatershed areas as listed in Table 7-2. The hydraulic conductivity (K) values were obtained from the models covering the different areas. Effective porosity (n) estimates were obtained from the East Helena area model. The ground water flow gradient estimates were made using the potentiometric surface map for April 2011 constructed for the Helena Area from water levels, and presented for each subwatershed in Section 6.0.

Table 7-2 Ground Water Flow Rate Estimates for Subwatersheds

	K	Gradient Calculation			n	Velocity	
Subwatershed		**Elevation Change**	**Distance**	**Gradient**	**eff**		**K - Data Source**
	ft/day	**ft**	**ft**		**%**	**ft/day**	
East North Hills-Upper	10	200	6000	0.033	0.2	1.7	Waren et al., 2012
East North Hills-Lower	150	50	6000	0.008	0.2	6.3	Waren et al., 2012
West North Hills	10	250	10000	0.025	0.2	1.3	Waren et al., 2012
Lower Silver Creek	150	50	7500	0.007	0.2	5.0	Waren et al., 2012
Lower Tenmile Creek	300	50	14000	0.004	0.2	5.4	Newfields, 2014
Lower Prickly Pear Creek	300	100	22000	0.005	0.2	6.8	Newfields, 2014
East Helena Valley	500	50	11000	0.005	0.2	11.4	Newfields, 2014
Scratchgravel Hills Basin	1	250	5000	0.050	0.2	0.3	Bobst et al., 2013

Nitrogen compounds released into the subsurface are typically converted to nitrate by microorganisms in a process called nitrification. The process requires free oxygen to be present to facilitate the process. Ground waters in the Helena Area consistently show dissolved oxygen levels consistently exceeding 50% saturation in ground water samples. As a result, it is assumed that nitrification of nitrogen compounds occurs efficiently and completely in local ground waters, noting that there are local exceptions. Confirmation of the nitrification process can be evaluated by comparing total nitrogen results to nitrate data. All of the Helena area ground water data for total nitrogen and nitrate are compared in Figure 7-2. The data show that LCWQPD monitoring well samples consistently show nitrate levels exceeding total nitrogen results. The trend is not present in MBMG sample results. While there are a few exceptions, there is a close correlation of total nitrogen to nitrate results. These data confirm that nitrification is occurring for all nitrogen compounds.

The efficiency of the nitrification process can be evaluated by comparing the ratio of nitrate to total nitrogen. The ratio approaches one as all nitrogen is converted to nitrate. Variability in analytical methods results in nitrate concentrations exceeding total nitrogen results. An overview of the nitrate and total nitrogen data from Table 7-1 is presented in Table 7-3, with statistical summaries of the data

results for the detection in each subwatershed. The table includes data on the ratio between nitrate nitrogen and total nitrogen for sample sets. The entire dataset contains 332 samples for nitrate, 206 samples for total nitrogen, and 163 sample sets yielding a ratio between nitrate and total nitrogen. A comparison of nitrate concentrations with the efficiency ratio for samples is presented in Figure 7-3. The data shows that with only a few exceptions, the samples with nitrate concentrations exceeding 2.0 mg/L show nitrification efficiency exceeding 80 percent. For samples with concentrations exceeding 1.0 mg/L, considered background concentrations for this study, there are only 3 samples with nitrification efficiency less than 60 percent.

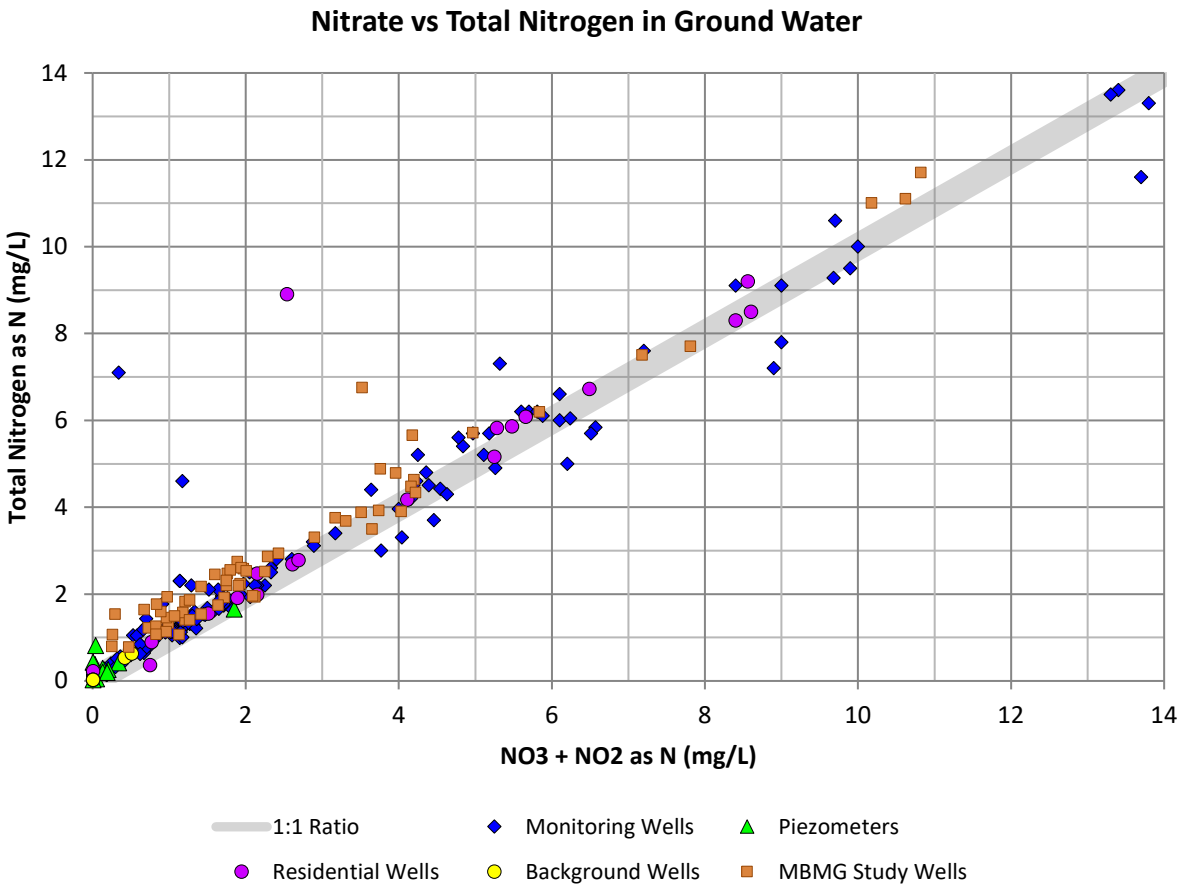


Figure 7-2 Comparison of Nitrate with Total Nitrogen Concentrations in Ground Water

Table 7-3 Summary Statistics for Nitrate and Total Nitrogen in Ground Water

Subwatershed		Total Samples	Total Detections	Max	Min	Average	Median	St Dev
East North Hills	Nitrate	32	30	2.97	0.14	1.08	0.98	0.63
	Total N	20	12	2.58	1.22	1.79	1.57	0.51
	N/Total N	12		0.87	0.41	0.71	0.73	0.14
West North Hills	Nitrate	49	47	10.21	0.18	2.47	2.09	2.04
	Total N	34	29	8.30	0.53	2.88	2.17	1.84
	N/Total N	29		1.10	0.48	0.87	0.91	0.17
Lower Silver Creek	Nitrate	53	50	14.36	0.05	3.36	1.79	3.78
	Total N	31	25	15.70	0.04	4.36	2.10	4.54
	N/Total N	25		1.19	0.19	0.83	0.83	0.20
Middle Silver Creek	Nitrate	6	4	1.18	0.57	0.86	0.85	0.34
	Total N	4	3	1.61	1.06	1.41	1.57	0.31
	N/Total N	2		1.07	0.75	0.91	0.91	0.22
Lower Tenmile Creek	Nitrate	37	34	5.66	0.03	2.11	1.87	1.69
	Total N	20	17	6.08	0.29	2.41	2.45	1.55
	N/Total N	17		1.02	0.08	0.79	0.90	0.27
Middle Tenmile Creek	Nitrate	8	6	2.90	0.20	1.97	2.03	0.99
	Total N	4	4	3.11	0.26	1.89	2.10	1.19
	N/Total N	4		0.97	0.77	0.91	0.95	0.09
Grizzly Gulch	Nitrate	17	17	16.00	0.19	9.46	9.38	4.45
	Total N	8	8	13.60	0.14	9.63	10.80	4.60
	N/Total N	8		1.36	0.05	0.97	1.02	0.39
Lower Prickly Pear Creek	Nitrate	46	44	16.00	0.01	2.97	1.19	**3.95**
	Total N	32	32	13.50	0.15	2.55	1.37	**3.02**
	N/Total N	30		1.03	0.05	0.82	0.89	**0.21**
East Helena Valley	Nitrate	33	28	9.70	0.01	4.14	5.21	3.41
	Total N	21	20	10.60	0.22	3.84	1.69	3.40
	N/Total N	19		2.08	0.56	0.98	0.92	0.29
Sevenmile Creek	Nitrate	26	13	9.47	0.06	1.24	0.48	2.51
	Total N	16	6	1.06	0.08	0.47	0.40	0.39
	N/Total N	2		0.61	0.25	0.43	0.43	0.26
Scratchgravel Hills	Nitrate	25	24	10.18	0.96	4.25	3.34	2.80
	Total N	16	15	11.00	1.13	5.12	3.88	3.14
	N/Total N	15		1.01	0.29	0.82	0.85	0.17

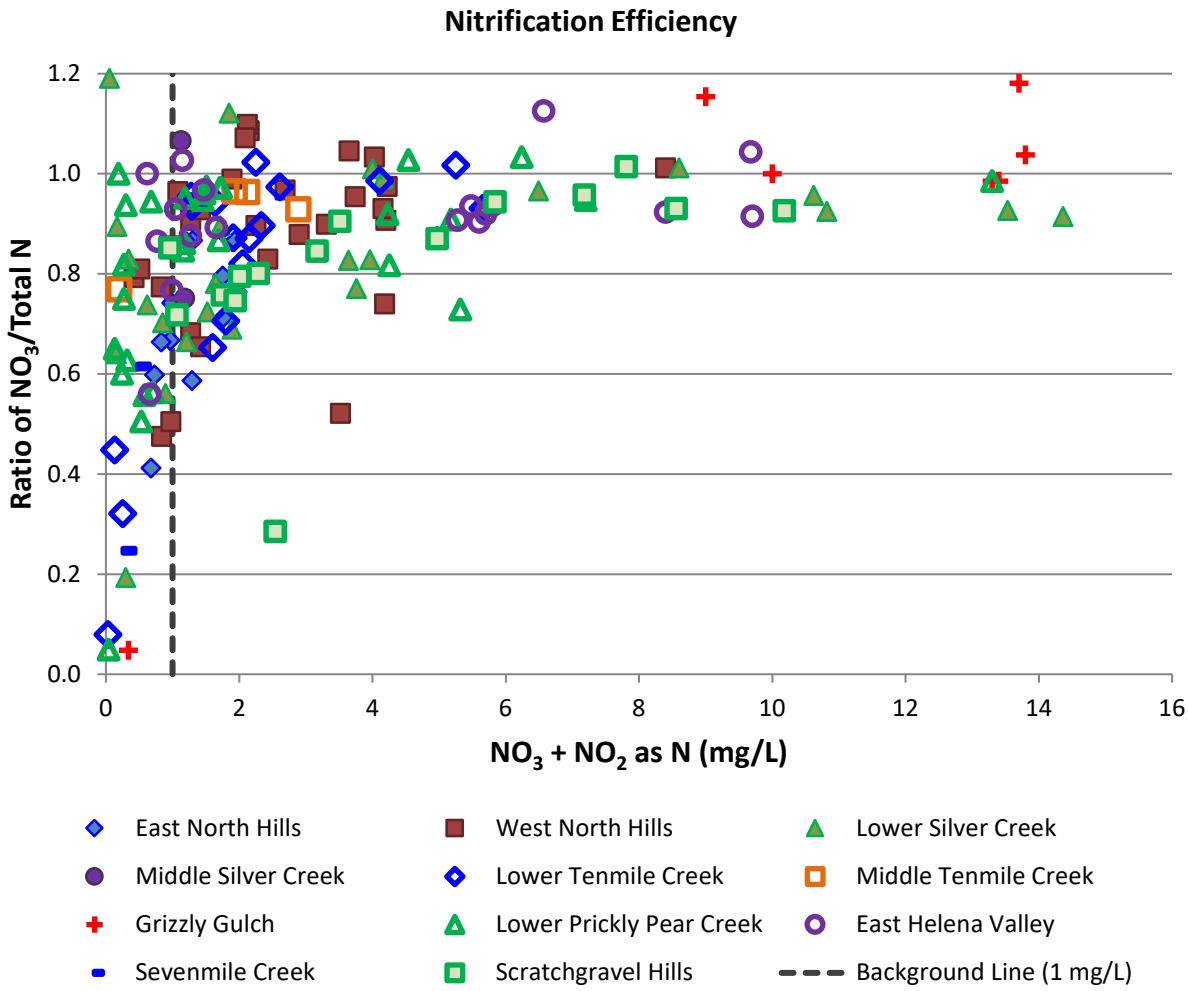


Figure 7-3 Comparison of the Nitrate/Total Nitrogen Ratio with Nitrate Concentrations

The source assessment for ground water included measuring chloride and bromide concentrations as a method of differentiating between different non-point sources for nutrient to ground water (Davis et al., 1998; Katz et al., 2011). These studies show that in certain hydrogeologic systems, increases in the ratio are interpreted to result from increases in chloride from septic system discharge, relative to a stable concentration of bromide. The ratio of chloride to bromide in drain samples showed wide variability, with bromide fluctuating compared to more constant chloride concentrations. While the background concentrations of the halides varied in different parts of the valley, the presence of recharge waters (irrigation, streams) with very low bromide could be confirmed by the low bromide concentration. Unfortunately, as the bromide concentration decreases with constant chloride, the mass ratio of chloride to bromide increases. Table 7-4 presents the summary statistics for the mass ratio of chloride to bromide within the different subwatershed areas. Graphs of the data are presented in the method of Katz et al (2011) in Figure 7-4. Nitrate and chloride concentrations are compared in Figure 7-5, and the Cl/Br Mass Ratio is compared with Nitrate in Figure 7-6. Given the differences and fluctuations of the data relative to the location in the valley and recharge waters, this method is considered inconclusive at this time; however, utilization of the data to characterize different subwatersheds may still be completed.

Table 7-4 Chloride/Bromide Mass Ratio Statistics for each Subwatershed

Subwatershed	Count	Max	Min	Average	Median	St Dev
East North Hills	31	300	35	159	149	48
West North Hills	43	860	46	288	146	244
Lower Silver Creek	42	650	78	245	207	115
Middle Silver Creek	6	191	134	159	151	26
Lower Tenmile Creek	20	2050	108	577	350	548
Middle Tenmile Creek	5	718	307	449	375	167
Grizzly Gulch	5	600	147	311	280	178
Lower Prickly Pear Creek	30	361	24	182	161	76
East Helena Valley	29	1000	10	187	158	185
Sevenmile Creek	24	300	44	142	132	54
Scratchgravel Hills	21	910	85	298	229	257

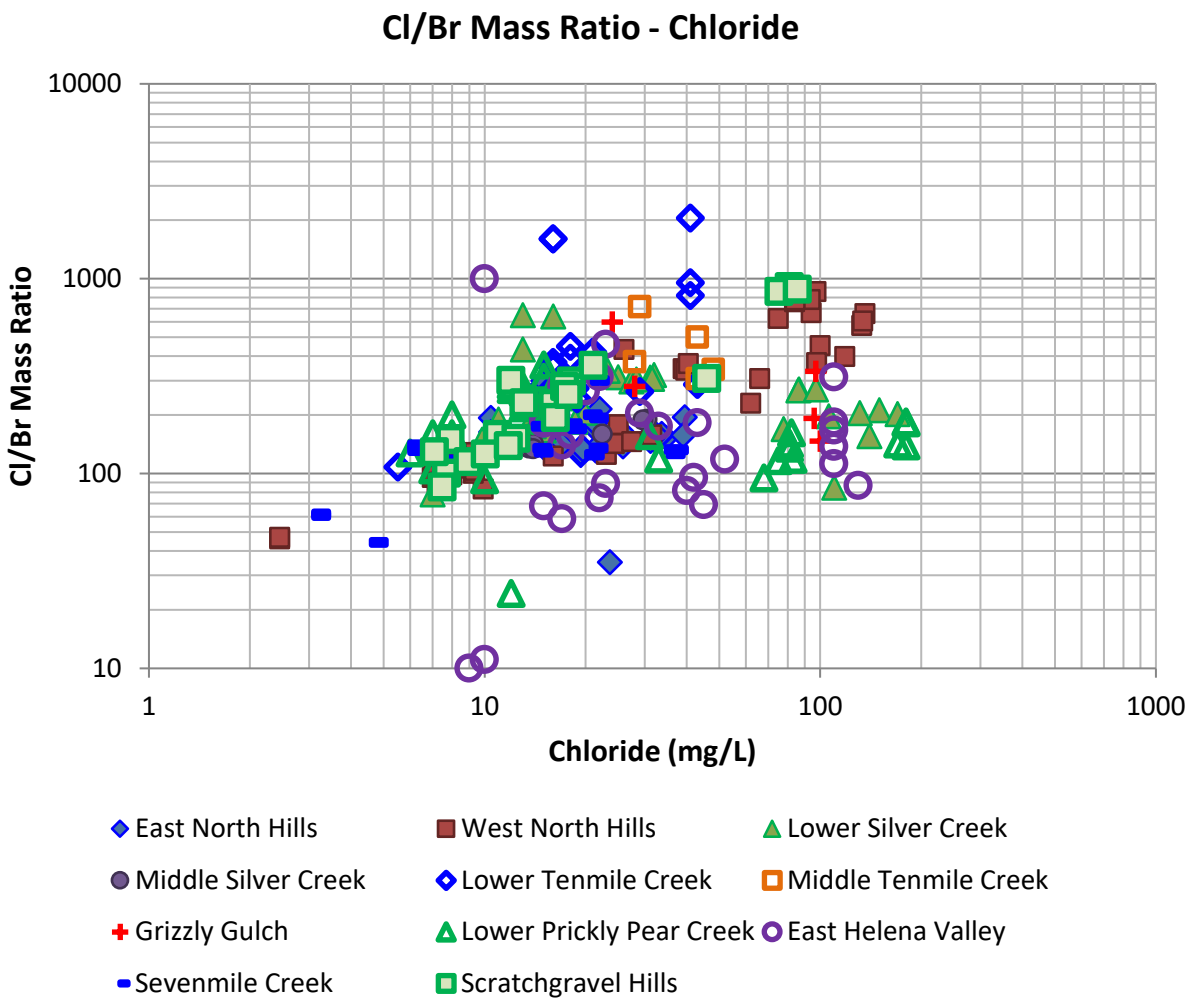


Figure 7-4 Comparison of the Cl/Br Mass Ratio with Chloride Concentrations

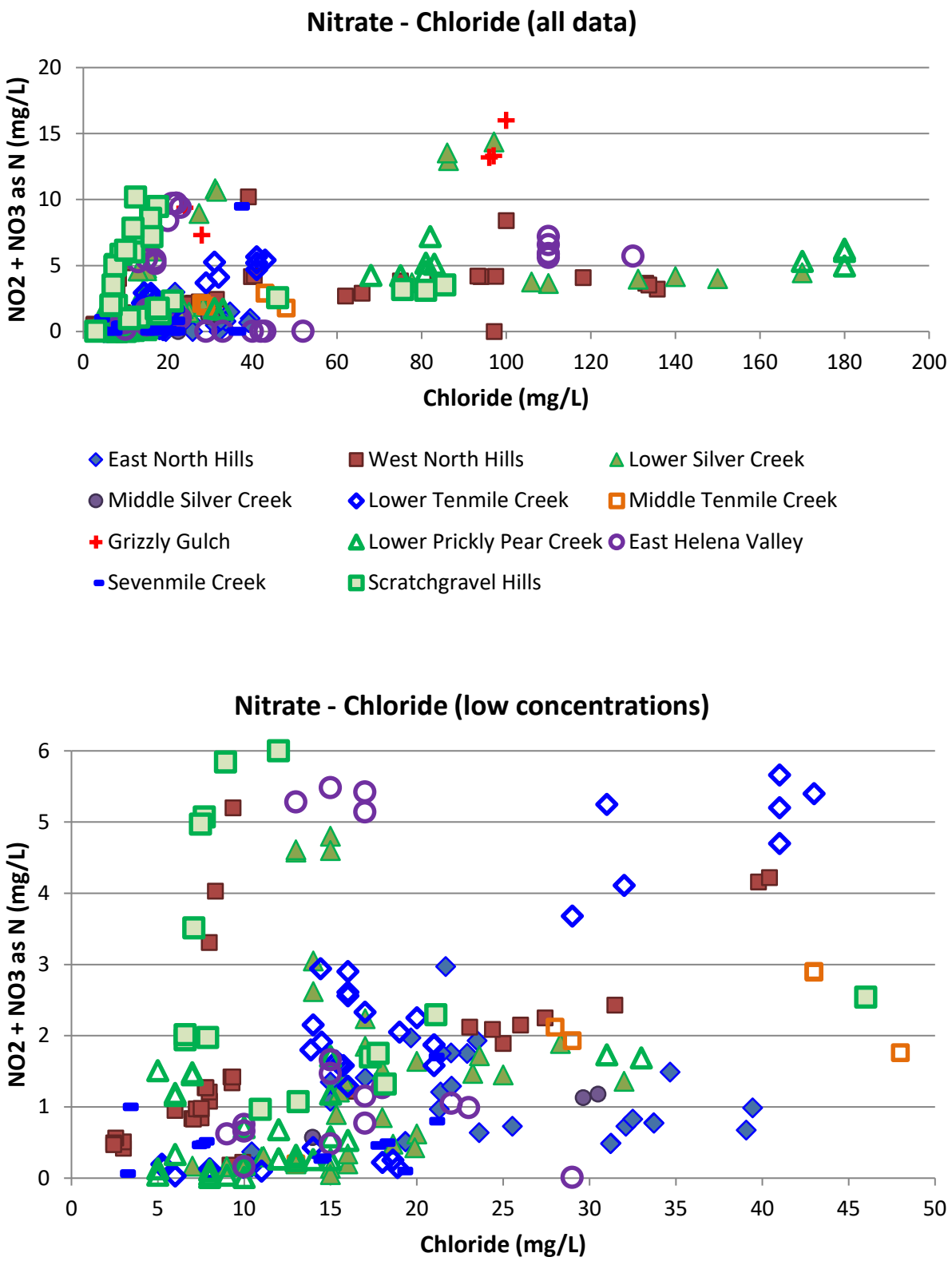
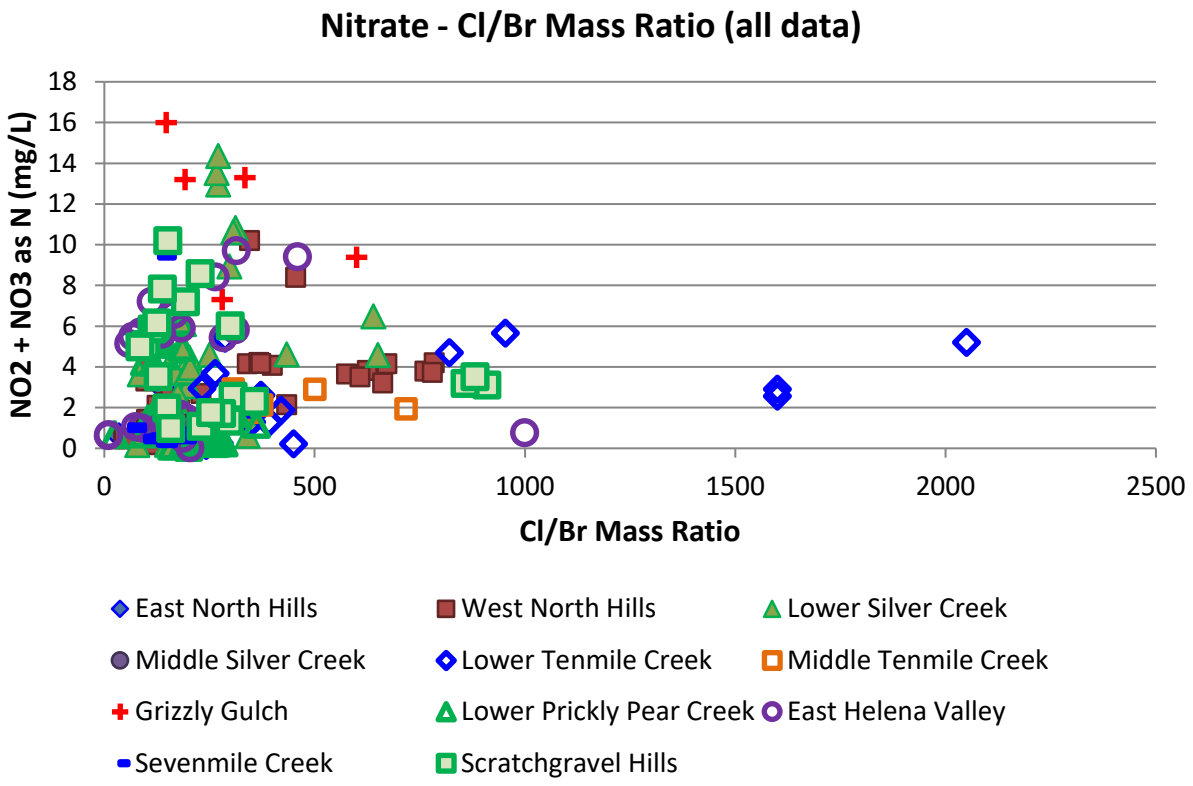


Figure 7-5 Comparison of the Nitrate with Chloride Concentrations



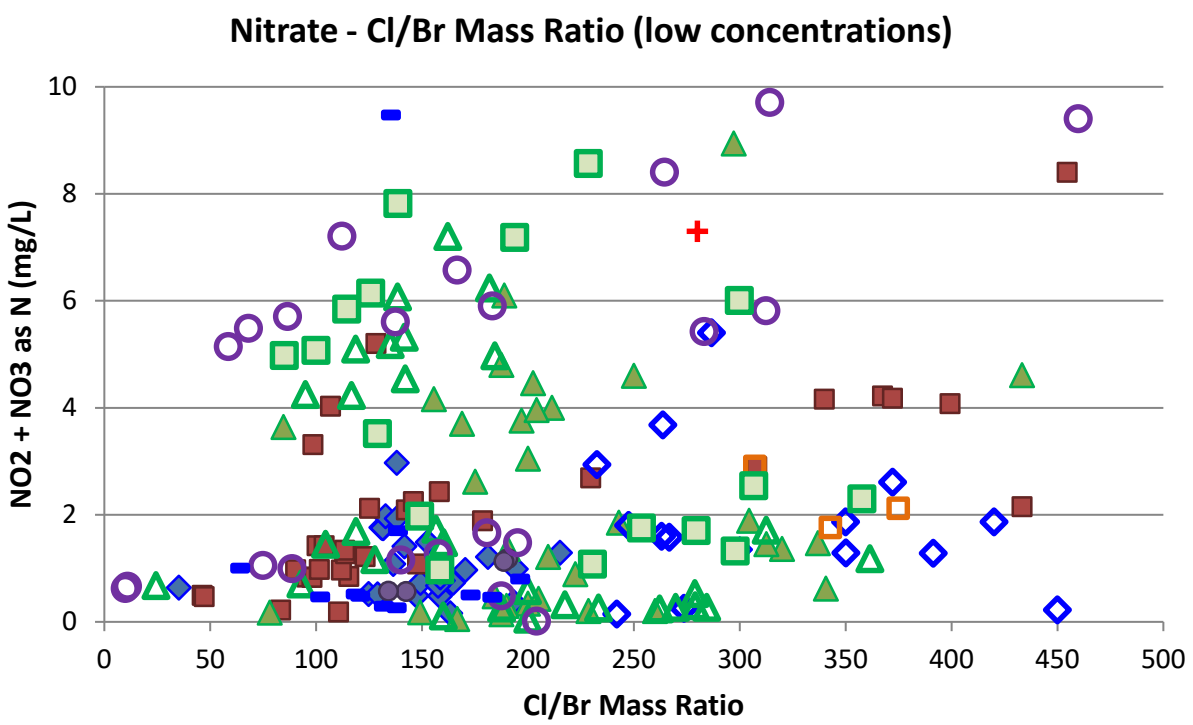


Figure 7-6 Comparison of the Cl/Br Mass Ratio with Nitrate Concentrations

8.0 Surface Water Loading to Lake Helena

Characterization of nutrient loading to surface water from ground water sources requires quantification of loading from streams. The LCWQPD has been implementing a surface water monitoring program, with data presented in Swierc (2013). While the monitoring program has recently been scaled back due to budget considerations, the program includes flow monitoring and the collection of water quality samples. The surface water monitoring sites are shown in Figure 8-1, with both mileage upgradient from the discharge point to Lake Helena and the location of the discharge points for municipal wastewater to Prickly Pear Creek noted. Loading varies with flow rates, which show considerable variation seasonally as depicted in Figure 8-2, a flow hydrograph for Prickly Pear Creek comparing the mean daily discharge rate for each year from 2009 through 2012 with data from the USGS Flow Monitoring gauge in Clancy, upstream from East Helena.

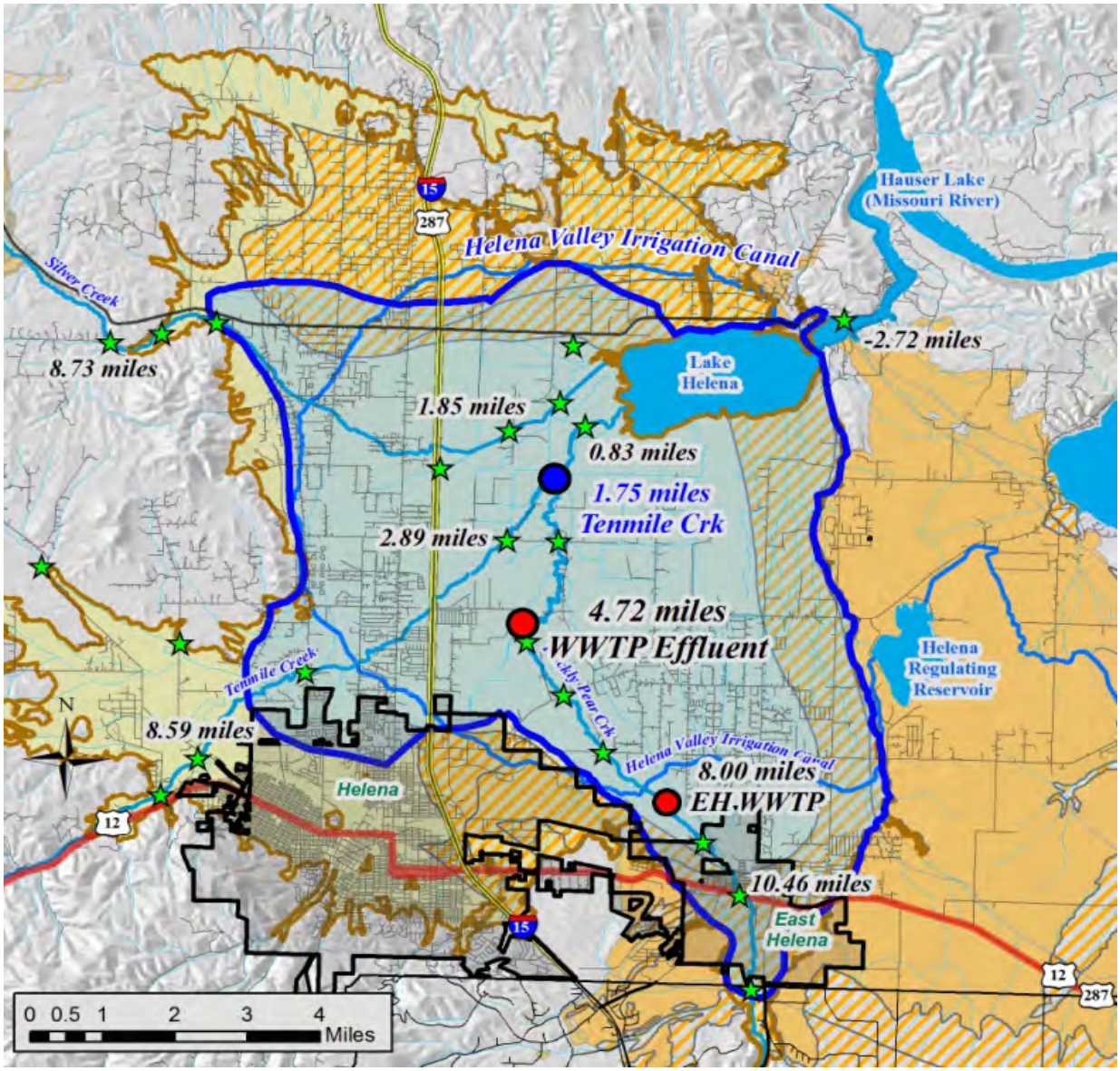


Figure 8-1 Surface Water Monitoring Locations and Stream Mileage Estimates

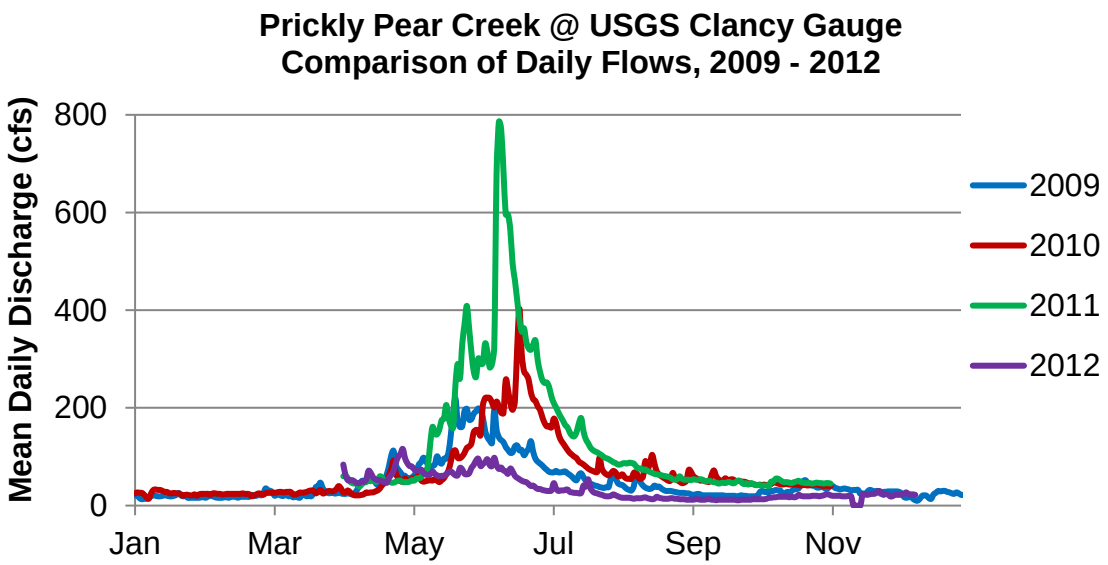
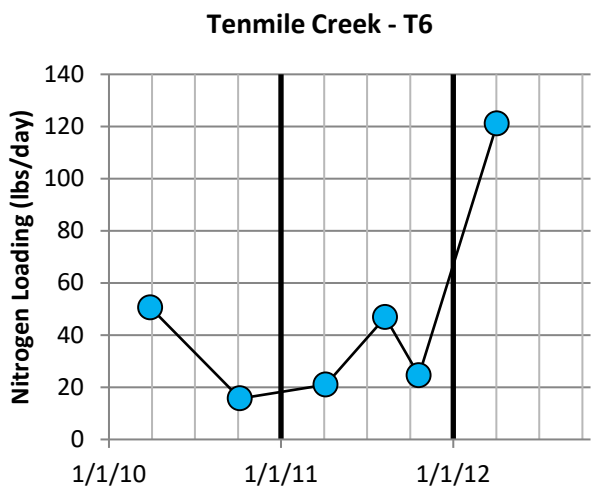


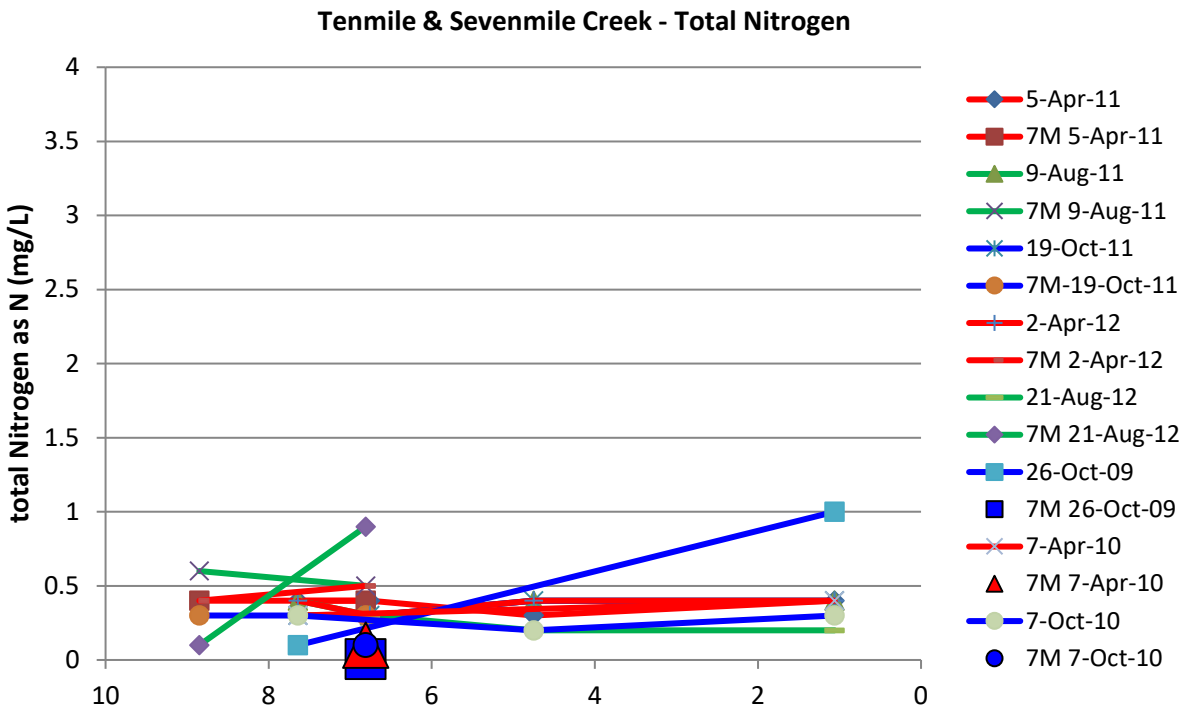
Figure 8-2 Comparison of Flow Hydrographs for Prickly Pear Creek at Clancy, 2009-2012

For this assessment, loading was estimated using similar methods to the drains, where flows are multiplied by concentration, then averaged between sampling intervals. The sampling program included events in early April, August and Late October to cover seasonal changes in water quality. Due to the variability in flows between years, the data results were averaged over a two year period. A sample calculation for site T6 on Tenmile Creek is listed in Table 8-1, noting that the annual loading rates are obtained by dividing the total load by the number of years of data (total number of days by 365). Loading concentrations for the streams, for each sampling event, are presented in Figures 8-3 through 8-5. The results are summarized in Table 8-2.

Table 8-1 Calculation of Nutrient Loading for Tenmile Creek at Site T6

	Tenmile Creek – T6 N-lbs/day	days	slope(avg)	Total lbs
3/30/10	51		54.60	
10/6/10	16	190	33.12	6293
4/6/11	21	182	18.31	3333
8/10/11	47	126	33.87	4268
10/20/11	25	71	35.66	2532
4/3/12	121	166	72.81	12086
	Totals	735	**total lbs**	28512
			lbs/yr	14159
			tons/yr	7.08





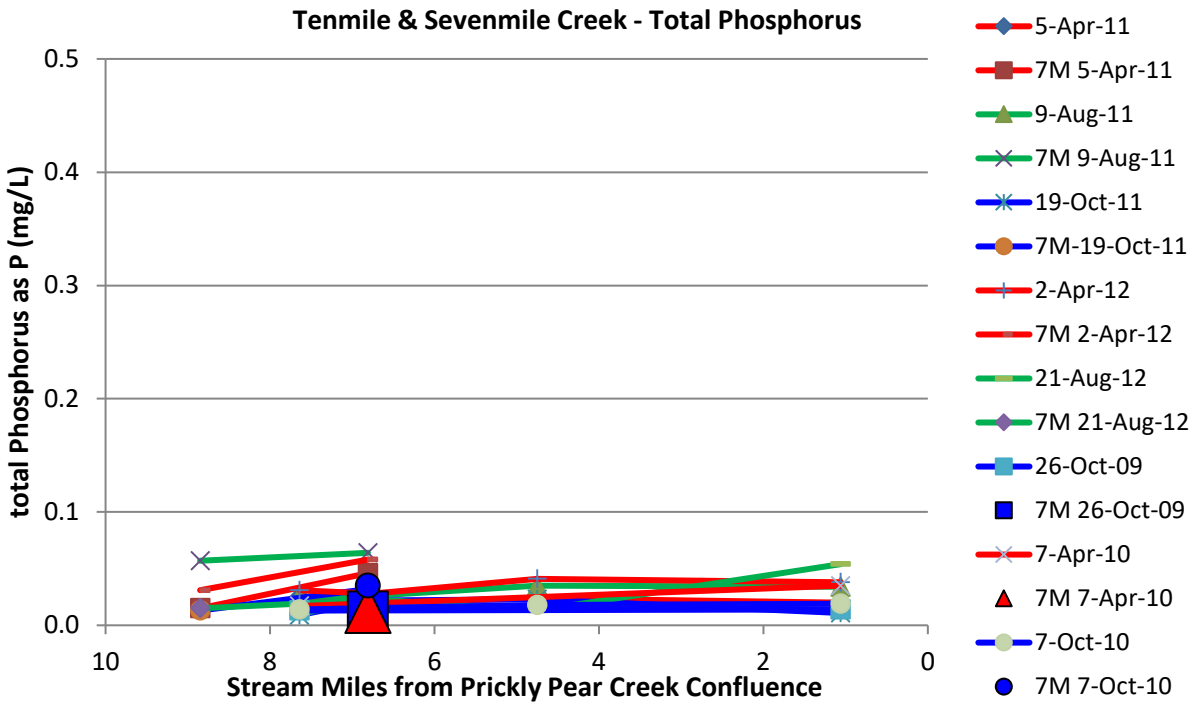
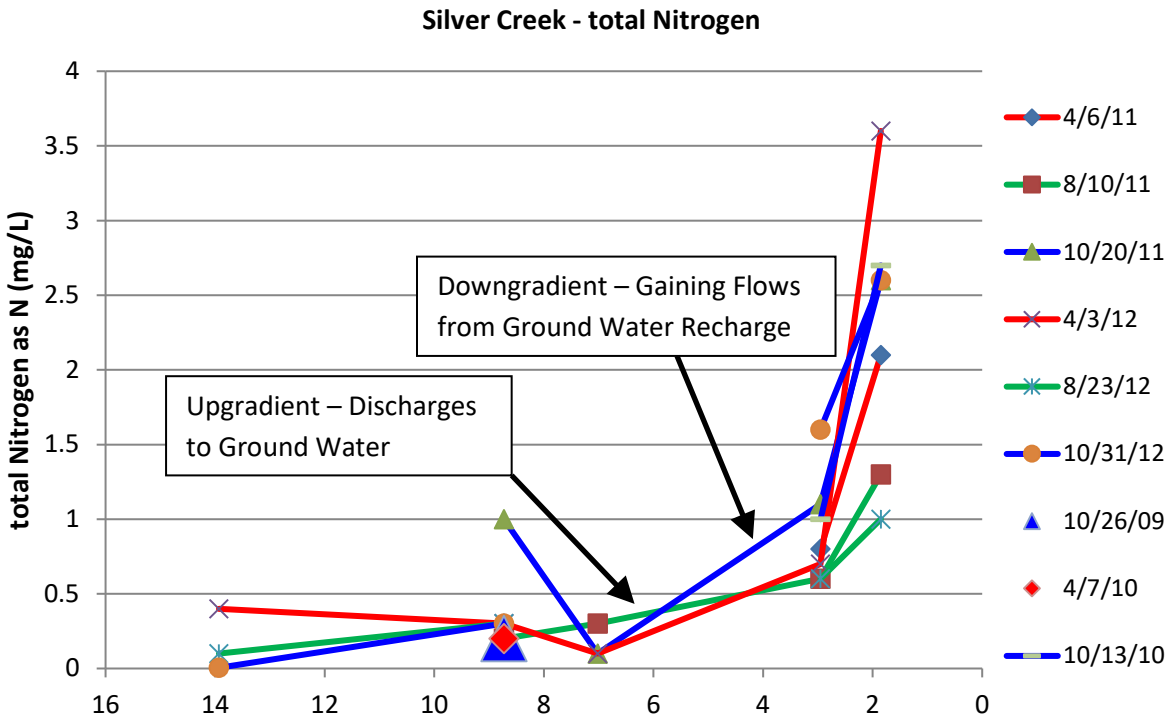


Figure 8-3 Total Nitrogen and Phosphorus Loading for Tenmile and Sevenmile Creeks
Stream miles are measured from the confluence with Prickly Pear Creek.



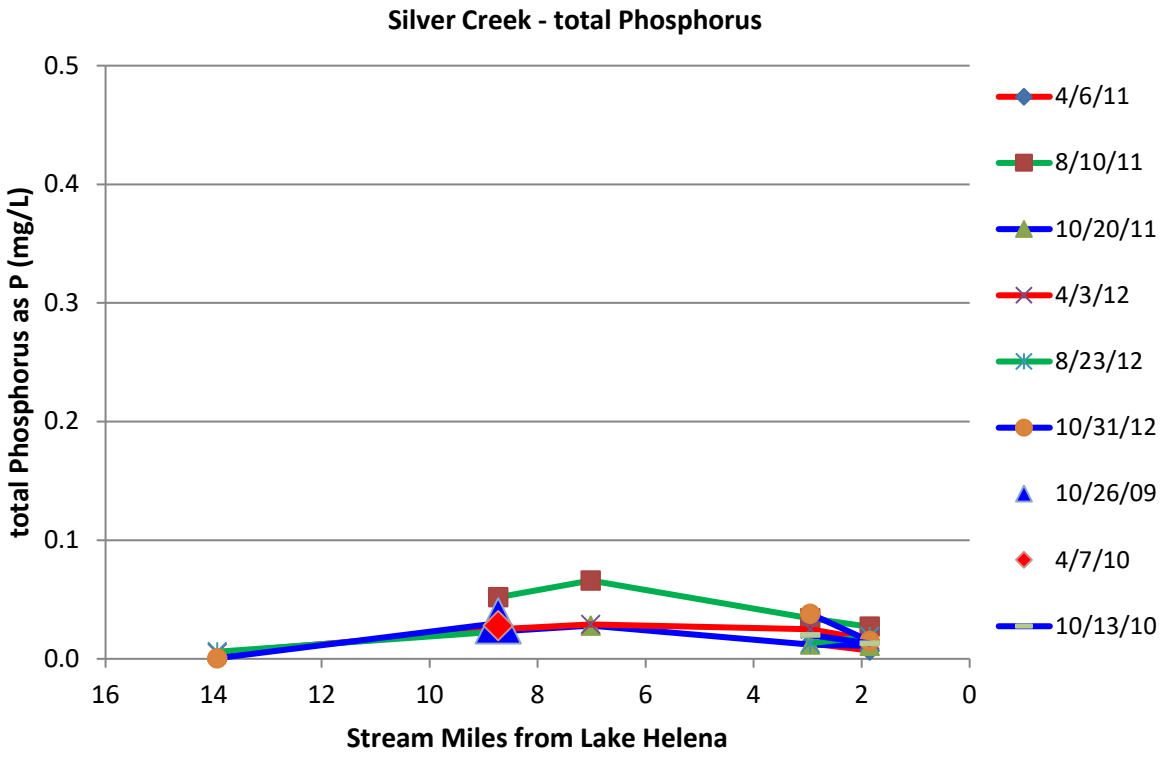


Figure 8-4 Total Nitrogen and Phosphorus Loading for Silver Creek
Stream miles are measured from the discharge point into Lake Helena.

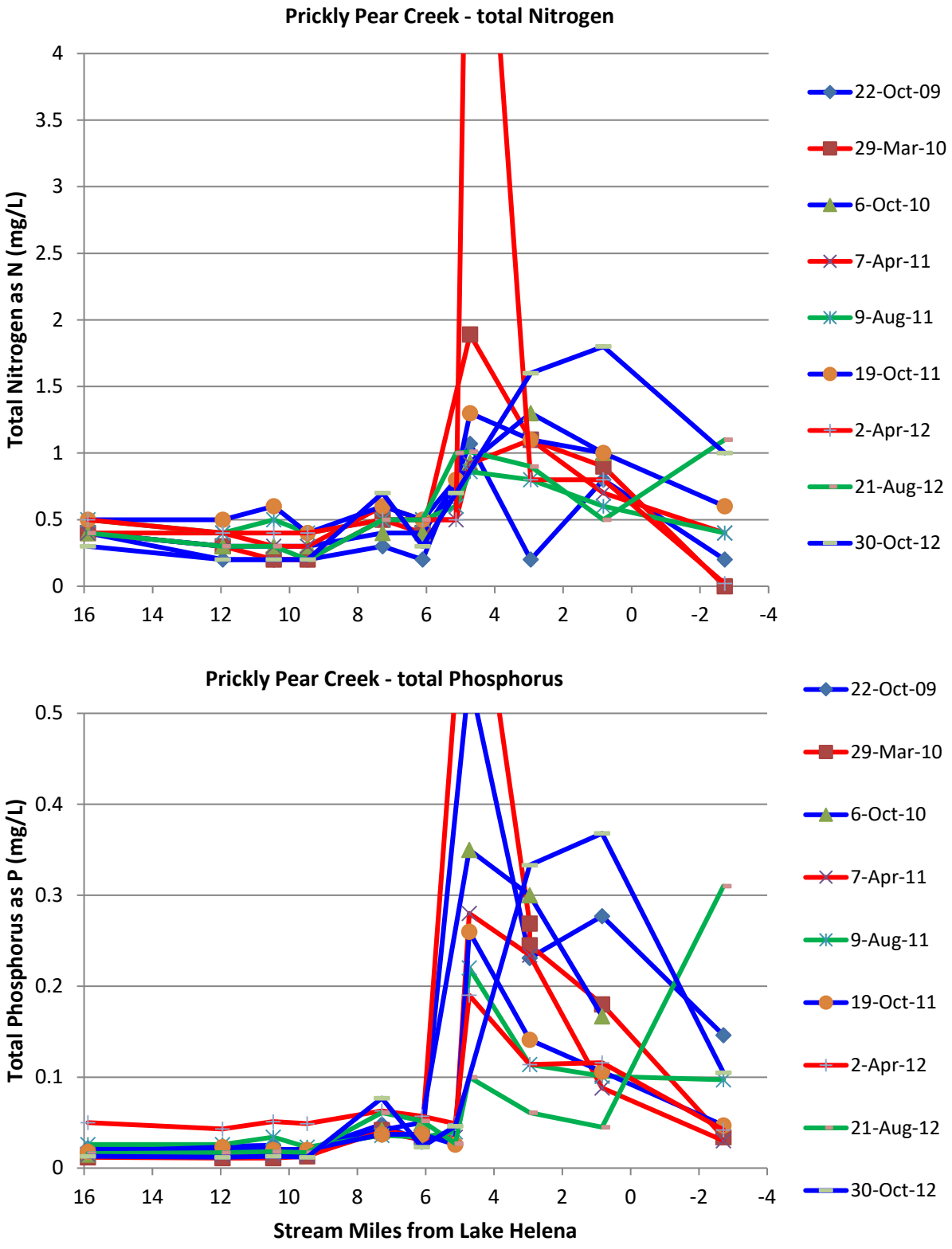


Figure 8-5 Total Nitrogen and Phosphorus Loading for Prickly Pear Creek

Stream miles are measured from the discharge point into Lake Helena. Note loading peaks occur at discharge point for wastewater treatment plants to Prickly Pear Creek

The data results for Silver Creek and Prickly Pear Creek both show increased loading in the central part of the valley, as the streams approach the confluence with Lake Helena. Specifically, for Prickly Pear Creek, the total nitrogen concentration increases from 57 tons/year at mile 2.95 to 66 tons/year at mile 0.85, while both points had total phosphorus loading at 11 tons/year. The increase in nitrogen loading supports a conclusion of ground water loading of nitrogen to the system, consistent with known conditions that stream flow increases from ground water recharge in these areas. The actual loading estimates for each stream to Lake Helena are compared with the initial estimates from the TMDL for the Lake Helena Watershed (USEPA, 2006) in Table 8-2.

Table 8-2 Nutrient Loading Estimates to Lake Helena

Stream	**TMDL Est. N**	**Actual N**	**TMDL Est. P**	**Actual P**
	tons/yr	tons/yr	tons/yr	tons/yr
Prickly Pear Creek[1]	186.1	66	35.5	11
Sevenmile Creek	15.4	2.1	2.3	0.3
Tenmile Creek	57.0	7.6	7.1	0.5
Silver Creek[2]	*None*	39	*None*	0.4
Helena WWTP[3]		103		1.5
Drains[4]		48.5		1.0

1 – Prickly Pear Creek loading includes loading from Sevenmile Creek, Tenmile Creek and Helena WWTP
2– Estimates for loading from Silver Creek were not completed for the Lake Helena TMDL
3 – The discharge effluent from the Helena WWTP mixes with the waters in Prickly Pear Creek
4 – The drain estimate is presented for comparison.

9.0 Discussion

The drain and ground water data provide a comprehensive dataset characterizing the cycling of nutrients through Helena area ground waters. The assessments show that the original estimates for sources of nutrient loading from the Lake Helena Watershed TMDL overestimate the actual loading rates from streams and area ground waters through drains. In order to obtain additional information to differentiate sources, the LCWQPD collected samples for analyses for nitrogen and oxygen isotopes of nitrate, supplementing the dataset compiled in Swierc (2013). The data results are plotted in Figure 9-1, following the methods presented by Kendall (1998). Since older nitrate biodegrades with time, the "lighter" fraction is easier to break down, enriching the heavier nitrogen isotopes. This pathway is shown on Figure 9-1, where as nitrate gets older, it moves to the right on the plot.

The data results are consistent with conclusions from the other datasets. Note that this assumes that the non-point nutrient sources in most locations are both septic system and agricultural land use, representing mixed sources. The drains from the North Hills show a fertilizer signature. The drains from the central part of the valley show a mixed signature, from both fertilizers and septic waste. The D2.1-1 drain shows a value with a greater component of manure and/or septic systems. The sample from the D3-2 drain represents a primarily manure/septic system source which is attributed to the location relative to Helena.

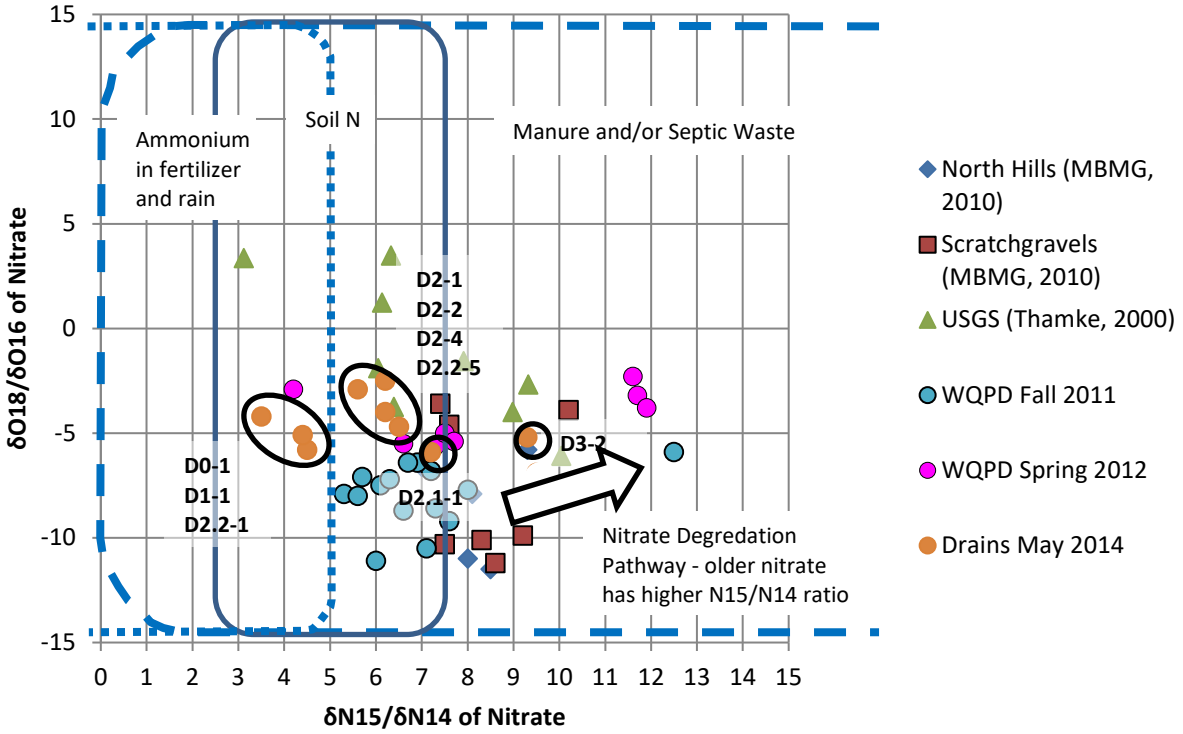


Figure 9-1 Nitrogen and Oxygen Isotopes of Nitrate Dataset

Shallow ground water discharges to surface waters flowing to Lake Helena in the downgradient part of the valley. As a result, the fate and transport of nutrients in ground water represents a critical component of watershed restoration actions for the area. Both agricultural practices ***and*** wastewater discharges from septic systems represent significant nutrient sources to the system, frequently mixing with data reflecting both sources.

Water quality impacts from septic system effluent are generally localized, with minimal impacts when septic systems and drainfields work correctly. Lewis & Clark County recently developed and implemented a maintenance program to help ensure that these systems are managed properly, and operate as efficiently as practical. This program can be considered a management barrier to protect water quality in the receiving ground water systems.

Reducing nutrient impacts to ground water from agricultural practices represents a significantly greater challenge, due to seasonal loading of fertilizers and irrigation waters, different crop nutrient uptake properties, and storage within the unsaturated zone. Best management practices to control release of excess nutrients are generally considered the best approach to reduce nutrient impacts from agriculture practices. A review of these practices with respect to the differences in local soils and hydraulic properties for Helena area agriculture is presented in Appendix II.

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