Orleans Landfill Nitrate Data Evaluation Report

Prepared for:

The Town of Orleans

and

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1.0 INTRODUCTION

MT Environmental Restoration and GHD have completed tasks defined in the January 21, 2015 proposal for consulting services including the evaluation of groundwater nitrate data in the vicinity of the Orleans Municipal Landfill (the landfill) in the Town of Orleans, Massachusetts. The landfill is located in the Town Cove/Nauset Estuarine System watershed. Nitrogen loading from point and non-point sources in Cape Cod's watersheds are impacting coastal estuaries including Town Cove. Nitrate in groundwater in the vicinity of the landfill has the potential to migrate to Town Cove and is being considered in light of efforts underway to restore coastal water quality.

The work included a visit to the landfill to observe site conditions on the ground and review of reports and information provided by the Orleans Health Department and GHD. Reports reviewed included environmental reports related to the landfill including the Initial Site Assessment Report (Coastal Engineering, 1992), Supporting Documentation for Septage Lagoon Closure (Coastal Engineering, 1992), Site Inspection Prioritization Report (Weston, 1998), Comprehensive Site Assessment Report (Coastal Engineering, 1999), Construction Certification Report, Town of Orleans Landfill Closure (Stearns & Wheeler, LLC, 2006), Orleans Municipal Landfill Semi-Annual Groundwater Monitoring Reports through 2014 (Stearns & Wheler, LLC and GHD), and other documentation. Data contained in these reports were evaluated to develop an initial Conceptual Site Model (a preliminary data interpretation) related to nitrate in groundwater and considering potential migration to Town Cove.

2.0 SITE DESCRIPTION

The landfill consists of approximately 20 acres located off Lots Hollow Road (Figure 1.) The property includes a natural kettle hole with an 11-acre area that was used for solid waste disposal from the 1950s until 1991. The fill area was closed and capped at a maximum elevation of approximately 110 ft above mean sea level (MSL) in 2005. The landfill property also includes an active solid waste transfer station and yard waste composting and stockpile area (Figure 2). The yard waste composting area includes land formerly used for septage waste lagoons and disposal. Six unlined former septage lagoons used between 1950 and 1989 were located just to the north of the capped solid waste area at an approximate elevation of 50 ft above MSL (Figure 3) (Coastal Engineering, 1999). The landfill property is adjacent to the Town of Orleans public well watershed property to the south, commercial properties and the Charles Moore Ice Arena to the west, and commercial properties to the north and east.

3.0 LANDFILL GROUNDWATER MONITORING WELLS

Historical groundwater nitrate concentration data are available from five monitoring well couplets, each with one shallow 10 ft screen (with the exception of MW-5S discussed below) at the water table and one deeper 10 ft screen set approximately 40 ft below the water table. The data set did not include ammonia or total nitrogen concentrations. The monitoring wells are located roughly around the perimeter of the landfill property. These monitoring wells are currently sampled semi-annually as part of the landfill monitoring program. Monitoring well locations are shown on Figure 2 and Figure 3 and include:

- MW-1S and 1D on the west side of the landfill property
- MW-2S and 2D to the north
- MW-3S and 3D to the east
- MW-4S and 4D to the south
- MW-5S and 5D to the northeast

Four of the shallow water table monitoring wells (MW-1S through MW-4S) were installed in 1992 as part of an assessment associated with the septage lagoon closure. Deeper screened monitoring wells (MW-1D, MW-2D, MW-3D, and MW-4D) were installed as part of the landfill Comprehensive Site Assessment in 1994, completing the well couplets at these locations. One additional couplet (MW-5S and MW-5D) was also installed in 1994. MW-5S was constructed with a 15 ft screen.

4.0 CONCEPTUAL SITE MODEL

A Conceptual Site Model (CSM) is a tool used to provide a framework of information to help understand and communicate what is known about a potential problem, visualize available information, identify gaps in data and prioritize response actions. The following paragraphs provide a narrative version of the CSM for the landfill concerning nitrate in groundwater.

4.1 Potential Sources of Nitrate in Groundwater

Municipal operations at the landfill, starting in the 1950s and continuing through the 1990s with solid waste disposal and operation of septage lagoons, and more recent transfer station operations including stockpiling and composting yard wastes may have resulted in increased nitrate concentrations in groundwater in the vicinity of the landfill.

4.2 Groundwater Flow and Potential Nitrate Transport

Nitrate in water recharging the aquifer in the vicinity of the landfill may be significantly increasing nitrogen loading to the downgradient Town Cove/Nauset Estuary System through groundwater transport of nitrate to the estuary. Groundwater flow directions observed in the immediate vicinity of the landfill are shown on Figure 3 to provide a visual aid for the CSM. Figure 4 provides a more regional perspective of groundwater flow, showing the range of groundwater flow directions observed at the landfill and the watershed delineation for Town Cove.

The landfill property is located above the Monomoy Lens of the Cape Cod Aquifer (Walter et. al., 2004). Boring logs for the landfill monitoring wells show subsurface sediments that consist of glacial outwash sands and gravel with thin layers of more silty sand, silt and clay. The depth to groundwater varies significantly with location due to land surface elevation differences associated with the kettle hole landform present in the area of the landfill. The approximate range for depth to groundwater at monitoring well locations is 50 to 85 ft, indicating that there is a significant unsaturated zone thickness in the area.

A regional groundwater contour map prepared by the United States Geological Survey (USGS) and assessment reports associated with the landfill indicate groundwater flow to the north

northwest, north, and northeast toward Town Cove (Walter et. al., 2004 and Coastal Engineering, 1999).

Groundwater elevation measurements, characterization of the aquifer sediments, and aquifer tests were used by Coastal Engineering to estimate groundwater velocity and flow direction in the vicinity of the landfill (Coastal Engineering, 1999). The hydraulic conductivity of aquifer materials was determined from aquifer testing at various locations. The hydraulic conductivity determined at shallow screen locations ranged from 5.6 ft /day at MW-1S to 70.88 ft/day at MW-2S. A higher hydraulic conductivity indicates the potential for faster groundwater flow, depending on the gradient. The hydraulic conductivity determined at deeper screen locations ranged from 14.14 ft /day at MW-3D to 147.74 ft/day at MW-1D (Coastal Engineering, 1999).

The slope of the potentiometric surface derived from water elevation measurements was used to determine the hydraulic gradient and flow direction. According to the Comprehensive Site Assessment prepared for landfill closure by Coastal Engineering in 1999, there is the potential for divergent flow (groundwater flow in more than one direction) from the landfill area. The shallow screen wells indicated a consistent gradient of 0.012 to the northeast while deeper screen wells showed variation in flow direction including flow to the north and north northwest. Measurements indicated an average gradient of 0.000625 to the northwest and an average gradient of 0.003 to the north in the deeper screened wells. The 1990s data also indicated vertical gradients at all monitoring well couplets (downward at MW-1, MW-2, MW-3, and MW-4 and upward at MW-5), that could be the due to local mounding effects, differences in sediment permeability, and the location of the landfill in a recharge area of the groundwater system. A downward vertical gradient indicates groundwater flow deeper into the aquifer. The porosity was estimated at 0.30 from soil samples collected during soil boring installation.

Based on these data, Coastal Engineering calculated the horizontal groundwater velocity at various locations as follows:

- MW-1S, MW-3S, MW-5S 0.25 ft/day
- MW-1D 0.31 ft/day
- MW-2S 2.84 ft/day
- MW-3D 0.029 ft/day

These values are approximate and groundwater velocity is highly variable form point to point depending on sediments present in the well screen interval, and velocity can be expected to vary along the long flow path from groundwater recharge to discharge. The very slow flow calculated for MW-3D is likely due to the fact that the well was screened in a silty sand layer. The fastest groundwater velocity was calculated for MW-2S screened in medium sand. For perspective, the distance from MW-2S, located on the northern edge of the landfill property, to Town Cove is approximately 5,450 ft on a heading of 40 degrees northeast, consistent with the direction of shallow groundwater flow. Based on the calculated groundwater velocity at MW-2S of 2.84 ft/day, travel time from the landfill to Town Cove is just over 5 years. If the groundwater velocity calculated for MW-1S, MW-3S and MW-5S of 0.25 ft/day is used to assess travel time, the travel time from the landfill to Town Cove is approximately 60 years. The USGS has mapped the location of the landfill in an area near a groundwater flow divide where groundwater

is likely to flow deeply into the aquifer, increasing travel time to the discharge location. The USGS map indicates groundwater recharged in the vicinity of the landfill will take more than 50 years but less than 100 years to reach Town Cove (Walter et. al., 2004). A travel time of approximately 50 years may be a good conservative estimate.

4.3 Nitrogen Assessment

Landfill monitoring well nitrate data collected over 20 years between September 1994 and March 2014 were reviewed for this assessment (Table 1). The 1990s data (September 1994 through December 2000) were collected during assessments related to closure of the septage lagoons and solid waste landfill. A gap in data collection occurred during the landfill capping operations and semi-annual monitoring was resumed starting in March 2005. More limited test data are available for MW-1D and MW-3S as they were sampled less frequently.

A reference background nitrate concentration of 0.46 mg/L was previously reported for Cape Cod by the USGS (LeBlanc, 1984). Earlier data from Frimpter and Gay, 1979, indicate uncontaminated groundwater may have less than 0.1 mg/L nitrate nitrogen. At the landfill, the lowest nitrate concentrations were observed in the upgradient deep screened monitoring well MW-4D and were consistent with background Cape Cod groundwater. All other wells tested showed nitrate concentrations above background.

Four of the monitoring wells (MW-1S, MW-2S, MW-2D, and MW-5S) had nitrate concentrations above the Massachusetts Drinking Water Maximum Contaminant Level (MMCL) of 10 mg/L on one or more sampling dates. Nitrate data are displayed in Charts 1 through 10 included in Appendix A. Selected charts are included on Figure 3 to provide a visual aid for the CSM. The charts show the variation in nitrate concentration over time. MW-4D is located upgradient of the landfill and has consistently shown only background concentrations of nitrate. MW-5S has shown a consistent elevated nitrate concentration over the entire 20-year sampling period (pre- and post-landfill capping), with the nitrate concentration ranging from 6.6 mg/L to 22 mg/L. Other wells including MW-1S, MW-2S, MW-2D, and MW-4S showed a marked increase in concentration with renewed post-capping groundwater monitoring starting in March 2005 compared to the 1990s data. One monitoring well, MW-2S, has shown an increasing but highly variable nitrate concentration starting after post-capping groundwater sampling was resumed. The concentration of nitrate at MW-2S reached a maximum concentration of 40 mg/L in September 2009 and was reported at 34 mg/L in March of 2014.

Landfill groundwater monitoring data also included measurements of dissolved oxygen. The dissolved oxygen measurements indicated that oxygen levels were below saturation in groundwater but the shallow groundwater was generally aerobic (greater than 1 to 2 mg/L dissolved oxygen). Deeper screened wells generally had lower dissolved oxygen concentrations and there may be some locations where groundwater is anaerobic. Biological attenuation of nitrate in groundwater by denitrification is inhibited under aerobic conditions. Attenuation of nitrate, at least in shallow groundwater, is unlikely during migration from the landfill to Town Cove. The significant thickness of the unsaturated zone above groundwater at the landfill property may be helping to maintain aerobic conditions, allowing for aeration of infiltrating groundwater. The depth to groundwater may also be limiting migration of organic carbon from

below the former septage lagoons and from composting operations to groundwater while allowing for conversion of infiltrating ammonia to nitrate under aerobic conditions.

5.0 CONCLUSIONS

The objective of the work was to review data contained in environmental reports related to the landfill, and develop an initial CSM for nitrate in groundwater considering the potential for migration of nitrate from the landfill to Town Cove. The CSM indicates there is a likely complete connection between groundwater with significant concentrations of nitrate at the landfill and increased nitrogen loading to Town Cove. Additional data collection would be necessary to confirm this connection.

Results of the review indicate groundwater flow is generally to the north northwest, north and northeast from the landfill property towards Town Cove. Significant concentrations of nitrate are present in groundwater, particularly on the downgradient side of the landfill property to the north (indicated by monitoring well couplets MW-1, MW-2, MW-3 and MW-5).

The mass flux of nitrate in groundwater migrating from the landfill toward Town Cove is the mass that passes through a defined cross sectional area affected by the landfill over a period of time. The area with elevated nitrate concentrations at the landfill appears to extend at least 800 feet cross-gradient (between MW-1 to the west and MW-3 to the east). Elevated nitrate concentrations also extend at least 40 ft below the water table as indicated by results from deep screen wells MW-2D and MW-5D, with concentrations greater than 10 mg/L observed at MW-2D. These conditions and groundwater flow data indicate there may be a significant mass flux of nitrate from the landfill. Elevated concentrations of nitrate have been present in groundwater at the landfill for at least 20 years, going back to the start of regular groundwater monitoring in 1994.

Historical landfill and septage lagoon operations that began operation around 1950 (65 years prior to date) were likely sources of nitrate. The estimated (very approximate) groundwater travel time of 50 years to Town Cove indicates that nitrate from the landfill property may already be contributing nitrate to Town Cove, and that given current conditions, nitrate would continue to migrate to Town Cove over a long term without corrective action.

Current yard waste composting operations may be a potential additional source of nitrate leaching to groundwater. Current infiltration of precipitation and runoff from the capped landfill near and/or through the former septage lagoons area may also be adding nitrate to groundwater.

The capping of the landfill and construction of infiltration facilities associated with capping may have altered the local direction of groundwater flow resulting in some of the observed variation in nitrate concentration from pre to post-capping conditions.

6.0 RECOMMENDATIONS

Additional data would be necessary to refine the CSM and confirm the connection to nitrogen loading to Town Cove. Important questions that arise from this assessment include:

- What are the reasons for observed increased concentrations of nitrate at MW-2 since 2005?
- How have infiltration patterns and the local direction of groundwater flow changed since capping operations were completed in 2005?
- What is the relative significance of the potential current sources of nitrate?
- Is nitrate attenuating under anaerobic conditions in deep groundwater at and downgradient of the landfill along the flow path to Town Cove?
- How fast is groundwater transporting nitrate from the landfill to Town Cove?
- What is the actual mass flux of nitrate and total nitrogen in groundwater from the landfill property?

Answers to these questions could be developed through a more comprehensive assessment of current operations, storm water management systems, and current groundwater conditions. Based on a more complete Conceptual Site Model corrective actions could be implemented at the landfill to limit migration of nitrate to groundwater, including potential changes in practices and management of infiltrating water, along with potential source area groundwater treatment. The assessment would also provide key information for planning response actions downgradient closer to Town Cove.

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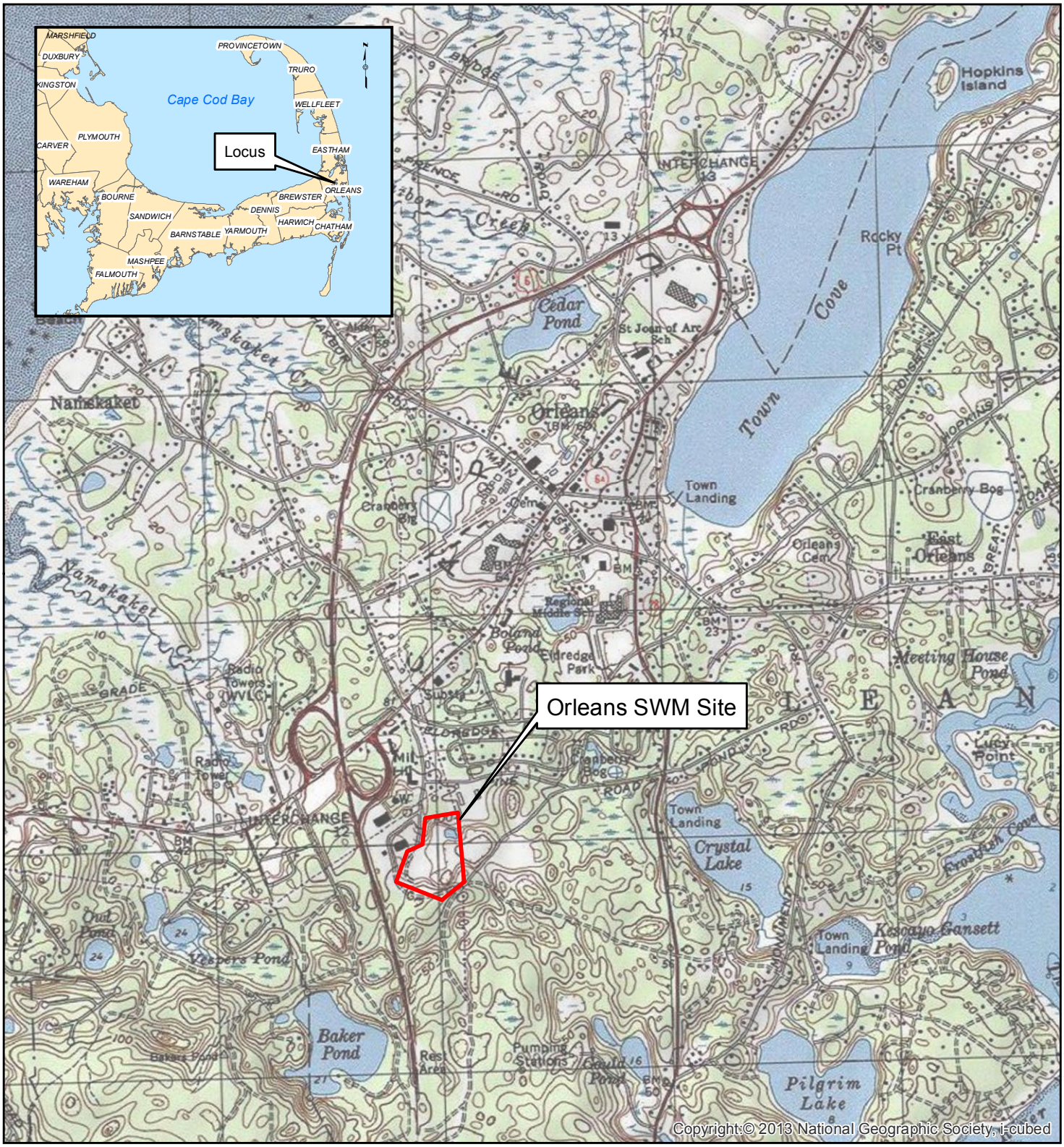
Weston Inc., 1998, Site Inspection Prioritization Report.

Table 1 Summary of Orleans Landfill Groundwater Monitoring Well Nitrate Data

	MW-1S	MW-1D	MW-2S	MW-2D	MW-3S	MW-3D	MW-4S	MW-4D	MW-5S	MW-5D
Date	Nitrate	Nitrate	Nitrate	Nitrate	Nitrate	Nitrate	Nitrate	Nitrate	Nitrate	Nitrate
	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Sep-94	5.15	NS	2.40	2.10	0.15	0.10	NS	0.03	6.60	0.1
Jan-95	<.1	NS	5.40	3.20	0.13	0.13	NS	0.02	**10.30**	0.22
May-95	0.20	NS	9.50	4.60	0.19	0.20	<.02	<.02	9.30	0.3
Aug-95	<.1	NS	0.90	1.70	0.30	<.02	<.02	<.02	**12.90**	0.40
Jul-98	<.02	NS	4.60	1.50	<.02	<.02	<.02	<.02	**17.00**	<.02
Aug-99	<.02	NS	4.80	1.50	0.09	<.02	0.09	0.02	**15.00**	<.02
Apr-00	0.07	NS	3.90	0.20	0.06	0.05	<.01	<.01	9.60	<.02
Dec-00	NS	NS	3.70	0.40	1.00	<.01	<.01	<.01	**10.00**	<.01
Mar-05	0.03	NS	1.90	**11.00**	7.70	NS	0.05	NS	9.80	<.01
Jul-05	4.50	NS	**18.00**	1.00	NS	0.98	<.01	<.01	**10.00**	7.90
Feb-06	0.22	NS	**11.00**	**11.00**	NS	0.67	<.01	0.11	**18.00**	1.00
Sep-06	0.46	2.10	**19.00**	**15.00**	NS	0.32	0.93	<.01	**14.00**	0.21
Mar-07	0.25	3.00	**16.00**	7.30	NS	<.01	5.60	<.01	**12.00**	<.01
Oct-07	1.90	NS	**31.00**	4.30	NS	<.01	2.70	<.01	**12.00**	<.01
Apr-08	2.20	NS	**32.00**	8.90	NS	<.01	5.50	0.1	**15.00**	<.01
Sep-08	**16.00**	NS	8.90	9.00	NS	<.01	2.80	<.01	**13.00**	<.01
May-09	1.80	NS	**30.00**	2.00	NS	<.01	3.60	<.01	**21.00**	<.01
Sep-09	**13.00**	NS	**40.00**	1.20	NS	0.53	2.50	<.01	**12.00**	0.30
Apr-10	2.60	NS	**17.00**	5.60	NS	0.20	4.20	<.01	**10.00**	0.10
Sep-10	**13.00**	NS	**28.00**	0.66	NS	0.25	2.40	<.01	**22.00**	0.15
Mar-11	1.80	NS	**28.00**	0.73	NS	0.39	4.00	<.01	**12.00**	0.19
Jun-11	1.50	NS	**26.00**	0.71	NS	0.26	1.40	0.15	8.40	0.51
Mar-12	0.54	NS	**27.00**	1.30	0.9	0.44	1.60	<.01	9.70	0.28
Sep-12	10.00	NS	**27.00**	<.02	<.01	<.01	1.40	<.01	**12.00**	<.01
Apr-13	3.30	NS	**38.00**	4.10	0.67	0.60	6.60	0.18	**17.00**	0.38
Sep-13	1.60	NS	**37.00**	**12.00**	<.01	0.01	2.90	<.01	8.70	0.73
Mar-14	1.80	NS	**34.00**	8.10	1.7	1.20	1.00	0.12	**14.00**	3.80

Notes: Concentration Greater than Groundwater Standard of 10 mg/L in Bold
NS = Not Sampled



LEGEND

Paper Size ANSI A

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Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane Massachusetts Mainland FIPS 2001 Feet

N

GHD

M T Environmental Restoration
Making Sense Out of Science
Molecular Translations, Inc.

Town of Orleans, Massachusetts

ORLEANS SOLID WASTE MANAGEMENT (SWM) SITE LOCUS MAP

Job Number	86-14842
Revision	A
Date	19 Mar 2015

Figure 1

1545 Iyannough Road, Hyannis Massachusetts 02601 USA **T** 1 508 362 5680 **F** 1 508 362 5684 **E** hyamail@ghd.com **W** www.ghd.com

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Paper Size ANSI B

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Map Projection: Lambert Conformal Conic
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LEGEND

Monitoring Well Location

GHD

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Town of Orleans, Massachusetts
Landfill Monitoring

Existing Site Plan

Job Number	86-14842
Revision	A
Date	19 Mar 2015

Figure 2

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Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:jjobrien

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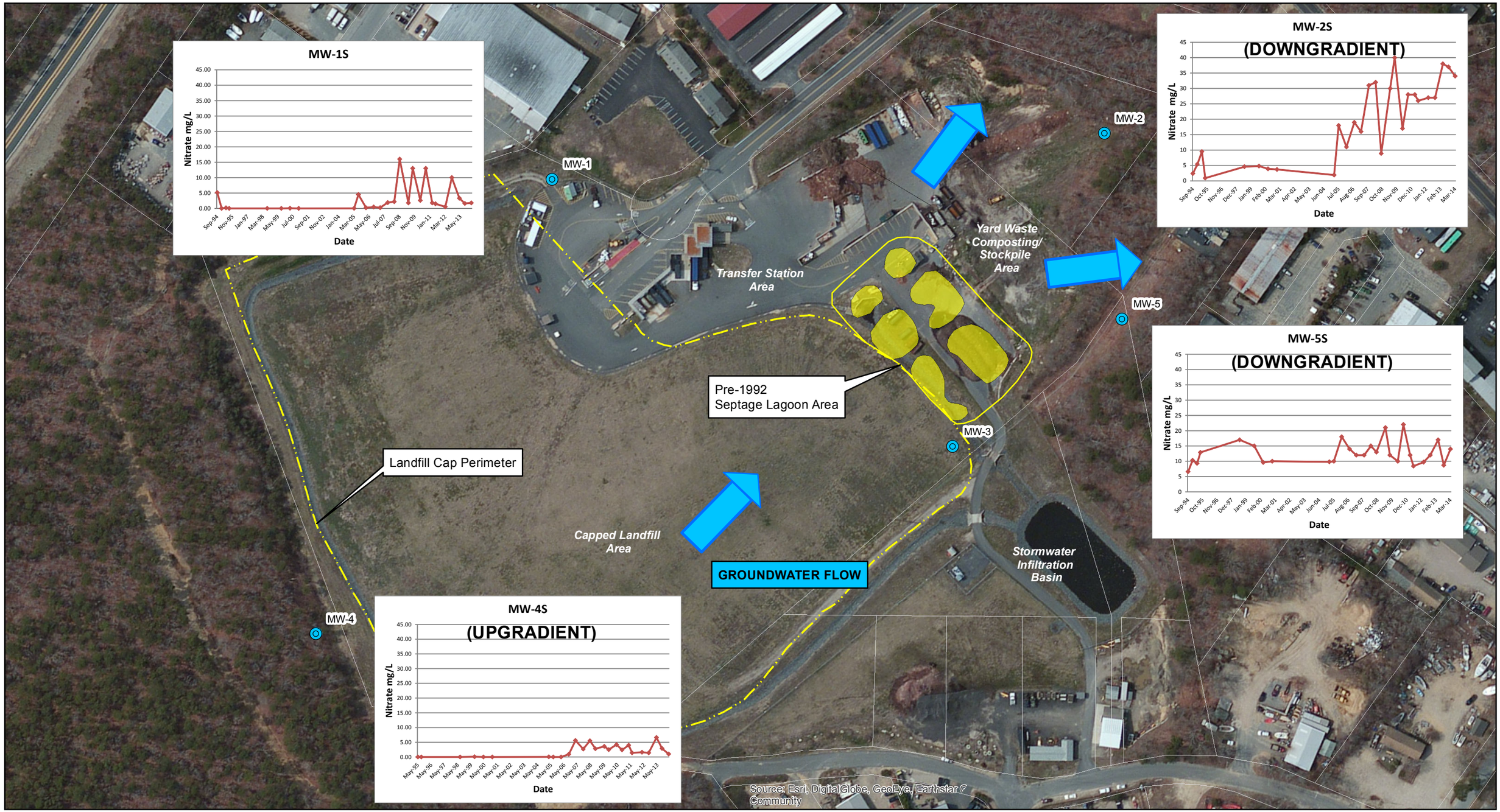

Paper Size ANSI B

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Map Projection: Lambert Conformal Conic
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LEGEND

Monitoring Well

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Town of Orleans, Massachusetts
Landfill Monitoring

Conceptual Site Model Plan

Job Number	86-14842
Revision	A
Date	08 Apr 2015

Figure 3

G:\86\14842\GIS\Maps\MXD_Deliverables\2015 FILES\Figure 3- Existing Site Septage.mxd

Data source: Data Custodian, Data Set Name/Title, Version/Date. Created by:jjobrien

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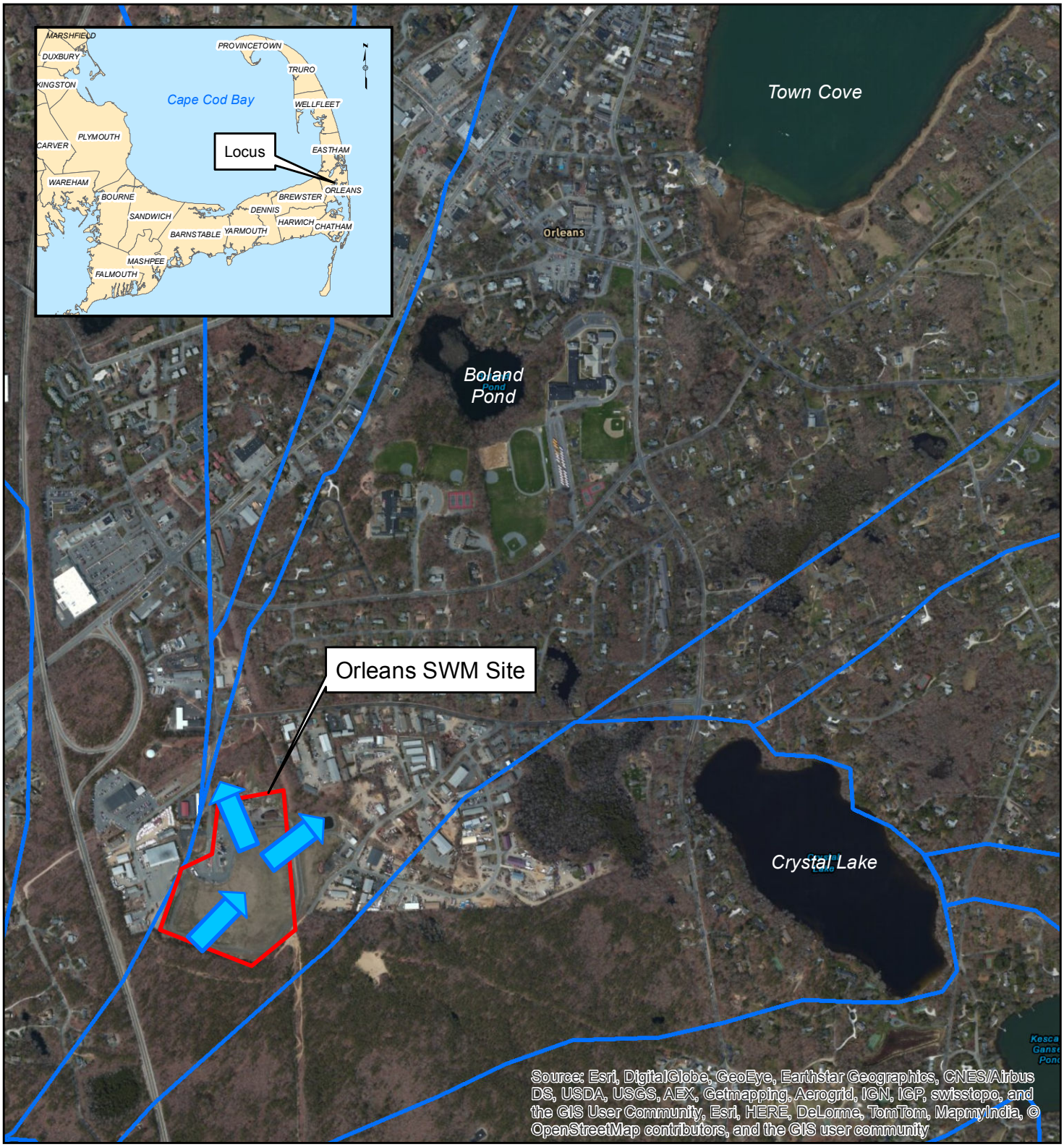

LEGEND

Mep Watershed

Groundwater Flow Direction

Paper Size ANSI A

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Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
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GHD

M T Environmental Restoration
Making Sense Out of Science
Molecular Translations, Inc.

Town of Orleans, Massachusetts

REGIONAL PERSPECTIVE ON WATERSHEDS

Job Number	86-14842
Revision	A
Date	16 Apr 2015

Figure 4

1545 Iyannough Road, Hyannis Massachusetts 02601 USA T 1 508 362 5680 F 1 508 362 5684 E hyamail@ghd.com W www.ghd.com

G:\86\14842\GIS\Maps\MXD_Deliverables\2015 FILES\Figure 4 - Regional Perspective.mxd

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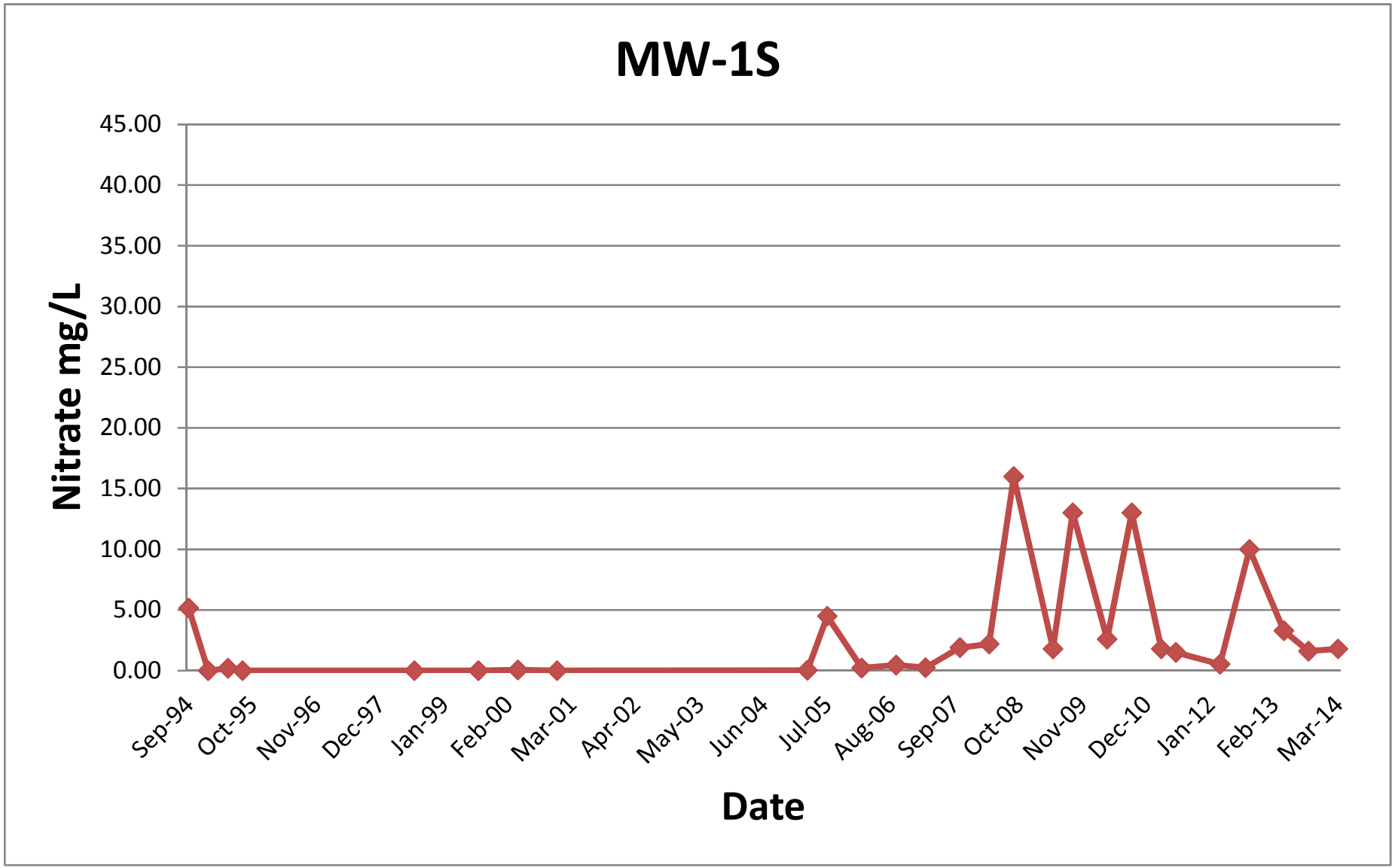
Appendix A – Monitoring Well Nitrate Data Charts


MW-1S
Nitrate mg/L
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40.00
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Sep-94
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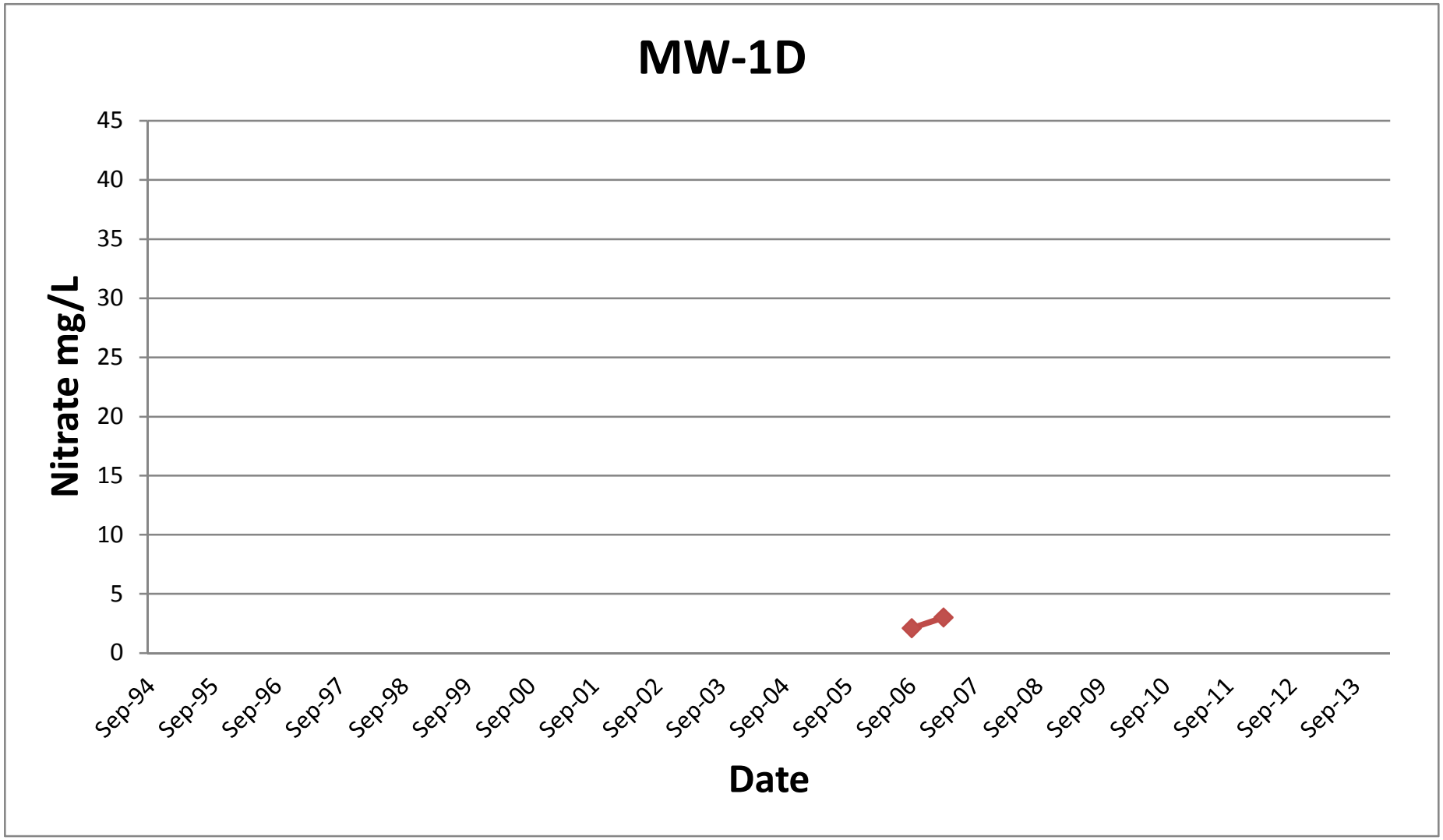
MW-1D
Nitrate mg/L
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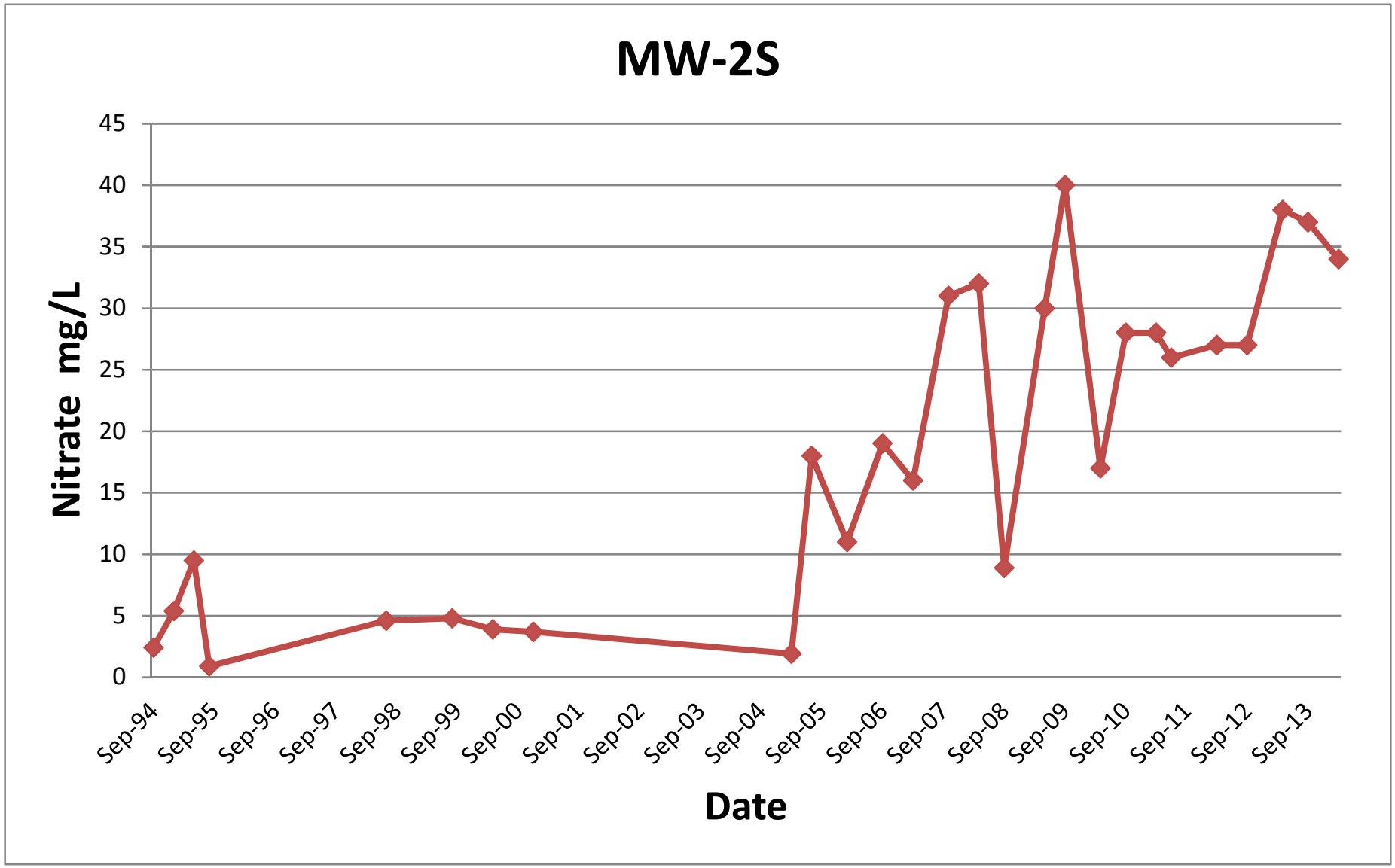
MW-2S
Nitrate mg/L
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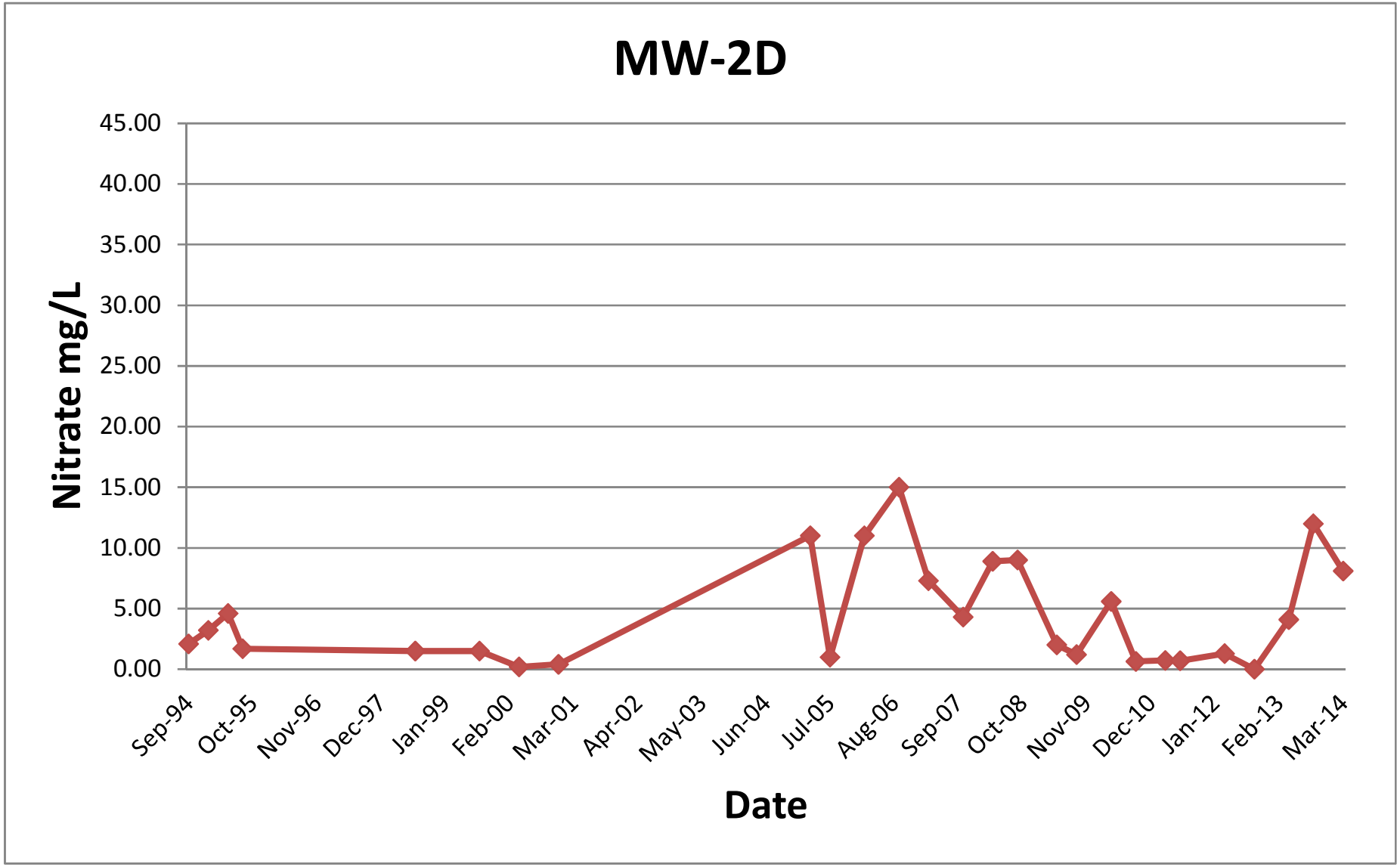
MW-2D
Nitrate mg/L
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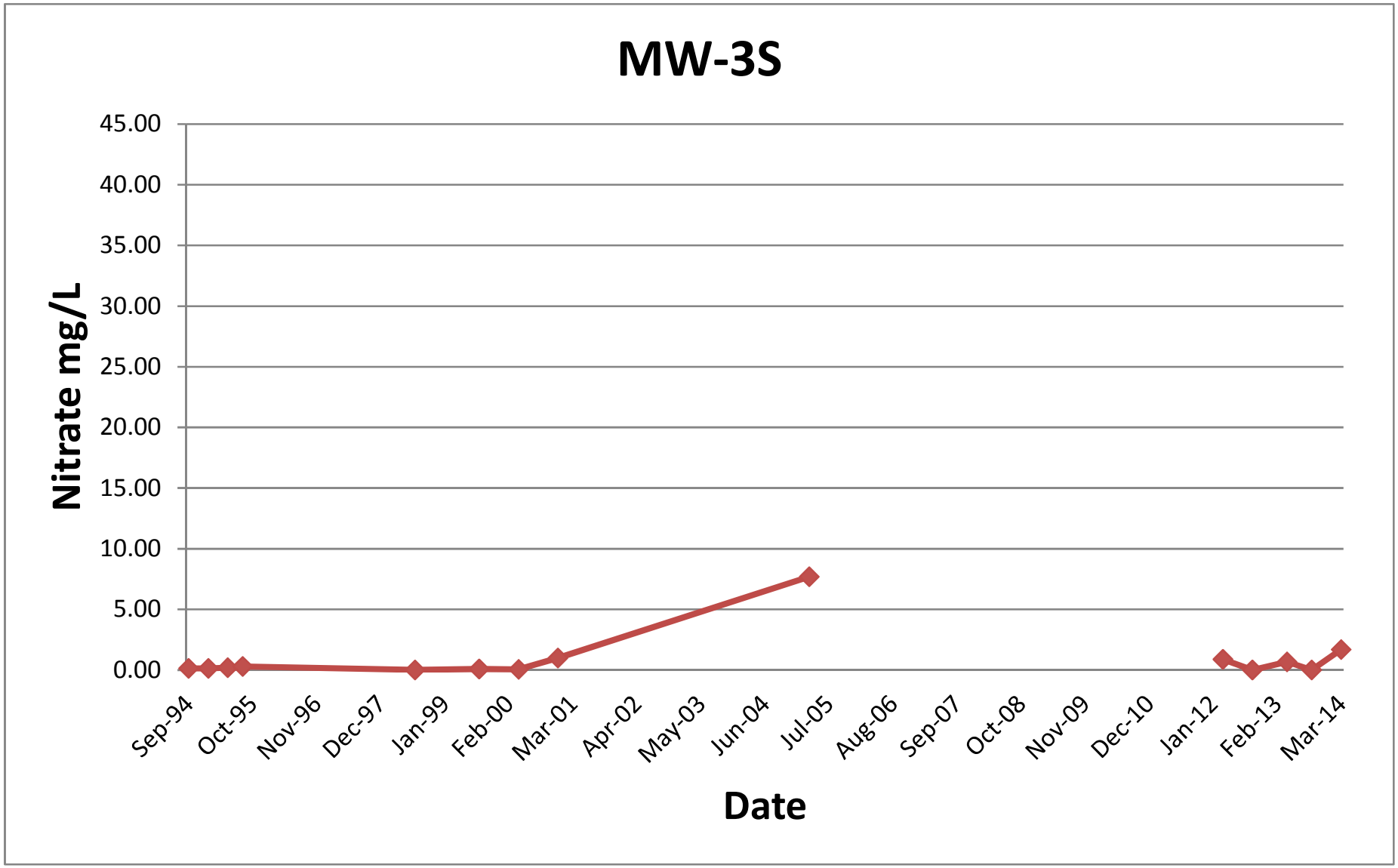
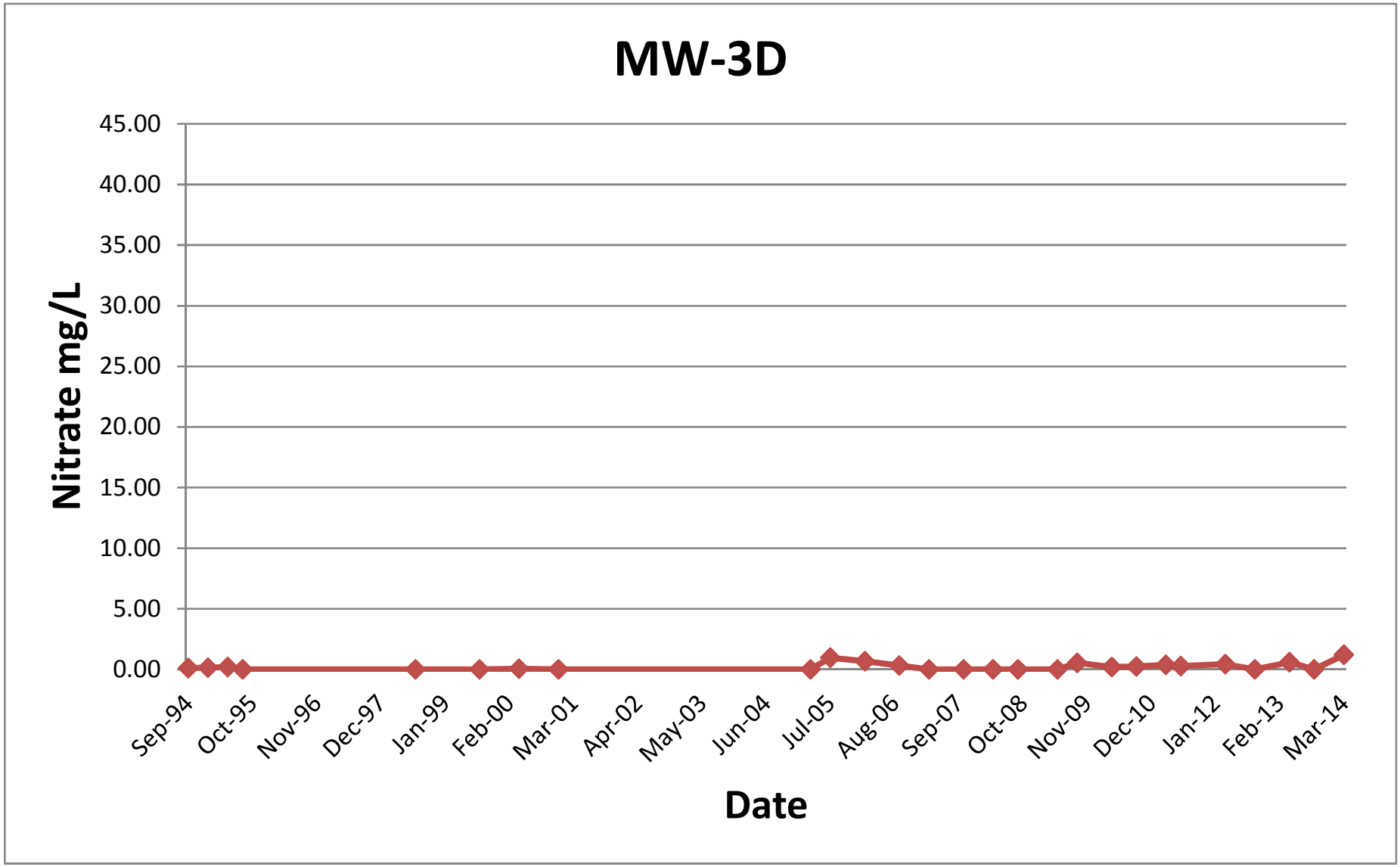
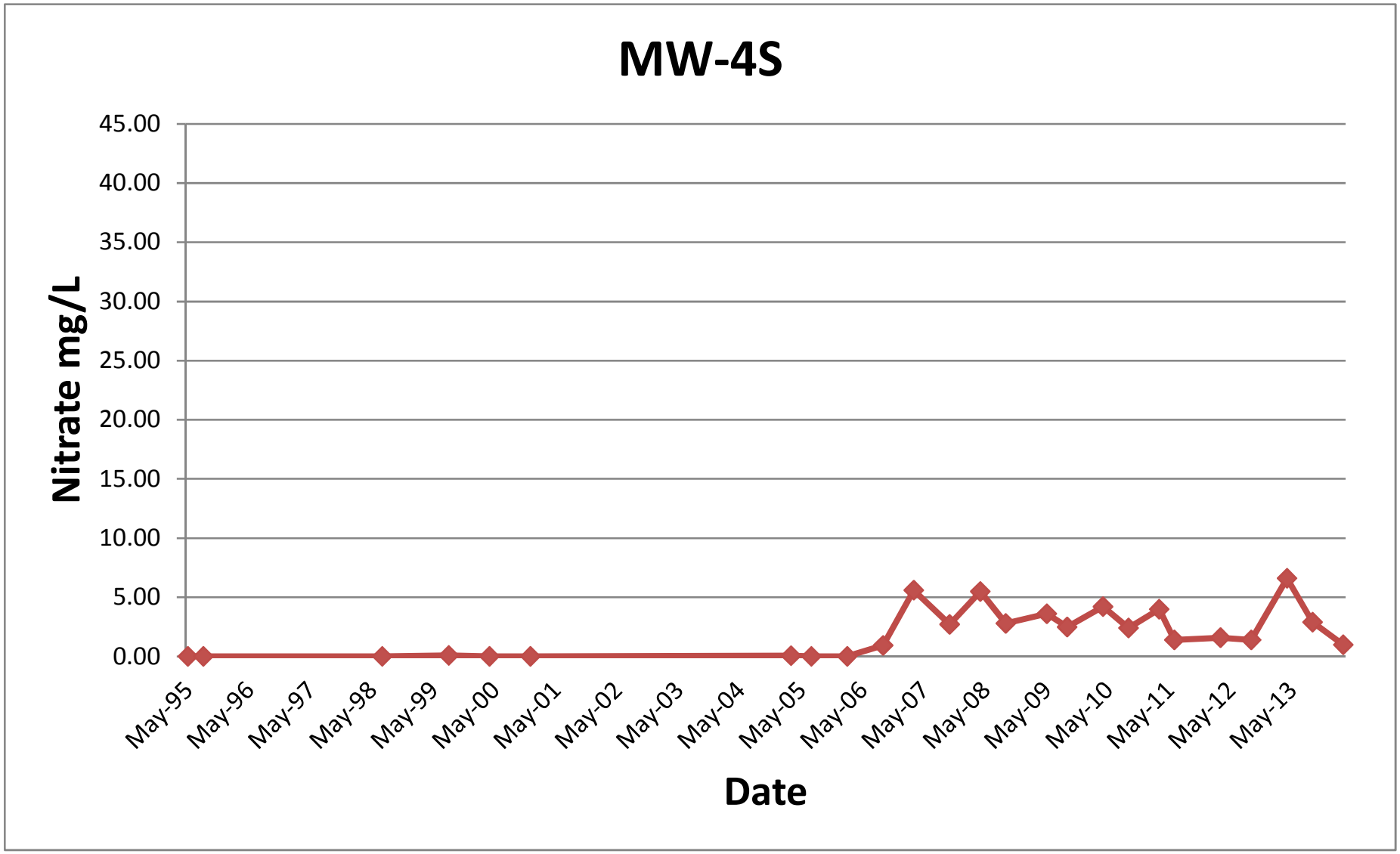
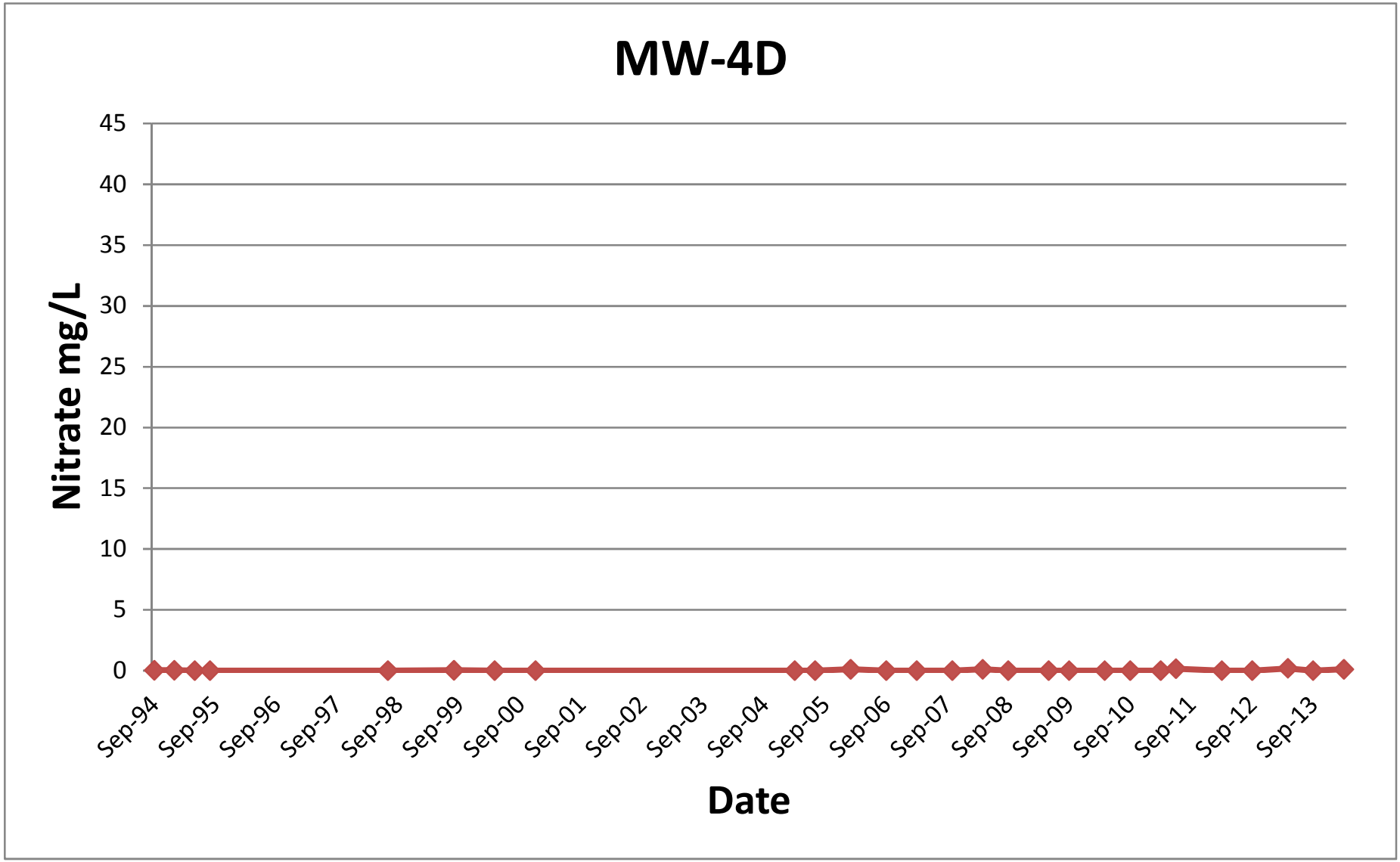

MW-3S
Nitrate mg/L
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Sep-94
Oct-95
Nov-96
Dec-97
Jan-99
Feb-00
Mar-01
Apr-02
May-03
Jun-04
Jul-05
Aug-06
Sep-07
Oct-08
Nov-09
Dec-10
Jan-12
Feb-13
Mar-14
Date


MW-3D
Nitrate mg/L
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Sep-94
Oct-95
Nov-96
Dec-97
Jan-99
Feb-00
Mar-01
Apr-02
May-03
Jun-04
Jul-05
Aug-06
Sep-07
Oct-08
Nov-09
Dec-10
Jan-12
Feb-13
Mar-14
Date


MW-4S
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Nitrate mg/L
May-95
May-96
May-97
May-98
May-99
May-00
May-01
May-02
May-03
May-04
May-05
May-06
May-07
May-08
May-09
May-10
May-11
May-12
May-13
Date


MW-4D
Nitrate mg/L
45
40
35
30
25
20
15
10
5
0
Sep-94
Sep-95
Sep-96
Sep-97
Sep-98
Sep-99
Sep-00
Sep-01
Sep-02
Sep-03
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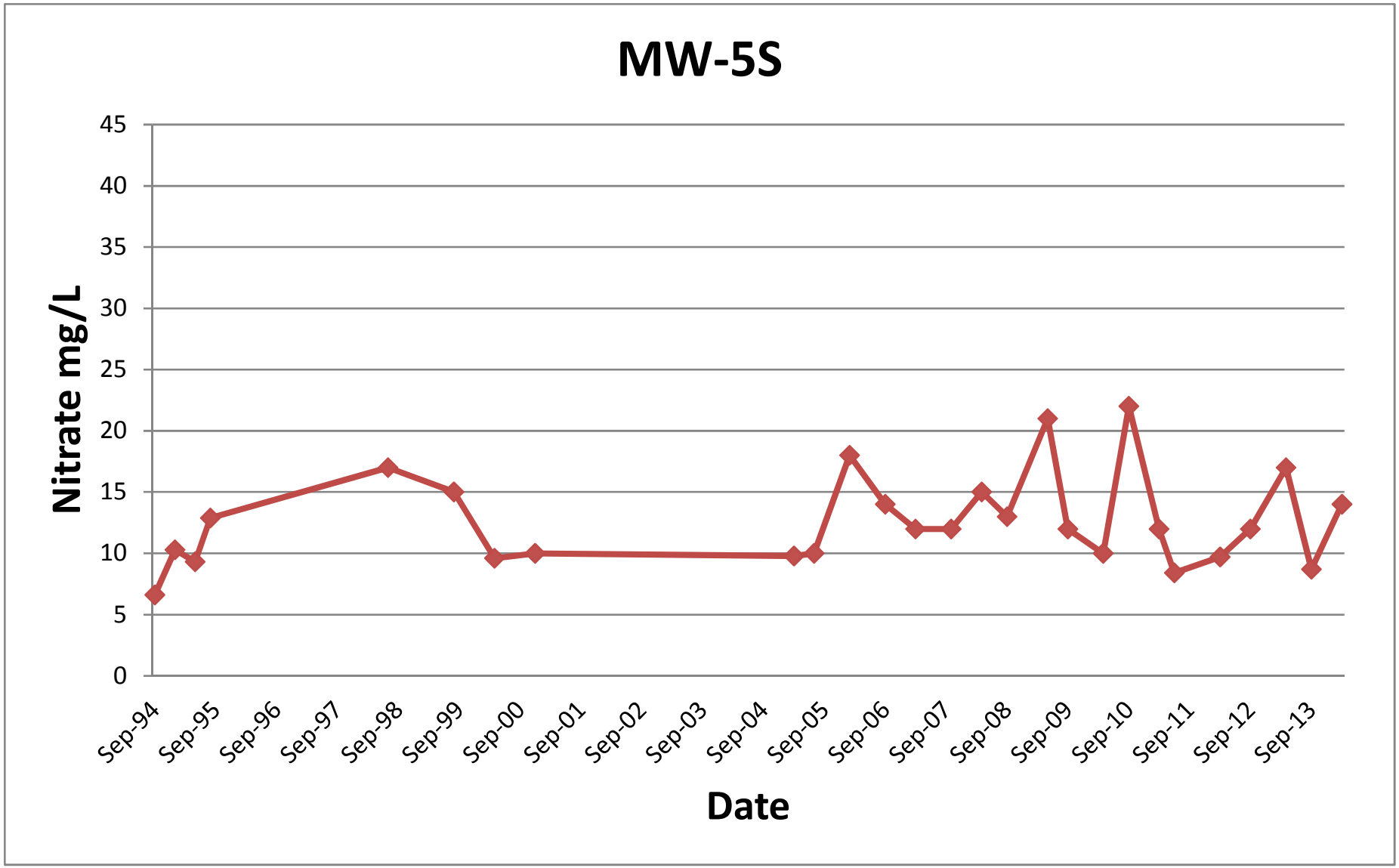
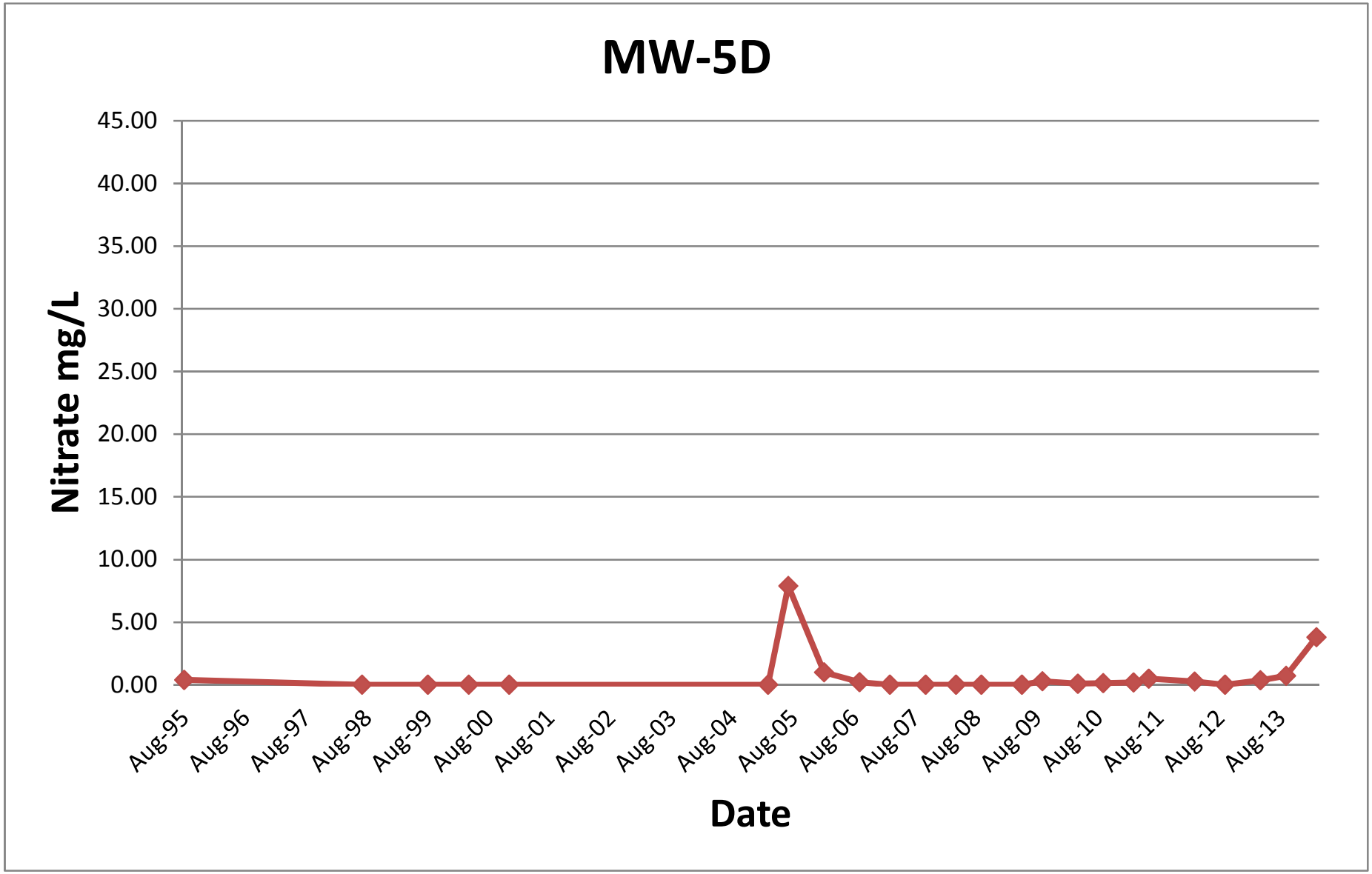
Sep-10
Sep-11
Sep-12
Sep-13
Date


MW-5S
Nitrate mg/L
45
40
35
30
25
20
15
10
5
0
Sep-94
Sep-95
Sep-96
Sep-97
Sep-98
Sep-99
Sep-00
Sep-01
Sep-02
Sep-03
Sep-04
Sep-05
Sep-06
Sep-07
Sep-08
Sep-09
Sep-10
Sep-11
Sep-12
Sep-13
Date


MW-5D
Nitrate mg/L
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
Aug-95
Aug-96
Aug-97
Aug-98
Aug-99
Aug-00
Aug-01
Aug-02
Aug-03
Aug-04
Aug-05
Aug-06
Aug-07
Aug-08
Aug-09
Aug-10
Aug-11
Aug-12
Aug-13
Date