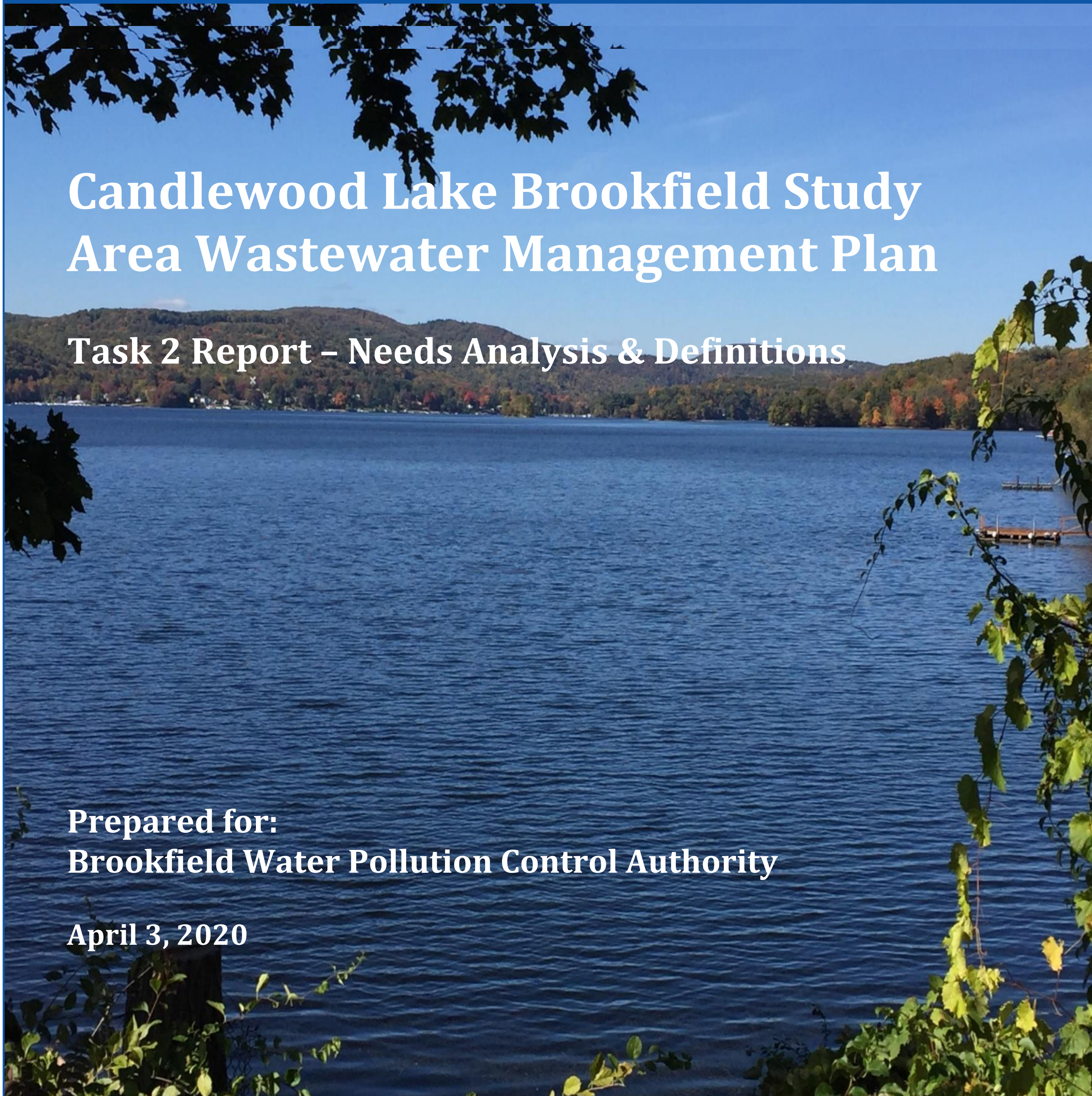

Candlewood Lake Brookfield Study Area Wastewater Management Plan

Task 2 Report – Needs Analysis & Definitions

Prepared for:
Brookfield Water Pollution Control Authority

April 3, 2020

TOWN OF BROOKFIELD CONNECTICUT SEAL 1788 PRO PATRIA

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1 INTRODUCTION & EXECUTIVE SUMARY

This Report presents the Task 2 Wastewater Management Needs Analysis and Definitions of the septic systems in the Brookfield Candlewood Lake Drainage Area and adjacent Areas of Concern. The purpose of the Wastewater Management Needs Report is to objectively define the wastewater improvement needs as accurately as possible based upon the cause of the Need – which enables the most precise, objective and transparent determination of the appropriate solution(s) and optimization of solution options cost-effectiveness.

In this Report, a property by property Wastewater Management Needs Definition is provided by determining needs in the categories of:

a. **Performance Need** – defined as septic systems not providing sufficient nitrogen, phosphorus and other constituents removal and thereby causing groundwater and/or surface water contamination such that the water bodies are not meeting their water quality standards and are therefore impaired. The primary areas of concern are septic impacts on:

    i. Quality of Candlewood Lake;
    ii. Groundwater aquifer, which is the water supply for the study area.

b. **Functional Need Due to Bacterial / Public Health Considerations** – defined as septic systems that are malfunctioning (such as flooded drainfield or breakout, inadequately draining waste fixtures, foul odors, excessive septic pumping, etc.) or have insufficient depth (minimum of 2 feet required) from drainfield bottom to seasonal high groundwater are classified as having a Functional Need. Malfunctioning systems are considered a public health threat.

c. **Insufficient Space** - lots having inadequate space for a CT Department of Health (DoH) code compliant wastewater system in the future when the current system fails. Properties with insufficient space require an off-site solution or DoH variances.

The methodologies used for determining the Needs in the various Categories are described in the following Sections that present the data and basis for addressing each Need type. Solution options are addressed in the Task 3 Report.

As described in this Report, the following Needs Definition conclusions have been determined by the Task 2 efforts.

1. **Impact on Quality of Candlewood Lake** – Wastewater represents a major source of nitrogen (N) and a significant but non-dominant source of phosphorus (P) to Candlewood Lake. Inputs of each are likely to be maximal in the littoral zone of the lake and likely promote the growths of milfoil and green algae mats in that area. The high ratio of N to P in groundwater inputs does not favor cyanobacteria, which are more likely to grow over deeper water where internal loading of P from sediment can be elevated and is likely to have a low ratio of N to P. However, the N and P recycled from the sediment ultimately came from the watershed, including the wastewater inputs, over many years, so management of watershed sources remains a valid approach to improving lake conditions. Consequently, it is likely that the internal load from sediments will have to be addressed separately, but in answer to the central question of the influence of wastewater on lake

water quality, wastewater is a major source of N and a minor source of P and its removal would be a benefit to the lake.

Reducing wastewater phosphorus and nitrogen contributions to the Lake will have a positive impact on milfoil control.

2. **Impact on Groundwater Drinking Water Aquifer** - Wastewater nitrate and PFOA/PFOS discharges to the Peninsula water supply have resulted in unhealthy nitrate and PFOA/PFOS concentrations. This wastewater impact on drinking is a serious public health issue. Solution options include:

    - Remove wastewater discharges to Peninsula drinking water aquifer;
    - Treat the water supply to remove nitrates and PFOA/PFOS;
    - Provide a new water supply source.

3. **Functional Need** – Approximately 25% of developed properties have reported a septic system problem.

4. **Insufficient Space** – Between 20% to 32%of developed properties have insufficient space to accommodate a CT Department of Health (DoH) code compliant septic system with the vast majority of those challenging sites on the Peninsula. For these properties, off-site solutions (i.e. sewers) will be required or code variances.

The following is recommended.

Based upon the numerous factors that point to the need for a community wide wastewater solution, it is recommended that a Peninsula and Non-Peninsula High Density area community-wide sewer system be implemented.

- The sewer system type and treatment/discharge option should be determined based technical and economic/financial optimization analysis to be performed in a subsequent project Report.

- Associated with a Peninsula (approximately 1,000 properties) community-wide wastewater system, Candlewood Lake studies should be performed to document improvements associated with the wastewater improvements.

- The degree to which wastewater improvements need to be implemented for the 400 +/- developed properties in the remaining Brookfield Candlewood Lake drainage area should be evaluated as part of the Peninsula wastewater improvement project.

2 PERFORMANCE NEEDS

Performance Needs are assessed by determining the Study Area septic system impacts on the water quality of Candlewood Lake and on area deep groundwater, which is the water supply for much of the study area. The methodologies used for these determinations are presented below.

2.1 SEPTIC SYSTEM INFLUENCE ON CANDLEWOOD LAKE & GROUNDWATER DRINKING WATER AQUIFER

STUDY METHODOLOGY

A. Background

The methodology used to determine septic system impacts on the quality of Candlewood Lake and groundwater water supply aquifer consisted of the following techniques that collectively enabled a scientific determination of septic wastewater purification prior to it reaching Candlewood Lake and the deep groundwater water supply aquifer. Then a quantitative estimate of septic impacts on Lake water quality will be performed by updating the Task 1 Report Table 4-6.

For Candlewood Lake quality impacts, phosphorus is the primary concern as it is considered to be the controlling nutrient for Lake's quality. Nitrate nitrogen, which for practical purposes all wastewater nitrogen forms get converted to, is a primary concern for protection of drinking water sources due to the public health limit of 10 parts per million (ppm), which is equivalent to milligrams per liter (mg/L). However it is noted that the US EPA issued an advisory in 2015 https://www.epa.gov/sites/production/files/documents/nandpfactsheet.pdf that phosphorus and nitrogen should both be considered to protect lake water quality. Other constituents of concerned are perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) which can cause adverse health effects and are sometimes referred to as forever chemicals as from a practical perspective, they do not degrade. As of January 2020, the CT drinking water standards for the total of PFOA + PFOS is 70 parts per trillion (ppt). Figure 2-1, from US EPA (https://federalleadership.chesapeakebay.net/130627_ches_bay_tech_assist_manual.pdf), illustrates how septic water travels to groundwater and then to surface water.

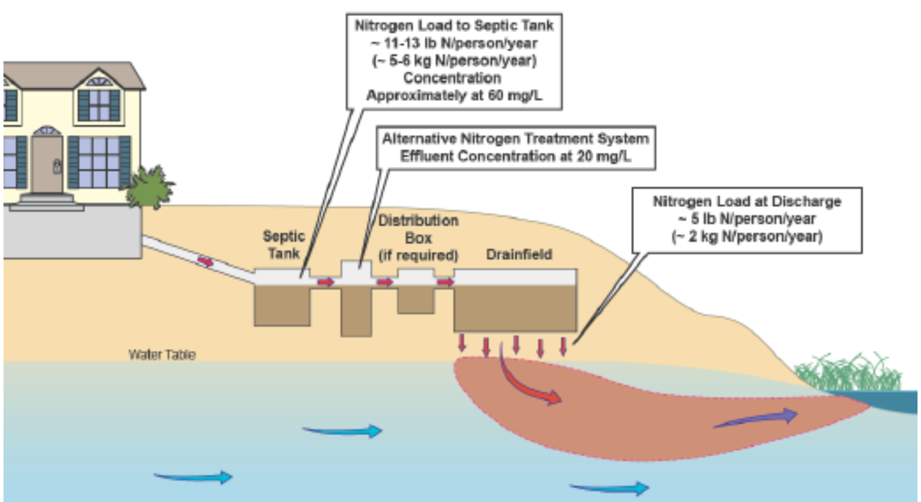


Figure 2-1 Septic Effluent Travel to Groundwater

In analyzing water quality, the following constituents are used as septic system tracers as they are typically absent or in low concentrations in waters not affected by septic systems.

Boron - a constituent used in laundry detergents
Chloride – common residential wastewater constituent, although road deicing salts can be a major contributor
Artificial sweeteners, in particular Acesulfame (ACE)
Electric conductivity – measure of ions as there will more ions in wastewater than groundwater
pH – typically, wastewater that passes through a drainfield will have a lower pH due to nitrification with its alkalinity consumption and pH Lowering
PFOA/PFOS - perfluorooctanoic acid (PFOA) and/or perfluorooctane sulfonate (PFOS)

For reference,

Phosphorus - Soluble Reactive Phosphorus (SRP) is the phosphorus form most readily available for algae. While phosphorus (P) chemistry is extremely complex, for simplicity Total phosphorus = SRP + organic P

Nitrogen - Total Nitrogen (TN) = Organic Nitrogen + Ammonia-N (NH_3) + Nitrite-N (NO_2) + Nitrate-N (NO_3)
Total Kjeldahl Nitrogen (TKN) = Organic Nitrogen + Ammonia-N

B. <u>Sites Selection for Testing</u>

To assess septic system impacts on the quality of Candlewood Lake and the groundwater drinking water aquifer, the following sites were selected as representative of the study area on which data would be collected to determined septic impacts, see the Site Testing Locations Map Figure 2-2:

- 76 South Lake Shore Drive
- 4 Longview Drive
- 74 North Lake Shore Drive

B.1 Drinking Water Aquifer

Additionally , drinking water from two (2) properties on the Peninsula (hereinafter defined as that area served by the Candlewood Shores Tax District (CSTD), Arrowhead Point Homeowners Association – see Figure 2-3) were sampled for the range of water quality constituents to ascertain whether septic systems are influencing the deep groundwater water supply aquifer. The two properties were:

- ✓ Residential property, 9 Arrowhead Road
- ✓ CSTD Office 55 Longview Drive

To enable a comparison, drinking water was also analyzed at 21 Main Drive, Brookfield, CT, which is a location outside of the Study Area and in the Aquarion of Western Brookfield District, that was understood not to be influenced by septic systems.

Drinking water supply wells are located within the districts as shown on Figure 2-3.

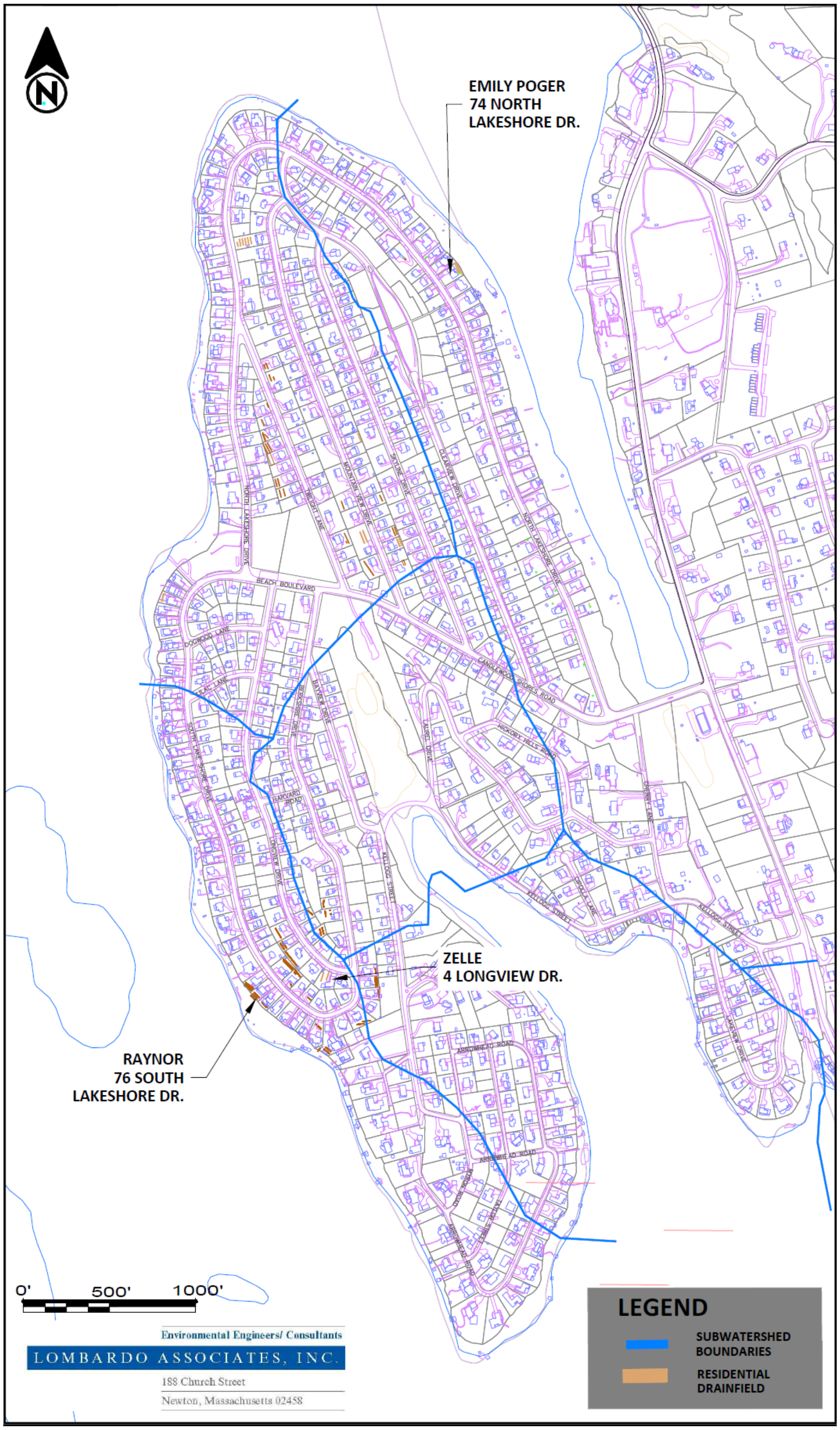


Figure 2-2 Site Testing Locations Map

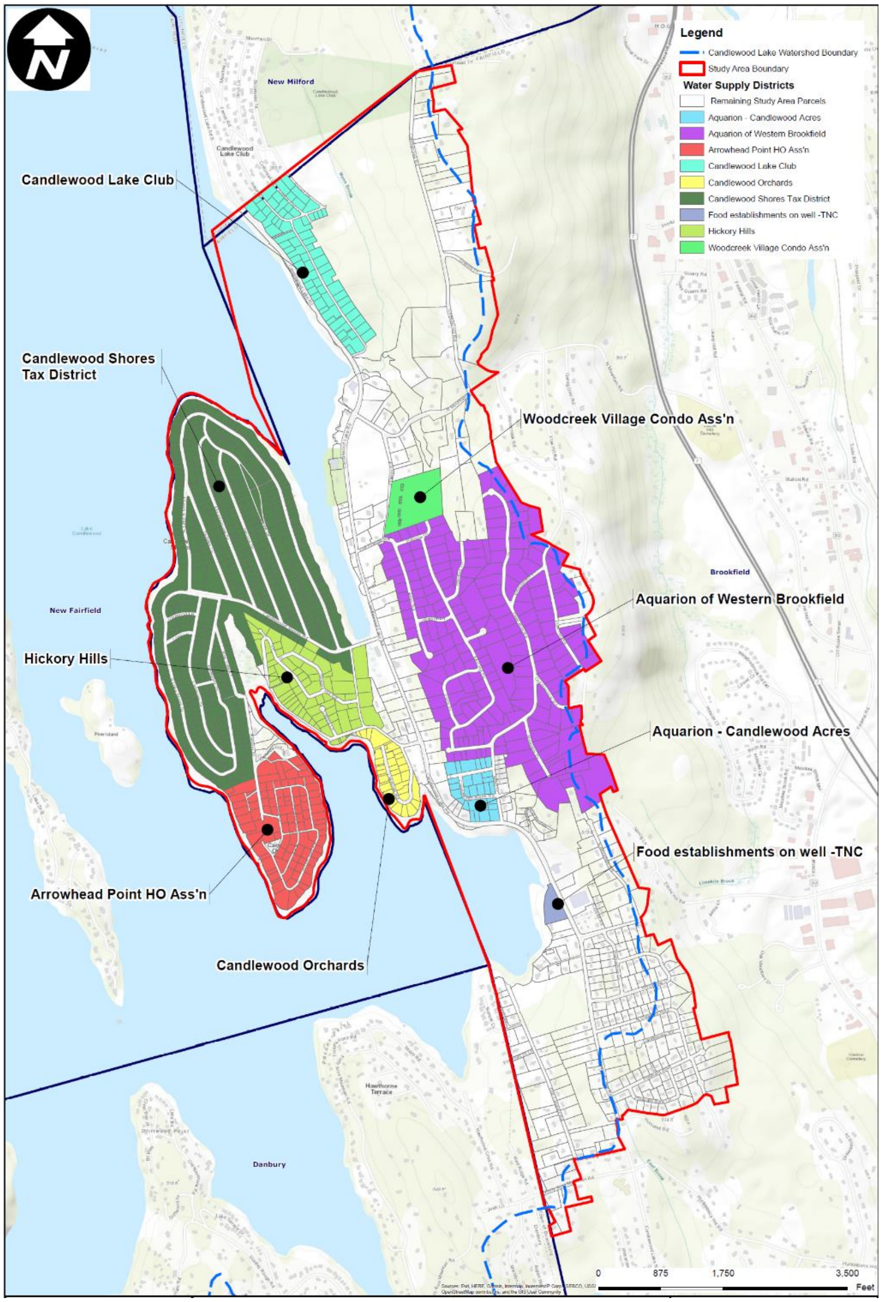


Figure 2-3 Study Area Water Supply Districts

B.2 Candlewood Lake Water Quality - Septic Tracers Sampling

Candlewood Lake water samples were collected near shore behind the property at 76 South Lake Shore Drive and analyzed for septic tracers of Boron and ACE.

B.3 Septic Wastewater Purification

To assess wastewater purification in septic systems and in the subsurface from the drainfield through the unsaturated soil and in groundwater prior to entering Candlewood Lake, the three residential properties listed above were selected for detailed testing of:

- Septic Tank effluent
- Drainfield soils to determine phosphorus removal within drainfield soils
- Groundwater quality immediately down gradient of the drainfields
- Groundwater quality slightly upgradient of the shoreline just prior to entering Candlewood Lake

Also, to assess septic purification from upland septic sources, groundwater quality was sampled across a cross section of a large area owned by FirstLight – located between the properties along 74 – 84 South Lake Shore Drive and Candlewood Lake. Soil samples from different elevations in the drainfield were analyzed for desorbable and acid extractable phosphorus and were examined with an electron microprobe to determine the degree to which septic wastewater phosphorus precipitates in the soils and thereby is removed.

The residential properties were selected in the following manner:

a. The quarterly water use records provided by CSTD were analyzed to identify properties that appeared to be full time residences – using the metric that average water use needed to be >> 100 gallons per day throughout the year.
b. Candidates were then sorted by those properties for which septic system record drawings existed.
c. Letters requesting expressions of interest in being test sites and willingness to sign an Access Agreement were sent to the remaining candidate property owners.
d. For properties expressing interest in being test sites, telephone interviews were performed and potentially viable candidate sites identified.
e. Site visits were then made to the potentially viable candidate sites (8 sites) to assess site conditions, in particular access and likely depth to groundwater.
f. The following residential sites were selected and property owners Access Agreements obtained, after which the sampling program was implemented.

    i. 76 South Lake Shore Drive (SLSD)
    ii. 4 Longview Drive (LV)
    iii. 74 North Lake Shore Drive (NLSD)

Figures 2-4 through 2-6 are site plans of the three sites with septic system and soils/groundwater sampling locations indicated, respectively. Figures 2-7 and 2-8 illustrate section views of sampling locations for the 76 South Lake Shore Drive and 74 North Lake Shore Drive sites. As groundwater was not located (due to its excessive depth), no groundwater sampling was performed at 4 Longview Drive.

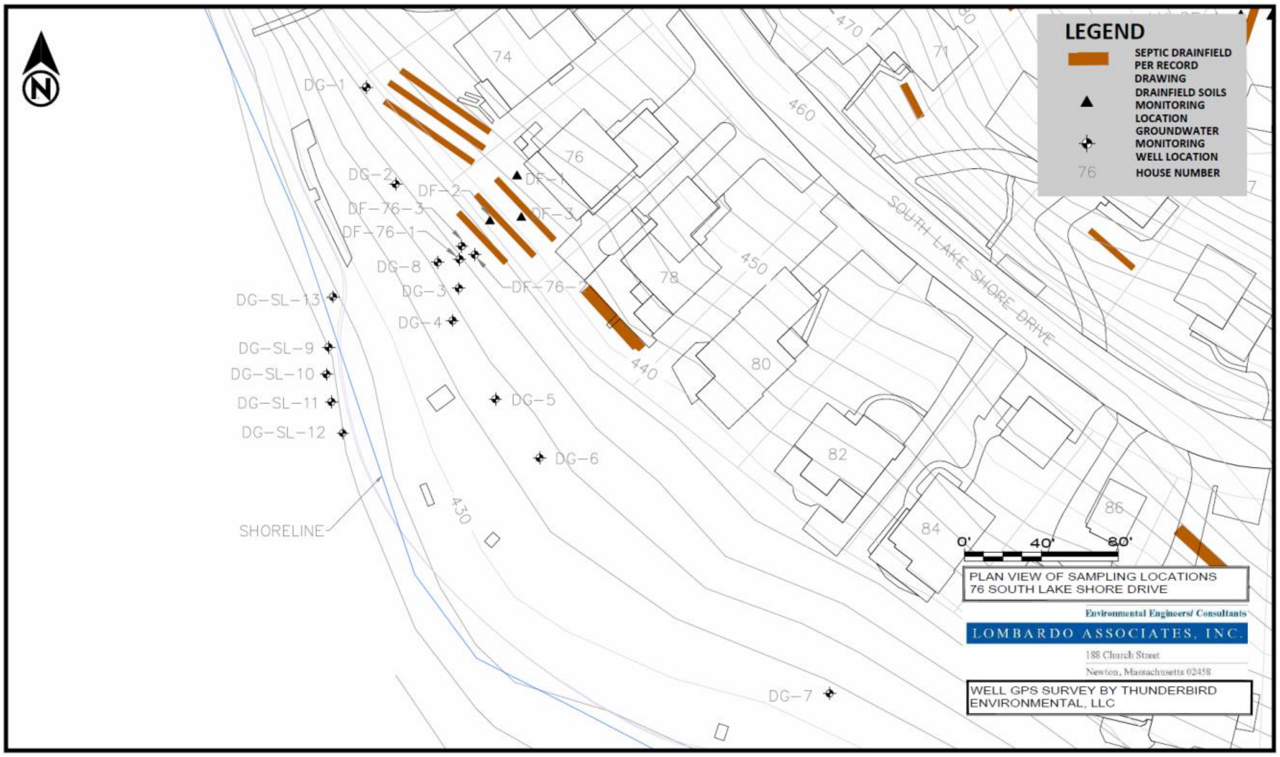


Figure 2-4 Site Plan – 76 South Lake Shore Drive

Figure 2-5 Site Plan – 4 Longview

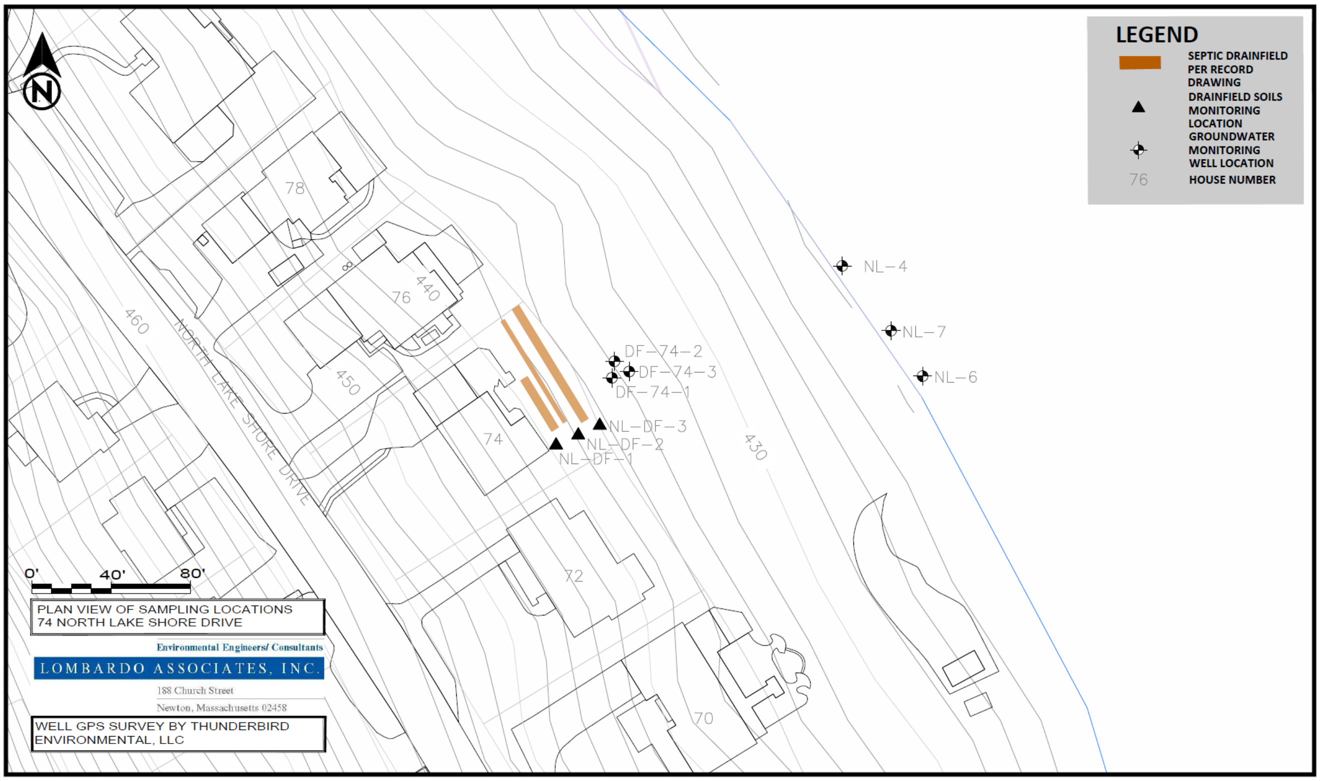


Figure 2-6 Site Plan – 74 North Lake Shore Drive

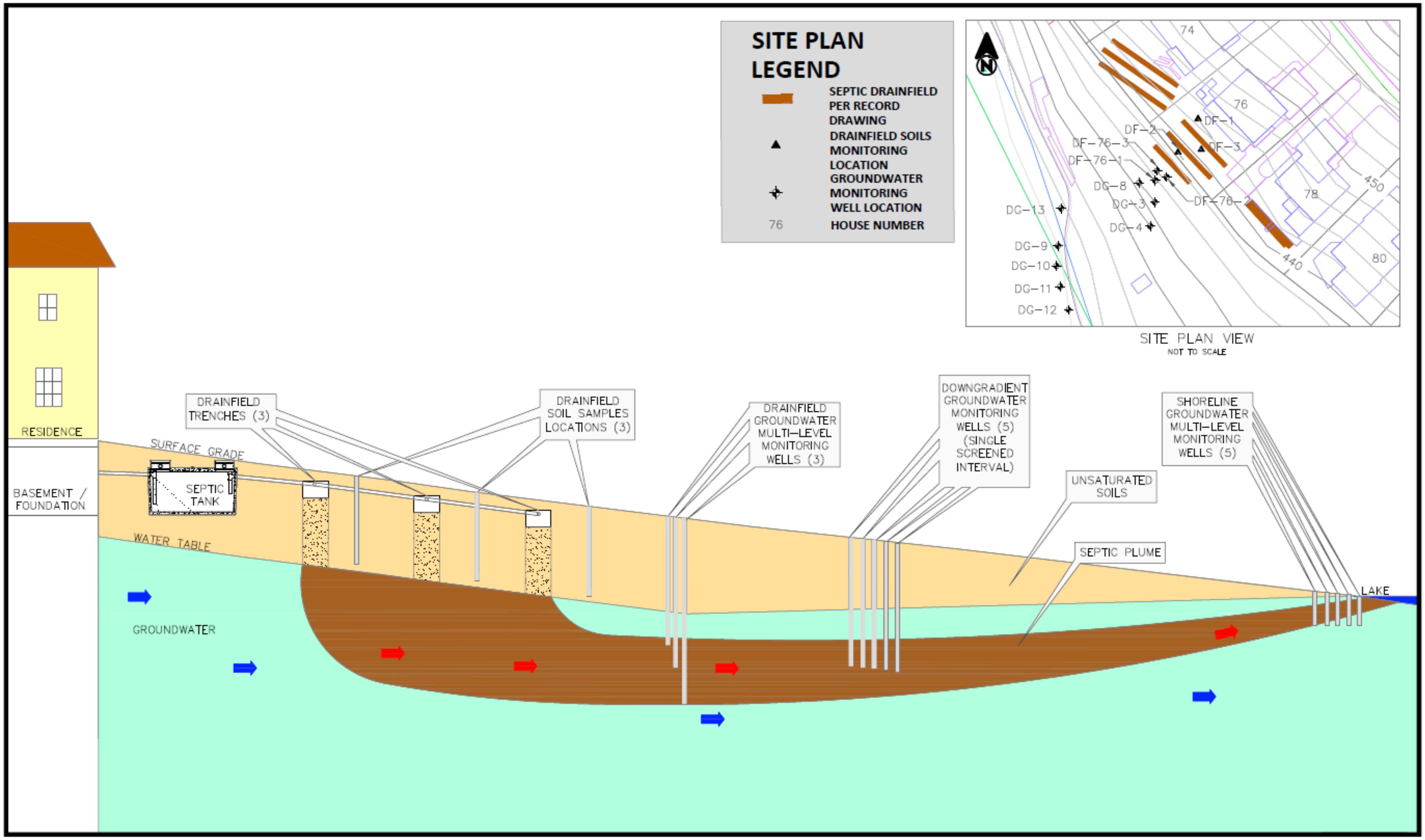


Figure 2-7 Section View of Sampling Locations - 76 South Lake Shore Drive

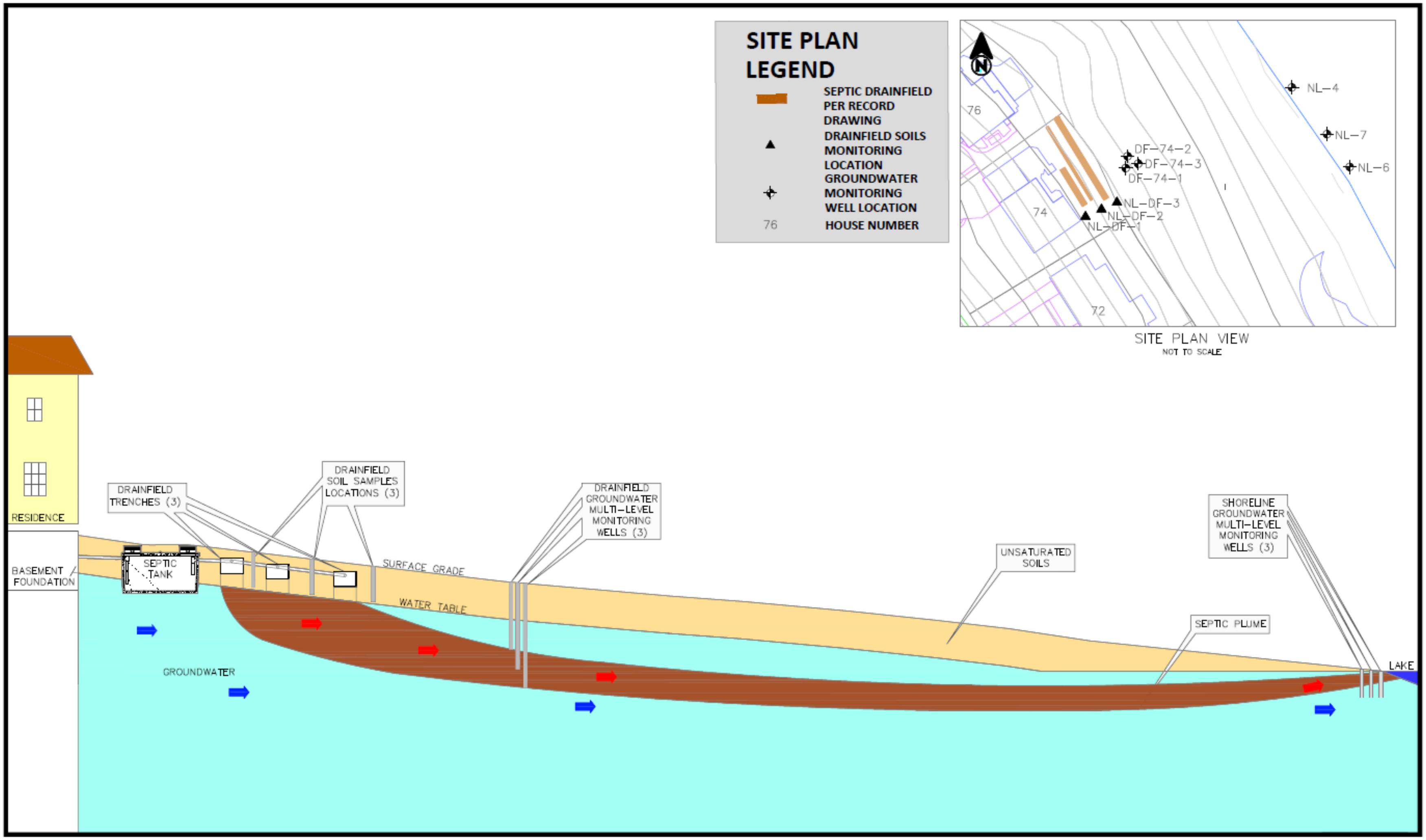


Figure 2-8 Section View of Sampling Locations – 74 North Lake Shore Drive

DATA

A.1 Drinking Water Aquifer

Table 2-1 presents the results of water supply sampling with Table 2-2 presenting the drinking water quality data from the water suppliers annual reports. The Chain of Custodies and laboratory reports for the drinking water sampling program are presented in Appendix I.

Septic system influence is strongly suggested by the nitrate-N and PFOA/PFOS concentrations. While determining the amount of the water supplies that is wastewater derived is beyond the scope of this project, the phosphorus concentrations suggest very high levels of septic wastewater phosphorus removal by soils. In accordance with CT guidance, PFOA/PFOS was sampled for twice to confirm concentrations.

Table 2-1 Drinking Water Supply Quality Data

Candlewood Lake Water Supplies - Drinking Water Analysis								
Water Source / Utility			Candlewood Shores	Arrowhead	Aquarion Western	Lake		
Sampling Date			14-Aug-19	22-Aug-19	16-Sep-19	16-Sep-19	18-Dec-19	
	Units	Det. Lim.				@ 76SLSD	@ 76SLSD	
Alkalinity	mg/L as $CaCO_3$	2	166	180				
Chloride	mg/L	10	94	93			33.1	35.1
pH	SU	n/a	7.1	7.5				
Nitrate-N	mg/L	0.100	6.99	6.85			0.67	0.99
TP	mg/L	0.010	0.015	0.017				
ortho-P	mg/L	0.005	0.016	0.018			<0.01	<0.01
Boron (1)	mg/L	0.030	0.054	0.038	ND	ND	<0.05	<0.05
Acesulfame K (2)	ppt-ng/L	100	532	1,040	204	102		
Sucralose	ppt-ng/L	1,000			1,900	ND		
Saccharin	ppt-ng/L	100			ND	ND		
PFOA	ppt-ng/L	1.72	24.6	8.14				
PFOS	ppt-ng/L	1.72	28.3	5.73				
PFOA/PFOS Total	ppt-ng/L	1.72	52.9	13.87				
Sampling Date			04-Sep-19	04-Sep-19	04-Sep-19	04-Sep-19		
PFOA	ppt-ng/L	1.72	20.3	8.69	10.7	3.71		
PFOS	ppt-ng/L	1.72	24.7	7.5	13.1	2.14		
PFOA/PFOS Total	ppt-ng/L	1.72	45.0	16.19	23.8	5.85		

(1) Sampled 4 Sept 2019 (2) Level of Quantification (LOQ) ND=Non Detect

Table 2-2 Study Area Water Supply Quality from Annual Reports

Water System		Nitrate (NO_3-N) Conc. (mg/L)		Sodium (Na) Conc. (mg/L)		Chloride (Cl) Conc. (mg/L)	
No.		MCL	Latest Actual	NL	Latest Actual	NL	Latest Actual
1	**Aquarion - Candlewood Acres**	10	0.7	28	16.2	250	7
2	**Aquarion of Western Brookfield**		3.5		53		53
3	**Arrowhead Point HO Ass'n**		7.9		24.8		100
4	**Candlewood Lake Club**		1.3		6.46		8.4
5	**Candlewood Orchards**		0		9.9		3.4
6	**Candlewood Shores Tax District**		7.5		31		31
7	**Food establishments on well -TNC**						
8	**Hickory Hills - Aquarion**		0.5		8.1		7.1
9	**Woodcreek Village Condo Ass'n**		0.7		18.7		129
	MCL = Maximum Contaminant Level						
	NL = State of Connecticut customer notification level. Elevated levels of sodium, coupled with dietary intake, can potentially affect those on a sodium-restricted diet.						

A.2 Candlewood Lake Water Quality - Septic Tracers Sampling

Table 2-1 also presents the results of Candlewood Lake water sampling for septic tracers of boron, ACE and PFOA/PFOS. The Chain of Custodies and laboratory reports for the Candlewood Lake septic tracers sampling program are presented in Appendix II.

A.3 Septic Wastewater Purification

Table 2-3 presents the chronology of data collection. Detailed information on installed wells is presented in Section 2.2.

To identify plumes from nearby property septic systems along 74-84 SLSD and septic influences from further upgradient sources, groundwater quality data was collected along an approximate 500 foot cross section of a large area owned by FirstLight – located between the properties along 74 – 84 South Lake Shore Drive (SLSD) and Candlewood Lake. The data is presented on Table 2-4.

Tables 2-4 and 2-5 present septic tank and groundwater quality data for the sampling events of 17 Oct 2019, 4 Nov 2019 and 18-23 Dec 2019 for 76 SLSD / 4 Longview and 74 NLSD, respectively. The Chain of Custodies and laboratory reports for the septic wastewater purification sampling program are presented in Appendix III.

Table 2-6 presents groundwater pH and Electric Conductivity (EC) field measurements at the shoreline down gradient wells.

Figure 2-9 presents the Groundwater Seep Location Map & Quality Data that has been collected by FirstLight. The data is owned by FirstLight Power and was collected by North East Aquatic Research at the request of FirstLight Power.

Appendix V presents the report on septic drainfield soils retention at the three study sites.

Table 2-3 Chronology of Field Data Collection

Chronology of Candlewood Lake Drainage Area Wastewater Data Collection							
Reporting Date	Activity	Locations	76 SLSD	4 LVD	74 NLSD	Water Supply	CL
8/22/2019	Samples collected for: Chloride, pH, Ammonia, Nitrate-N, Ortho-phosphate, Total Phosphorus, Alkalinity	CL					✓
8/29/2019	Samples collected for: PFOA/PFOS, Chloride, pH, Ammonia, Nitrate-N, Ortho-phosphate, Total Phosphorus, Alkalinity	CS				✓	
9/10/2019	Samples collected for: PFOA/PFOS, Chloride, pH, Ammonia, Nitrate-N, Ortho-phosphate, Total Phosphorus, Alkalinity	AR				✓	
9/11/2019	Samples collected for: Boron	AR, CS, CL, WA				✓	✓
9/12/2019	Samples collected for: Acesulfame K	AR				✓	✓
9/23/2019	Samples collected for: PFOA/PFOS, Boron	AR, CS, CL, WA				✓	
9/27/2019	Samples collected for: Acesulfame K	WA, CL				✓	✓
9/30/2019	Installation of Down Gradient wells	SLDS 74 to 84					
10/4/2019	Samples collected for: Nitrate-N, Total Phosphate, Total Phosphorus	[1]	✓	✓	✓		
10/18/2019	Installationof shore line wells and drain field soil sample collection	76 SLSD + 74 NLSD					
10/23/2019	Samples collected for: Chloride, Ammonia, TKN, Nitrate-N, Ortho-phosphate, Total Phosphorus, Boron	[2]	✓	✓	✓		
10/24/2019	Installation of Drain Field monitoring wells	76 SLSD + 74 NLSD					
11/7/2019	Samples collected for: Acesulfame K	[3]	✓		✓		
11/12/2019	Samples collected for: Chloride, Ammonia, TKN, Nitrate-N, Ortho-phosphate, Total Phosphorus, Boron	[4]	✓		✓		
11/15/2019	Samples collected for: Acesulfame K	[5]	✓		✓		
11/20/2019	Installation of ground water elevation continuous monitoring equipment at 76 SLSD & 74 NLSD	76 SLSD + 74 NLSD					
12/18/2019 12/23/2019	Samples collected for: PFOA/PFOS, Acesulfame K, Chloride, pH, Ammonia, Nitrate-N, Ortho-phosphate, Total Phosphorus, Alkalinity	76 SLSD, 4 LVD + 74 NLSD	✓	✓	✓		✓

Foot Notes

[1] SLSD (DG-1, DG-2, DG-3, DG-4, DG-5, DG-6, DG-7, DG-8)
[2] SLSD (Septic Tank, DG-13-2, DG-13-3), LV (Septic Tank), NL (Septic Tank, NL4-1, NL7-1)
[3] SLSD (Septic Tank, DG-9-2, DG-13-2, DG-13-3), LV(Septic Tank), NL(Septic Tank, NL-4-1, NL-6-1.5, NL-7-1)
[4] SLSD (DF-76-1, DF-76-2, DF-76-3, DG-9-2, DG-10-2, DG-13-2, DG-13-3), NL(DF-74-1, DF-74-2, DF-74-3, NL-4-1, NL-6-1.5)
[5] SLSD (DF-76-1, DF-76-2, DF-76-3), 74 NL (DF-74-1, DF-74-2, DF-74-3)

Legend

CL: Candlewood Lake
CS: CandleWood Shores
AR: Arrowhead
WA: Western Aquarion

Table 2-4 76 SLSD & 4 LV Consolidated ST and Groundwater Quality Data

76 South Lake Shore Drive Site											
	EC^2 (uS/cm)	pH^2	SRP (mg/L)	TP (mg/L)	Cl (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_4-N (mg/L)	TKN (mg/L)	ACE (ng/L)	B (mg/L)
STE Oct 17, 2019	14,000	6.1	2.36	2.56	200	1.6		19.5	21.2	60,800	0.71
STE Dec 18, 2019			4.12	6.63	228	<0.02		63	83.4	131,000	<0.25
Drainfield Wells Dec 18, 2019											
76-DF1	1,358	7.4	0.01	0.01	331	11.4		0.83		14,400	0.12
76-DF2	1,374	7.6	0.01	0.01	370	8.6		1.01		16,300	0.15
76-DF3	1,392	7.6	0.01	0.01	354	12.3		1.02		11,500	0.2
Drainfield Wells Dec 18, 2019											
76-DF1			<0.01		312	9.7	1.3			11,400	0.18
76-DF2			<0.01		405	6.73	0.417			14,200	0.18
76-DF3			<0.01		304	9.65	1.25			10,900	0.25
Down Gradient wells Oct 2, 2019											
76-DG1			0.04			11.5					
76-DG2			0.58			14.5					
76-DG3			0.11			9.5					
76-DG4			0.03			4.9					
76-DG5			0.04			5.5					
76-DG6			0.04			5.6					
76-DG7			0.09			4.8					
76-DG8			0.72			14.6					
Average			0.21			8.86					
Down Gradient wells Dec 18, 2019											
76-DG1			0.01			12.2	<0.01				
76-DG2			<0.01			12.3	<0.01				
76-DG3			<0.01			5.85	<0.01				
76-DG4			<0.01			5.7	0.058				
76-DG5			0.02			0.79	<0.01				
76-DG6			0.02			0.47	<0.01				
76-DG7			0.01			4.87	<0.01				
76-DG8			<0.01			5.6	<0.01				
Down Gradient (lakeshore) Wells Oct 17, 2019											
76-DG9-2	631	6.7								2.4	
9-3	660	6.2									
9-4PVC	720	7.1									
76-DG10-1	225	6.4									
10-2	212	6.1								<0.1	
10-3	250	6.7									
10-3PVC											
76-DG11-1	248	6.9									
-2	288	6.6									
-3	280	7									
-3PVC	318	7.1									
76-DG12-1	298	6.7									
-2	265	7.1									
-2PVC	297	7.4									
76-DG13-2	207	7	0.04	0.05	21	3.4		ND		5.4	ND
-3	654	6.2	0.02	0.03	100	6.1		ND		8.3	0.07
-4	542	6.2									

76 South Lake Shore Drive Site											
	EC[2] (uS/cm)	pH[2]	SRP (mg/L)	TP (mg/L)	Cl (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_4-N (mg/L)	TKN (mg/L)	ACE (ng/L)	B (mg/L)
Down Gradient (lakeshore) Wells Nov 4, 2019											
76-DG9 -2	684	6.1	0.011	0.016	163	7.5		<0.05			0.07
76-DG10-2	170	6.2	0.011	0.017	23	12.4		<0.05			0.09
76-DG13-2	1,073	6.1	0.011	0.013	270	12.4		<0.05			0.09
76-DG13-3	1,025	6	<0.01	0.022	299	14.1		<0.05			0.1
Down Gradient (lakeshore) Wells Dec 18, 2019											
76-DG9 -2			0.01		198	11.4	<0.01				0.06
76-DG10-2			<0.01		38	4.98	<0.01				<0.03
76-DG13-2			<0.01		304	13.5	<0.01				0.09
76-DG13-3			0.01		316	14.7	<0.01				0.09

LV Site											
	EC[2] (uS/cm)	pH[2]	SRP (mg/L)	TP (mg/L)	Cl (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_4-N (mg/L)	ACE (ng/L)	TKN (mg/L)	B (mg/L)
Tank Effluent (1) Oct 17/19	1,377	7	6.1	5.5	140	ND		40	27,000	44	0.076
Tank Effluent (2) Dec 18, 19			4.71	5.9	136	<0.02	0.014	43.7	2,000	54	0.07

Table 2-5 74 NLSD Consolidated ST and Groundwater & Lake Quality Data

NL Site (74 North Lake Shore Drive)											
	EC[2] (uS/cm)	pH[2]	SRP (mg/L)	TP (mg/L)	Cl (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	NH_4-N (mg/L)	TKN (mg/L)	ACE (ng/L)	B (mg/L)
Tank Effluent (1) Oct 17/19	1,252	6.8	4.3	4.8	140	0.3		14.2	37.4	57,000	0.062
Tank Effluent (2) Dec 18, 19			3.83	4.37	135	<0.02	<0.01	43.3	47.5	39,000	0.06
Drainfield Wells, Nov 4, 2019											
NL-DF1	588	7.6	0.01	0.03	38	10.3		<0.1		906	<0.05
NL-DF2	634	7.1	0.01	0.01	62	6.4		<0.1		3,620	<0.05
NL-DF3	642	7.1	0.01	0.05	70	4.9		<0.1		6,240	<0.05
Drainfield Wells, Dec 23, 2019											
NL-DF1			0.01		36	10.7	0.011			1	<0.05
NL-DF2			0.01		62.2	6.05	<0.01			6	<0.05
NL-DF3			0.01		85	2.63	<0.01			12	<0.05
Down Gradient (lakeshore) wells Oct 17, 2019											
NL4-1	660	6.7	0.02	0.02	44	3.2		ND		454	0.044
4-2											
4-2.5PVC	698	7.3									
NL6-1	906	7.1									
6-1.5	872	6.9								198	
6-2PVC	700	7									
NL7-1	958	6.6	0.02	0.02	84	0.88		0.09		2,600	0.12
7-1.5											
7-2PVC	965	6.8									
Down Gradient (lakeshore) wells Nov 4, 2019											
NL4-1	403	7	0.012	0.016	38	1.7		0.07			<0.05
6-1.5	752	7	0.013	0.014	63	5.8		<0.05			0.06
Down Gradient (lakeshore) wells Dec 23, 2019											
NL7-1			0.01		76.1	1.14	<0.01				0.01

Candlewood Lake													
		EC[2]	pH[2]	SRP	TP	Cl	NO_3-N	NO_2-N	B	PFOA	PFOA	Total PFOA+PFOS
		(uS/cm)		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	ng/L	ng/L	ng/L
at 76 SLSD	18-Dec-19			<0.01		33.1	0.67	0.011	<0.05	2.95	3.27	6.22
at 74 NLSD	23-Dec-19			<0.01		35.1	0.99	0.011	<0.05			

Table 2-6 Septic Tank & Shoreline Groundwater pH and EC data

ST & Shoreline Groundwater pH & EC Data October 17, 2019				
76 South Lake Shore Drive - Field Measurements				
Well ID	DBGS (feet)	Yield*	EC (uS/cm)	pH
Septic Tank			14,000	6.1
DG-9	2	G	631	6.1
	3	G	660	6.2
	4	P	720	7.1
DG-10	1	G	225	6.4
	2	G	212	6.1
	3	F	250	6.7
	3	P		
DG-11	1	G	248	6.9
	2	G	288	6.8
	3	P	280	7
	3	F	318	7.1
DG-12	1	G	298	6.7
	2	G	265	7.1
	2	P	297	7.4
DG-13	2	G	207	7
	3	G	654	6.2
	4	G	542	6.1
74 North Lake Shore Drive - Field Measurements				
Septic Tank	DBGS		1,252	6.8
NL-4	1	G	660	6.7
	2	P		
	2.5	P	698	7.3
NL-6	1	F-G	906	7.1
	1.5	F-G	872	6.9
	2	F-G	700	7
NL-7	1	G	958	6.6
	1.5	P		
	2	G	965	6.8
4 Longview Drive - Field Measurements				
Septic Tank			1,377	7.2
Notes: DBGS = Depth Below ground surface				
* Yield of Well P=Poor; F=Fair; G=Good; VG = Very Good				

Study Area Groundwater Seeps Water Quality Data[1] (parts/million - mg/L)				
Date	**Seep # / Location**	**NO_x**	**TN**	**TP**
4-Feb-19	9	2.7	3.24	0.030
	12	1.59	2.13	0.061
	17	4.79	5.27	0.035
	18	9.12	7.26	0.013
	19	9.66	7.38	0.017
	20	8.11	7.08	0.014
	21	6.54	6.49	0.009
	23	2.14	2.53	0.022

(1) Data provided by Firstlight Power

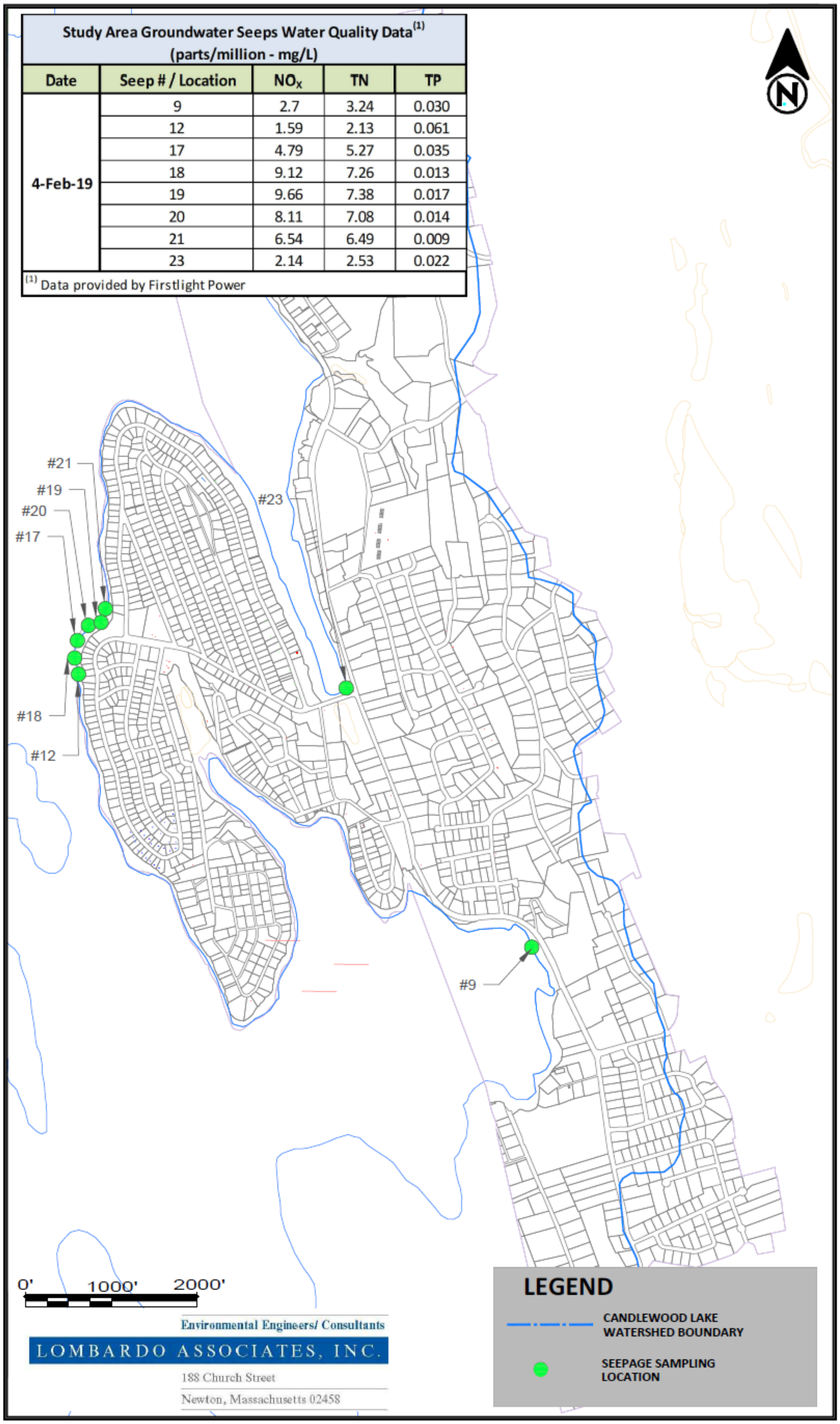


Figure 2-9 Groundwater Seep Location Map & Quality Data

2.2 Groundwater Contours, Slopes and Flow

To estimate groundwater flow direction and rate, the following was performed:

- groundwater monitoring wells top of casings were surveyed by CCA Engineering of Brookfield,
- depth to groundwater measurements were continuously monitored using a Hobo data logger at 76 SLSD well DF-76-1 and 74 NLSD well DF-74-1,
- manual depth to groundwater measurements were taken periodically at wells DG-76-1 through DG-76-8,
- Candlewood Lake elevations were obtained periodically from Firstlight at Lake Level 24 Hour Phone Line: 888-417-4837 and adjusted to NAVD 88

Table 2-7 presents the groundwater and Candlewood Lake elevation data and calculated groundwater slopes for 76 South Lake Shore Drive and 74 North Lake Shore Drive sites for various measurement dates. **Based upon the groundwater and Lake elevation data, groundwater linear velocity range for the examined period was approximately 0.2 to 3.5 feet/day at 76 SLSD and 1.07 to 1.27 feet/day at 74 NLSD.**

Table 2-7 Groundwater Elevation Data 76 SLSD & 74 NLSD

Groundwater Elevation Data - 76 South Lake Shore Drive													
K	6	porosity	0.25	20-Nov-19	Lake Elev.	426.20			18-Dec-19	Lake El	426.40		
Well Name	TOC Elev	Screened Interval (feet into GW)	Distance to Lake (feet)	TOC Depth to GW (ft)	GW Elevation (ft)	GW Slope to Lake (%)	GW slope - DF to DG	GW Linear Velocity (ft/day)	TOC Depth to GW (ft)	GW Elevation (ft)	GW Slope (%)	GW slope to DG	GW Linear Velocity (ft/day)
DF-76-1	437.72	0-1.5	74.01	10.52	427.20	1.35%	6.37%	1.53		430.10	5.00%	14.42%	3.46
DF-76-2		1.5-3	82.25										
DF-76-3		3-5	77.26										
DG-76-1	435.22	5	60.36	8.61	426.61	0.68%		0.16	7.35	427.87	2.44%		0.58
DG-76-2	432.74	5	54.80	6.21	426.53	0.60%		0.14	5.56	427.18	1.42%		0.34
DG-76-3	432.48	5	68.85	5.91	426.57	0.54%		0.13	4.05	428.43	2.95%		0.71
DG-76-4	430.76	5	60.50	4.17	426.59	0.64%		0.15	2.51	428.25	3.06%		0.73
DG-76-5	431.89	5	68.76						3.22	428.67	3.30%		0.79
DG-76-6	432.41	5	80.82						3.65	428.76	2.92%		0.70
DG-76-7	432.12	5	63.92						4.19	427.93	2.39%		0.57
DG-76-8	432.44	5	62.71	5.96	426.48	0.45%		0.11	3.97	428.47	3.30%		0.79

Groundwater Elevation Data - 74 North Lake Shore Drive										
K	6	porosity	0.25	20-Nov-19	Lake Elev.	426.2		18-Dec-19	Lake Elev.	426.4
Well Name	TOC Elev	Screened Interval (feet into	Distance to Lake (feet)	TOC Depth to GW (ft)	GW Elevation (ft)	GW Slope (%)	GW Linear Velocity (ft/day)	GW Elevation (ft)	GW Slope (%)	GW Linear Velocity (ft/day)
DF-74-1	436.68	0-1.5	122.89	5.00	431.68	4.46%	1.07	432.90	5.29%	1.27
DF-74-2		1.5-3	117.12							
DF-74-3		3-5	113.94							

Figure 2-10 presents groundwater contour maps for 76 South Lake Shore Drive and 74 North Lake Shore Drive sites on November 20, 2019.

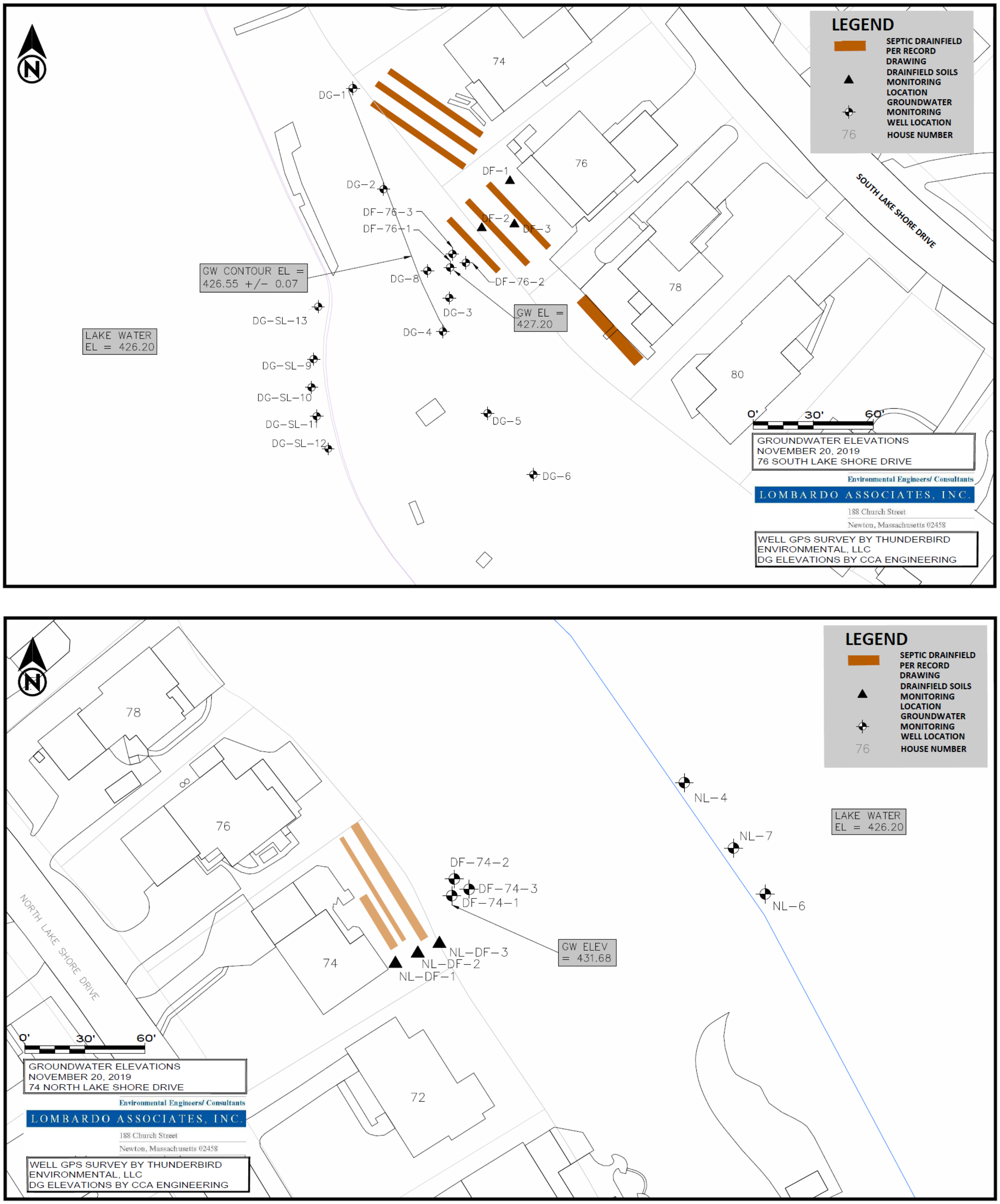


Figure 2-10 Groundwater Contour Maps – 76 SLSD & 74 NLSD – Nov. 20, 2019

3 SYSTEM QUESTIONNAIRE – FUNCTIONAL PERFORMANCE ANALYSIS

A septic system questionnaire, with a representative copy along with the response statistics as prepared by the WPCA in Appendix IV, was sent to all property owners in the Study Area. A summary of the questionnaire results is presented on Table 3-1 with details in Appendix IV.

Table 3-1 Septic System Questionnaire Results

Questionnaire Responses Summary			
	No.	Percentage of Developed Properties	Properties with a Septic Issue as % of Responses
Developed Properties	1,338		
Responses	550	41.1%	
Properties Reporting a Septic Issue	148		26.9%

4 AVAILABLE AREA ANALYSIS – SPACE NEEDS

Each Study Area lot was analyzed to determine whether there is sufficient space to site a CT DoH code compliant conventional onsite wastewater treatment system (OWTS), i.e. septic system – with no changes to the building footprint and no code variances.

For analytical purposes, for a parcel to be classified as having sufficient space for a Code compliant OWTS, the available area must be greater than the total required area plus a reasonable safety factor. Available and required area are defined as follows:

Available Area is calculated as the area remaining after buildings and applicable setbacks from property lines, buildings and other items are subtracted from the total parcel area. The remaining area is termed the parcel's Available Area**.**

Required Area is the OWTS footprint per Code for the site's use plus required Reserve Area. The required septic tank and drainfield area is determined by using DoH code, the site's design wastewater flow and percolation rate. For properties without percolation data, soil texture is used to estimate an approximate percolation rate. As Study Area soils are predominately fine sandy loams, a percolation rate of 20 mpi is used. Reserve area equal to 50% of the required drainfield area is used.

Available Area Determination

The available area on a parcel is defined as the area on a parcel that is not used by a building and is not within a setback buffer area from a building or property line. The minimum separation requirements for OWTS are listed below.

- Property line 10'
- Building 10'
- Groundwater Drain 25'
- Stormwater Catch Basin/MH 25'
- Wetlands 75'
- Streams 100'
- Public Water Supply Wells 200'

While the Town has jurisdiction for activities within 200' of Candlewood Lake shoreline, no minimum separation distances of the septic system components to the shoreline are being used. There are approximately 215 Study Area properties within 200' of Candlewood Lake and approximately 193 Peninsula properties within 200' of Candlewood Lake.

Properties were categorized in the following 3 categories:

- ***<u>Code Compliant System Not Feasible – Off-site Solution Likely Required</u>***. Properties in this category have available area that is less than 120% of the required area. While the total available area may exceed the required area, the likelihood of engineering a Code compliant layout within the available footprint is very low.

- ***<u>Code Compliant System Potentially Feasible – Case by Case Analysis</u>*** Properties in this category have available area between 120% - 200% of required area. These properties are better candidates for a code complaint system. However, the shape and location of the available area may not be conducive for a Code compliant system.

- ***Code Compliant System Likely Feasible*** Properties in this category have available area that is greater than 200% of the required area. These properties have a high likelihood of being able to site a Code compliant system.

Tables 4-1 and 4-2 present summaries of Study Area developed parcels within each of the above categories for the entire Study Area and Peninsula – where the vast majority of the problem sites are located - respectively.

Table 4-1 OWTS Available Area – Study Area Property Totals

OWTS Space Analysis Category - Study Area	# of Developed Parcels	% of Developed Parcels
Code Compliant Septic System Not Feasible - Off-site Solution Likely Required	266	19.8%
Code Compliant Septic System Potentially Feasible - Case by Case Analysis	169	12.6%
Code Compliant Septic System Likely Feasible	911	67.7%
Total	1,346	100%

Table 4-2 OWTS Available Area – Peninsula Parcels Only

OWTS Space Analysis Category - Peninsula Properties Only	# of Developed Parcels	% of Developed Parcels
Code Compliant Septic System Not Feasible - Off-site Solution Likely Required	229	32.6%
Code Compliant Septic System Potentially Feasible - Case by Case Analysis	143	20.3%
Code Compliant Septic System Likely Feasible	331	47.1%
Total	703	100%

Required Area Determination

In order to design a Code compliant septic system, the required effective area must be calculated. This area is defined as the minimum area into which wastewater can be disposed of. The required area is a function of:

- Required Effective Leaching Area
- Leaching system effective area (ft^2 / LF)
- # of trenches/rows required

- Required minimum spacing between the rows

Minimum effective leaching areas are based on Code defined criteria. For residential systems, it is based on the percolation rate of the soils and the number of bedrooms in the residence. Table 4-3 presents the Code required minimum effective leaching area as a function of percolation rate and number of bedrooms.

Table 4-3 Code Required Effective Leaching Area for Residential Buildings

Percolation Rate	Square Feet of Required Effective Leaching Area (ELA)				
(Minutes to Drop One Inch)	2-Bedroom Building	3-Bedroom Building	4-Bedroom Building	For Each Bedroom Above 4	
				Single Family	Multi-family
LESS THAN 10.1	375	495	660	82.5	165
10.1-20.0	500	675	900	112.5	225
20.1-30.0	565	750	1000	125	250
30.1-45.0	675	900	1200	150	300
45.1-60.0	745	990	1320	165	330

Non-residential buildings are divided into two categories:

- Problematic Sewage, which covers restaurants, bakeries, food service establishments, residential institutions, laundromats, beauty salons and similar uses
- Non-Problematic Sewage, which covers all other uses.

Tables 4-4 and 4-5 present the hydraulic loading rate (HLR) based on percolation rate for the above two categories. The effective leaching area is calculated by dividing the design flow by the HLR as presented in the following formula:

Minimum Effective Leaching Area = Design Wastewater Flow / Hydraulic Loading Rate

Table 4-4 Code Application Rate for Problematic Sewage

Percolation Rate (Minutes to Drop One Inch)	Application Rate (GPD per square foot of ELA)
LESS THAN 10.1	0.8
10.1 to 20.0	0.7
20.1 to 30.0	0.6
30.1 to 45.0	0.5
45.1 to 60.0	0.4

Table 4-5 Code Application Rate for Problematic Sewage

Percolation Rate (Minutes to Drop One Inch)	Application Rate (GPD per square foot of ELA)
LESS THAN 10.1	1.5
10.1 to 20.0	1.2
20.1 to 30.0	0.9
30.1 to 45.0	0.7
45.1 to 60.0	0.6

Once the minimum effective leaching area has been determined, a conceptual layout is required to calculate the footprint that a Code complaint system will require. To do this, the following was assumed for each property:

- Eljen Mantis System with a linear loading rate of 11-gpd/ft^2 used
- Trench Length assumed to be 35-ft
- 12-ft spacing required between each trench

To calculate the minimum required area, the following steps were taken:

- Effective Leaching Area was divided by 11-gpd/ft^2 to determine the total length of trench needed
- Total trench length was divided by 35-ft to determine the number of rows required
- Total required area was calculated using the Mantis trench width of 3-ft, spacing at 12-ft and the total number of rows required

The septic tank and distribution box represent a small portion of the total required area. The required area for these components was assumed to be 150-ft^2.

The final piece of required area is reserve area. The Code requires "an acceptable reserve leaching area of suitable soil" without defining the exact amount. For the purpose of this analysis, a 50% reserve area is assumed to be required for future expansion / trench replacement. The total required area is calculated as follows:

Total Required Area = Septic Tank / D-Box + Minimum Leaching Area + Reserve Area

Tables 4-1 and 4-2 presented the number of properties that fall into the three defined available area categories. Figures 4-1 and 4-2 illustrate the results of the Available Area Analysis on a parcel by parcel basis, for the entire Study Area and Peninsula – where the vast majority of the problem sites are located - respectively.

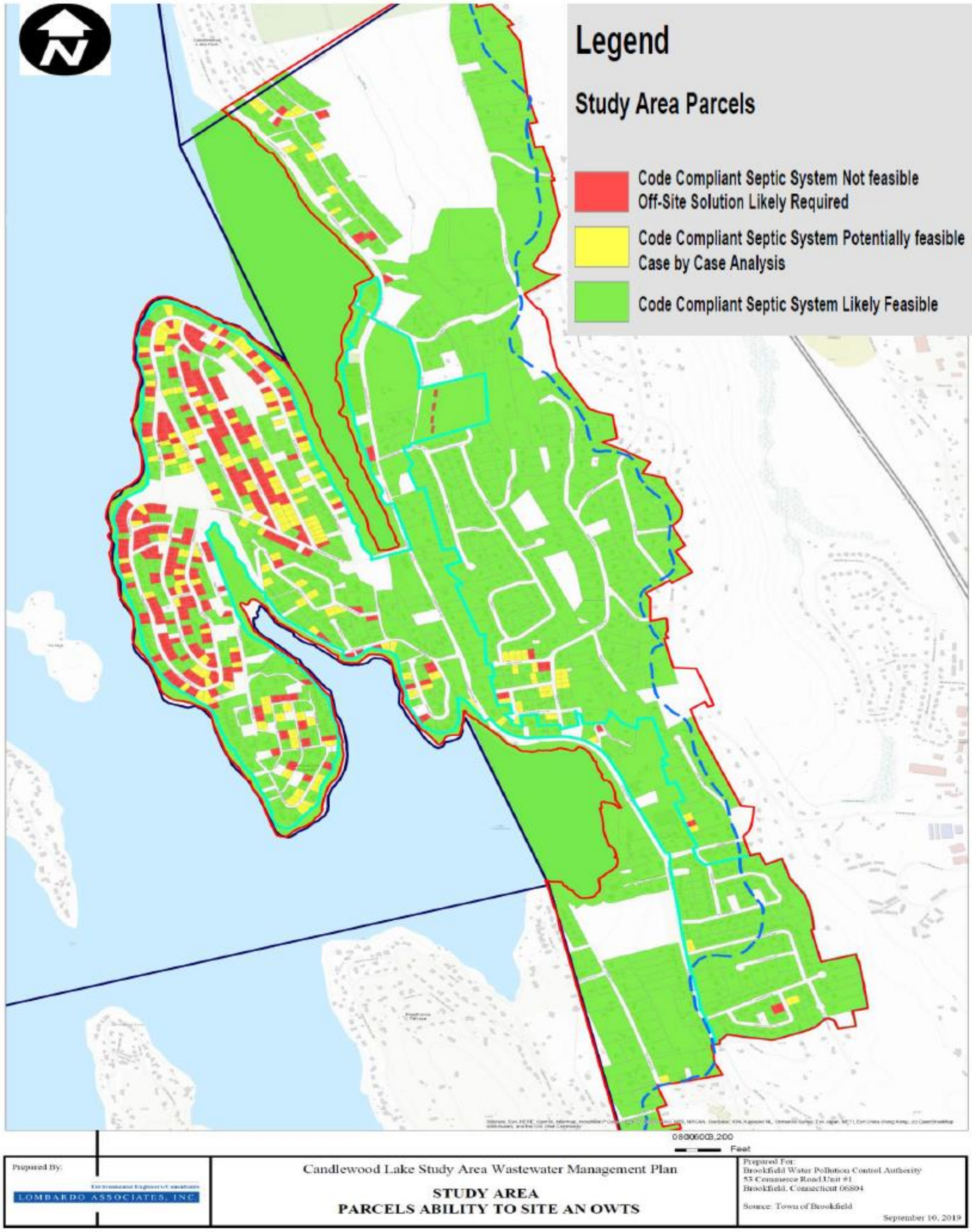


Figure 4-1 Parcels Space Ability to Site an OWTS

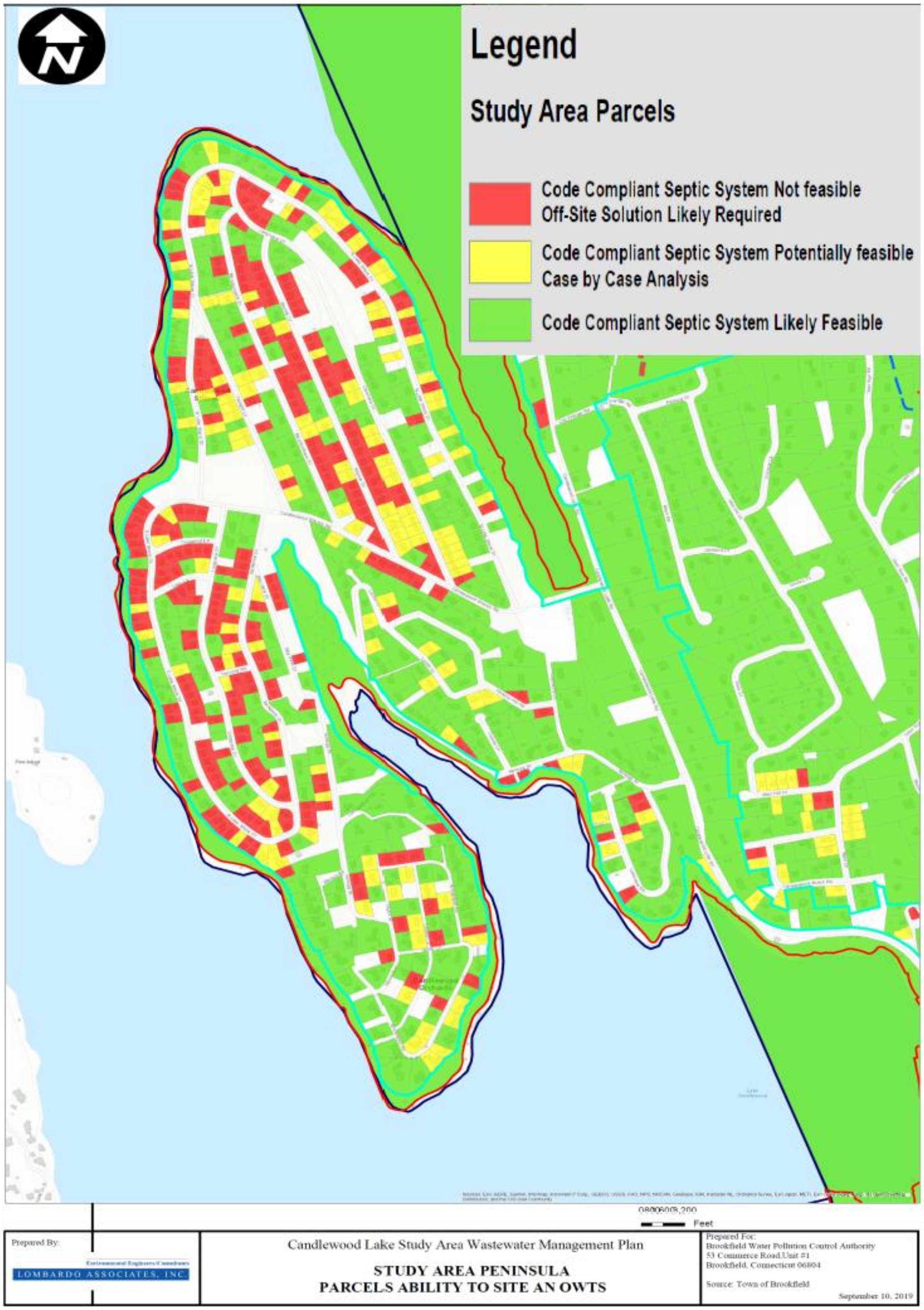


Figure 4-2 Peninsula Parcels Space Ability to Site an OWTS

5 CONCLUSIONS – NEEDS ANALYSIS

5.1 Performance Need

5.1.1 Impact on Quality of Candlewood Lake

Table 5-1 presents the incremental increase in phosphorus and nitrogen concentrations based upon the soils removal / attenuations as described in Chapter 2.

Table 5-1 Septic N & P Discharges to & Impact on Candlewood Lake

Estimated Household N & P dischares to Drainfield & Lake		
Flow (gpd)	100	
	Phosphorus	**Nitrogen**
Septic Tank Effluent Nutrient Conc. (mg/L)	7	65
Nutrient Loading (lbs/yr)	2.1	19.8
Estimated Percent Attenuation/Removal	90%	50%
Nutrient Loading to Lake (lbs/yr)	0.21	9.9
(1) Phosphorus STE conc. average of 10 years of data for MA sites		
Brookfield Contributions to Candlewood Lake P & N Levels		
Number of Households	1,346	
Nutrient Loading to Lake (lbs/yr)	287	13,316
Nutrient Loading to Lake (kg/day)	0.4	16.6
Lake Volume Annual Turnover (gal)	15,690,909,000	
Incremental P & N conc. (ug/L) due to septic discharges	2.2	102
All Towns Contributions to Candlewood Lake P & N Levels		
Brookfield Septics as % of Total in Watershed	25%	
Watershed wide Incremental P & N conc. (ug/L) due to septic discharges	8.8	407

Table 5-1 illustrates that with 90% P removal by soils, septic wastewater will increase Lake P levels by approximately 9 ppb. As the target Lake P concentration for good water quality is 10 +/- ppb, this Needs analysis conclusion is that septic wastewater P needs to be reduced.

Lake studies over the years, which are summarized in Section 4 of the Task 1 Report show that

1. Phosphorus is the limiting nutrient
2. Sediments are a major contributor to P levels in the Lake, in particular in late summer. It is noted that many Lake blooms occur in late summer – early fall, appear to be fed by phosphorus and nitrogen from deep waters that are released from sediments.
3. Sediment nutrients are a legacy problem – caused by decades of algae growth which was accelerated / enhanced by septic phosphorus discharges since 1950s – for over 60 years.

Removing septic discharges will arrest to some extent the eutrophication process. Coupled with a plan for reducing sediment phosphorus release is this study's recommendation for Candlewood Lake water quality restoration and protection.

This recommendation has been submitted to a group of Lake water quality experts for peer review on December 18, 2018 who opined that removing septic wastewater discharges would have a positive impact on the milfoil weed and its negative impacts in the Lake. Limnologist Dr. Kenneth Wagner of Water Resource Services LLC opined as follows:

"Wastewater represents a major source of nitrogen (N) and a significant but non-dominant source of phosphorus (P) to Candlewood Lake. Inputs of each are likely to be maximal in the littoral zone of the lake and likely promote the growths of milfoil and green algae mats in that area. The high ratio of N to P in groundwater inputs does not favor cyanobacteria, which are more likely to grow over deeper water where internal loading of P from sediment can be elevated and is likely to have a low ratio of N to P. However, the N and P recycled from the sediment ultimately came from the watershed, including the wastewater inputs, over many years, so management of watershed sources remains a valid approach to improving lake conditions.

Consequently, it is likely that the internal load from sediments will have to be addressed separately, but in answer to the central question of the influence of wastewater on lake water quality, wastewater is a major source of N and a minor source of P and its removal would be a benefit to the lake."

Limnologist George Knoecklein of North East Aquatic Research opined that removing septic wastewater would have a positive impact on milfoil control.

5.1.2 Impact on Groundwater Drinking Water Aquifer

The groundwater aquifer is the water supply and partial recipient of wastewater discharges for much of the study area. As shown on Tables 2-1 and 2-2, the groundwater aquifer water supply for Candlewood Shores (CS) and Arrowhead are negatively impacted by septic discharges. Table 5-2 presents a water balance that strongly suggests that wastewater is a significant percent of the groundwater which is used for water supply and also discharges to the Lake. Based upon soils hydraulic conductivity of 6 feet/day, depth to refusal of 6 +/- feet and the expected significantly lower bedrock hydraulic conductivity, it is expected that the amount of septic wastewater and rainfall infiltration that reaches the water supply bedrock aquifer is a relatively small percent of septic wastewater and rainfall infiltration.

It is noted that the Table 2-1 water supply data and groundwater weep data of Figure 2-9 reasonably agree with the Table 5-2 estimate for nitrogen, while the phosphorus data is approximately 1/3 to 1/10 the Table 5-2 estimate. However, it is noted that the average phosphorus concentration of the eight (8) DG monitoring wells sampled on October 12, 2019 matches the rainfall dilution estimate.

However, it is noted that the CS and AR water supplies have very high nitrate-N levels and nitrate-N public health violations have occurred in the past. Also, the PFOA/PFOS levels are very high. While not violating existing CT and US EPA standards, those standards are under review. Many states have or are considering lowering the standard such that if adopted by US EPA and/or CT, would cause the CS and AR water supplies, and possibly others, to be in violation.

Table 5-2 Septic N & P Discharges & Rainfall Dilution

Brookfield Candelwood Lake Drainage Area Wastewater - Peninsula Only		
Rainfall Dilution of Wastewater		
# Developed Properties		703
	Acres	320
Rainfall Infiltration	(feet/year)	1.0
	gpd	285,700
	gpd/property	410
Average Wastewater Flow (gpd)		70,300
Wastewater + Rain Infil Flow (gpd)		356,000
Average Wastewater Flow (gpd/property)		100
Groundwater Conc. as % of WW Conc.		20%
Wastewater Dilution Factor by Rain		510%

Estimated Groundwater Quality Due to Septic Wastewater		
	Phosphorus	Nitrogen
Wastewater (mg/L)	7	65
Attenuation	90%	50%
Rain Dilution Factor	5.1	5.1
Est. GW Quality	0.14	6.4
Measured Avg. DG wells at 76 SLSD - 10-12-19	0.21	8.9
Measured Avg. DG wells at 76 SLSD - 12-18-19	0.02	6.0

Estimated Average Daily Peninsula Groundwater Quantity Discharge to Candlewood Lake (gpd)		
Shoreline length (ft)	20,000	
Aquifer thickness (ft)	6	
Groundwater (GW) Slope	1%	5%
GW Lake Discharge (gpd)	53,856	269,280

Tables 5-2A and 5-2B present nitrogen and phosphorus removal rates using chloride (Cl) as the tracer for 76 South Lake Shore Drive and 74 North Lake Shore Drive sites.

Table 5-2A Nitrogen & Phosphorus Removal Rates – 76 S. Lake Shore Drive

Mean N and P concentrations, concentrations corrected for dilution using a conservative tracer (Cl) and percent removal, in the septic system plume core zone extending from the drainfield to the Candlewood Lake shoreline.									
				TIN (NH4 + NO3-N)			SRP/TP		
76 South Lake Shore Drive, Brookfield, CT	**Distance[4] (ft)**	**Cl (mg/L)**	**Dilution Factor**	**TIN (mg/L)**	**Corr. TIN (mg/L)**	**Remove %**	**SRP (mg/L)**	**Corr. SRP (mg/L)**	**Remove %**
Septic Tank Effluent Oct 17, Dec18/19 (n=2)	0	346[(1)]	1	41	41	0	4.6	4.6	0
Drainfield Wells, DF1-3 Nov 4, Dec 18/19 (n =6)	5 - 10	346[(1)], +/-38	1	10	10	76	0.01	0.01	> 99
Downgradient Wells, DG1-8, Dec 18[3] (n =8)	20-50	No data	?	6	62		0.015	0.0152	> 99
Shore Wells, DG13-2,3, Oct 17, Nov 4, (n = 4)	60	297	0.86	14	16	61	0.01	0.012	> 99
1) Considering that the three Drainfield wells had uniformly high Cl values averaging 346 mg/L, during two sampling episodes, values that were much high than background values of 20-30 mg/L, it is likely that these wells more accurately represent the mean effluent Cl value, than the Cl values measured in the tank, which was only sampled twice and showed relatively lower Cl values of 200 and 228 mg/L.									
2) assumed undiluted									
3) Oct 2/19 samples are excluded because these were collected shortly after well installation when drilling disturbance may have affected results.									
4) Distance from the drainfield									

Table 5-2BA Nitrogen & Phosphorus Removal Rates – 74 N. Lake Shore Drive

Mean N and P concentrations, concentrations corrected for dilution using a conservative tracer (Cl) and percent removal, in the septic system plume core zone extending from the drainfield to the Candlewood Lake shoreline.									
				TIN (NH4 + NO3-N)			SRP/TP		
764 North Lake Shore Drive, Brookfield, CT	**Distance[4] (ft)**	**Cl (mg/L)**	**Dilution Factor**	**TIN (mg/L)**	**Corr. TIN (mg/L)**	**Remove %**	**SRP (mg/L)**	**Corr. SRP (mg/L)**	**Remove %**
Septic Tank Effluent Oct 17, Dec18/19 (n=2)	0	138	1	42	42	0	4.6	4.6	0
Drainfield Wells, DF1-3 Nov 4, Dec 18/19 (n =6)	15 - 20	59	0.43	6.8	16	62	0.02	0.046	99
Downgradient Wells, DG1-8, Dec 18[3] (n =8)	150	61	0.44	2.5	5.7	86	0.02	0.045	99
1) Distance from the drainfield									

As a point of reference, the US EPA Ambient Water Quality Criteria Recommendations for Lakes and Reservoirs in Nutrient Ecoregion XIV, with Candlewood Lake being located in subregion 59, https://www.epa.gov/sites/production/files/documents/lakes14.pdf are:

Total phosphorus (ug/L)	8 – 20
Total nitrogen (mg/L)	0.32 – 0.41
Chlorophyll a (ug/L)	2.1 – 6
Secchi (meters)	1.2 – 4.9

As stated in the US EPA document, "The values presented in this document generally represent nutrient levels that protect against the adverse effects of nutrient over enrichment." Candlewood Lake's N and P concentration ranges (see Task 1 Report Chapter 4) for 2018 are:

Total phosphorus (ug/L)	3 – 79
Total nitrogen (mg/L)	0.44 – 1.45

Also, for reference, Table 5-3 presents the Candlewood Lake 2018 Water Quality Data by Month.

5.1.3 Functional Need

As shown in Section 3, approximately 13 % of properties who have returned the septic system questionnaire have reported a problem. Approximately 22% of properties returned the questionnaire.

5.1.4 Insufficient Space

As shown in Section 4, between 23% to 36% have insufficient space to accommodate a CT Department of Health (DoH) code compliant septic system with the vast majority of those difficult sites on the Peninsula. Also, the Brookfield Health Department by its letter of January 2018 (see Figure 5-1), recommended a sewer system for the Peninsula.

TOWN OF BROOKFIELD

BROOKFIELD, CT 06804

FC COPY

January 24, 2018

John Siclari
Director, Brookfield Water Pollution Control Authority
Brookfield Town Hall
100 Pocono Road
Brookfield, CT 06804

Re: Sanitary sewers for Brookfield's Candlewood Shores Lake communities

John:

The Brookfield Health Department recommends the Brookfield Water Pollution Control Authority (WPCA) take the necessary steps to provide sanitary sewers to the Candlewood Shores peninsula including the Candlewood Shores Tax District (CSTD), Arrowhead Point, Hickory Hills and Candlewood Orchards. The area has been highlighted in red as an "area of concern," on the WPCA's sewer map for several years now and with good reason. The small average lot size, the age of most of the homes, the fact that the vast majority of the homes were built for seasonal use and are now occupied year-round, and the environmental sensitivity associated with managing the relatively large volume of sewage on the relatively densely populated peninsula surrounded by Candlewood Lake must all be considered moving forward.

Average lot size on the peninsula is less than three-tenths of an acre. Due to the relatively restrictive sized lots, repairing septic systems often requires exceptions to technical standards of the Connecticut Public Health Code. In some of these repair instances, the final permits issued are required to state that the systems are undersized for the total number of bedrooms in the homes. Housing stock in the Shores is generally between 40 and 70 years old and homes still served by their original septic systems are likely near the end of their useful life, while many of the rest are on their second system. Most of the original septic systems were designed for seasonal use only and today most of the homes are occupied throughout the year. This means that many of the original systems are undersized relative to use expectancy. State and local health officials have recognized a significant rise in blue-green algal blooms in recent years. These blooms have the potential for causing harm to humans and wildlife. Nutrients such as phosphorus and nitrogen both sourced from septic system drain fields, along with landscape fertilizers, feed these blooms. Home values are tied to the recreational value of the lake which is impacted by water quality. Though sewage management is only one of several concerns regarding lake water quality, it is not the least important, especially when considering several of the factors cited above.

Health Department – 100 Pocono Rd., Brookfield, CT 06804 (203) 775-7315

TOWN OF BROOKFIELD

BROOKFIELD, CT 06804

John Siclari
Director, Brookfield WPCA
January 24, 2018
Page 2

The Health Department does not make this recommendation lightly. Four other neighboring municipalities, including the City of Danbury, all with homes bordering Candlewood Lake and therefore within the lake watershed, must also consider long term sewage management moving forward. The company that owns the lake, First Light, is determined to eliminate all septic systems that are on their property as some are, and this presents another concern for the Towns. At a recent seminar sponsored by First Light, an engineer for the company highlighted five Connecticut lakes that have been ordered by the State to sewer their lake communities. Now is the time for Brookfield to take up sanitary sewer expansion on behalf of our largest lake communities, those within the Candlewood Shores area, and on behalf of the lake itself.

Do not hesitate to call us at the number below with any questions or concerns moving forward.

Sincerely,

Paul Avery, R.S.
Town Sanitarian

Dr. Raymond Sullivan
Director of Health

cc: Steve Dunn, Brookfield First Selectman
Alice Dew, Brookfield Land Use Director

Figure 5-1 Brookfield Health Department Letter Recommending Sewers for Peninsula

Table 5-3 Candlewood Lake 2018 Water Quality Data by Month

Table 6. Summary statistics (mean ± standard deviation) of nutrient data collected at Candlewood Lake in the 2018 season by month. All data are in mg/L with the exception of TP which is in µg/L and TN:TP which is a ratio. NH4 = Ammonia; NO_3^- = Nitrate; TKN = Total Kjeldahl Nitrogen; TN = Total Nitrogen; TP = Total Phosphorus; and TN:TP = the Redfield ratio of Total Nitrogen to Total Phosphorus. Epi = epilimnion; Meta = metalimnion; and Hypo = hypolimnion.

NH_4	May	June	July	Aug	Sep	Oct	Season
Epi	0.0±0.0	0.12±0.01	0.0±0.0	0.0±0.0	0.0±0.0	0.0±0.0	0.02±0.05
Meta	0.0±0.0	0.13±0.02	0.0±0.0	0.0±0.0	0.0±0.0	0.09±0.18	0.04±0.08
Hypo	0.0±0.0	0.16±0.04	0.05±0.09	0.18±0.12	0.36±0.24	0.77±0.21	0.25±0.29
NO_3^-	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Season**
Epi	0.01±0.03	0.06±0.00	0.0±0.0	0.03±0.03	0.0±0.0	0.0±0.0	0.02±0.03
Meta	0.05±0.06	0.07±0.01	0.01±0.03	0.01±0.03	0.0±0.0	0.0±0.0	0.02±0.03
Hypo	0.15±0.05	0.15±0.15	0.08±0.17	0.10±0.17	0.0±0.0	0.0±0.0	0.08±0.12
TKN	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Season**
Epi	0.50±0.16	0.94±0.34	0.44±0.02	1.20±0.27	0.16±0.04	0.66±0.16	0.65±0.39
Meta	0.44±0.02	0.92±0.34	0.45±0.08	0.89±0.13	0.17±0.03	0.80±0.15	0.61±0.32
Hypo	0.40±0.04	1.11±0.15	0.50±0.22	1.34±0.58	0.53±0.04	1.20±0.17	0.85±0.45
TN	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Season**
Epi	0.51±0.16	1.00±0.34	0.44±0.02	1.22±0.28	0.16±0.04	0.66±0.16	0.66±0.40
Meta	0.48±0.05	0.99±0.35	0.47±0.06	0.90±0.15	0.17±0.03	0.80±0.15	0.63±0.33
Hypo	0.55±0.06	1.26±0.21	0.59±0.38	1.45±0.67	0.53±0.04	1.20±0.17	0.93±0.49
TP	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Season**
Epi	16.3±15.1	13.0±5.0	20.0±1.6	20.8±2.9	23.0±5.9	19.3±2.4	18.7±7.1
Meta	12.8±5.7	7.3±2.4	25.3±5.0	24.8±2.2	31.5±3.4	20.3±3.8	20.3±9.0
Hypo	9.5±3.7	3.0±1.4	25.5±4.8	40.8±14.8	79.0±14.7	49.3±13.0	34.5±27.7
TN:TP	**May**	**June**	**July**	**Aug**	**Sep**	**Oct**	**Season**
Epi	47±25	78±14	22±3	60±19	7±1	36±14	42±28
Meta	43±18	136±10	19±5	37±7	5±1	41±15	47±44
Hypo	73±53	506±253	26±23	46±42	7±1	25±5	114±204

6 RECOMMENDATIONS

Based upon the numerous factors that point to the need for a Peninsula wide wastewater solution, it is recommended that a Peninsula community-wide sewer system be implemented with sewer system type and treatment/discharge option be determined based technical and economic/financial optimization analysis to be performed in subsequent project Reports. Associated with a Peninsula (approximately 703 developed properties) community-wide wastewater system, Candlewood Lake studies should be performed to document improvements associated with the wastewater improvements. The degree to which wastewater improvements need to be implemented for the 643 +/- developed properties in the remaining Brookfield Candlewood Lake drainage area should be evaluated as part of implementation the Peninsula wastewater improvement project.

APPENDIX I - CHAIN OF CUSTODIES AND LABORATORY REPORTS – WATER SUPPLY

TABLE OF CONTENTS:

SAMPLING LOCATIONS

- Candlewood Shores Community Site Center (CS)
- Arrowhead Road (AR)
- Candlewood Lake (CL)
- Western Aquarion residential property (WA)

APPENDIX IV – SEPTIC SYSTEM QUESTIONNAIRE

CANDLEWOOD LAKE DRAINAGE AREA WASTEWATER MANAGEMENT STUDY

SEPTIC SYSTEM QUESTIONNAIRE

The project needs your assistance in defining properties in need of wastewater improvements by completing this questionnaire on the functioning of your septic system. ***The information that you provide the Engineer is vital for the Town to develop effective solutions for the area and protect Candlewood Lake. Your response will be kept confidential by the Engineers and will not be released without an order from a court of competent jurisdiction.***

Your participation in completing the questionnaire is vital for the protection of Candlewood Lake.

Any questions please call us at the Brookfield WPCA at (203) 775-7319 x 1000.

Questionnaire can be completed electronically at https://brookfieldwpca.org/survey

TRUST
14 SOMEWHERE DRIVE
BROOKFIELD, CT 06804

Lombardo Associates, Inc.
Environmental Engineers/Consultants
188 Church Street
Newton, MA 02458

CANDLEWOOD LAKE DRAINAGE AREA WASTEWATER MANAGEMENT STUDY

NEWSLETTER & SEPTIC SYSTEM QUESTIONNAIRE

Brookfield Water Pollution Control Authority
53A Commerce Road, Unit 1
Brookfield, CT 06804

TRUST
14 SOMEWHERE DRIVE
BROOKFIELD, CT 06804

Dear Property Owner

As you may have learned, the Brookfield Water Pollution Control Authority (WPCA) has commissioned a Wastewater Management Plan with a State Clean Water Fund grant for the area in Brookfield that drains to Candlewood Lake. The Plan is to determine the public health and environmental adequacies of wastewater practices in the Study Area and develop technically viable, cost-effective solutions to correct identified deficiencies. In particular, the Plan will assess the impacts, if any, of wastewater on the water quality of Candlewood Lake on a property by property basis for all 1,509 properties in the Study Area. We want to be sure we have the most accurate information on each property. Project documents and the recently published Task 1 Report on Existing Conditions can be viewed online at https://brookfieldwpca.org/candlewood

This next phase of the Study includes a septic system questionnaire and field studies to determine the extent to which typical existing septic systems are removing the nutrients of phosphorus and nitrogen. The quality of Candlewood Lake is controlled by phosphorus levels.

Please complete the following septic system questionnaire and then simply fold and staple it so that only the return address to Lombardo Associates, Inc. shows. Then mail the questionnaire as soon as possible but no later than November 10, 2019. Alternatively, you can fax to (617) 332-5477 (only 2 page questionnaire needed) or email the completed questionnaire to GaryR@LombardoAssociates.com

Nelson Malwitz, Chairman

NEWSLETTER & QUESTIONNAIRE

CANDLEWOOD LAKE DRAINAGE AREA WASTEWATER MANAGEMENT STUDY

Questionnaire can be completed electronically at https://brookfieldwpca.org/survey

A. GENERAL

Contact Person: ______________________________

Property Address: ______________________________

Phone: ______________ Email: ______________

B. PROPERTY USE

Please provide as much information, and with as much accuracy, as you can. If you do not know the answer to a particular question, please leave the response space blank. Thank you.

How many people live in this home?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 or more

How much is the house occupied?
☐ Year round ☐ 3 seasons ☐ 2 seasons ☐ Summer + occasional weekends ☐ Summer

Do you have a garbage disposal? ☐ No ☐ Yes ☐ Yes, but never use

Is the area around the septic or drainfield wet? ☐ Never ☐ Sometimes ☐ Often

How often do you pump your septic system? ☐ Every 4 years ☐ Every 3 years ☐ Every 2 years ☐ Every year ☐ Twice a year ☐ Every 3 months ☐ Every month ☐ Don't know

Does your laundry or shower discharge into a separate septic system or location?
☐ Yes ☐ No ☐ Don't Know

C. SEPTIC SYSTEM

Where is the septic system located? ☐ Front of house ☐ Back of house ☐ Left side (when facing front of house) ☐ Right side (when facing front of house) ☐ Don't know

Where is the drain field located? ☐ Front of house ☐ Back of house ☐ Left side (when facing front of house) ☐ Right side (when facing front of house) ☐ Don't know

Have there been repairs/upgrades to your septic system in the last 10 years?
☐ Yes ☐ No ☐ Don't Know

If Yes above, describe repairs/upgrades and provide the dates: ______________________________

____

____

NEWSLETTER & QUESTIONNAIRE

CANDLEWOOD LAKE DRAINAGE AREA WASTEWATER MANAGEMENT STUDY

Within the last **5 years** have you had any of the following problems?

A. Slow drains	☐ Yes	☐ Yes, rarely	☐ No	☐ Not sure
B. Sewage backing up into house	☐ Yes	☐ Yes, rarely	☐ No	☐ Not sure
C. Bad smell near tank or drain field	☐ Yes	☐ Yes, rarely	☐ No	☐ Not sure
D. Wet spots near tank or drain field	☐ Yes	☐ Yes, rarely	☐ No	☐ Not sure
E. Sewage on or at the surface	☐ Yes	☐ Yes, rarely	☐ No	☐ Not sure
F. Sewage flowing to ditch	☐ Yes	☐ Yes, rarely	☐ No	☐ Not sure

G. Other, please specify ______________________________

____

____

Do the problems indicated above still exist? ☐ Yes ☐ No ☐ Sometimes ☐ Not applicable

Comments:

____

____

____

____

____

QUESTIONS?

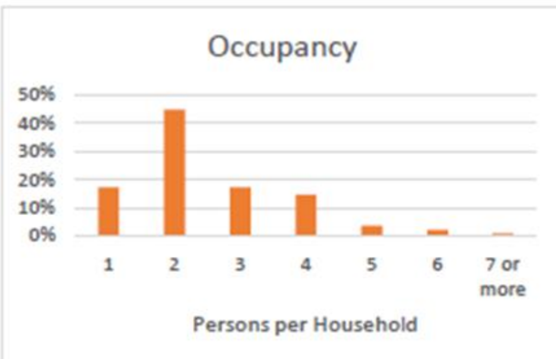
If you have any questions or would like to talk to the engineers about your wastewater system, please contact Pio Lombardo, P.E. Pio@LombardoAssociates.com or Gary Rubenstein GaryR@LombardoAssociates.com at Lombardo Associates, Inc. Tel: (617) 964-2924 Fax: (617) 332-5477

53A COMMERCE ROAD, BROOKFIELD, CT 06804
(203) 775-7319 HTTPS://BROOKFIELDWPCA.ORG

Septic Survey
Candlewood Lake Watershed Properties – Brookfield, CT

There are 1371 properties in the Brookfield study area within the watershed of Candlewood Lake. Of these, approximately 70 are lots have an address only for tax purposes, leaving about 1300 improved properties eligible for the survey. The survey instrument can be viewed at https://brookfieldwpca.org/survey

The survey was active for four months from mid-November 2019 until mid-March 2020. It was sent out by mail with a self-addressed stamped reply envelope. The survey was also available online. A total of 575 unique submissions were received from improved properties—250 by mail and the remaining 325 electronically. That is a 42% return which pollsters consider very good. The results are statically significant allowing appropriate conclusions.



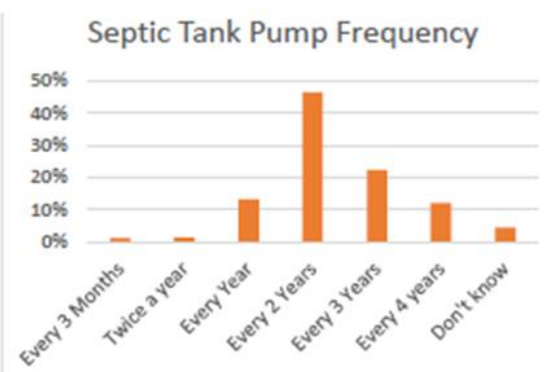
The survey showed that the occupancy of lake area properties is typically by two persons. The average is 2.4 persons per single family unit. The properties at 7+ are condos, hotel and group homes.

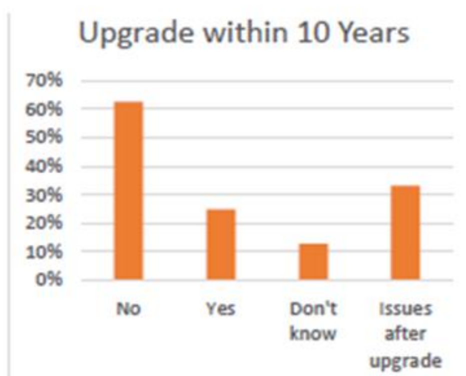
Of these properties 82% on the peninsula and 87% overall are occupied all four seasons. The remainder are used summer or two-seasons only. This is evidence of the transition from the use of properties from summer cottages back in the 50s, to year-round residences in the 90s. Currently the trend is to transition to high end residences in 2000s and beyond.

There was a question that asked: **Laundry or shower in a separate septic location?**

Of all respondents, over 15% indicated that they have a separate system for laundry. This is indicative of a significant inadequacy of soils to handle a septic system serving the remainder of the household. Separate systems have historically been added as a low-cost solution when the primary septic system capacity falls short.

The survey found that lightly less than half of all owners pump the septic system every other year. In general, septic systems are being serviced in appropriate frequency.

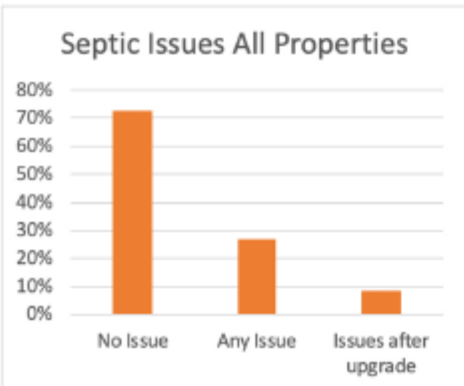


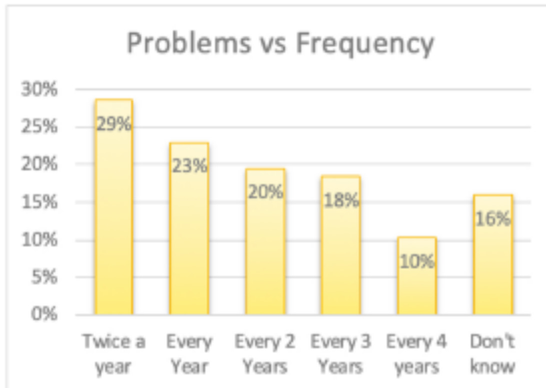


When queried if their septic system was upgraded within the last 10 years, one-quarter of the study area owners indicated **Yes**. And of those, more than 1/3 indicated there remain ongoing issues. This is a high rate of remediation. It also shows that septic repairs are often not effective due to low depth to rock and otherwise poor soil conditions for on-site wastewater treatment systems (OWTS).

Owners were asked if there were any issues with their system specifically with a history of slow drains, backups, smell, wetness, sewage on the surface or in a ditch and if the issues still exist. Over one-quarter, 27%, report one or more of these problems. This is a relatively high incidence of septic system issues for any jurisdiction.

Further, of those reporting septic system service due to a problem, one in three (33%) of those report an issue persists, that is 8% of the total septic system count.





It was interesting to correlate those reporting issues with the frequency of pumping. It indicates those that pump more frequently do so because it is needed.

Comments

At the presentation of the survey to property owners, it was promised the results would be assembled for statistical analysis only. That is the case and this is the report. But anecdotal feedback from the community was that some declined to participate because they did not want to indicate to the Town their septic system was troubled. If that is even partially true, then these results are optimistic. It is likely that a greater underlying wastewater problem than indicated by this survey.

One question that was not asked has to do with the observations of brown spots in the area of the septic drainfields. The system might not have slow drains, backups, smell, wetness, sewage on the surface or in a ditch, but brown spots indicate septic surface breakthrough distressing the lawn. That is observed on many properties.

Septic Technology Overview

A well-designed septic system will remove organic matter and eliminate bacteria. This is what it is designed to do. However, even if working properly, every septic system will still pass nutrients and what is referred to as "forever" chemicals. To what extent is this the issue?

The water supplies to the communities in the Candlewood Lake Brookfield watershed are provided by deep wells situated above the land where the community wastewater is serviced by septic systems. Part of the Clean Water Fund Study for Task 2 was to determine if there is septic influence in the drinking water. Drinking water contamination would also indicate if there is septic influence from ground water flow into the lake. Wells suppling Candlewood Shores and Arrowhead Point communities were tested.

It was found that the occurrence of e-coli and phosphorus was low. These contaminates are both generally removed by the soil as flow trickles down to the deep-water supply wells. However, that is not the case for nitrogen which is not bound by the soils. Levels of nitrogen approach and sometimes exceed the EPA actionable limit of 10 ppm (parts per million). Of course, nitrogen from septic contamination is not only in the drinking water, but also a nutrient from septic systems feeding the Lake.

Another indicator is the finding of a persistent artificial sweetener in the water supply. Even more concerning is the presence of PFAS (polyfluoroalkyl substances) in the drinking water. These are considered "emerging" pollutants. Searching the Internet on "PFAS" will uncover a myriad of articles, papers and opinions. The response to PFAS contamination is determined by each state. So far, Connecticut has adopted the Federal EPA limits for a total PFAS allowed in drinking water. The EPA "lifetime" limit is 70 ppt (parts per trillion). That means someone can safely drink water with 70 ppt total PFAS all their life. Other states have set far more stringent limits at 10-20 ppt. At this writing Connecticut is still evaluating the issue. The wells in the Candlewood peninsula exceed the new lower limits adopted elsewhere. Testing shows PFAS contaminates are in both the deep well drinking water and the lake. See the data for the Candlewood peninsula taken from Appendix A1 of the Task 2 Report included below.

Summary and Conclusions

Task 2 of the Candlewood Lake Wastewater Management Plan shows there is clear evidence of contamination of the ground water from septic systems. For example, the drinking water is high in both nitrogen and PFAS. The tap water is also high in artificial sweetener Acesulfame K. This compound is not degraded in septic systems and can only come from septic discharge.

While phosphorus is normally retained by the soils, separate studies show that large rain events release both retained phosphorus and nitrogen into the lake. Limnologists, scientists that study biological, chemical, and physical features of lakes and other bodies of fresh water, agree that septic flow is a primary reason the quality of lakes generally decline due to the accumulation of nutrients.

Further, there is a high incidence of performance issues with septic systems in the form of slow drains, backups, smell, wetness, sewage on the surface or in a ditch. When problems are identified and septic systems serviced, about one in four continue to have issues. This is due to the geology of the peninsula—low depth to bedrock and soils that have poor drainage causing channeling of septage outflow.

No one argues that intercepting septic flow from entering the ground around the lake will not improve the lake. Candlewood is the largest lake in Connecticut and an important economic engine for Brookfield and the region. Like any other resource, the lake needs to be maintained.

Two stories:
Lake Kenosia. This is a small lake on the west side of Danbury. There is a trailer park adjacent to the lake that was on a septic system. In 2016 the area was put on the Danbury sewer system. In one year, Lake Kenosia turned from green to blue. The visual depth, that is the clarity, doubled.

Lake Hopatcong (huh-pat'-cong):
This is the largest lake in New Jersey. Last year (2019) the lake failed. The most likely cause is from decades of accumulated septic discharges in the heavily settled area around this popular lake. Many are large expensive properties in the watershed. News articles at the time reported that the algae bloom was so bad, officials warned against even touching the water. Vacation rentals cancelled, business shuttered with no customers, and homes with mortgages relying on rental income went into foreclosure. No one wishes this situation at Candlewood Lake.

Task 3 of the Wastewater Management Plan report recommends a sewer system be installed within the Brookfield peninsula. It also outlines a detailed sewer system plan to address the cleanup both the water supply and the lake.

The Candlewood Lake Brookfield Wastewater Management Study is partially sponsored by a Clean Water Fund Grant by Connecticut DEEP. For all the study reports see https://brookfieldwpca.org/candlewood.

DATA

A.1 Drinking Water Aquifer

Table 2-1 presents the results of water supply sampling with Table 2-2 presenting the drinking water quality data from the water suppliers annual reports. The Chain of Custodies and laboratory reports for the drinking water sampling program are presented in Appendix I.

Septic system influence is strongly suggested by the nitrate-N and PFOA/PFOS concentrations. While determining the amount of the water supplies that is wastewater derived is beyond the scope of this project, the phosphorus concentrations suggest very high levels of septic wastewater phosphorus removal by soils. In accordance with CT guidance, PFOA/PFOS was sampled for twice to confirm concentrations.

Table 2-1 Drinking Water Supply Quality Data

Candlewood Lake Water Supplies - Drinking Water Analysis								
Water Source / Utility			Candlewood Shores	Arrowhead	Aquarion Western	Lake		
Sampling Date			14-Aug-19	22-Aug-19	16-Sep-19	16-Sep-19	23-Dec-19	
	Units	RL				@ 765LSD	@ 765LSD	@ 74 NLSD
Alkalinity	mg/L as $CaCO_3$	2	166	180				
Chloride	mg/L	10	94	93			33.1	35.1
pH	SU		7.1	7.5				
Nitrate-N	mg/L	0.100	6.99	6.85			0.67	0.99
TP	mg/L	0.010	0.015	0.017				
ortho-P	mg/L	0.005	0.016	0.018			<0.01	<0.01
Boron [1]	mg/L	0.030	0.054	0.038	ND	ND	<0.05	<0.05
Acesulfame K [2]	ppt-ng/L	100	532	1,040	204	102		
Sucralose [3]	ppt-ng/L	1,000			1,900	ND		
Saccharin [3]	ppt-ng/L	100			ND	ND		
PFOA	ppt-ng/L	1.72	24.6	8.14				
PFOS	ppt-ng/L	1.72	28.3	5.73				
PFOA/PFOS Total	ppt-ng/L	1.72	52.9	13.87				
			04-Sep-19	04-Sep-19	04-Sep-19	04-Sep-19		
PFOA	ppt-ng/L	1.72	20.3	8.69	10.7	3.71		
PFOS	ppt-ng/L	1.72	24.7	7.5	13.1	2.14		
PFOA/PFOS Total	ppt-ng/L	1.72	45.0	16.19	23.8	5.85		
[1] Sampled 4 Sept 2019 [2] Level of Quantification (LOQ) ND=Non Detect								

Table 2-2 Study Area Water Supply Quality from Annual Reports

Water System		Nitrate (NO_3-N) Conc. (mg/L)		Sodium (Na) Conc. (mg/L)		Chloride (Cl) Conc. (mg/L)	
No.		MCL	Latest Actual	NL	Latest Actual	NL	Latest Actual
1	Aquarion - Candlewood Acres	10	0.7	28	16.2	250	7
2	Aquarion of Western Brookfield		3.5		53		53
3	Arrowhead Point HO Ass'n		7.9		24.8		100
4	Candlewood Lake Club		1.3		6.46		8.4
5	Candlewood Orchards		0		9.9		3.4
6	Candlewood Shores Tax District		7.5		31		31
7	Food establishments on well -TNC						
8	Hickory Hills - Aquarion		0.5		8.1		7.1
9	Woodcreek Village Condo Ass'n		0.7		18.7		129
	MCL = Maximum Contaminant Level						
	NL = State of Connecticut customer notification level. Elevated levels of sodium, coupled with dietary intake, can potentially affect those on a sodium-restricted diet.						

APPENDIX V - PHOSPHORUS RETENTION IN BROKFIELD SEPTIC DRAINFIELD SOILS

Characterization of Phosphorus Solids Retained in Drainfield Sediments at Three Septic System Sites, Candlewood Lake, CT

Report Prepared for;
Lombardo Associates,
Newton, MA

Prepared By;
Will Robertson and Richard Elgood
Environmental Geochemistry Laboratory,
University of Waterloo, ON

December 27, 2019

Introduction

A site visit was undertaken on the week of October 14, 2019, during which samples were collected from the drainfield sediments at three active septic system sites located near Candlewood Lake, CT (76, LV and NL sites). The septic systems at all three sites service single family homes, have been in operation for more than 10 years and are located within 300 ft of the lake shoreline. Cores were retrieved at three locations within each of the septic system drainfields (Figs 1-3), using a hand auger and /or power auger. During coring, sediment samples were collected at 0.5' intervals and were retained in plastic bags. Silty sand with variable stone content was encountered at all sites and coring was advanced to refusal, which occurred at 3-5' depth.

Methods of Sediment Analysis

Sediment acid-extractable cations, including P, Ca, Fe and Al concentrations, were analyzed at Activation Laboratories, Ancaster, ON, using an aqua regia technique in which 0.5 g of sample was digested in concentrated HCl and HNO_3 under heat, diluted to 250 mL and then analyzed with a Varian Vista 735, ICP-OES. This method liberates elements associated with carbonate, hydroxide and sulfide minerals, but not silicate minerals.

Sediment readily desorbable (plant available) P was determined at the Agriculture and Food Laboratory, University of Guelph, ON, by leaching with 0.5M $NaHCO_3$ solution (McBride, 1994).

Morphology and composition of drainfield sand grains was analyzed at Surface Science Western Laboratories, London, ON, using a scanning electron microscope with energy dispersive X-ray (EDX) elemental analysis. These analyses were conducted using a Leo 440 scanning electron microscope with Quartz XOne EDX system (Carl Zeiss Microscopy).

Results

Phosphorus Retention in the Drainfield Sediments

The drainfield sediments at all three sites are non calcareous (Ca < 2 wt %) and have typical concentrations of acid extractable Al and Fe (1-3%, Table 2), presumably reflecting the presence of oxyhydroxide mineral phases in the drainfield sediments. At all three sites, variable amounts of P enrichment was observed in the drainfield coreholes. Desorbable P values of up to 139 mg/kg were measured within distinct P enrichment zones (e.g. 76-1, 3.0 ft depth) compared to background values of about 5 mg/kg (Table 2, Fig. 4). Acid extractible P was enriched in the same zones, but to a much greater extent. For example, in sample 76-1, 3.0 ft depth, acid extractible P was measured at 2320 mg/kg, compared to background values of ~800 mg/kg (Table 2). This indicated P enrichment of ~1500 mg/kg, which is an order of magnitude higher than the desorbable P amount of 139 mg/kg. This demonstrates that most of the P retained in the P enrichment zones is not readily desorbable, but rather, suggests the presence of less soluble secondary P-mineral phases (see below). Background values of acid extractible P (~800 mg/kg) are presumed to reflect the presence of trace amounts of primary apatite in the sediment. A prominent apatite grain was, in fact, captured in one of the SEM/EDX analyses (NL2, 4 ft depth, Appendix A).

Morphology and Composition of the Phosphorus Solids

Distinct secondary mineral coatings were readily observed in all of the sediment samples submitted for scanning electron microscope analysis. Coatings were typically 5-20 uM in thickness and occurred on a variety of mineral grains including quartz, feldspar and ferro magnesium minerals (Figs. 5-7). The coatings almost always contained phosphorus (0.5- 2.5 wt %) and always had Al and Fe as the dominant cations (5-20 wt %), whereas Ca was usually only a minor component (< 3 wt %, Figs. 5-7, Appendix A). Similar secondary mineral coatings have been observed in the drainfield sediments at other septic system sites, particularly at sites where the sediments are non calcareous (Robertson et al., 2019). These coatings reflect mineral precipitation reactions that likely play a dominant role in limiting phosphorus concentrations occurring in the related groundwater plumes. The precipitation reactions result in zones of P enrichment within the drainfield sediments (Fig. 4) and these zones are almost always focused within 2-4' below the infiltration pipes, even in drainfields that vary widely in age (Robertson et al., 2019). This indicates that mineral precipitation reactions occur rapidly after the effluent enters the subsurface and that they are sustainable over the long term. In one previous study where the drainfield sediments where sampled in greater detail, it was determined that almost all of the P mass loaded to the drainfield over 20 years of operation (20 kg), was retained within the drainfield sediments as secondary mineral coatings (Parry Sound site, Robertson, 2012). The morphology, composition and abundance of secondary P-solids observed in the drainfield sediments at Candlewood Lake, are consistent with that observed in previous studies at other sites.

References

Robertson, W.D., Van Stempvoort, D. and S. L. Schiff. 2019. Review of phosphorus attenuation in groundwater plumes from 24 septic systems. Sci. Total Environ. 692: 640-652.

Robertson, W.D. 2012. Phosphorus retention in a 20-year-old septic system filter bed. J. Environ. Qual., 41:1437-1444.

Table 1. Candlewood Lake; summary of fall 2019 field and laboratory results of groundwater and septic tank effluent quality.

	76 Site								
	EC[2] (uS/cm)	pH[2]	SRP (mg/L)	TP (mg/L)	Cl (mg/L)	NO_3-N (mg/L)	NH_4-N (mg/L)	ACE (µg/L)	B (mg/L)
Tank Effluent (1) Oct 17/19	14000	6.1	2.36	2.56	200	1.6	19.5	60.8	0.71
Tank Effluent (2) Nov/19									
Drainfield Wells Nov 4/19									
76-DF1	1358	7.4	0.01	0.01	331	11.4	0.83	14.4	0.12
76-DF2	1374	7.6	0.01	0.01	370	8.6	1.01	16.3	0.15
76-DF3	1392	7.6	0.01	0.01	354	12.3	1.02	11.5	0.2
Down Gradient wells Oct 2/19									
76-DG1			0.04			11.5			
76-DG2			0.58			14.5			
76-DG3			0.11			9.5			
76-DG4			0.03			4.9			
76-DG5			0.04			5.5			
76-DG6			0.04			5.6			
76-DG7			0.09			4.8			
76-DG8			0.72			14.6			
Down Gradient (lakeshore) Wells Oct 17/19									
76-DG9-2	631	6.7						2.4	
9-3	660	6.2							
9-4PVC	720	7.1							
76-DG10-1	225	6.4							
10-2	212	6.1						<0.1	
10-3	250	6.7							
10-3PVC									
76-DG11-1	248	6.9							
-2	288	6.6							
-3	280	7.0							
-3PVC	318	7.1							
76-DG12-1	298	6.7							
-2	265	7.1							
-2PVC	297	7.4							
76-DG13-2	207	7.0	0.04	0.05	21	3.4	Nd	5.4	Nd
-3	654	6.2	0.02	0.03	100	6.1	nd	8.3	0.07
-4	542	6.2							
Down Gradient (lakeshore) Wells, Nov 4/19									
76-DG9 -2	684	6.1	0.011	0.016	163	7.5	<0.05		0.07
76-DG10-2	170	6.2	0.011	0.017	23	12.4	<0.05		0.09
76-DG13-2	1073	6.1	0.011	0.013	270	12.4	<0.05		0.09
13-3	1025	6.0	<0.01	0.022	299	14.1	<0.05		0.10

	NL Site (74 North Lake Shore Dr)								
	EC[2] (uS/cm)	pH[2]	SRP (mg/L)	TP (mg/L)	Cl (mg/L)	NO_3-N (mg/L)	NH_4-N (mg/L)	ACE (µg/L)	B (mg/L)
Tank Effluent (1) Oct 17/19	1252	6.8	4.3	4.8	140	0.3	14.2 37.4TKN	57.0	0.062
Tank Effluent (2) Nov/19									
Drainfield Wells, Nov 4/19									
NL-DF1	588	7.6	0.01	0.03	38	10.3	<0.1	0.91	<0.05
NL-DF2	634	7.1	0.01	0.01	62	6.4	<0.1	3.62	<0.05
NL-DF3	642	7.1	0.01	0.05	70	4.9	<0.1	6.24	<0.05
	Down Gradient (lakeshore) wells Oct 17/19								
NL4-1	660	6.7	0.02	0.02	44	3.2	nd	0.45	0.044
4-2									
4-2.5PVC	698	7.3							
NL5-1									
5-2									
NL6-1	906	7.1							
6-1.5	872	6.9						0.20	
6-2PVC	700	7.0							
NL7-1	958	6.6	0.02	0.02	84	0.88	0.09	2.60	0.12
7-1.5									
7-2PVC	965	6.8							
Down Gradient (lakeshore) wells Nov 4 /19									
NL4-1	403	7.0	0.012	0.016	38	1.7	0.07		<0.05
4-2									
4-2.5PVC									
NL5-1									
5-2									
NL6-1									
6-1.5	752	7.0	0.013	0.014	63	5.8	<0.05	<0.05	0.06
6-2PVC									
NL7-1									
7-1.5									
7-2PVC									

LV Site									
	EC[2] (uS/cm)	pH[2]	SRP (mg/L)	TP (mg/L)	Cl (mg/L)	NO_3-N (mg/L)	NH_4-N (mg/L)	ACE (µg/L)	B (mg/L)
Tank Effluent (1) Oct 17/19	1377	7.2	6.1	5.5	140	nd	40 (44TKN)	27.0	0.076
Tank Effluent (2) Nov/19									
Drainfield Wells, Nov 4/19									
LV-DF1									
LV-DF2									
LV-DF3									

Table 2. Candlewood Lake; Chemical characteristics of drainfield sediments at three septic system sites. All samples consist of silty sand with variable stone content and were collected by coring with a hand auger or power auger.

76 Site; Filter bed cored October, 2019						
Borehole Depth (ft)	Desorbable P (mg/kg)	Acid Extractible Composition				
		P (mg/kg)	Ca (wt%)	Fe (wt %)	Al (wt %)	Mg (wt%)
76-1-1.5	39	1380	0.21	2.8	2.5	0.57
-2.5	75*	1820	0.24	2.8	2.3	0.56
-3.0	139*	2320	0.31	2.9	2.2	0.55
-3.5	57	1500	0.23	2.8	2.3	0.55
-4.0	93*	1860	0.25	2.9	2.5	0.58
-5.0	56	1210	0.23	3.9	2.9	0.79
76-2-1.5	38					
-2.0	39					
-2.5	39					
-3.0	40					
-3.5	46					
76-3-1.5	26					
-2.0	30					
-2.5	25					
-3.0	42					

LV Site; Filter bed cored October, 2019						
Borehole Depth (ft)	Desorbable P (mg/kg)	Acid Extractible Composition				
		P (mg/kg)	Ca (wt%)	Fe (wt %)	Al (wt %)	Mg (wt%)
LV1-1.0		780	0.93	2.3	2.7	4.1
-1.5	3.8	740	1.12	2.3	2.8	4.5
-2.5	21*	770	0.46	2.6	2.2	1.5
-3.0	21*	930	0.42	3.0	2.4	1.2
-3.5	20*	1210	0.36	3.7	3.0	0.82
-4.0	20*	930	0.33	3.7	3.0	1.1
LV2-1.5	3.6					
-2.0	5.1					
-2.5	4.3					
-3.0	4.3					

LV3-1.0	3.8					
-1.5	5.6					
-2.0	11.3					
LV3-2.5	11.2					
-3.5	11.1					
-4.0	11.3					
NL Site; Filter bed cored October, 2019						
Borehole Depth (ft)	Desorbable P (mg/kg)	Acid Extractible Composition				
		P (mg/kg)	Ca (wt%)	Fe (wt %)	Al (wt %)	Mg (wt%)
NL1-1.5	35*					
-2.0	15					
-2.5	18					
-3.5	5.7					
-4.0	5.7					
NL2-1.5	7.6					
-2.0	47*					
-2.5	35					
-3.5	35					
-4.0	58*					
NL3-1.0	18	1020	1.6	2.3	1.6	1.3
-1.5	17	1030	3.4	2.1	1.3	2.4
-2.0	71*	1333	0.35	2.2	2.0	0.50
-2.5	40	1222	0.32	2.8	1.9	0.63
-3.0	36	1250	1.2	2.8	1.8	1.0

* Sample submitted for SEM/EDX analysis

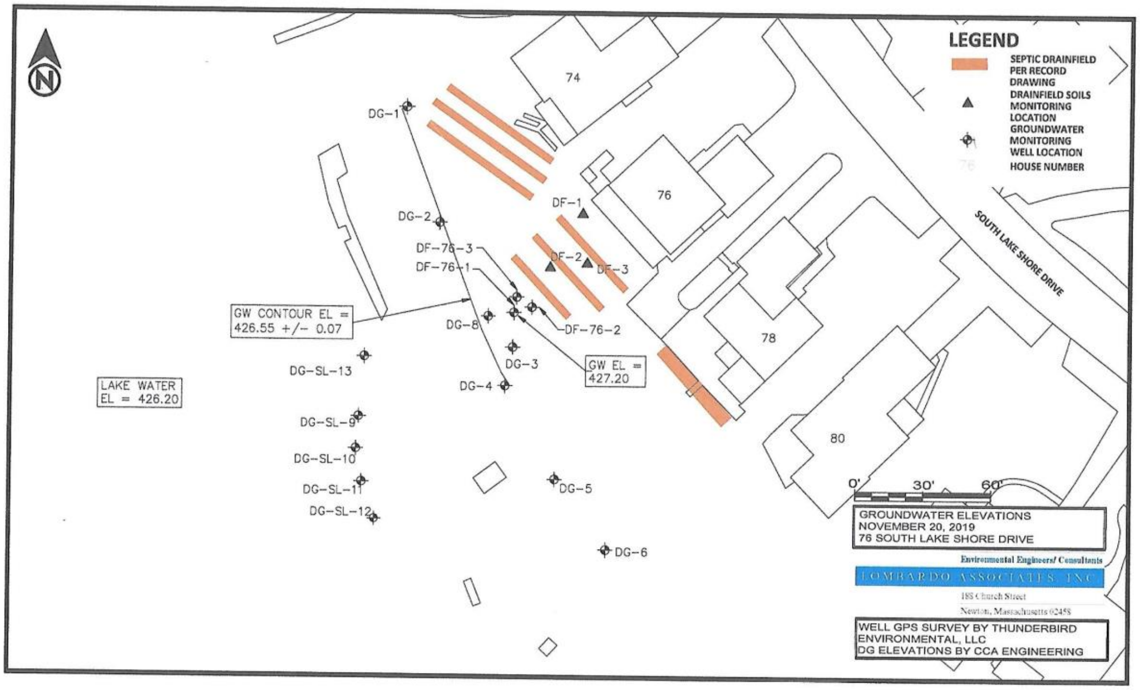


Fig.1. 76 site map, showing location of drainfield and boreholes/monitoring wells.

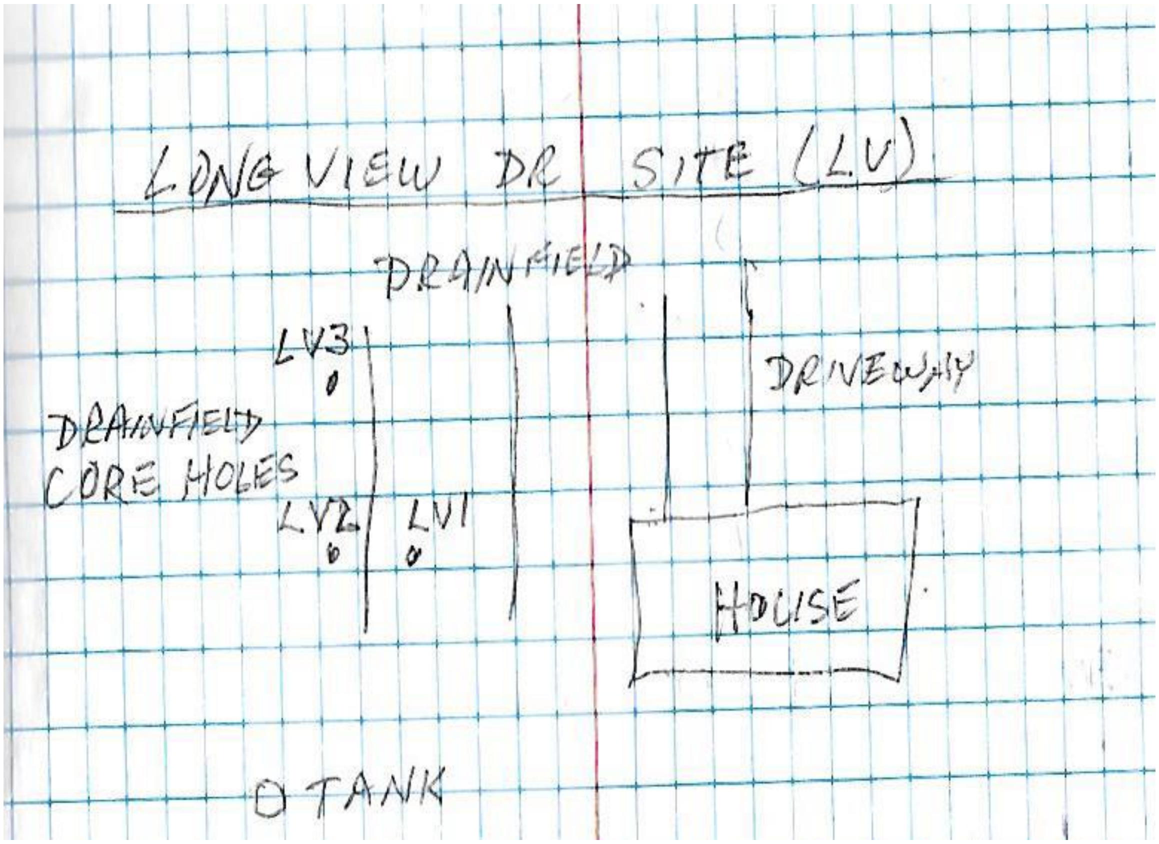


Fig.2. LV site map, showing location of drainfield and drainfield coreholes.

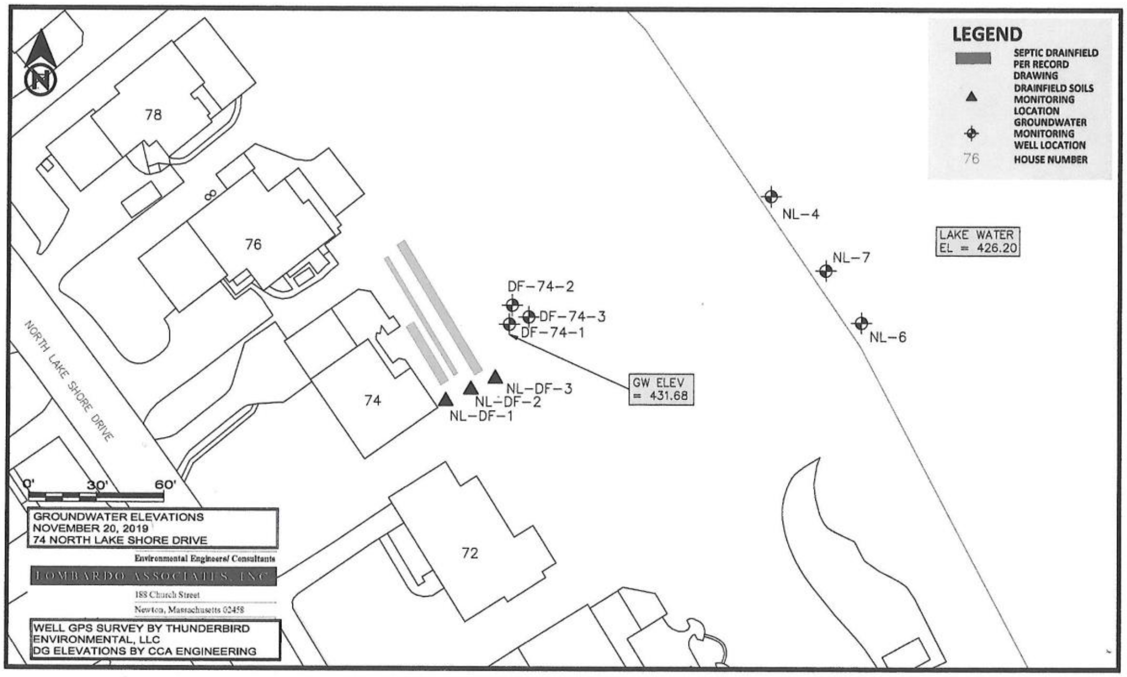


Fig.3. NL site map, showing locations of drainfield and boreholes/monitoring wells.

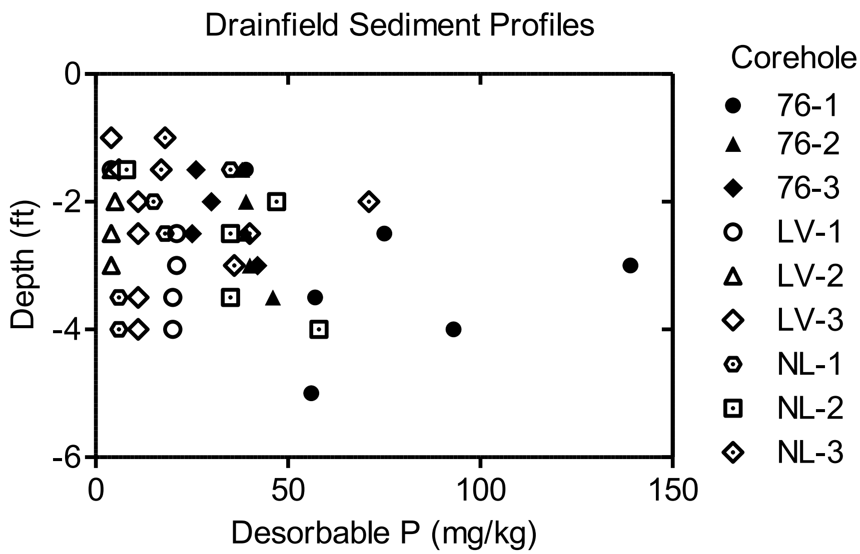


Fig. 4. Depth profiles of desorbable phosphorus in the drainfield sediments at the three study sites.

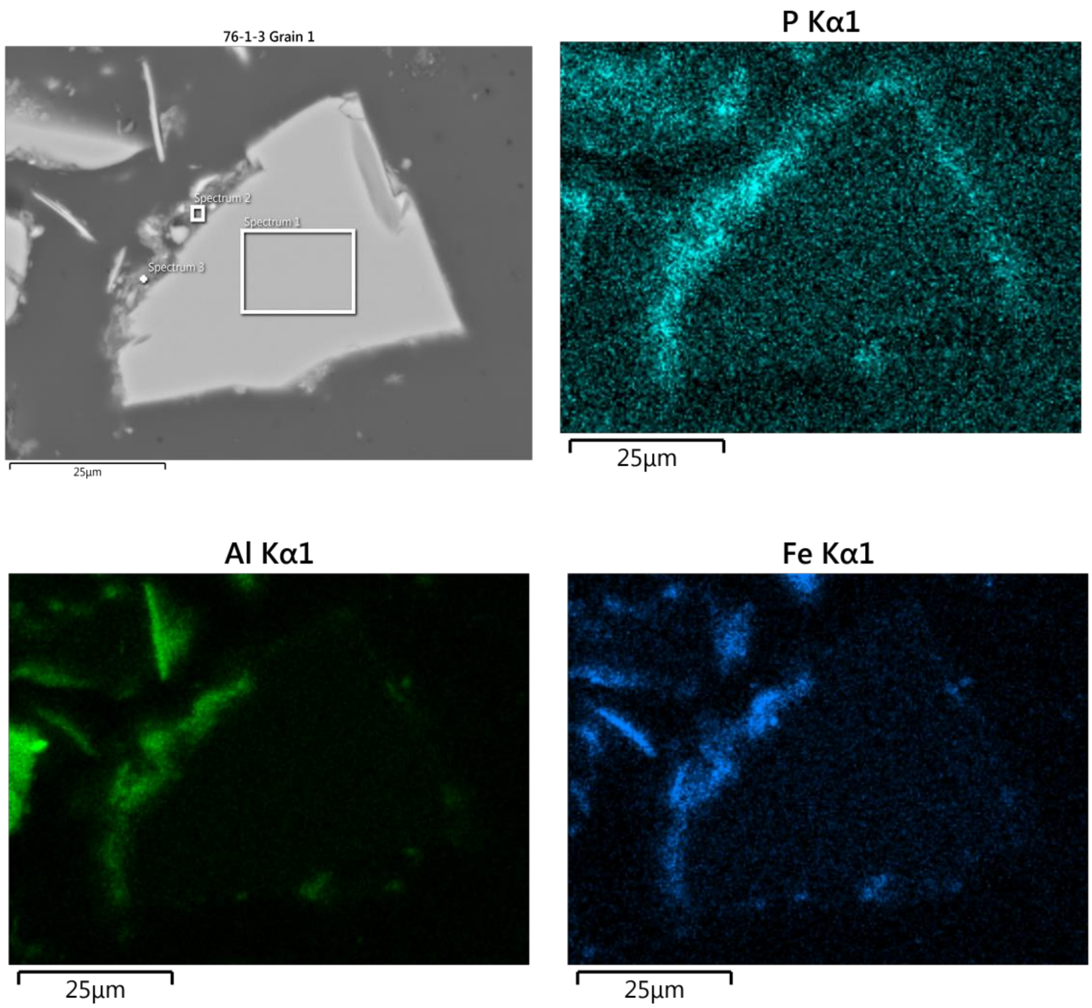


Fig. 5. Scanning electron microscope image and Xray elemental analysis of drainfield sand grain from the 76 site, showing secondary mineral coating on a quartz grain (core 76-1, 3' depth). Coating composition (Spot 2) is 2.4 % P, 8.4 % Al, 8.6 % Fe and 1.2 % Ca. For full compositional analysis see Appendix A.

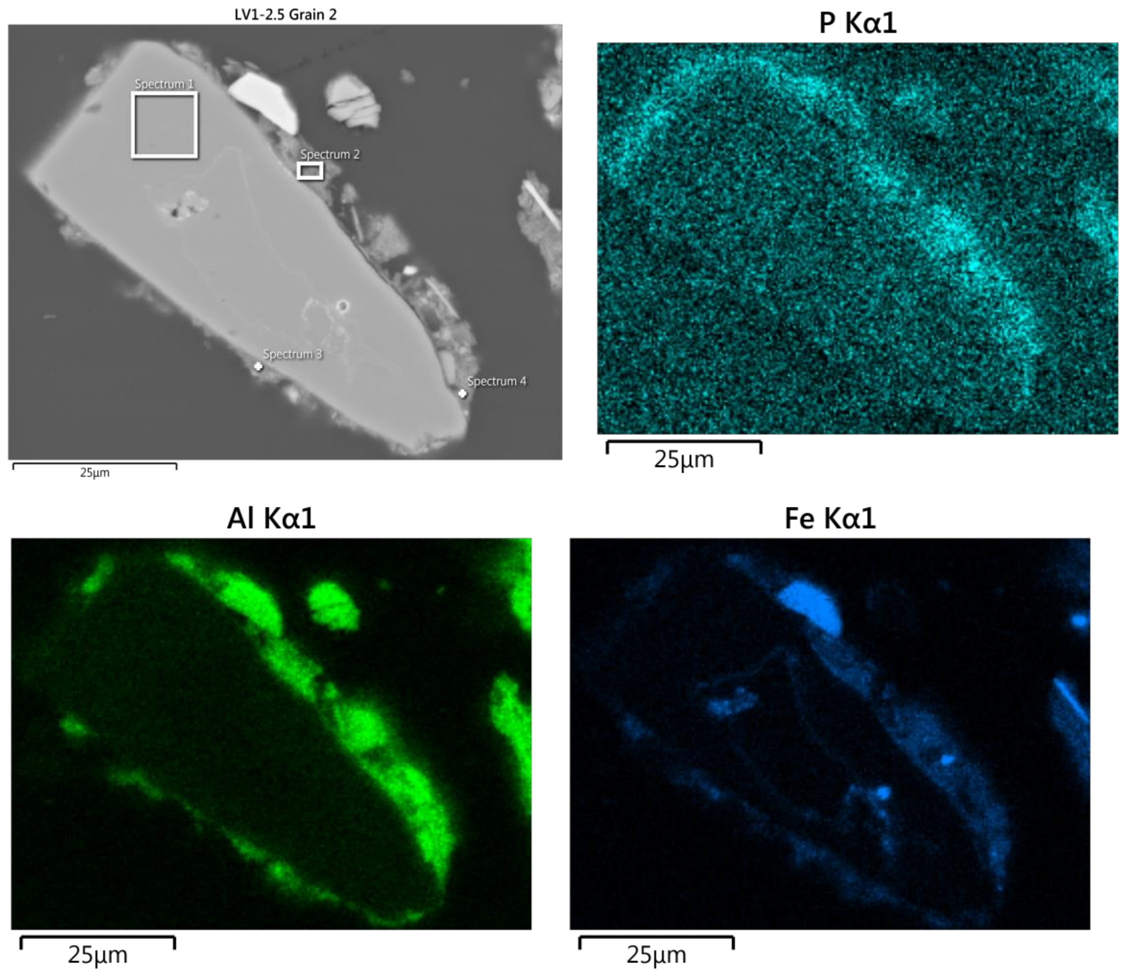


Fig. 6. Scanning electron microscope image and Xray elemental analysis of drainfield sand grain from the LV site, showing secondary mineral coating on a quartz grain (core LV1, 2.5' depth. Coating composition (Spot 2) is 0.7 % P, 13.6 % Al, 10.2 % Fe and 0.9 % Ca. For full compositional analysis see Appendix A.

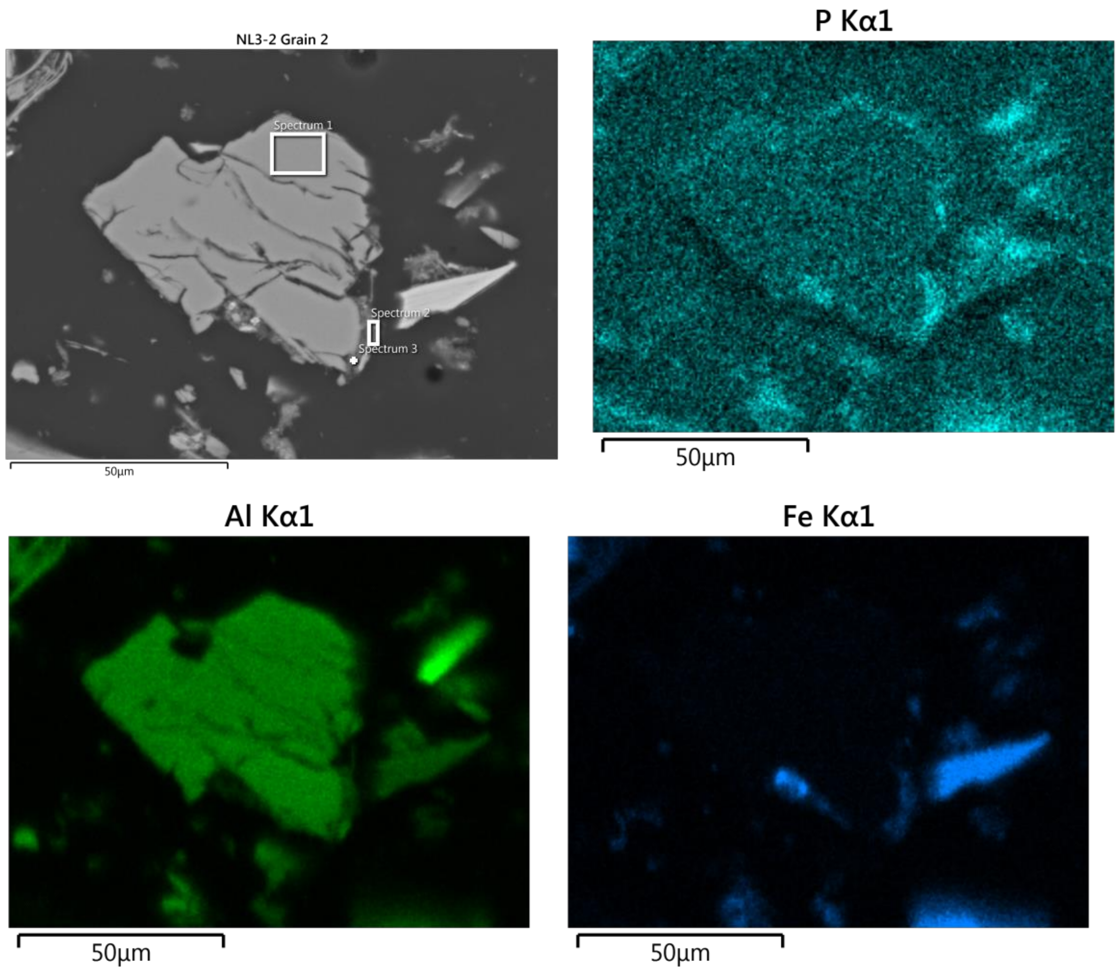


Fig. 7. Scanning electron microscope image and Xray elemental analysis of drainfield sand grain from the NL site, showing secondary mineral coating on a plagioclase feldspar grain (core NL3- 2' depth). Coating composition (Spot 2) is 1.2 % P, 9.0 % Al, 8.1 % Fe and 1.1 % Ca. For full compositional analysis see Appendix A.

Characterization of Phosphorus Solids Retained in Drainfield Sediments at Three Septic System Sites, Candlewood Lake, CT

Report Prepared for;
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Newton, MA

Prepared By;
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Environmental Geochemistry Laboratory
University of Waterloo, ON

December 26, 2019

Appendix A

SEM/EDX analyses of 11 drainfield sediment samples

**Analyses completed by
Surface Science Western, laboratories, London, ON, Canada**

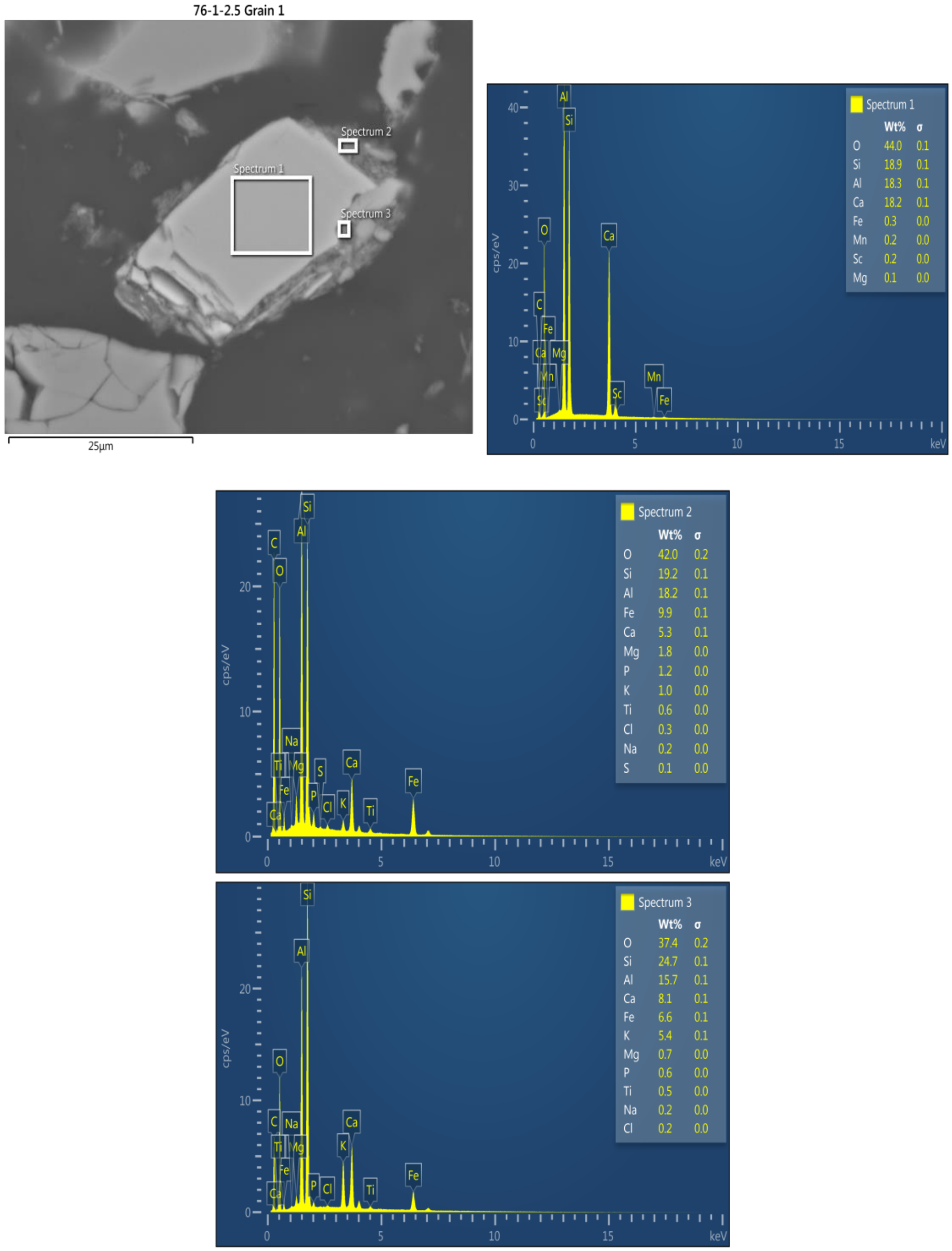


Fig. A1. Drainfield sample 76-1, 2.5’ depth , grain 1.

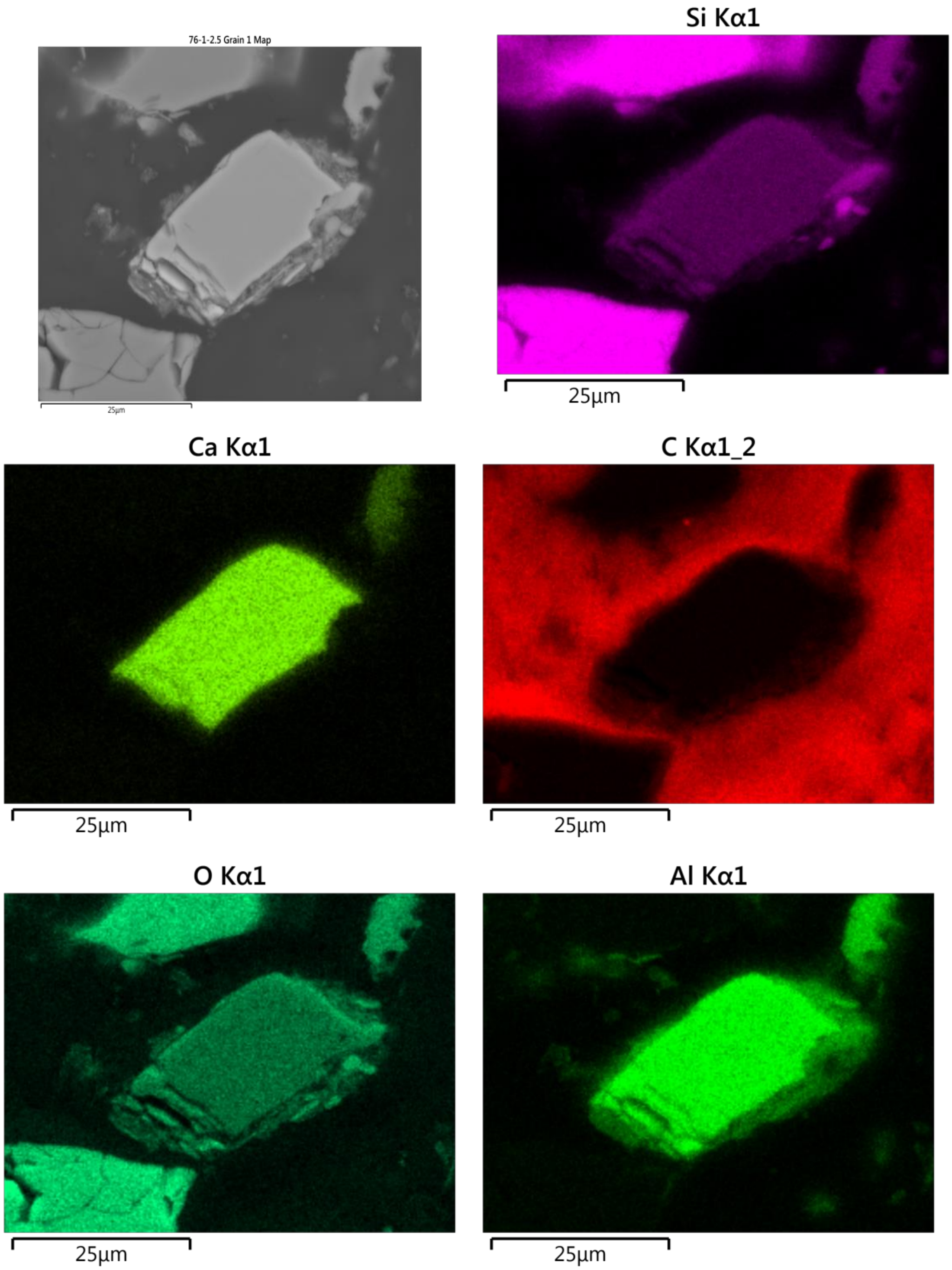
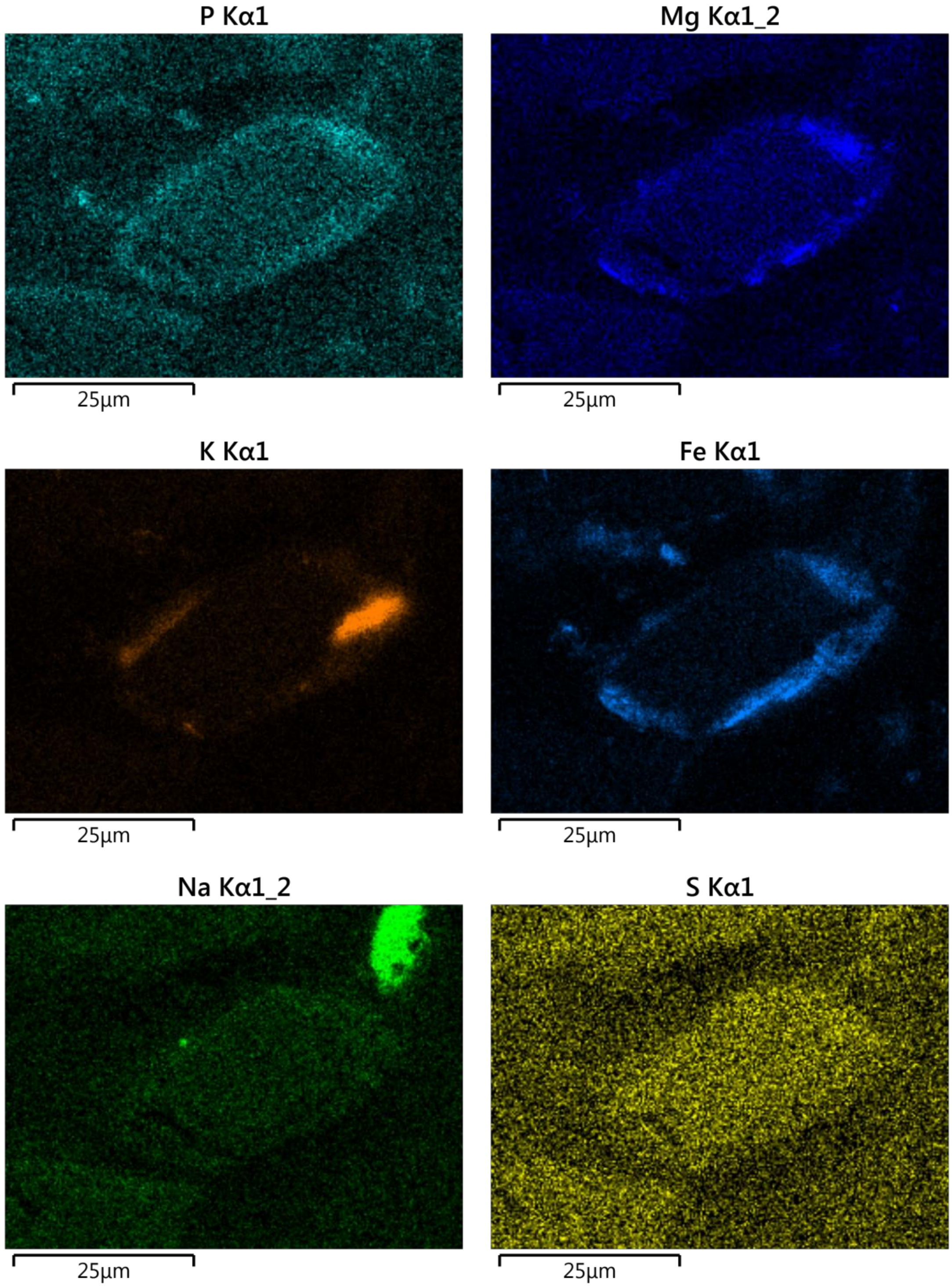


Fig. A1. Continued



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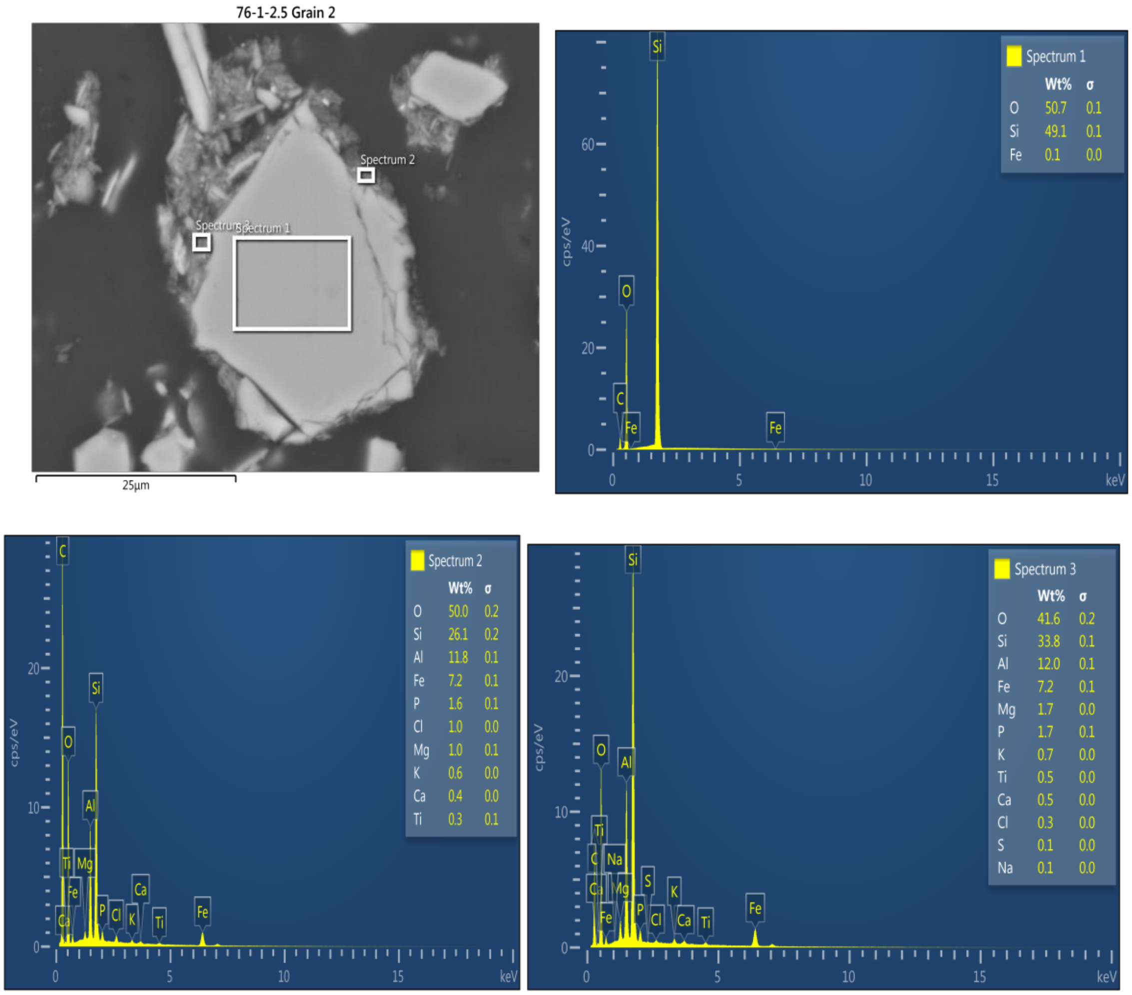
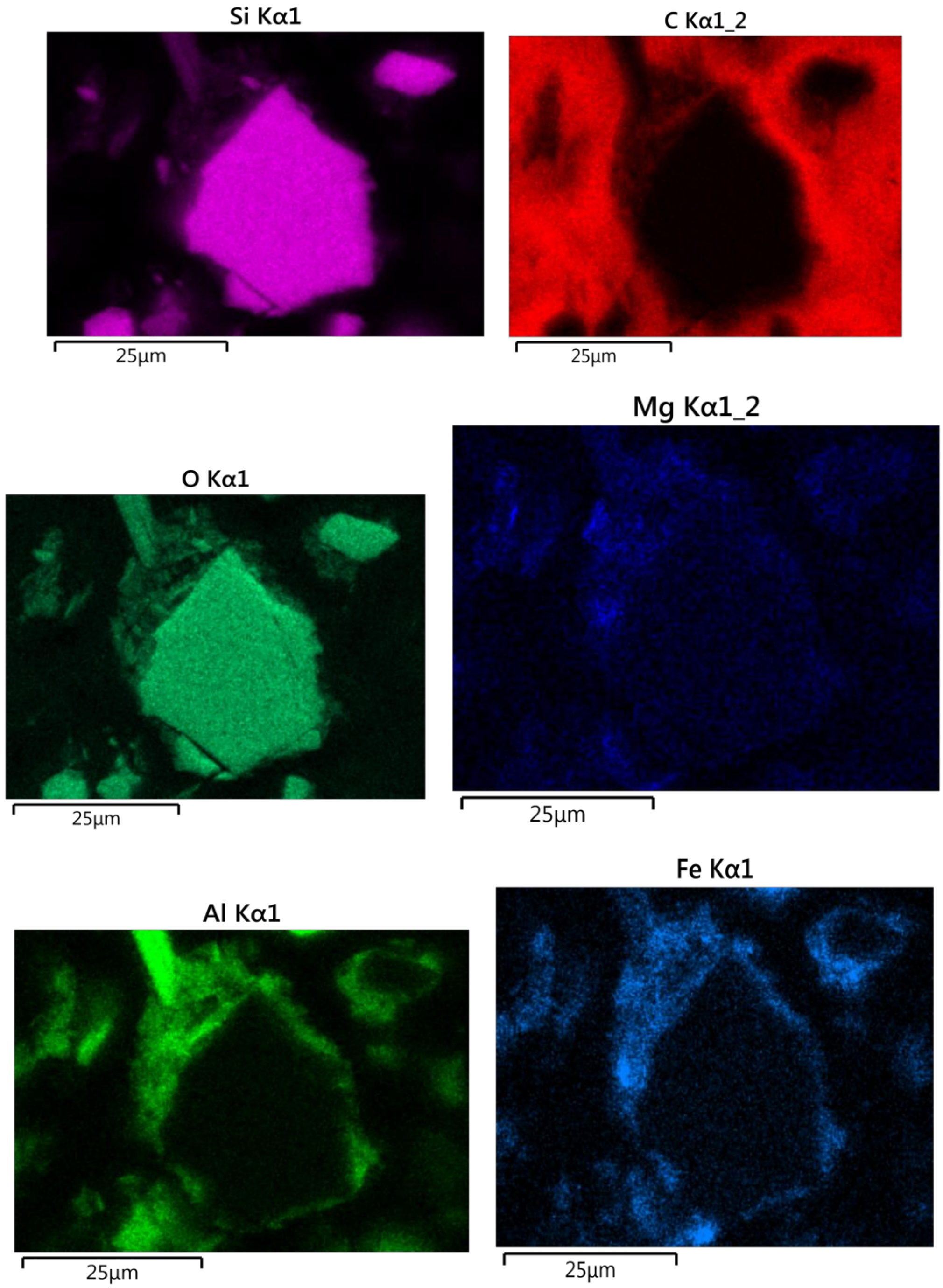


Fig. A2. Drainfield sample 76-1, 2.5’ depth, Grain 2.



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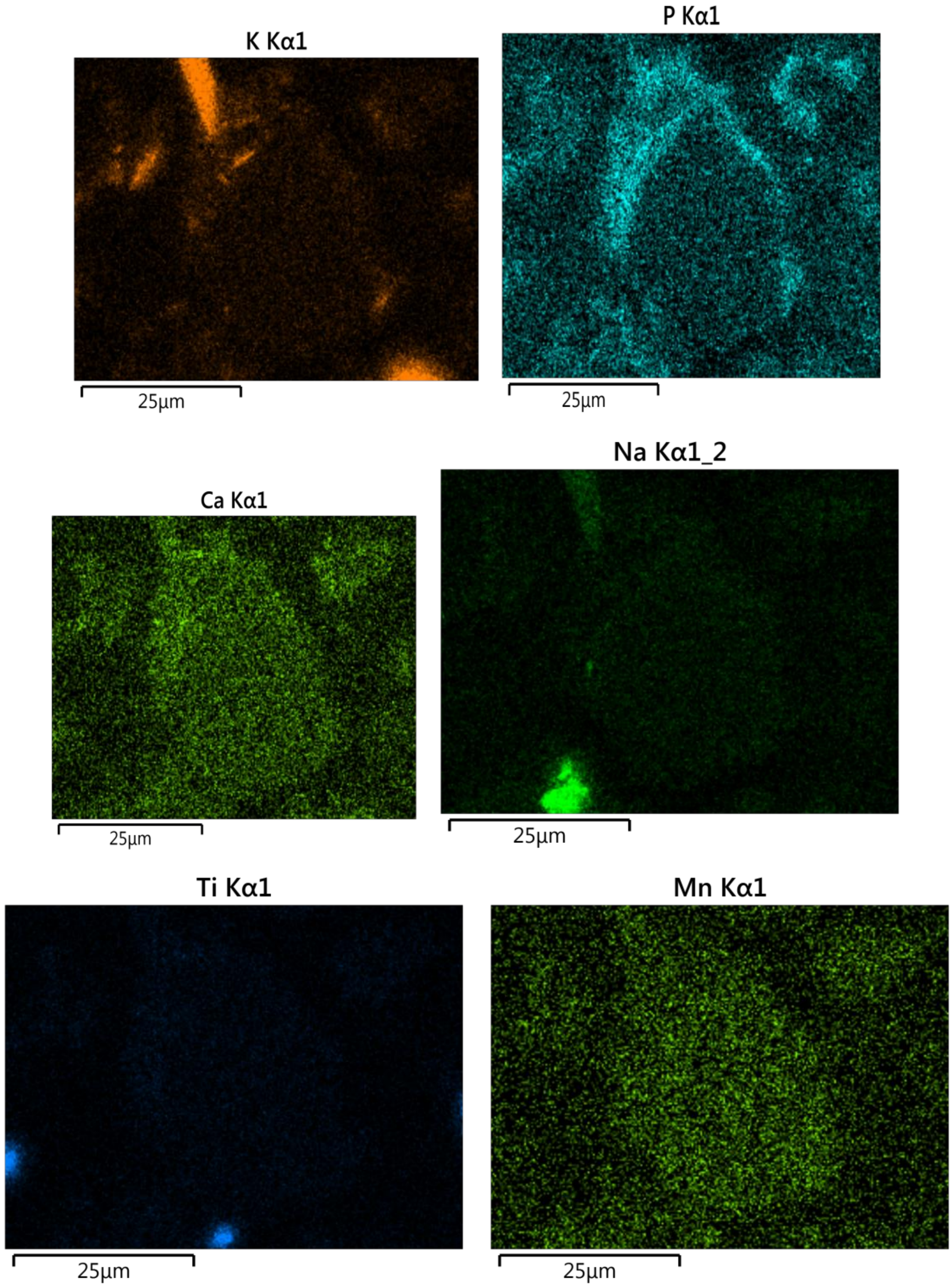

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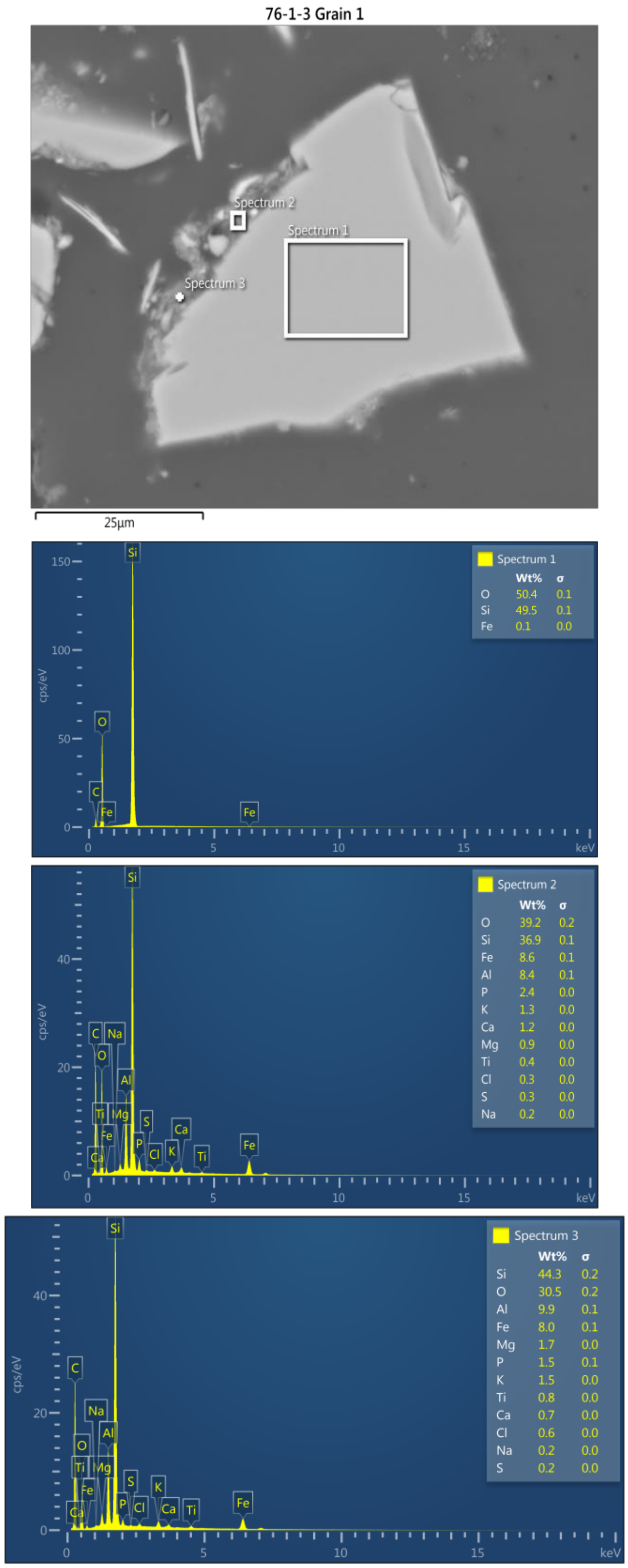


Fig. A3. Drainfield sample 76-1, 3.0' depth, grain 1.

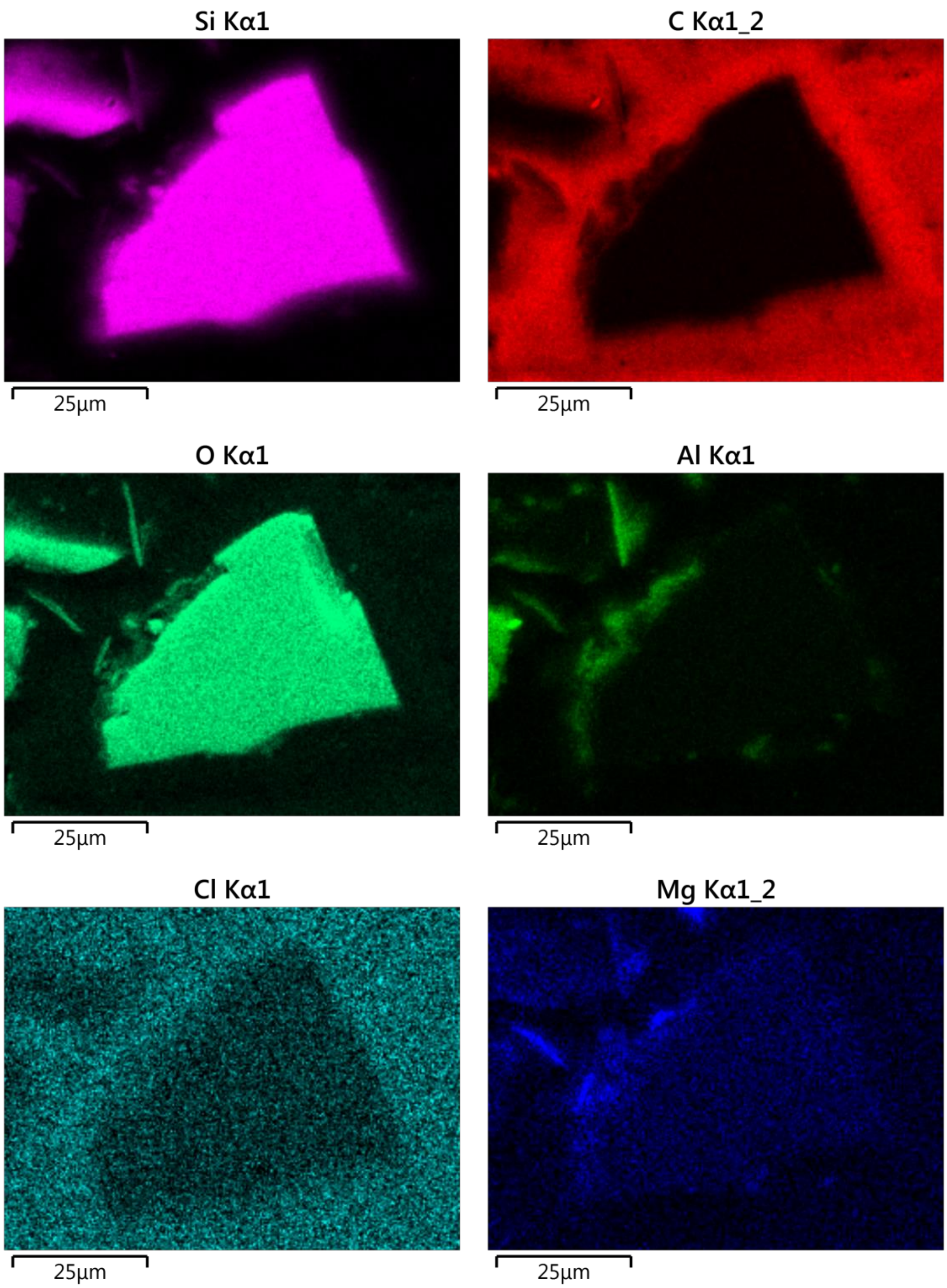
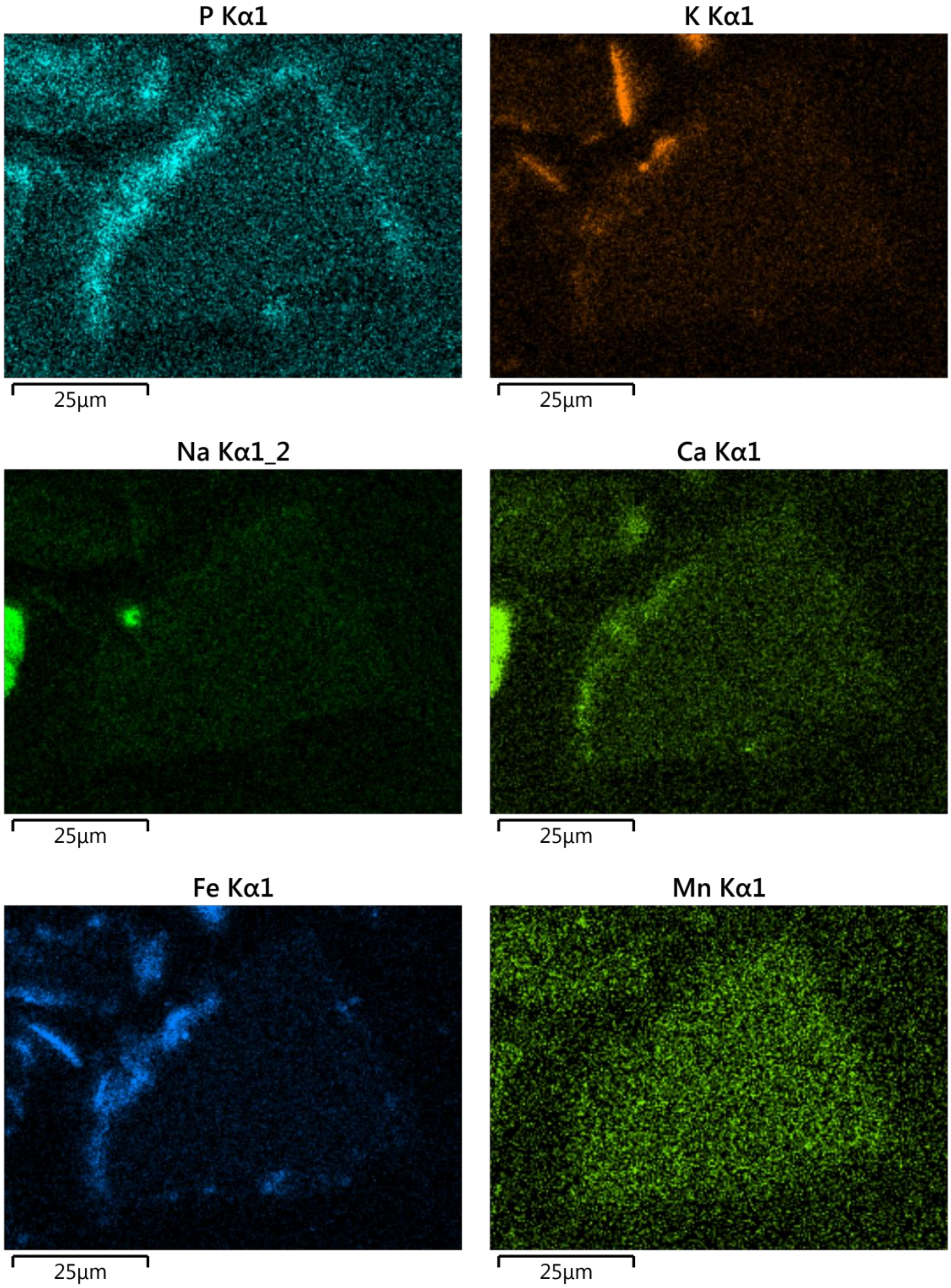


Fig. A3. Continued



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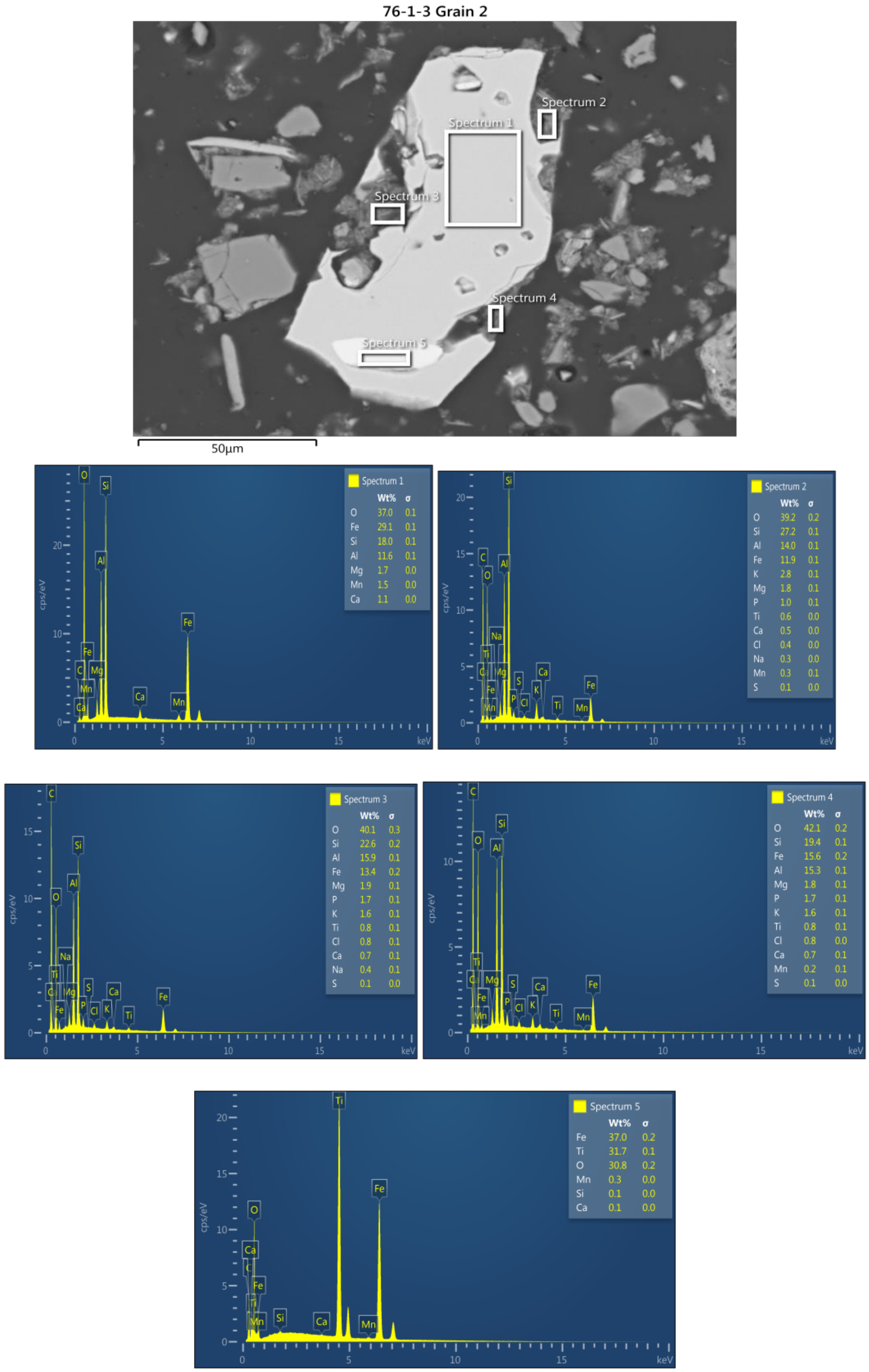


Fig. A4. Drainfield sample 76-1, 3.0’ depth, grain 2.

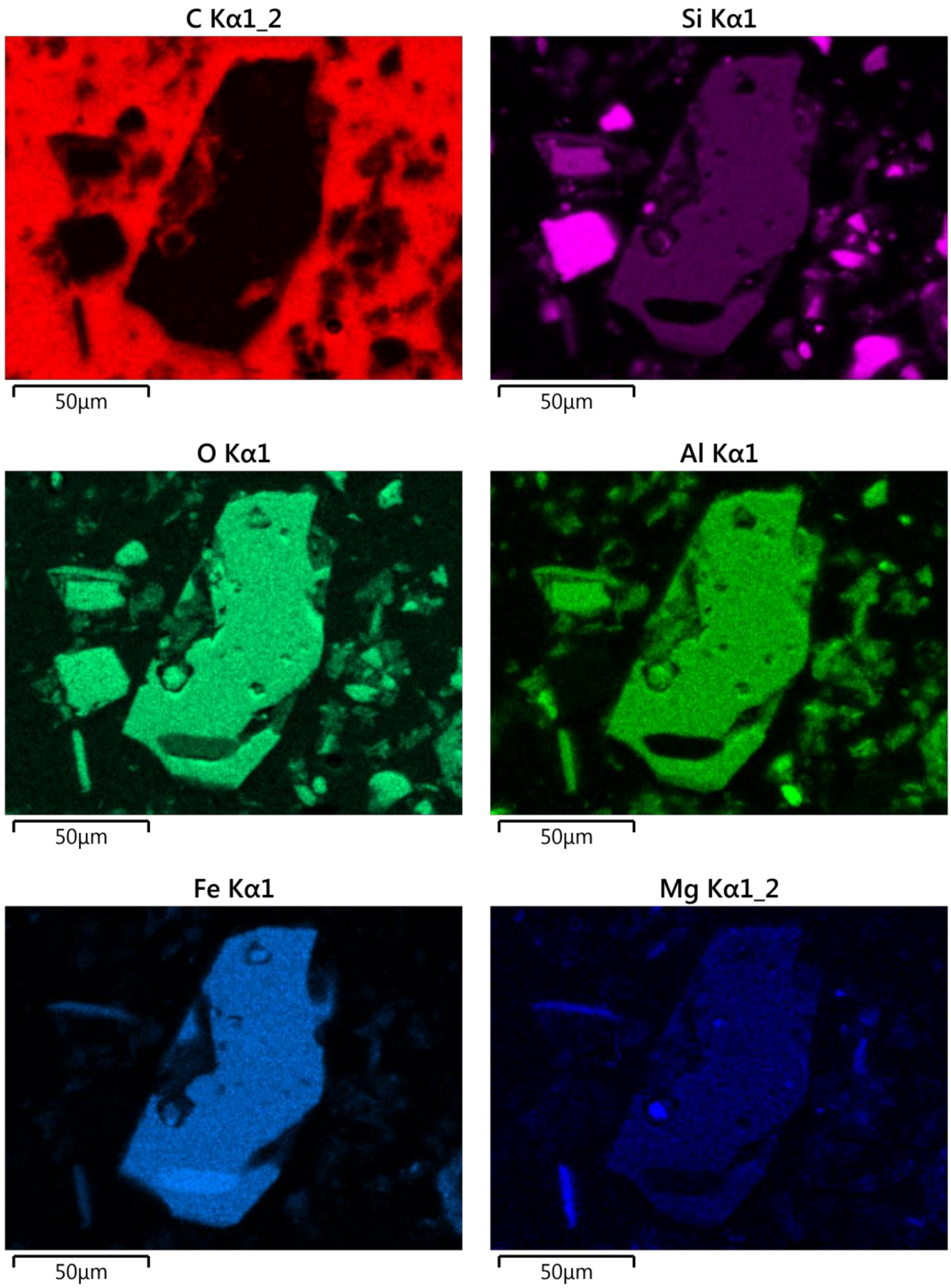
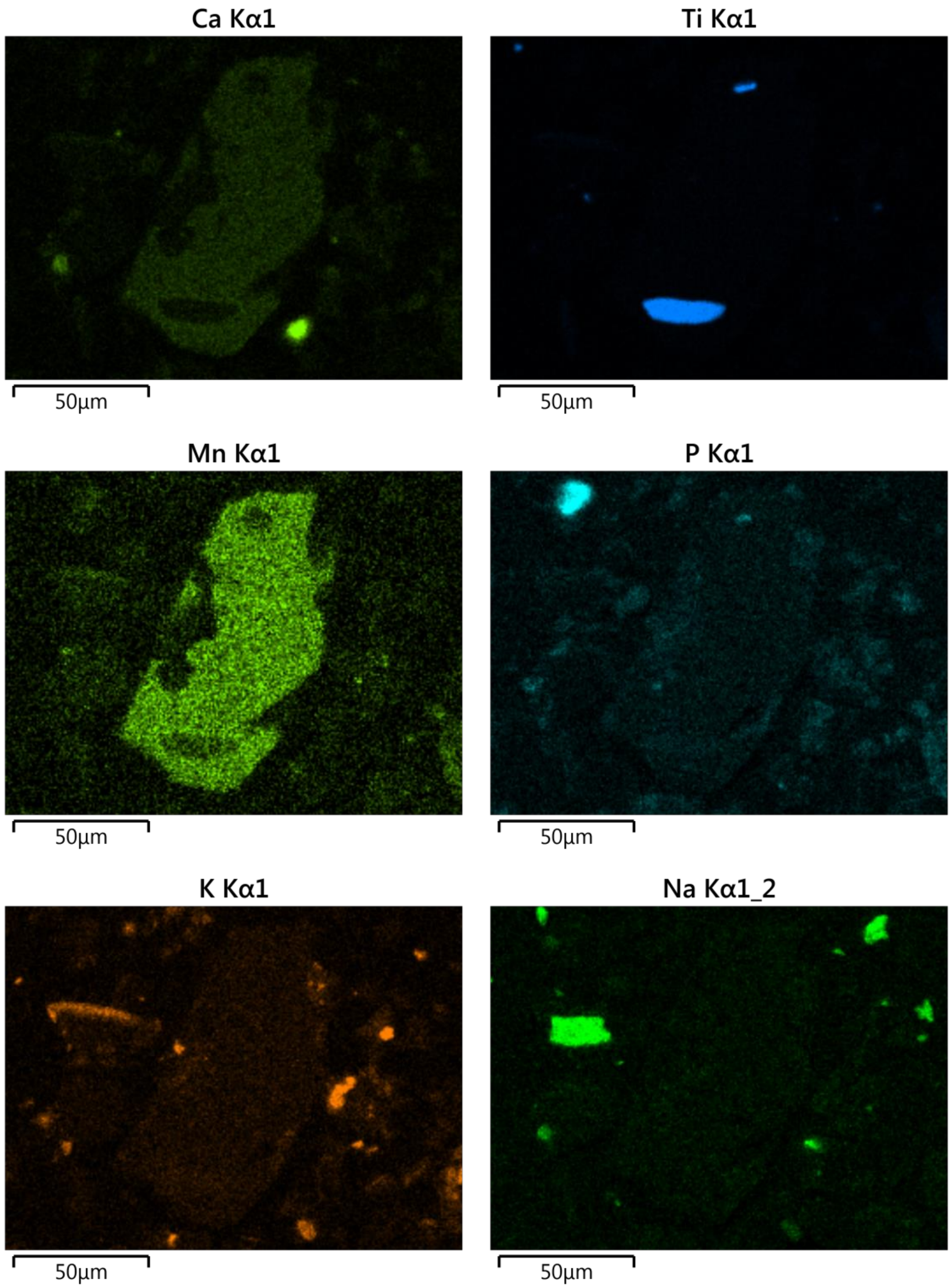


Fig. A4. Continued



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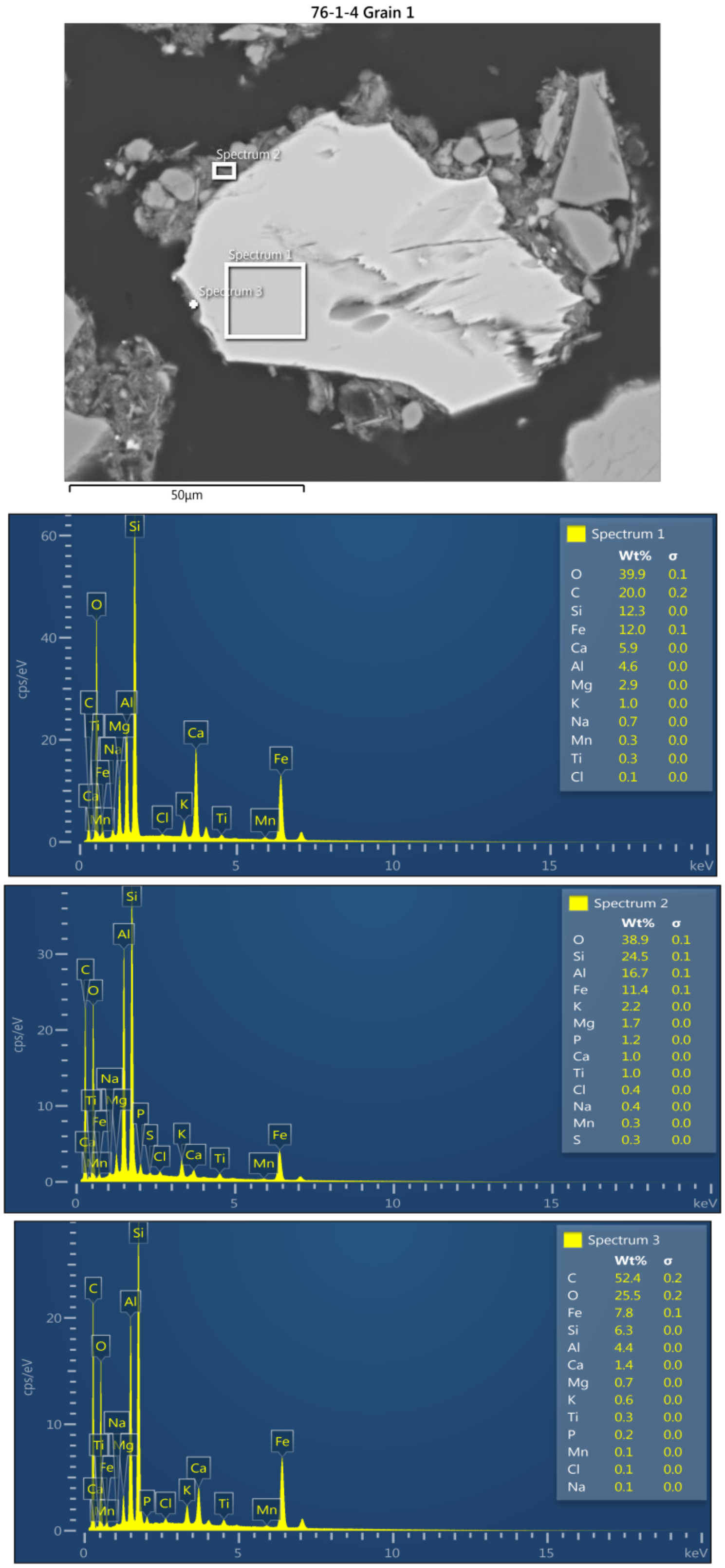
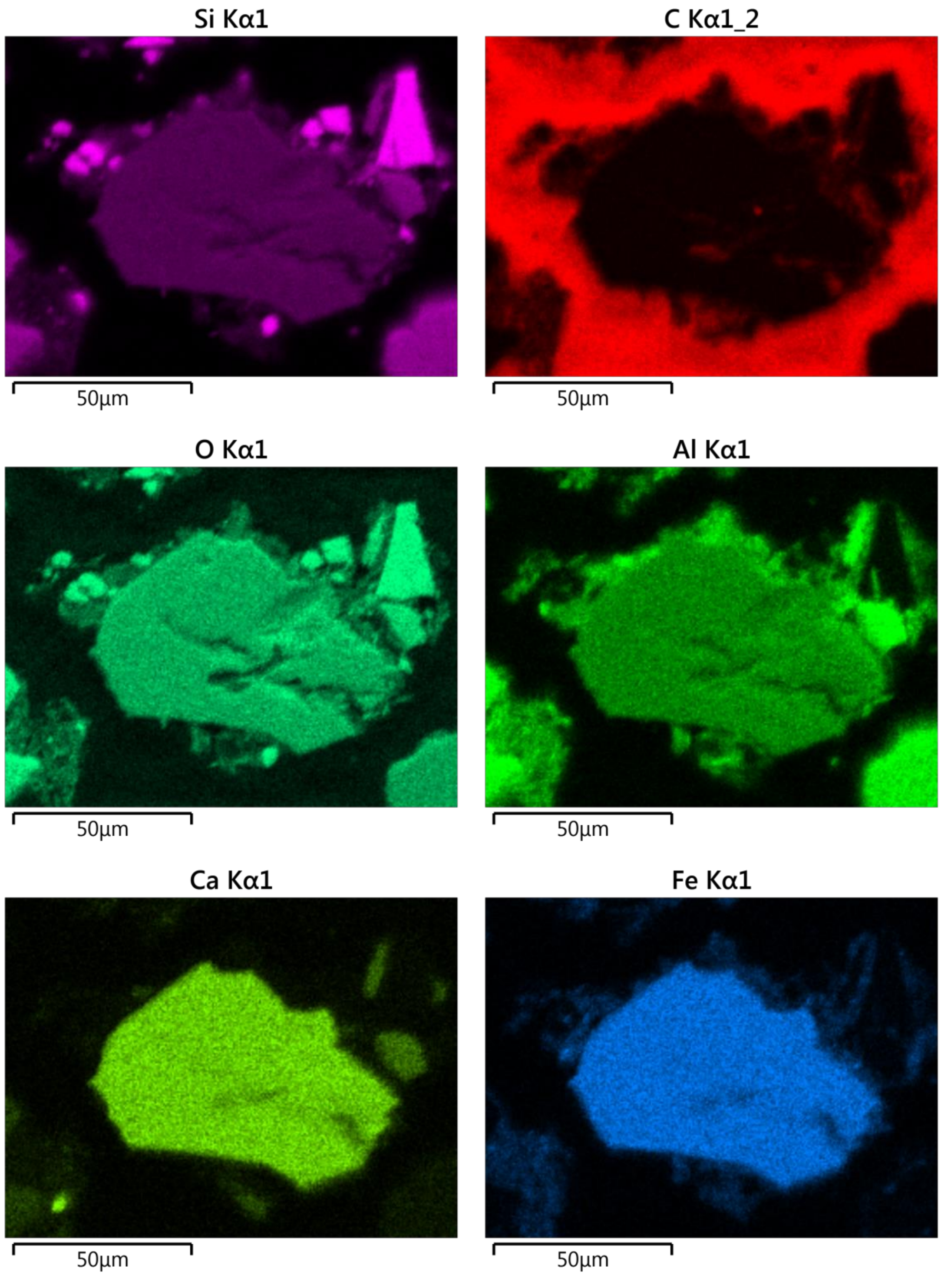


Fig. A5. Drainfield sample 76-1, 4.0’ depth, grain 1.



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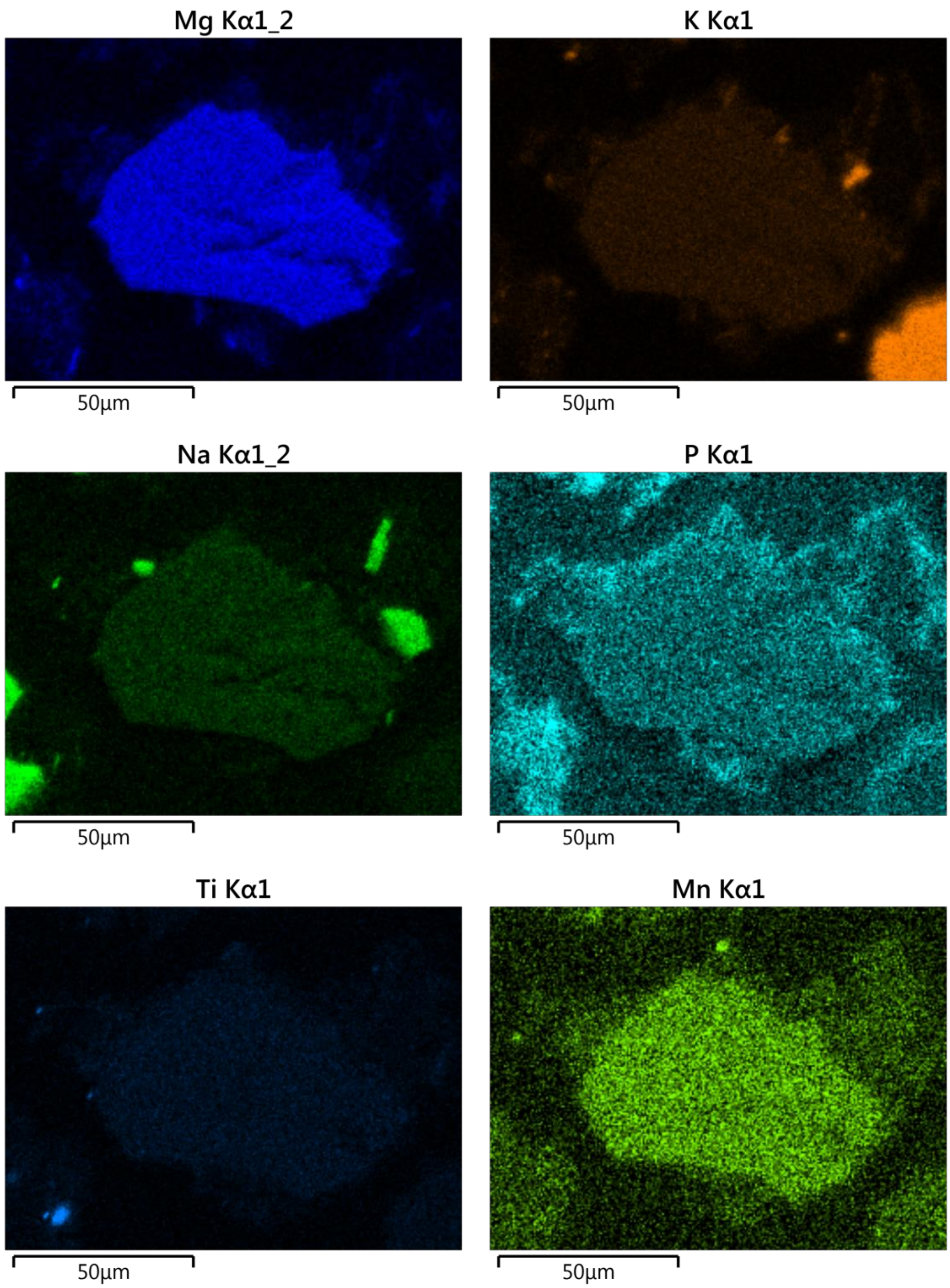

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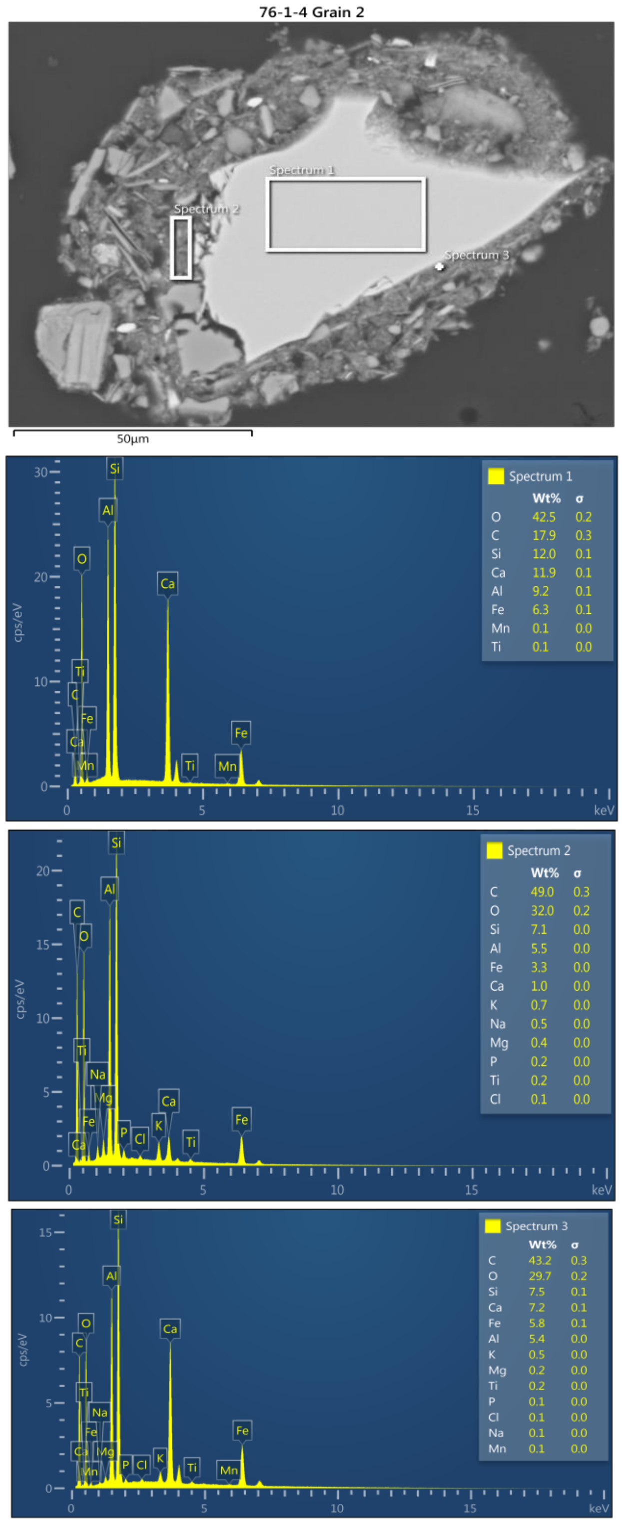
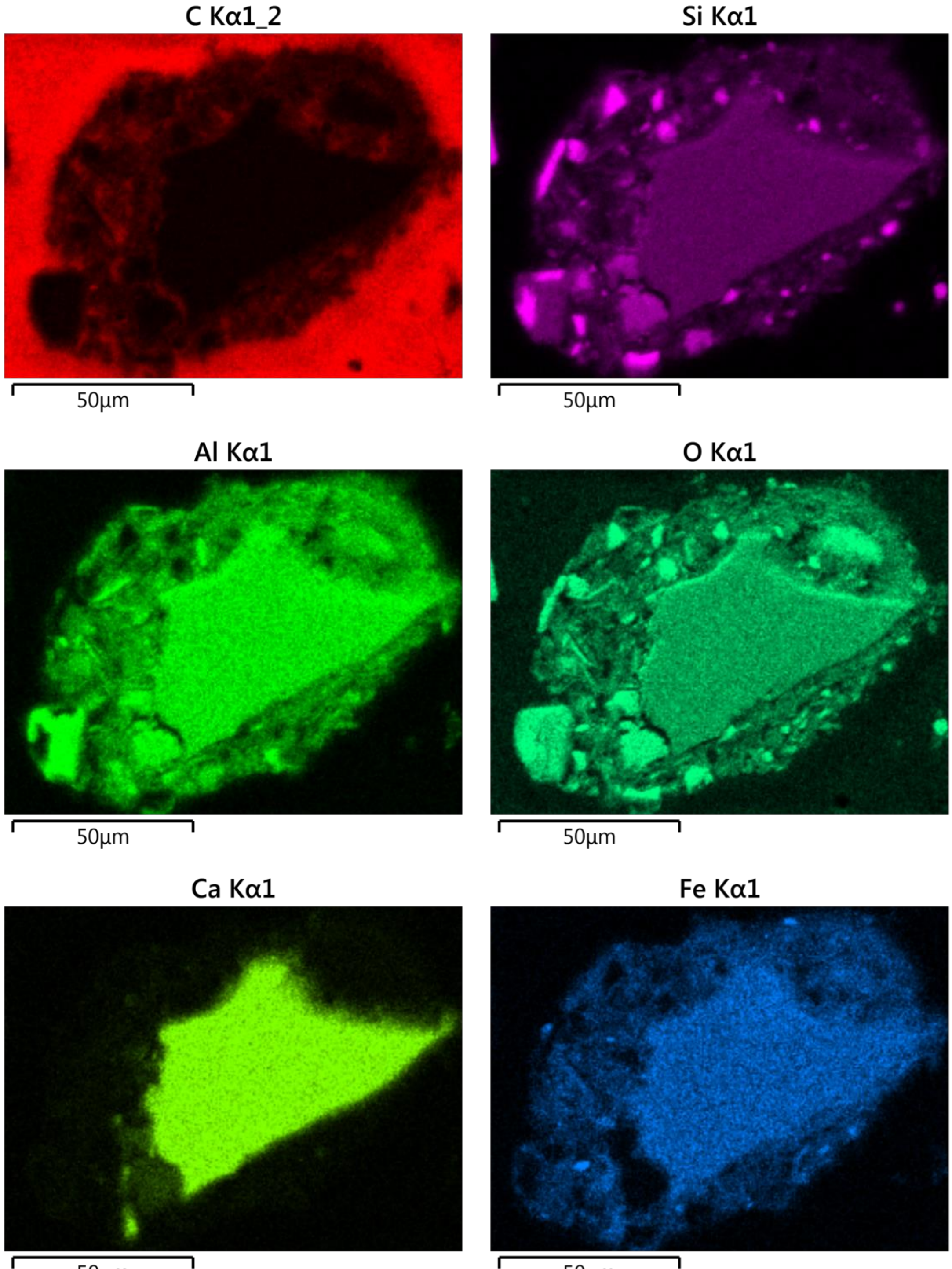


Fig. A6. Drainfield sample 76-1, 4' depth, grain 2.



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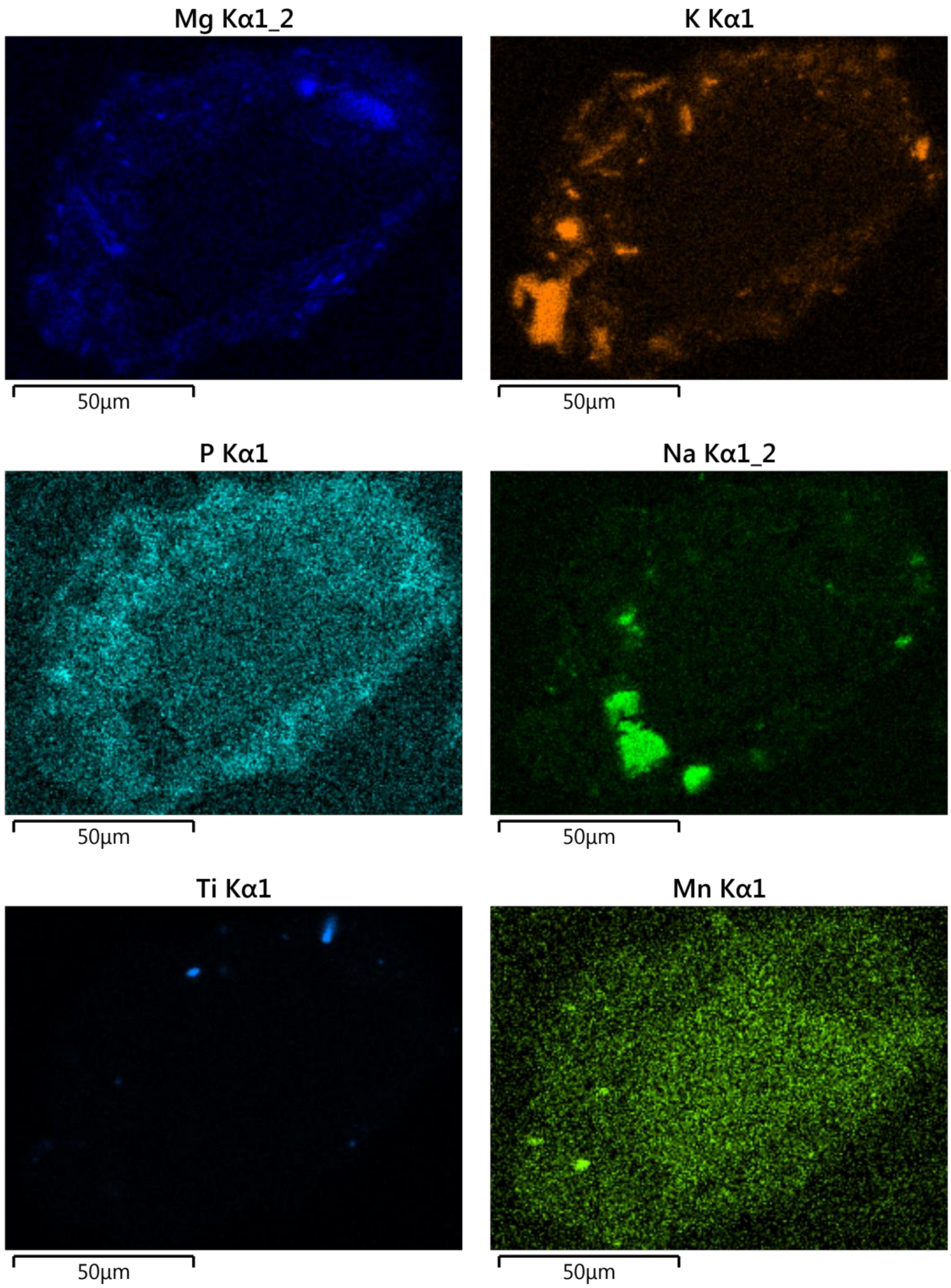

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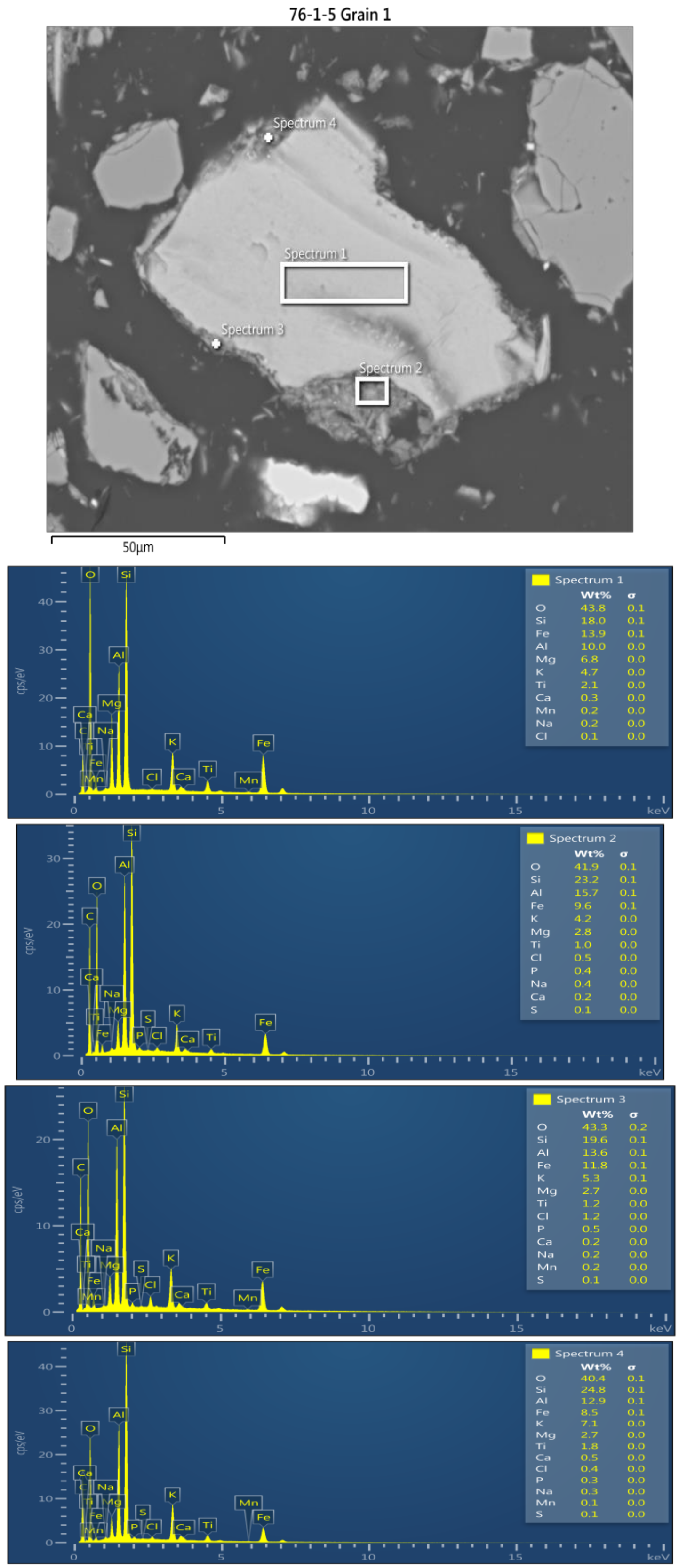


Fig. A7. Drainfield sample 76-1, 5.0’ depth, grain 1.

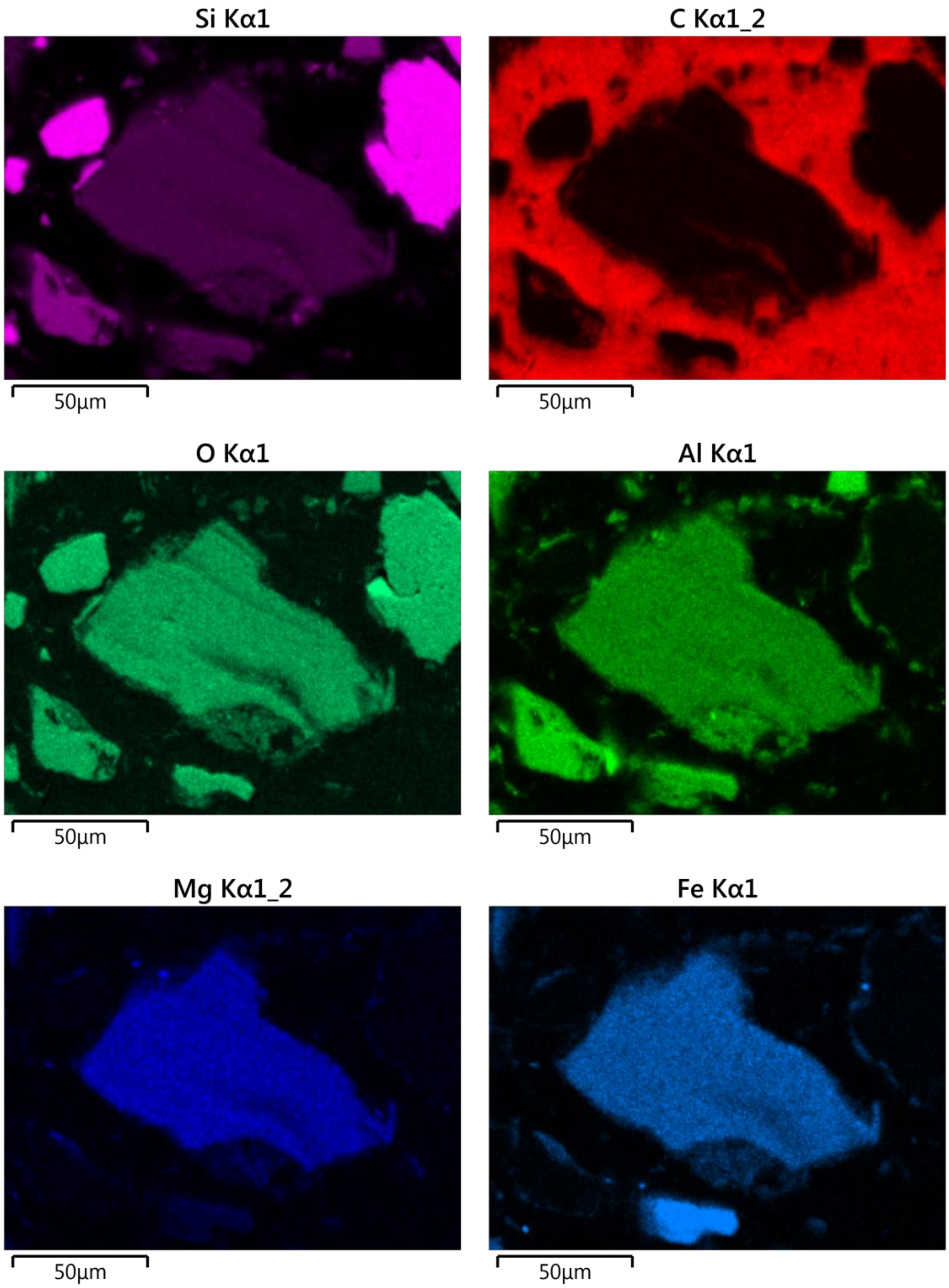
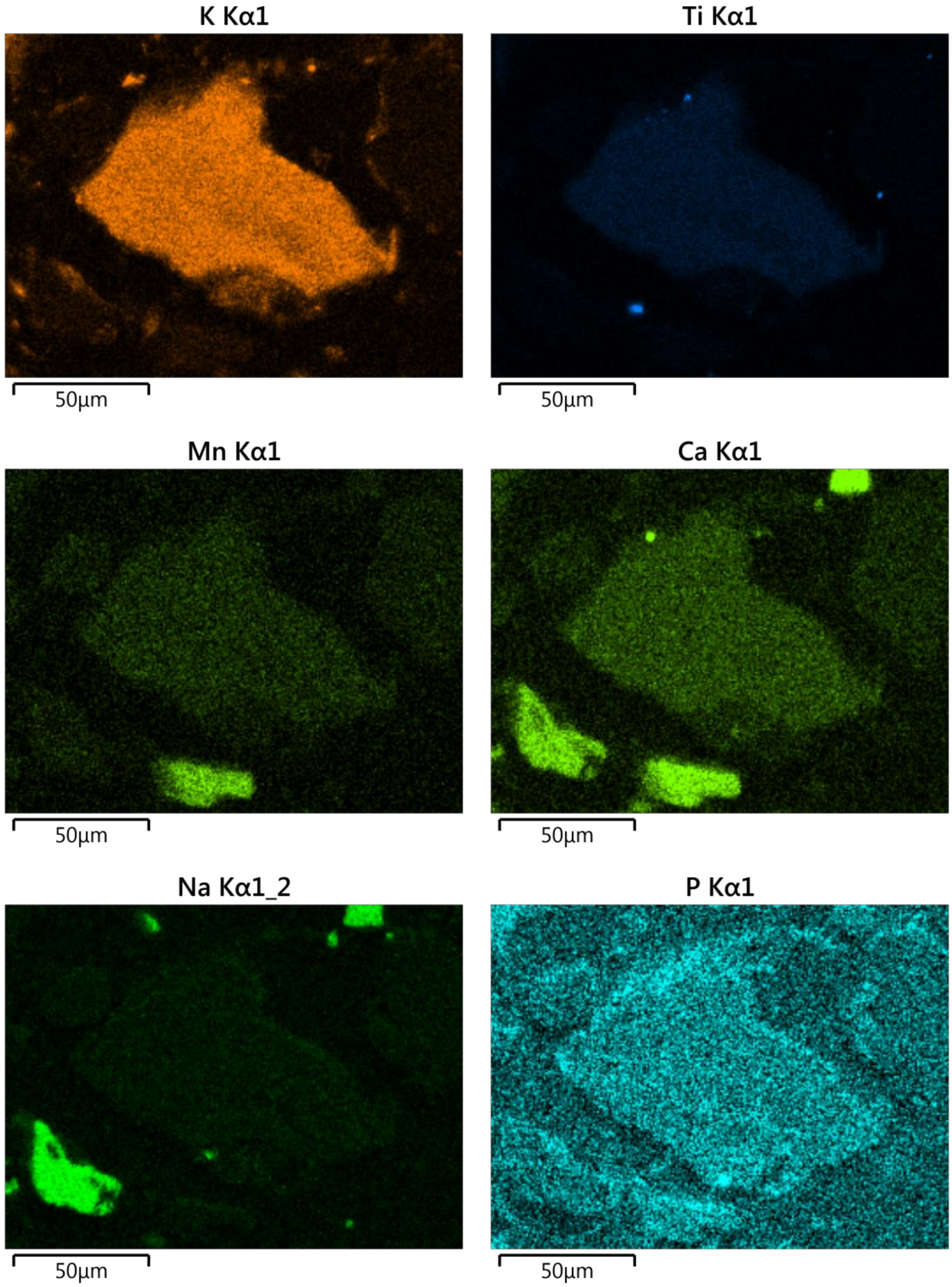


Fig. 7A. Continued.



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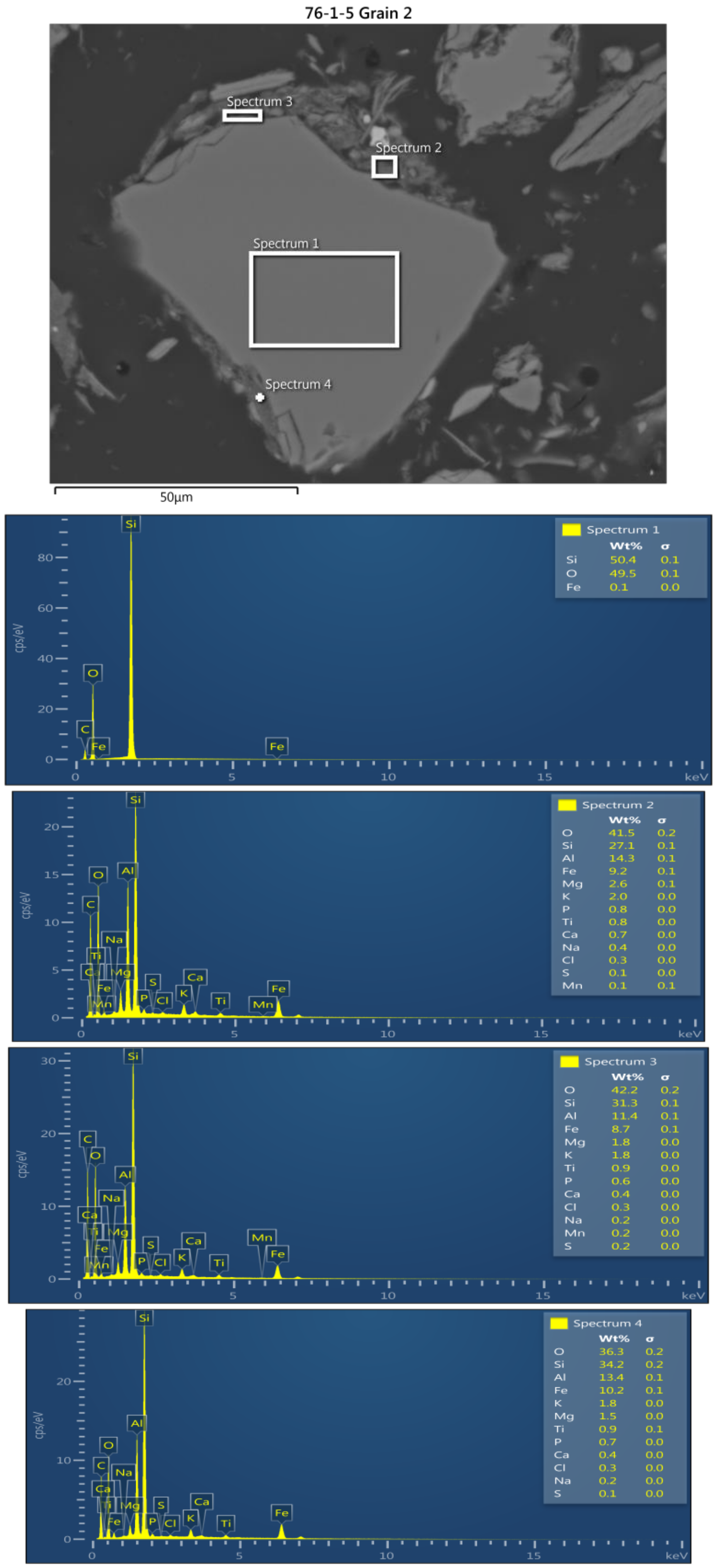


Fig. A8. Drainfield sample 76-1. 5.0’ depth, grain 2.

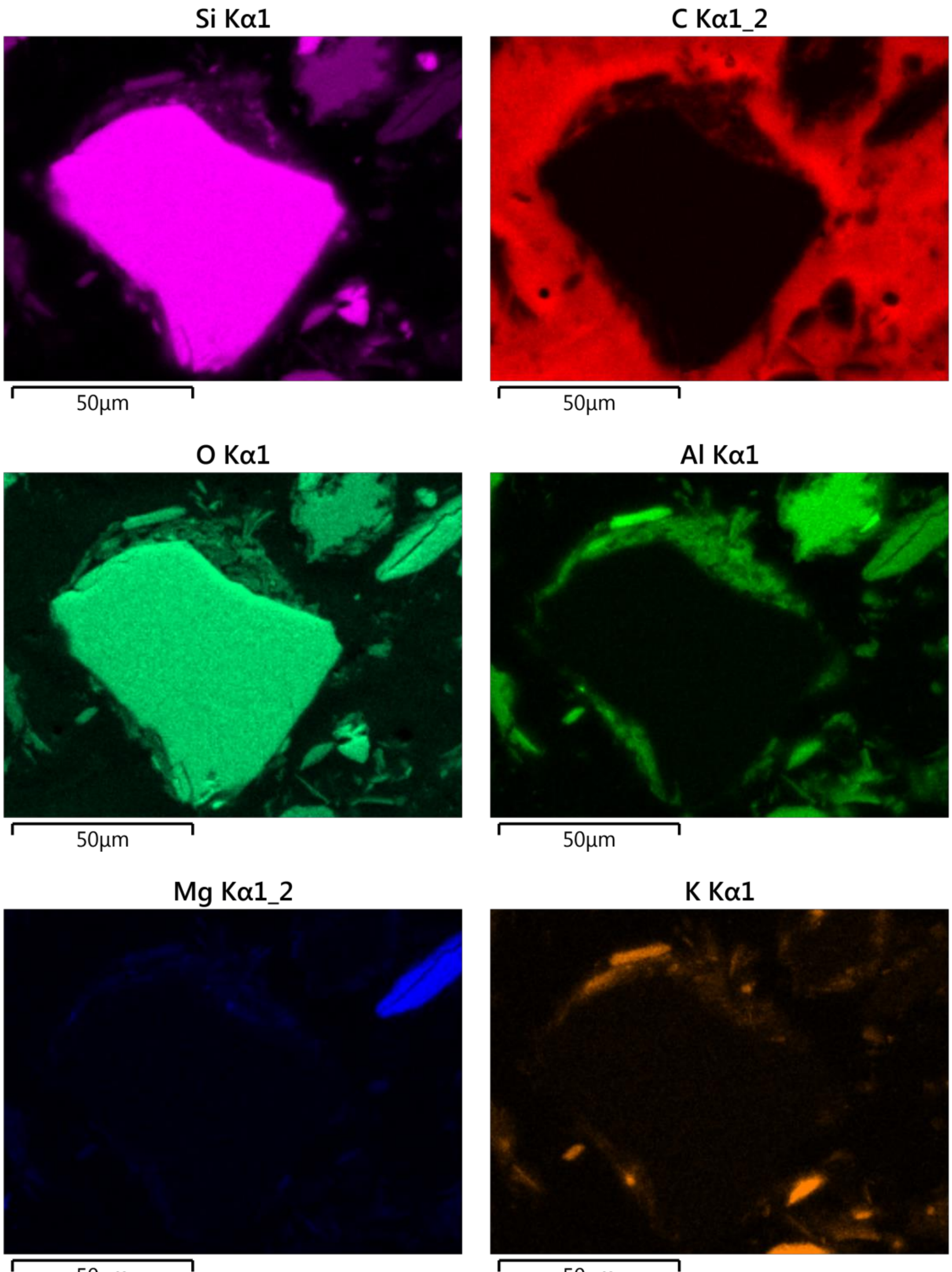


Fig. A8. Continued.

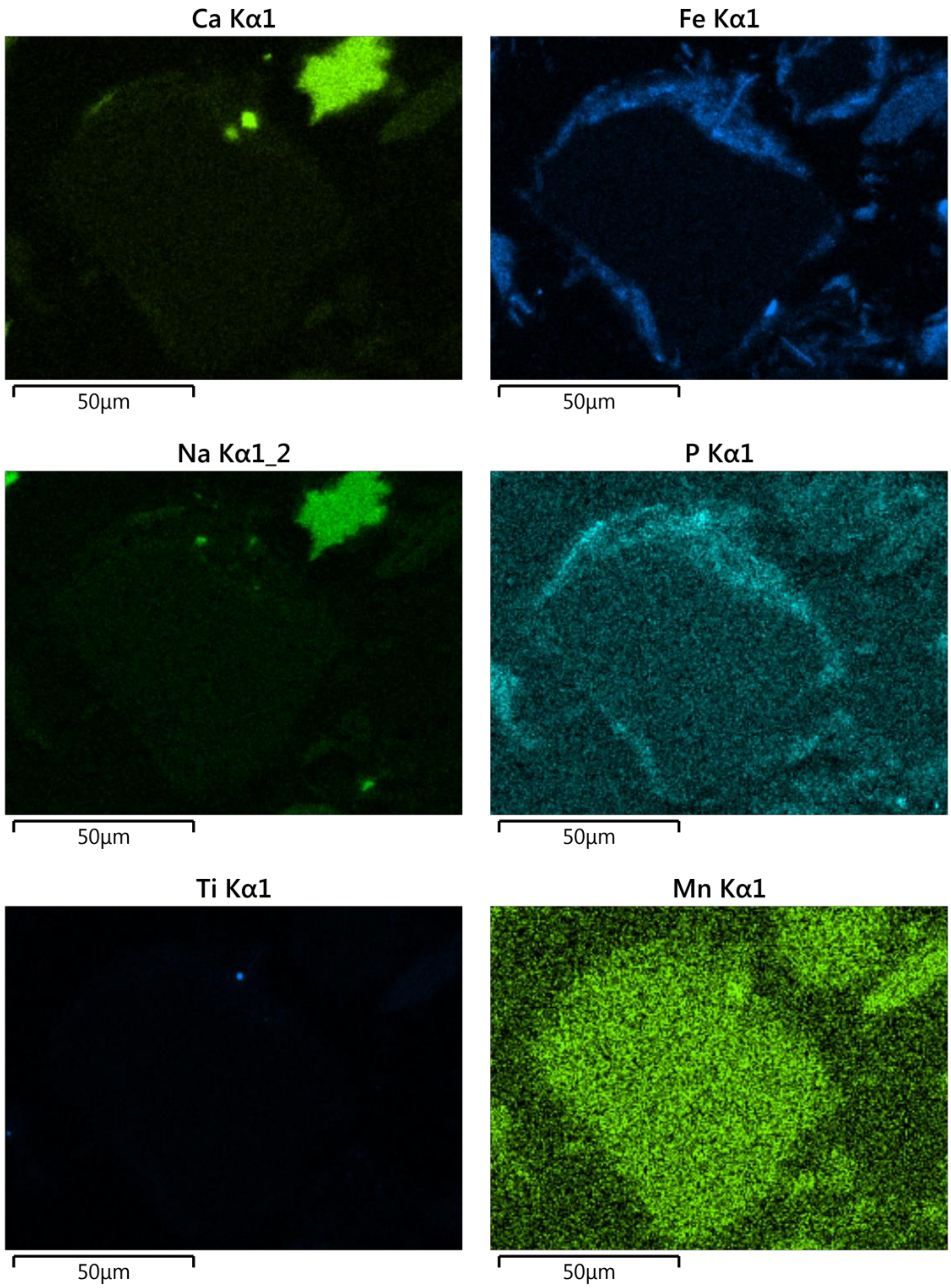


Fig. A8. Continued.

LV1-2.5 Grain 1

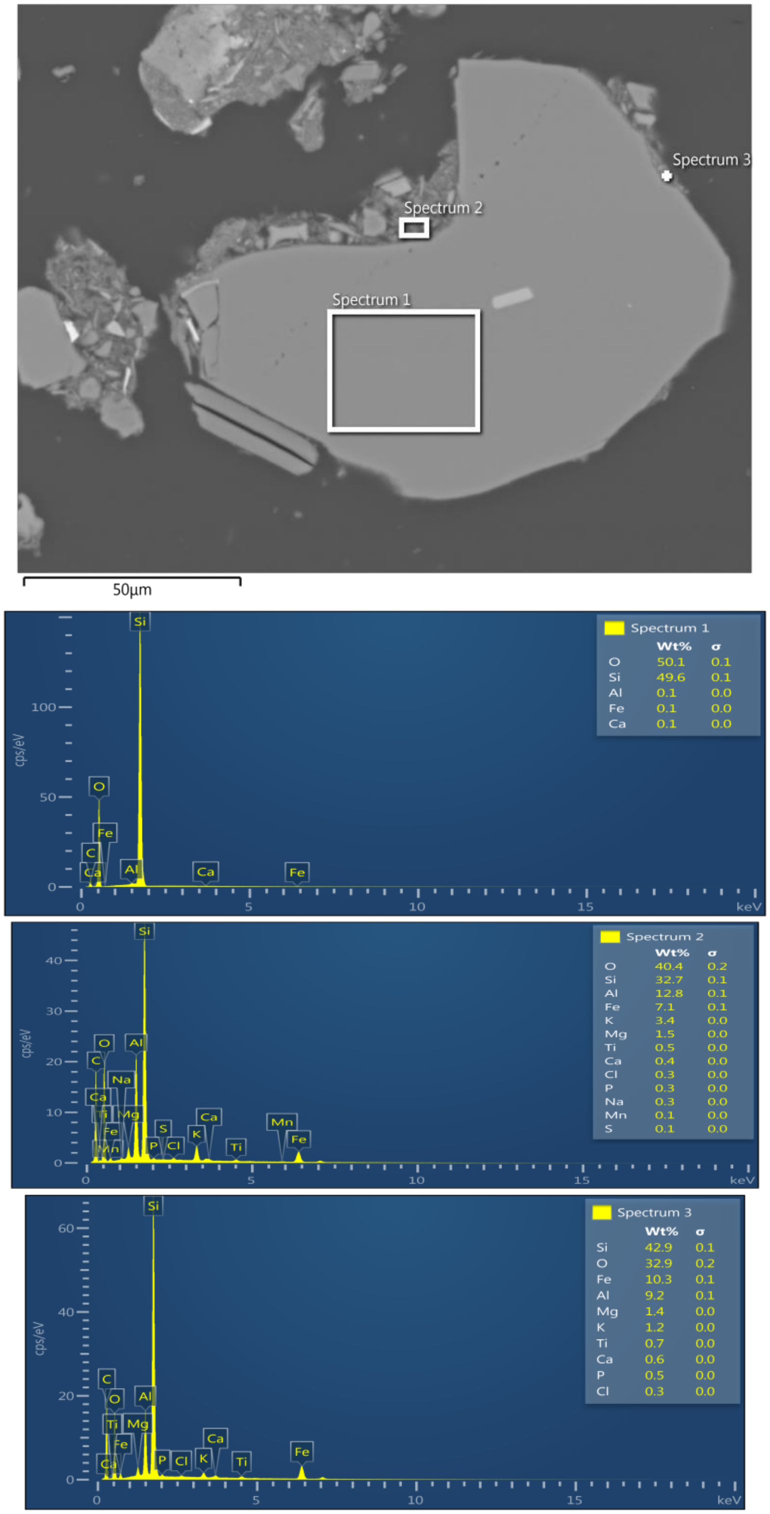


Fig. A9. Drainfield sample LV1-2.5’ depth, grain1.

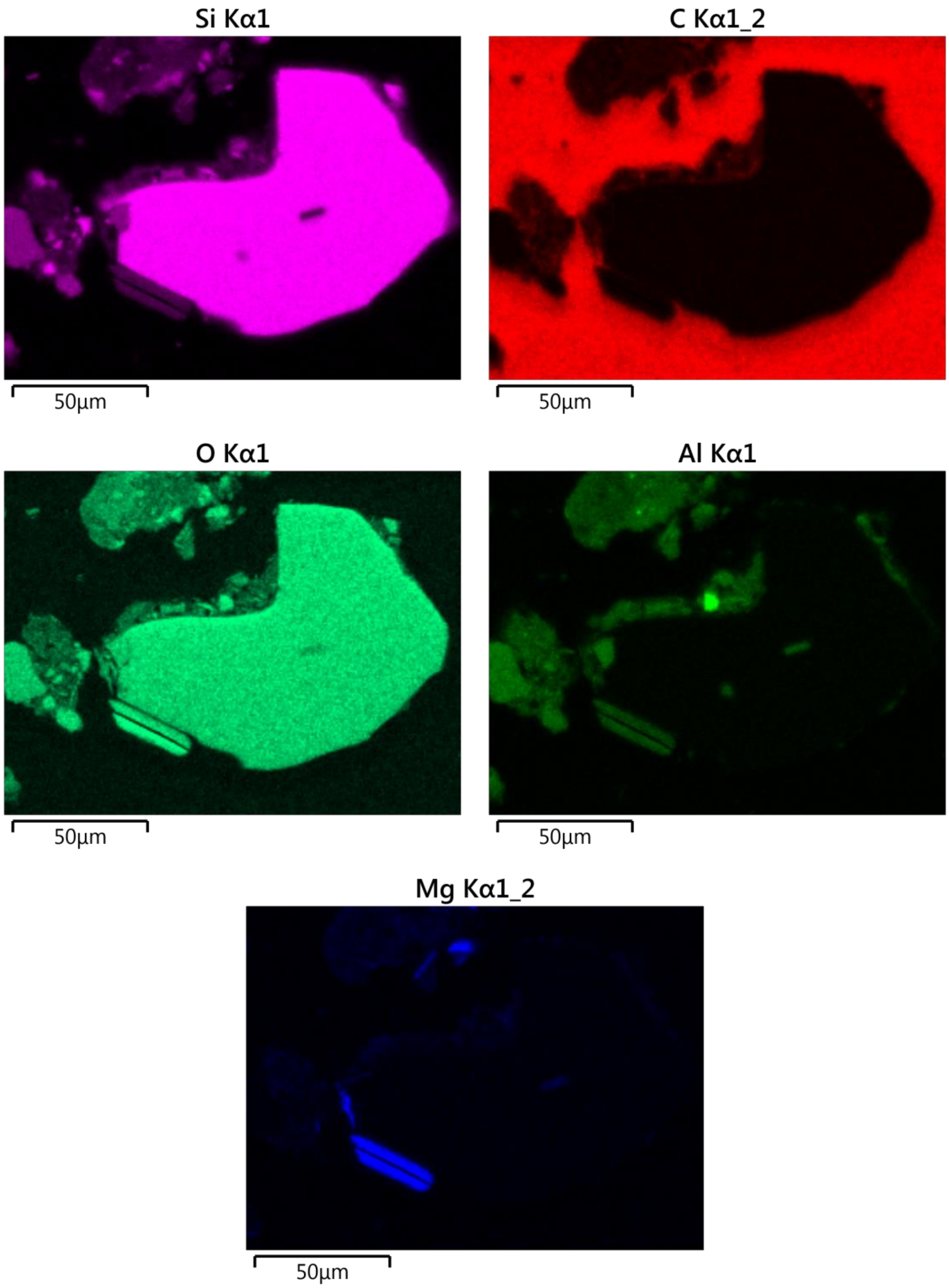
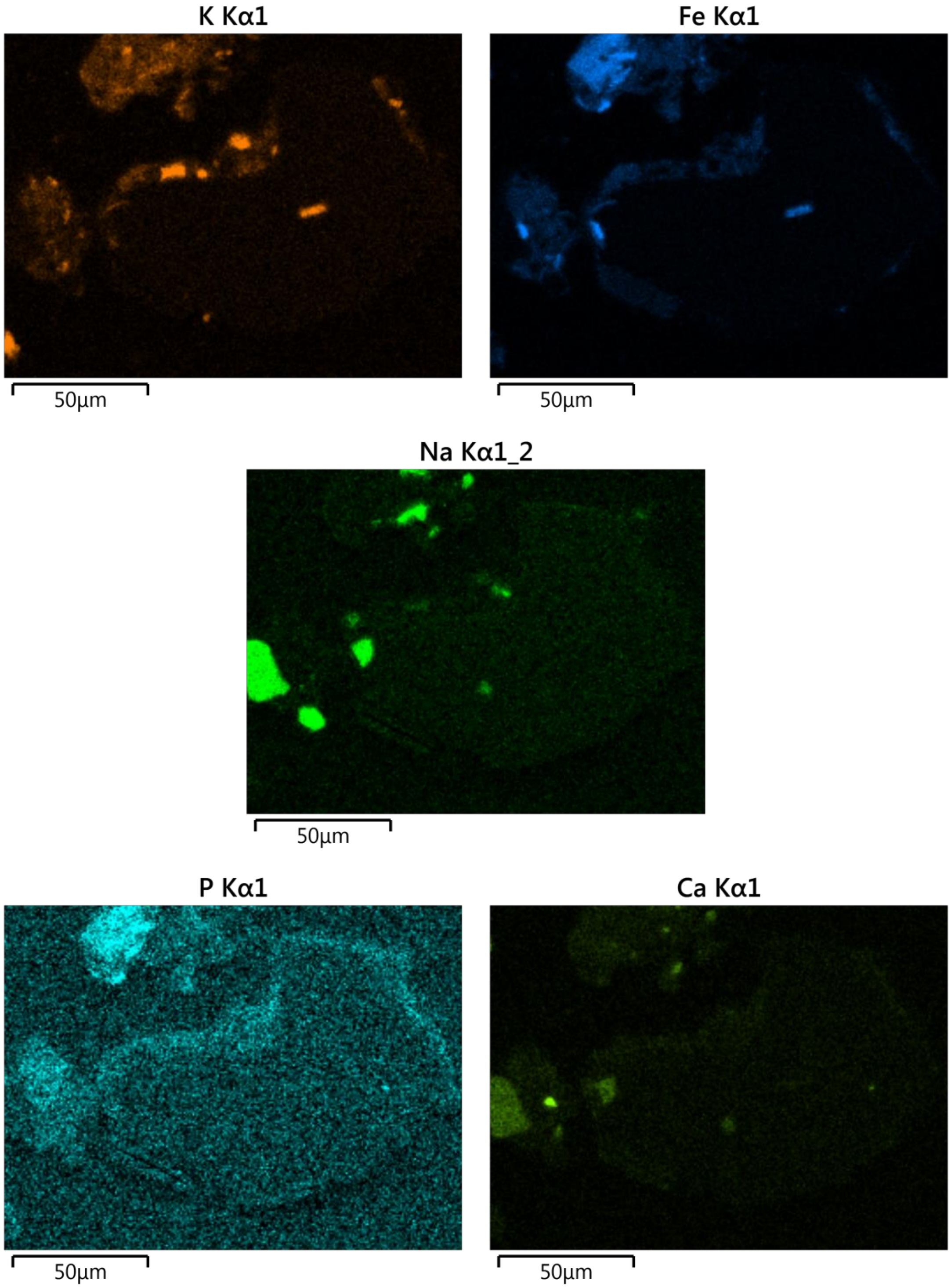


Fig. A9. Continued.



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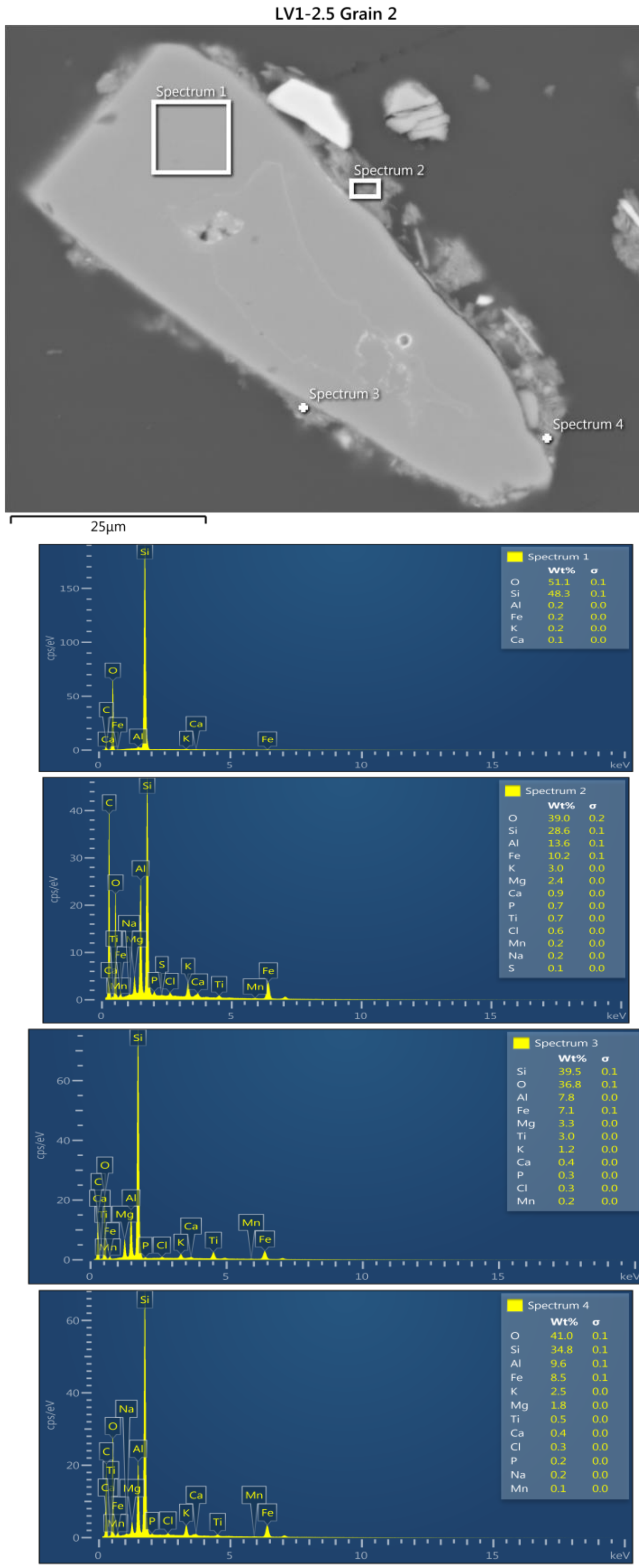


Fig. A10. Drainfield sample LV1-2.5' depth, grain 2.

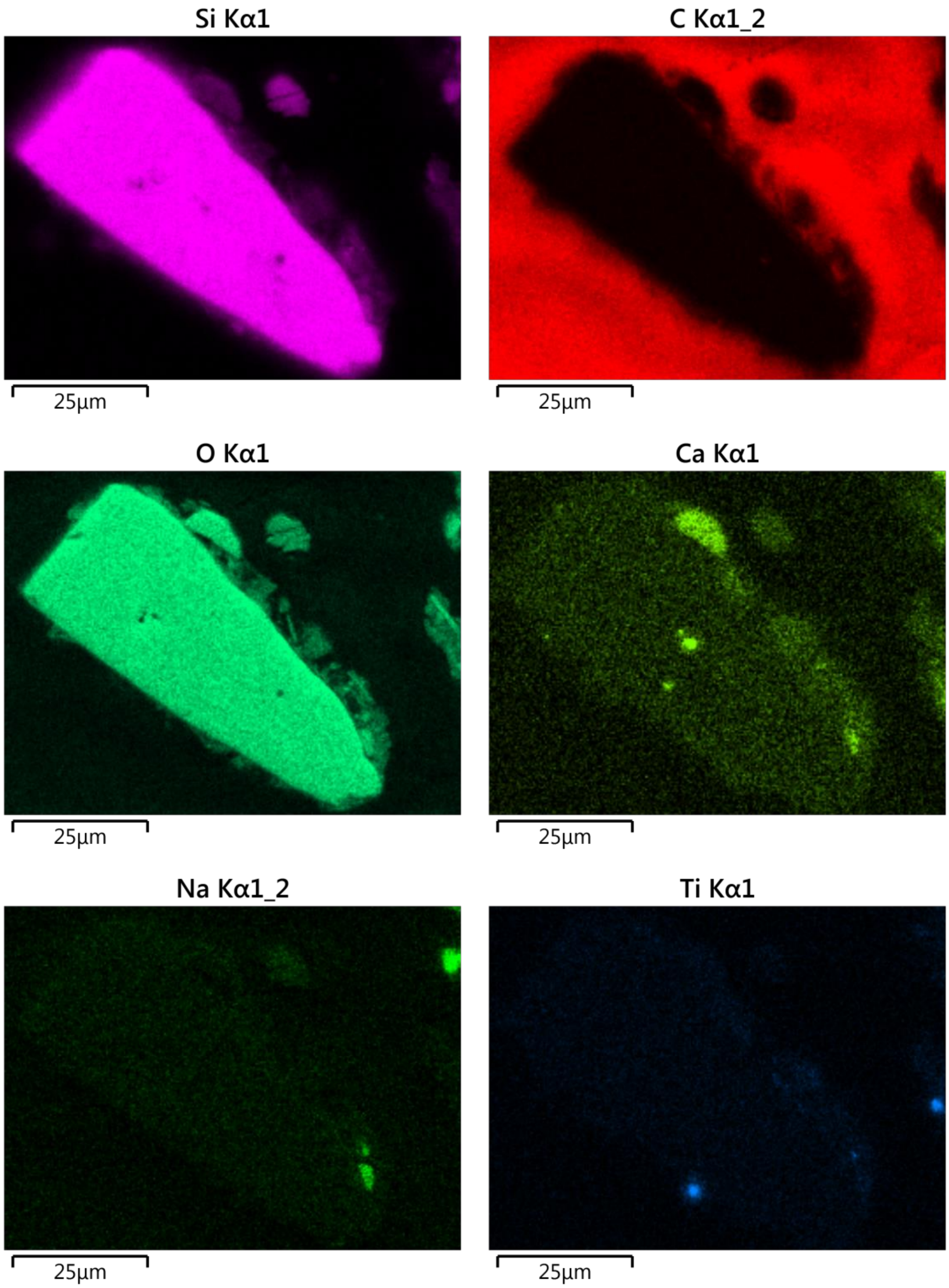


Fig. A10. Continued.

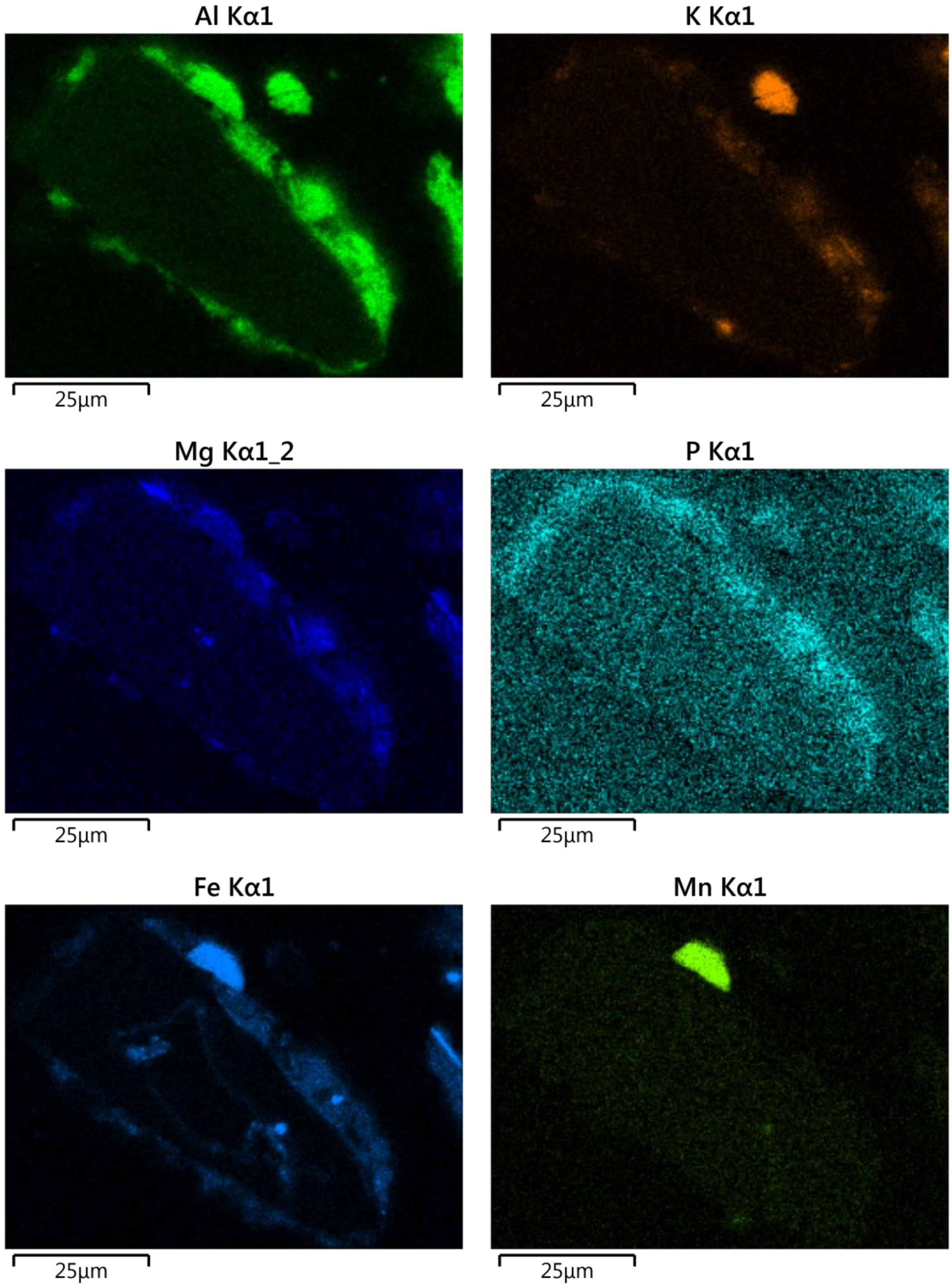


Fig. A10. Continued.

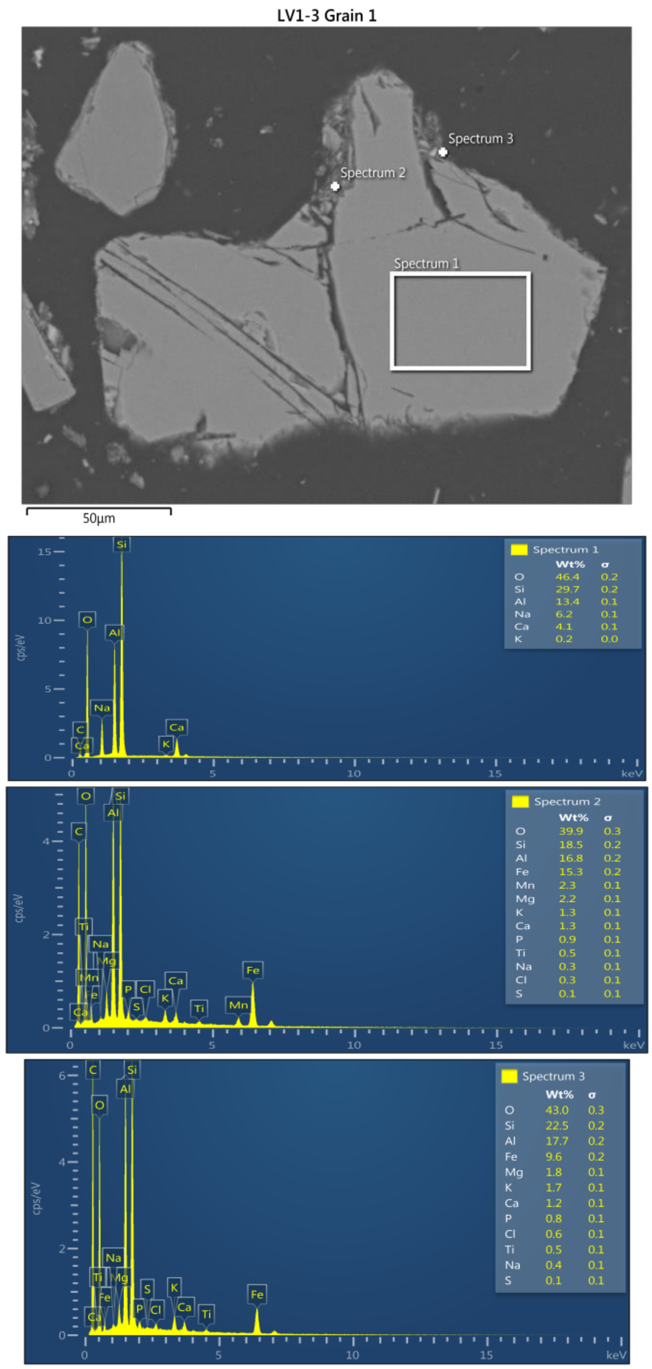


Fig. A11. Drainfield sample LV1-3.0'depth, grain 1.

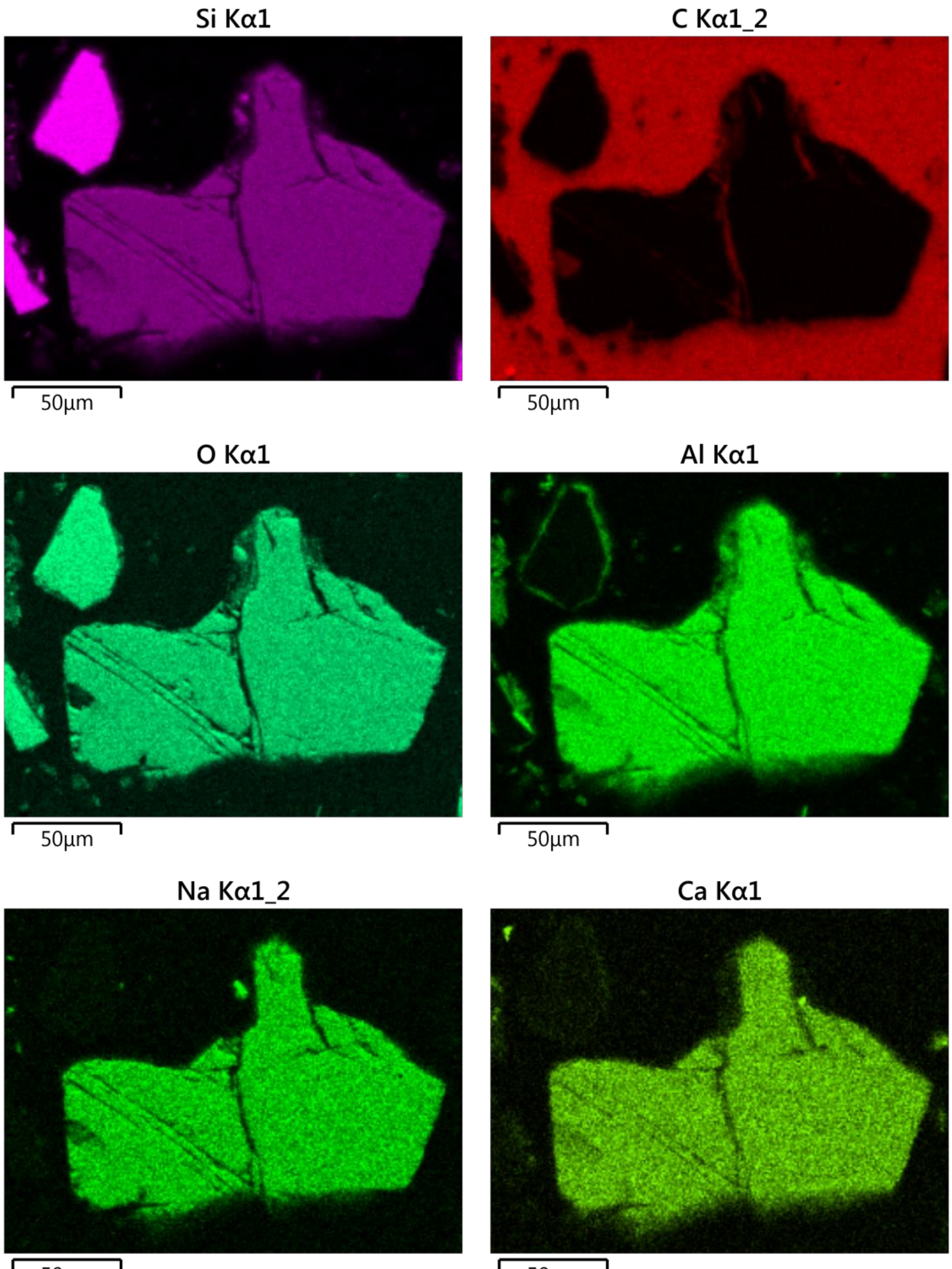


Fig. A11, Continued.

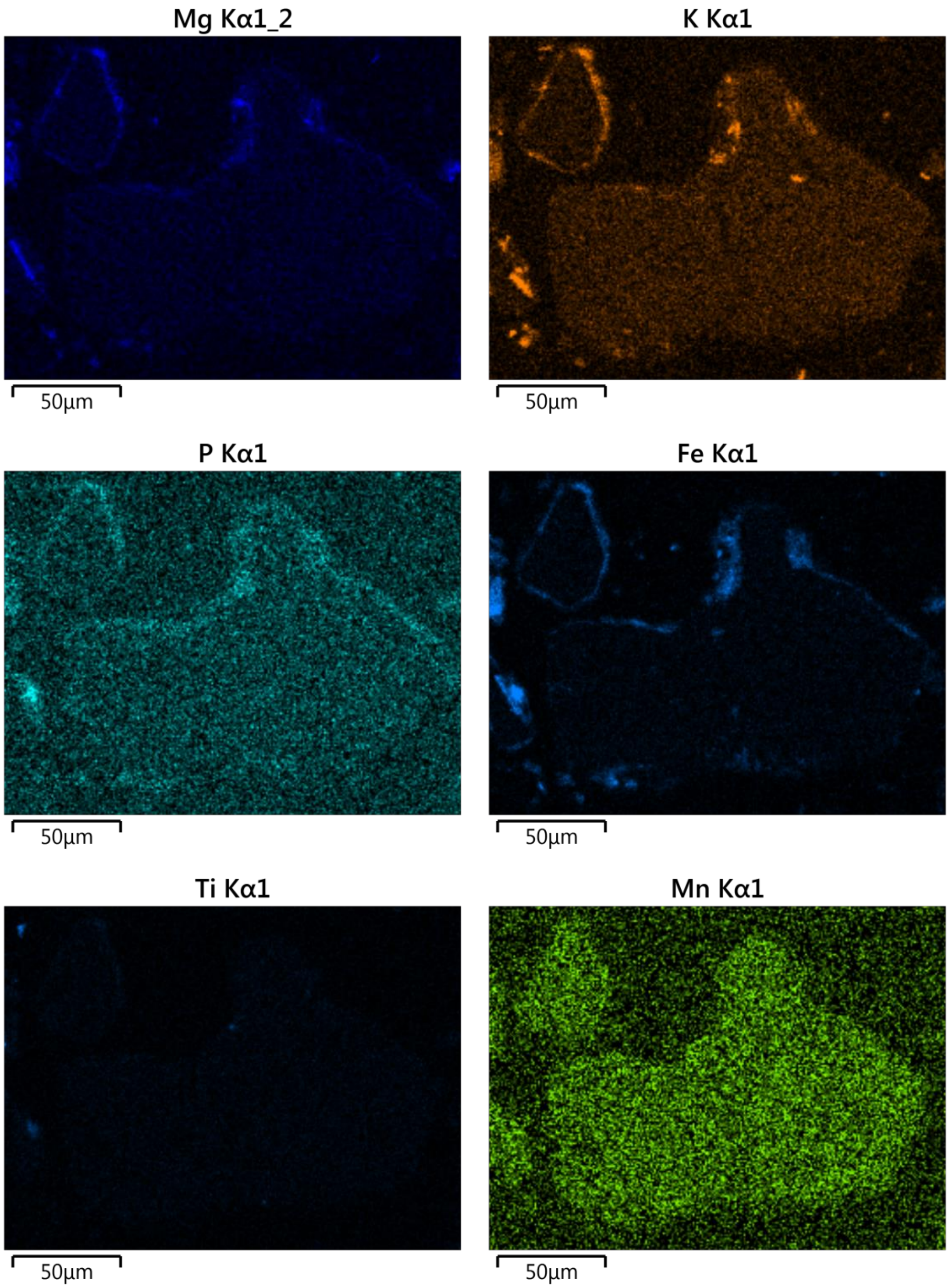


Fig. A 11. Continued.

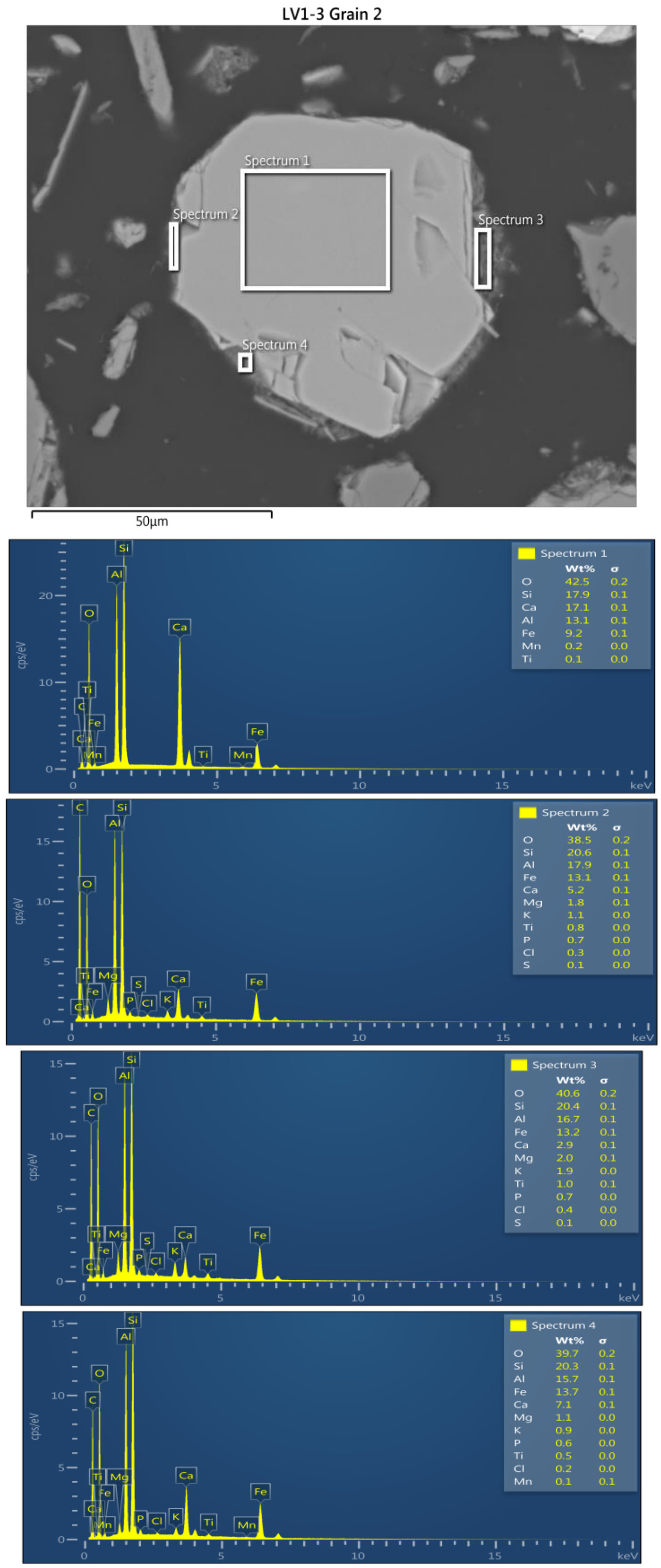


Fig. A12. Drainfield sample LV1-3.0’ depth, grain 2.

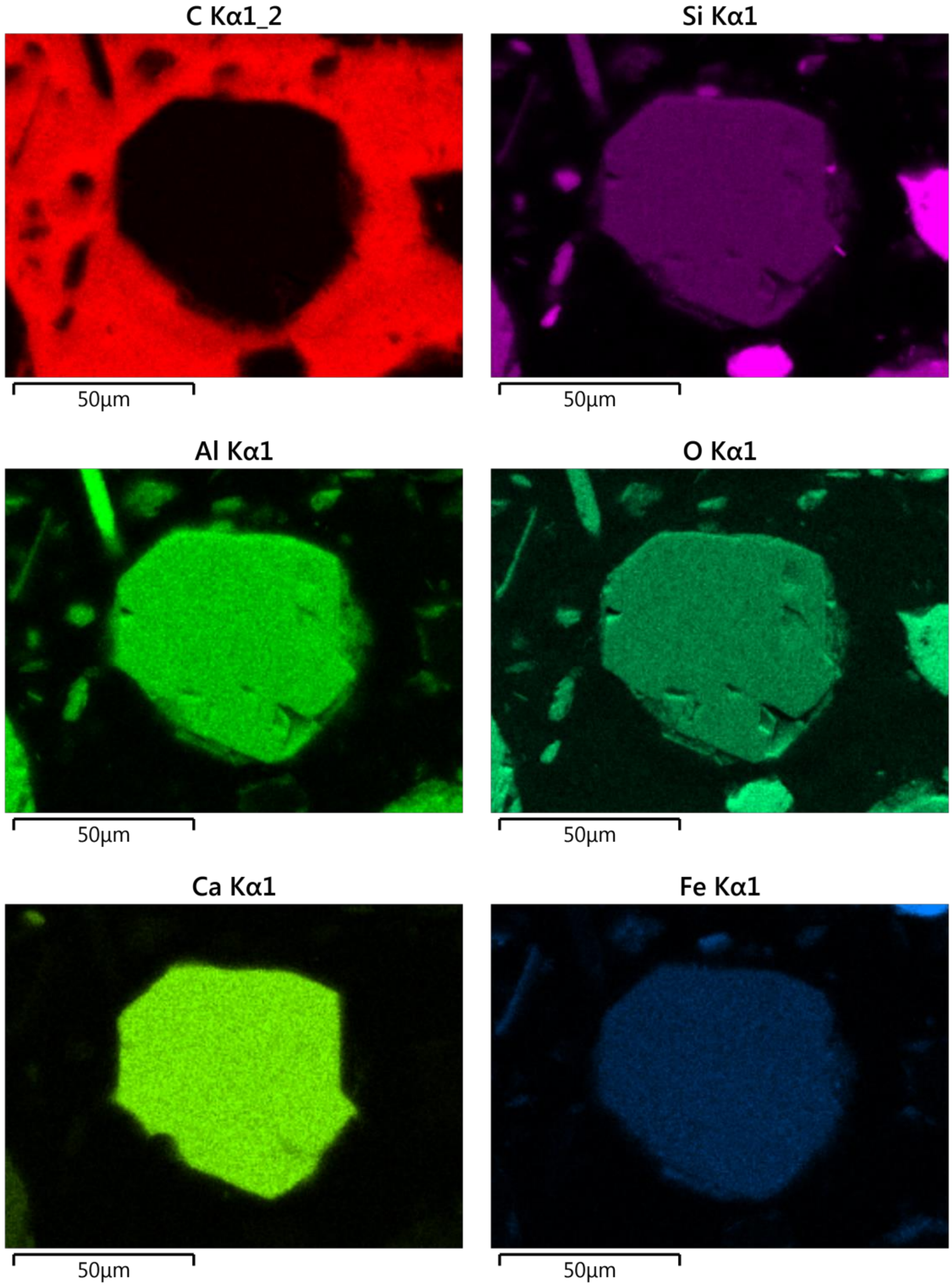


Fig. A12. Continued.

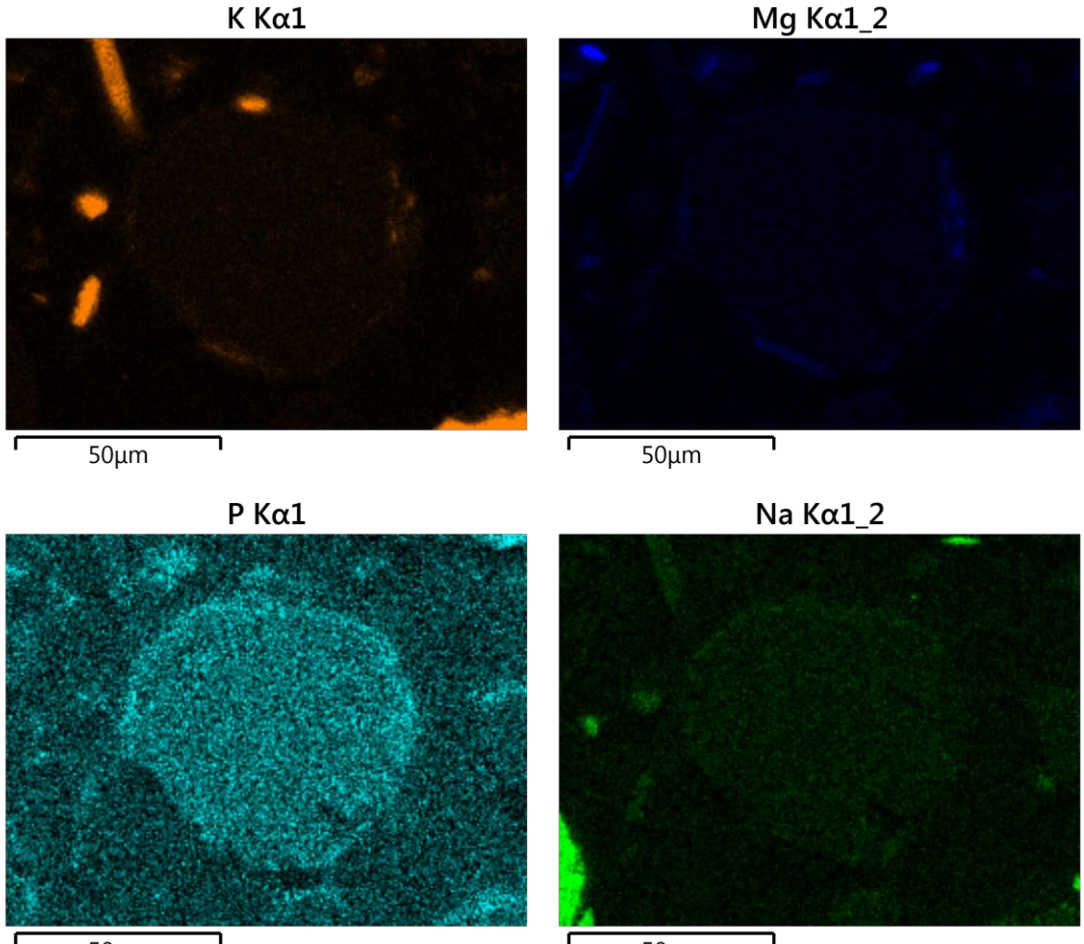


Fig. A12. Continued.

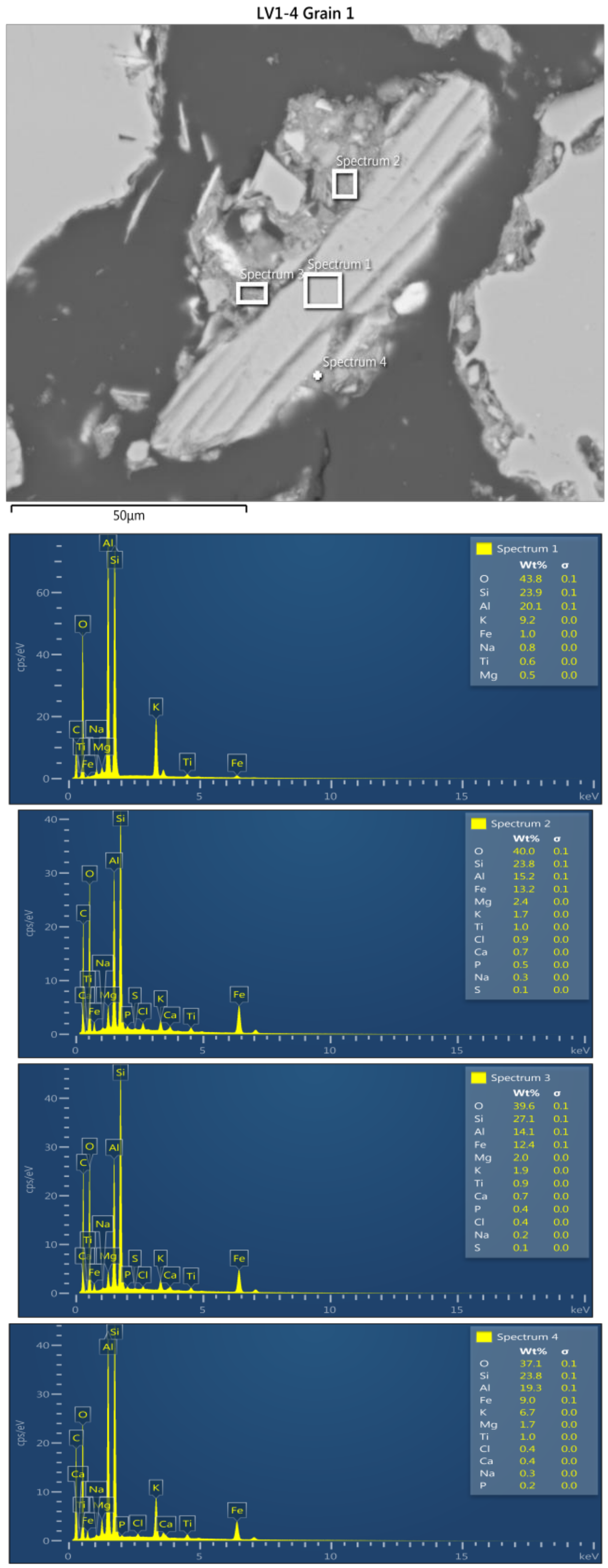


Fig. A13. Drainfield sample LV1-4.0’ depth, grain1.

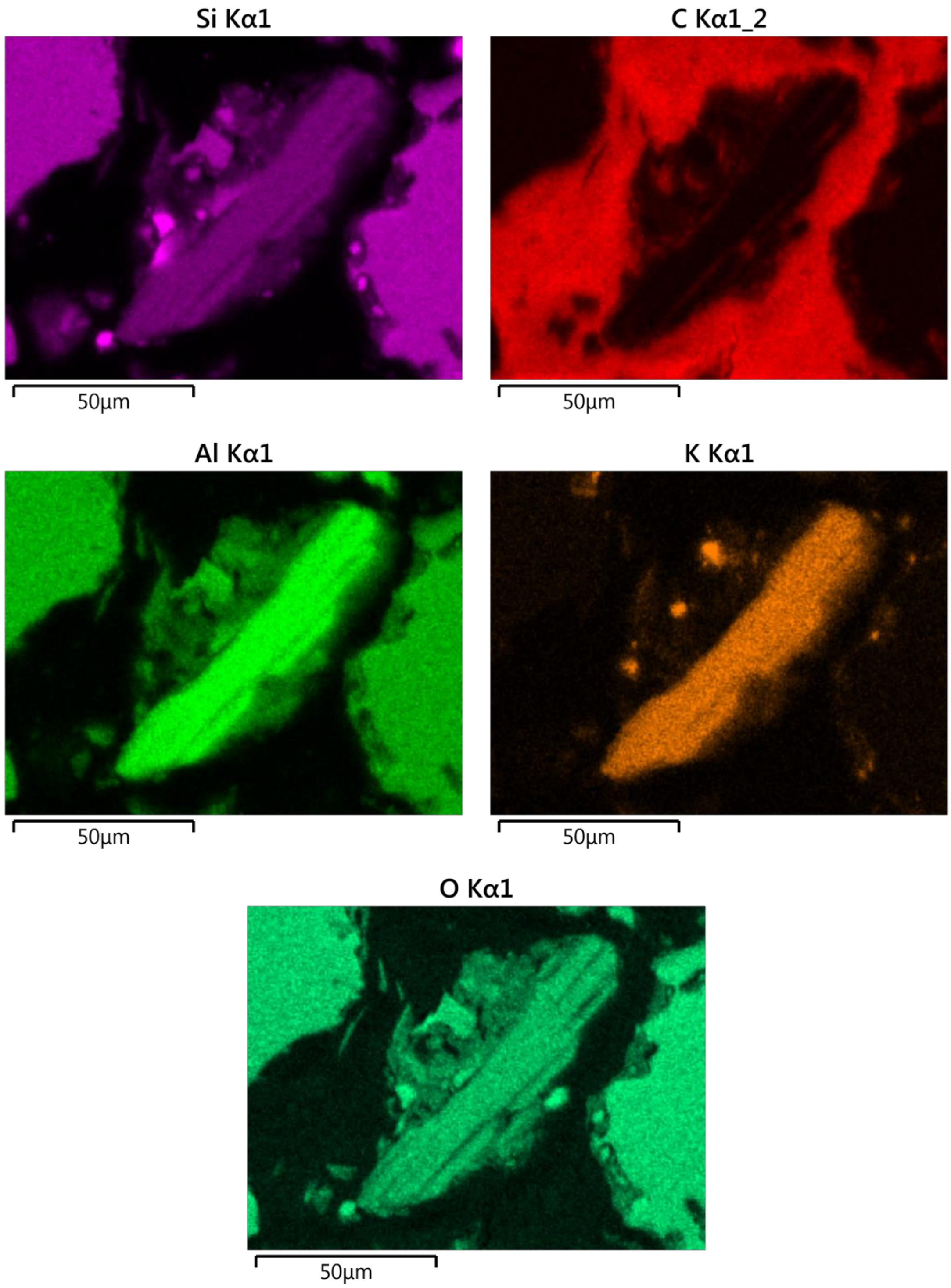


Fig. A13. Continued.

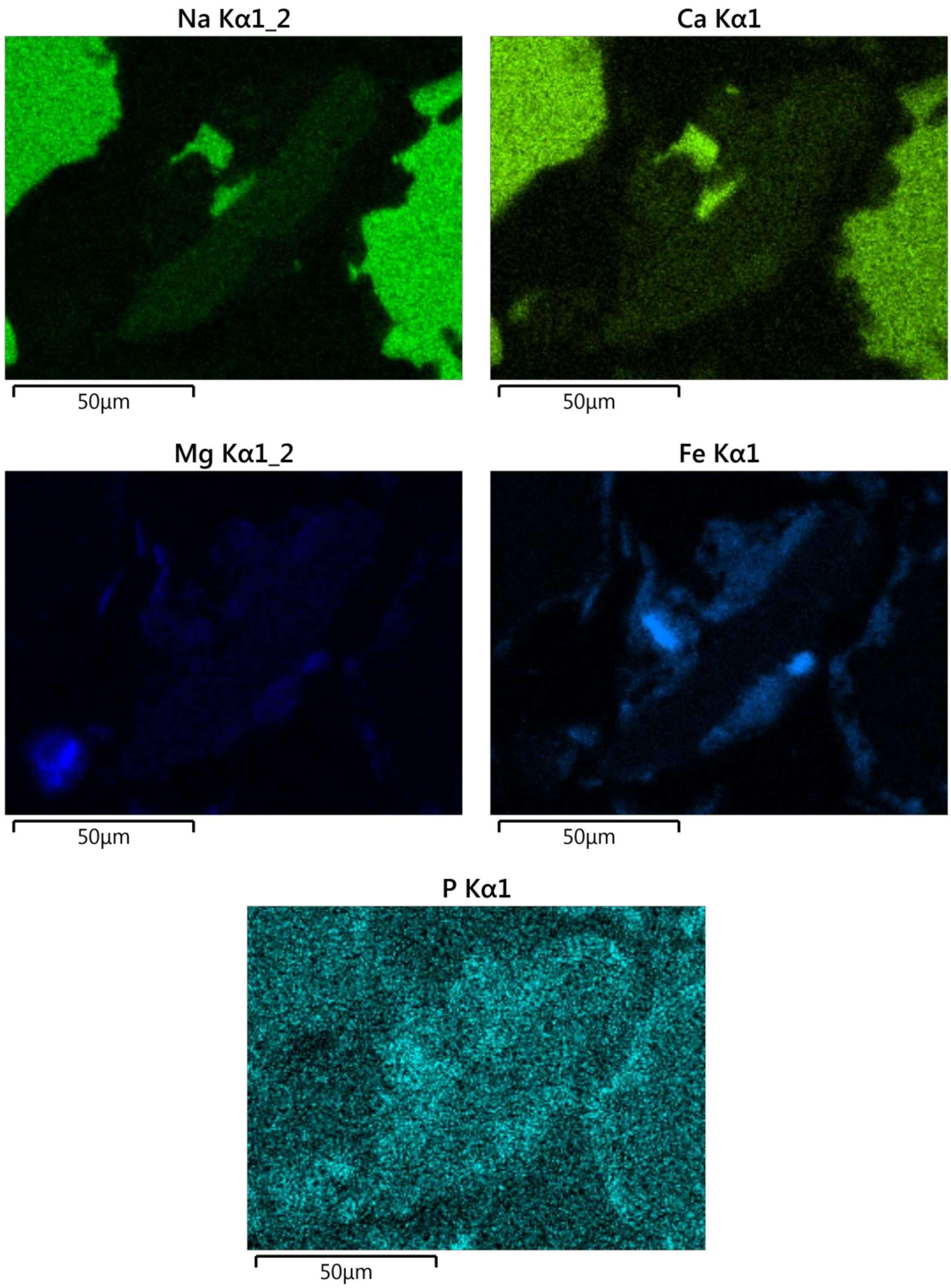


Fig. A13. Continued.

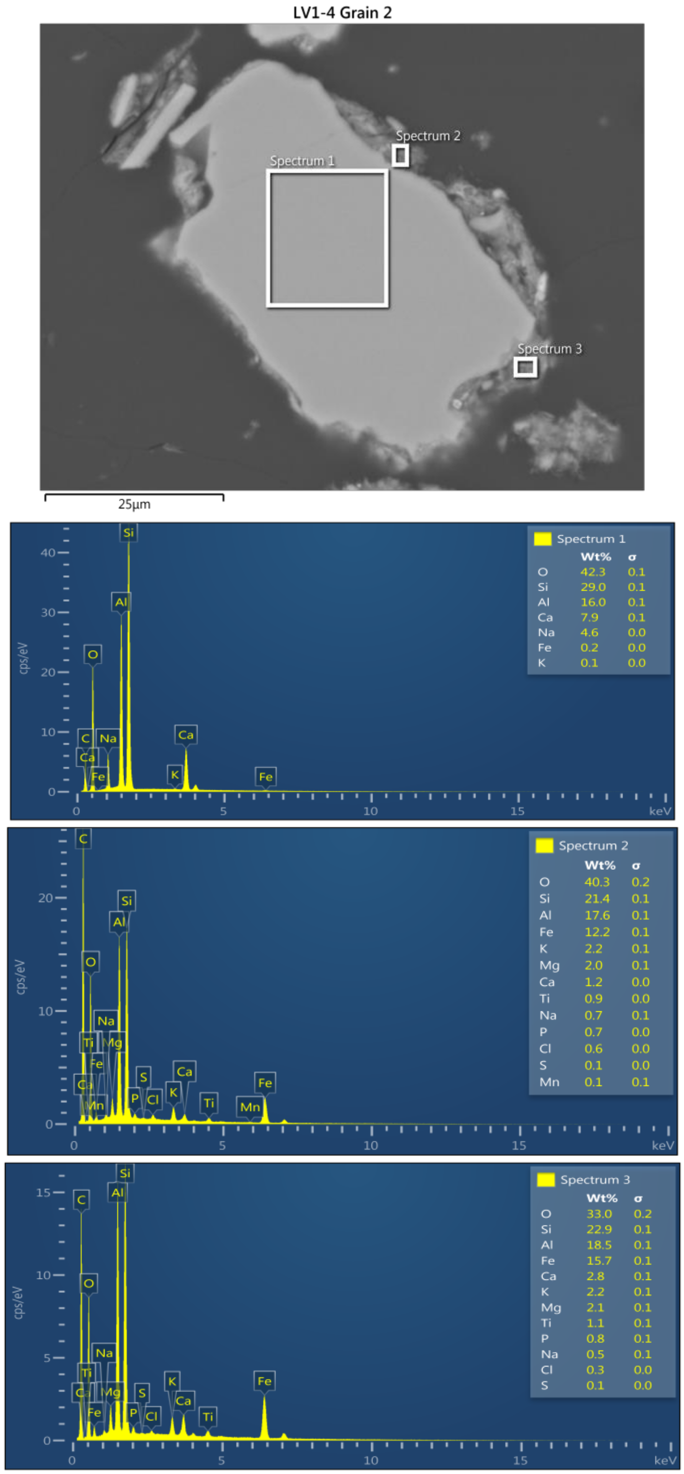


Fig. A14. Drainfield sample LV-4.0’ depth, grain 2.

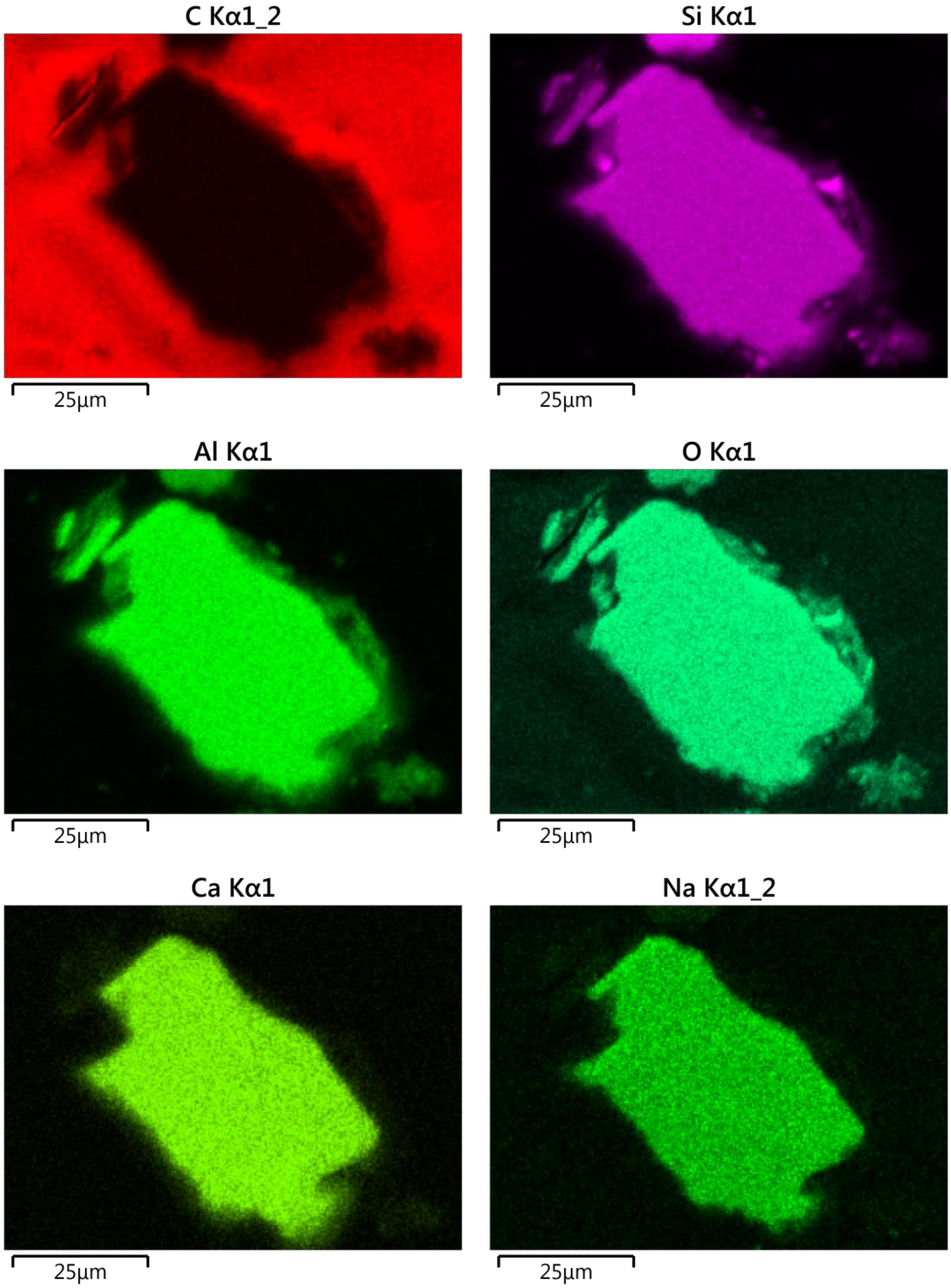


Fig. A14. Continued.

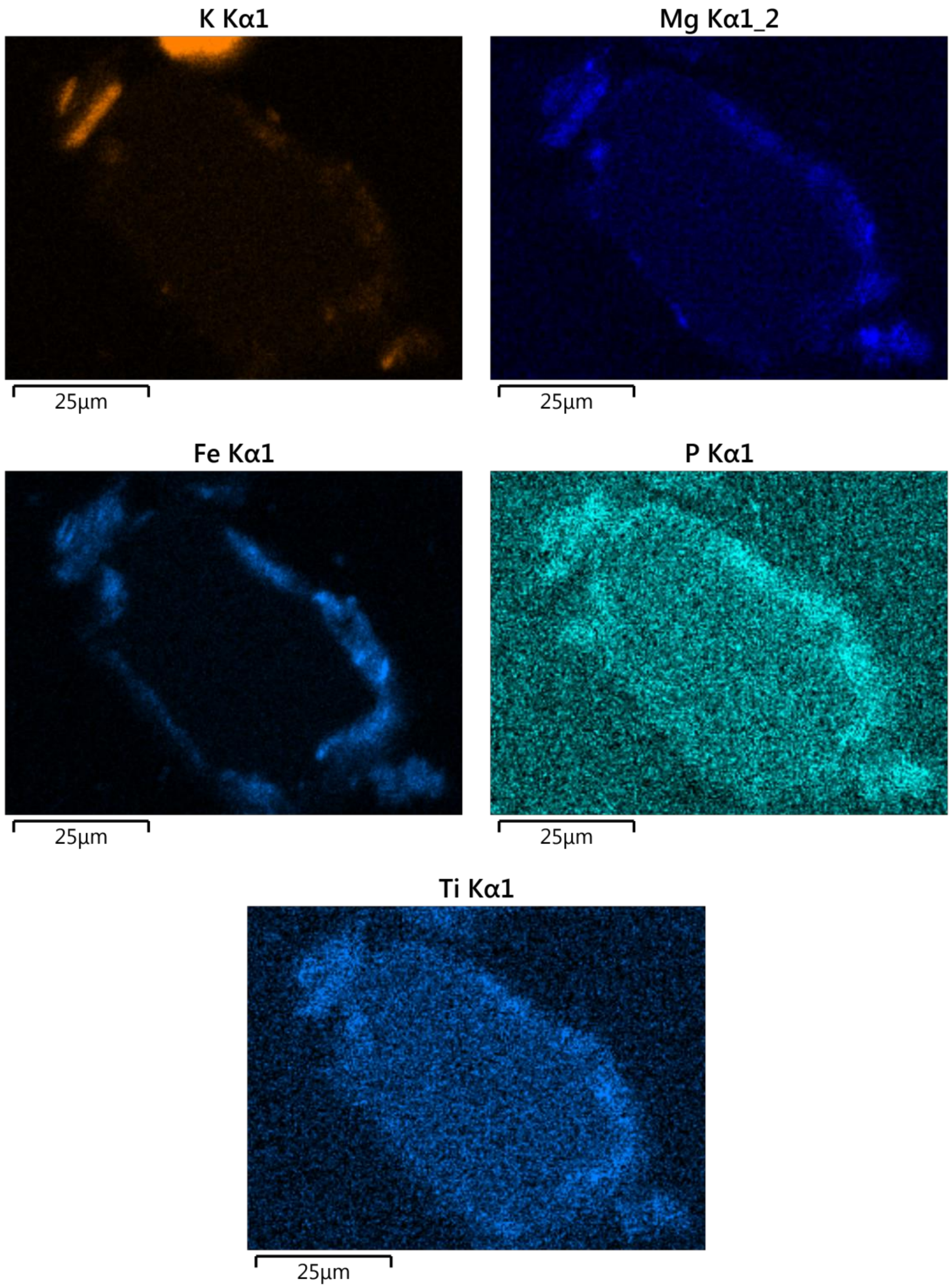


Fig. A14. Continued.

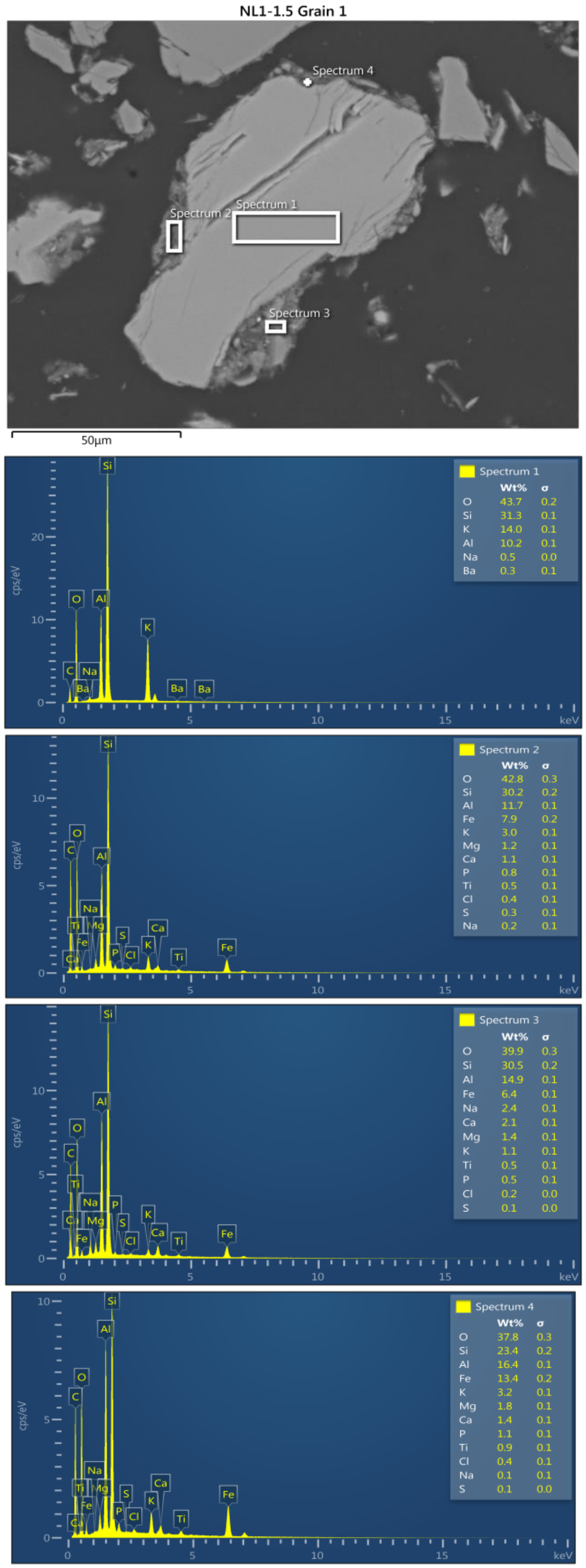


Fig. A15. Drainfield sample NL1-1.5’ depth, grain 1.

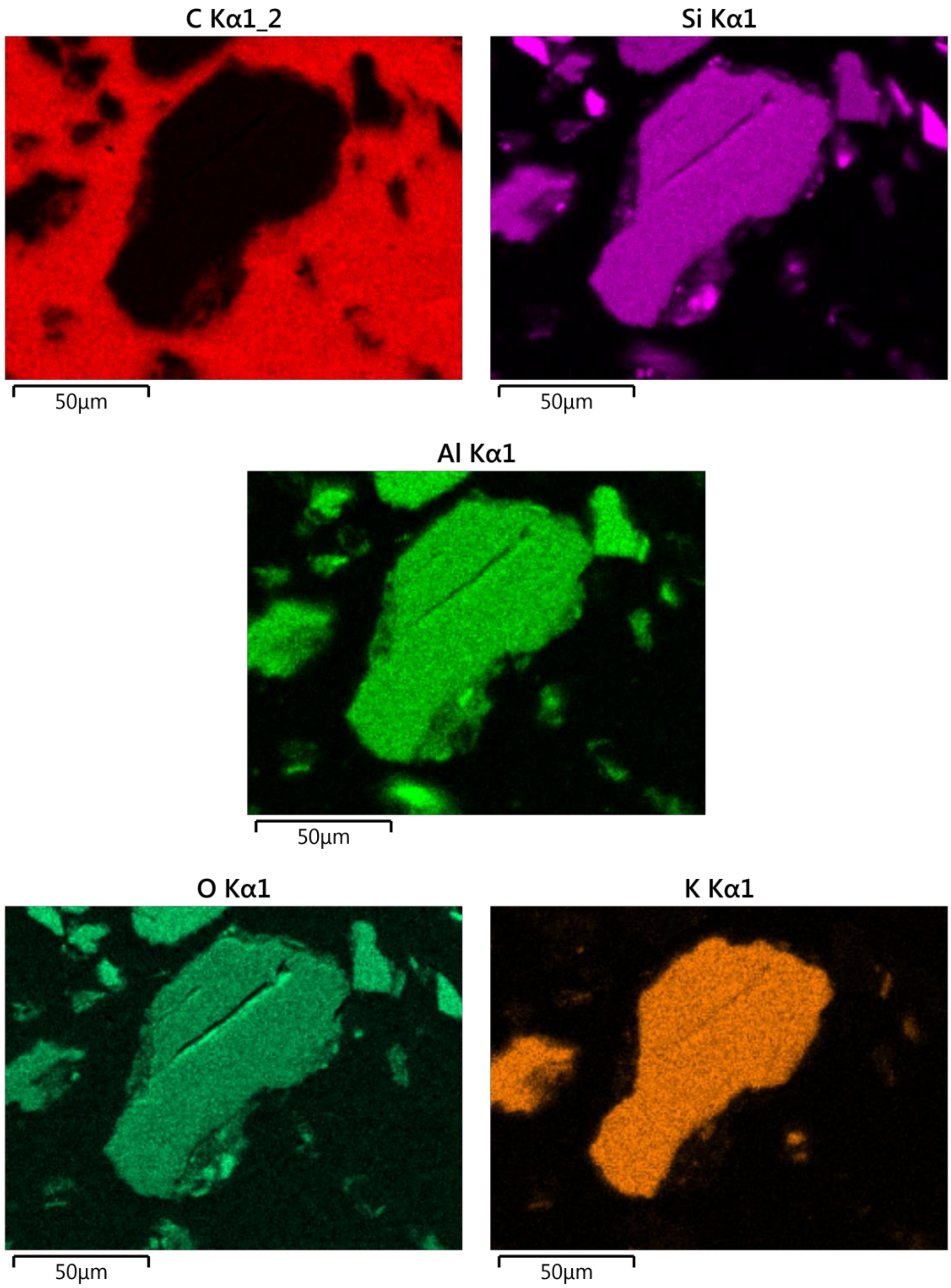


Fig. A15. Continued.

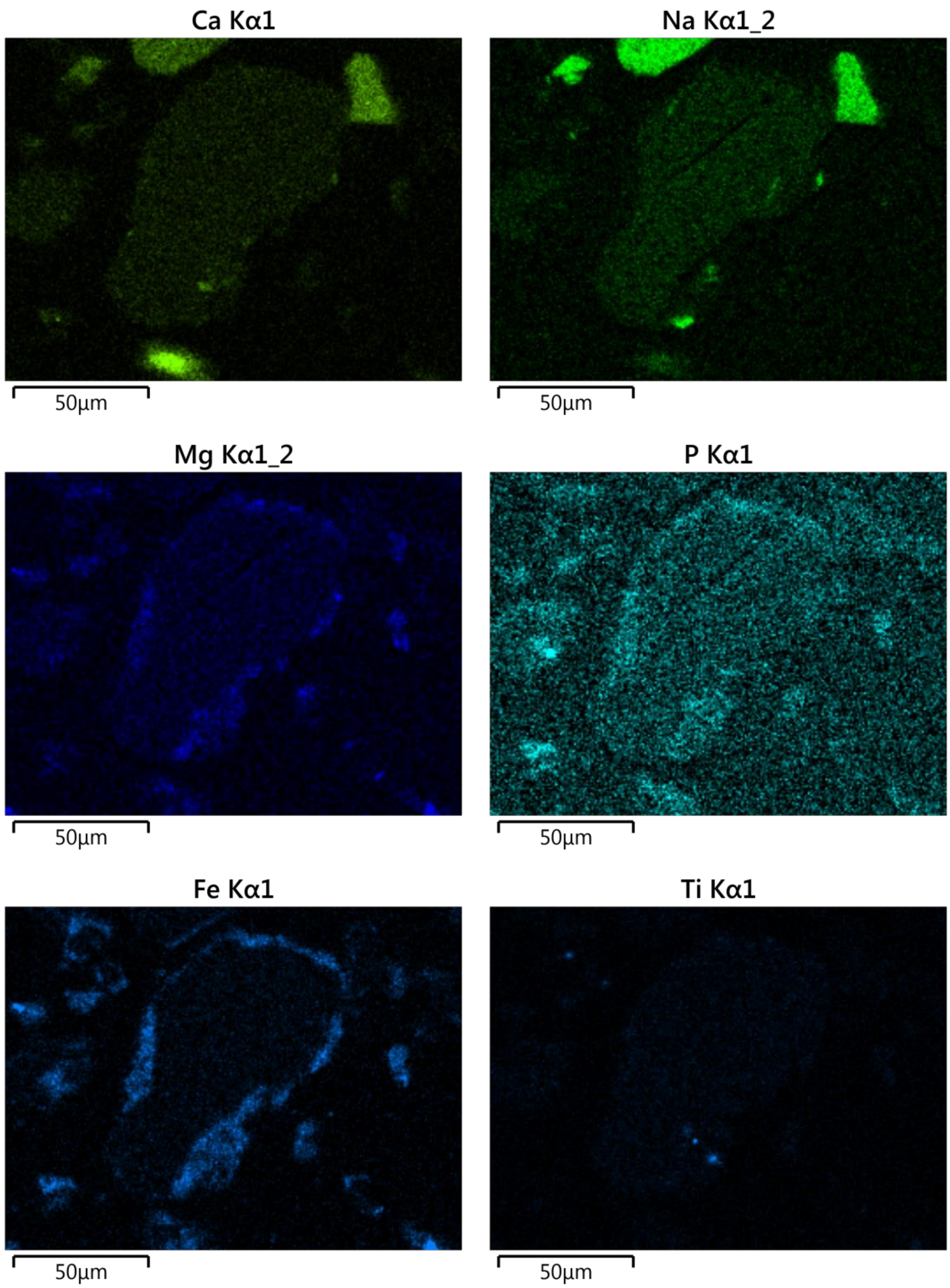


Fig. A15. Continued.

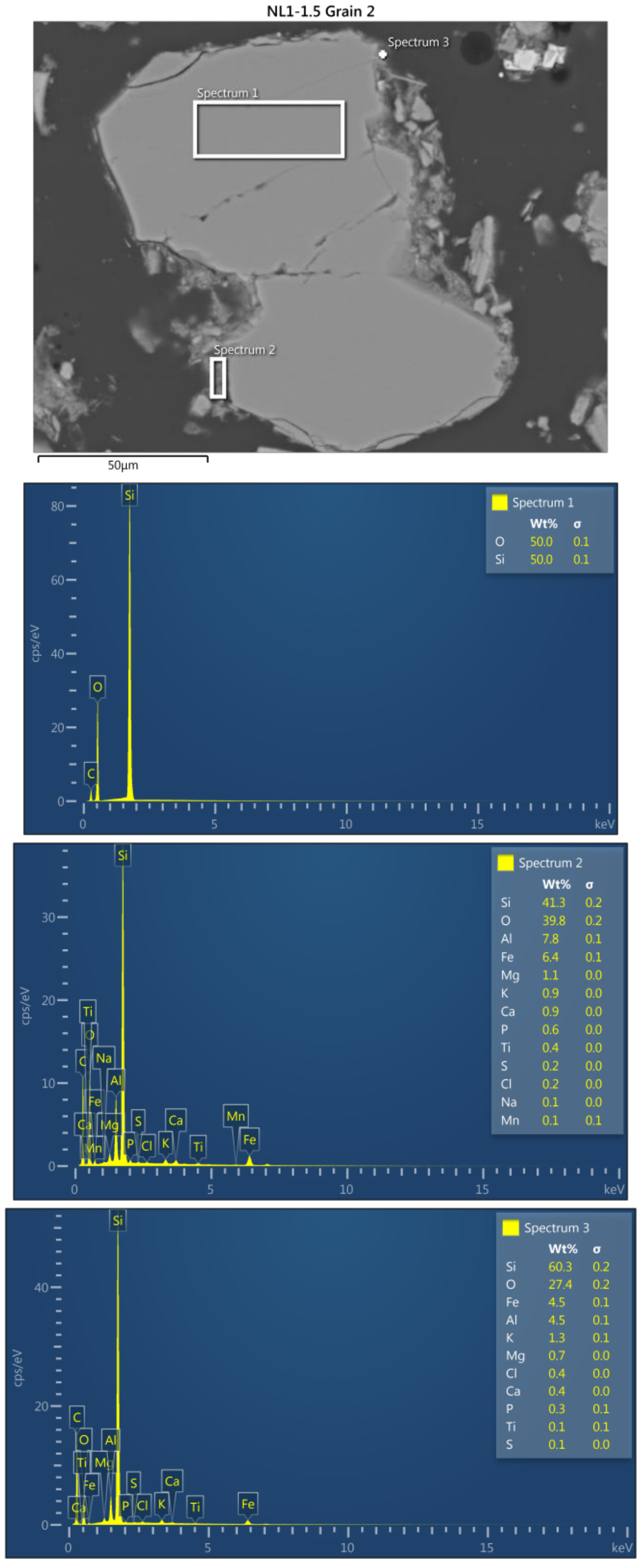


Fig. A16. Drainfield sample NL1-1.5’ depth, grain 2.

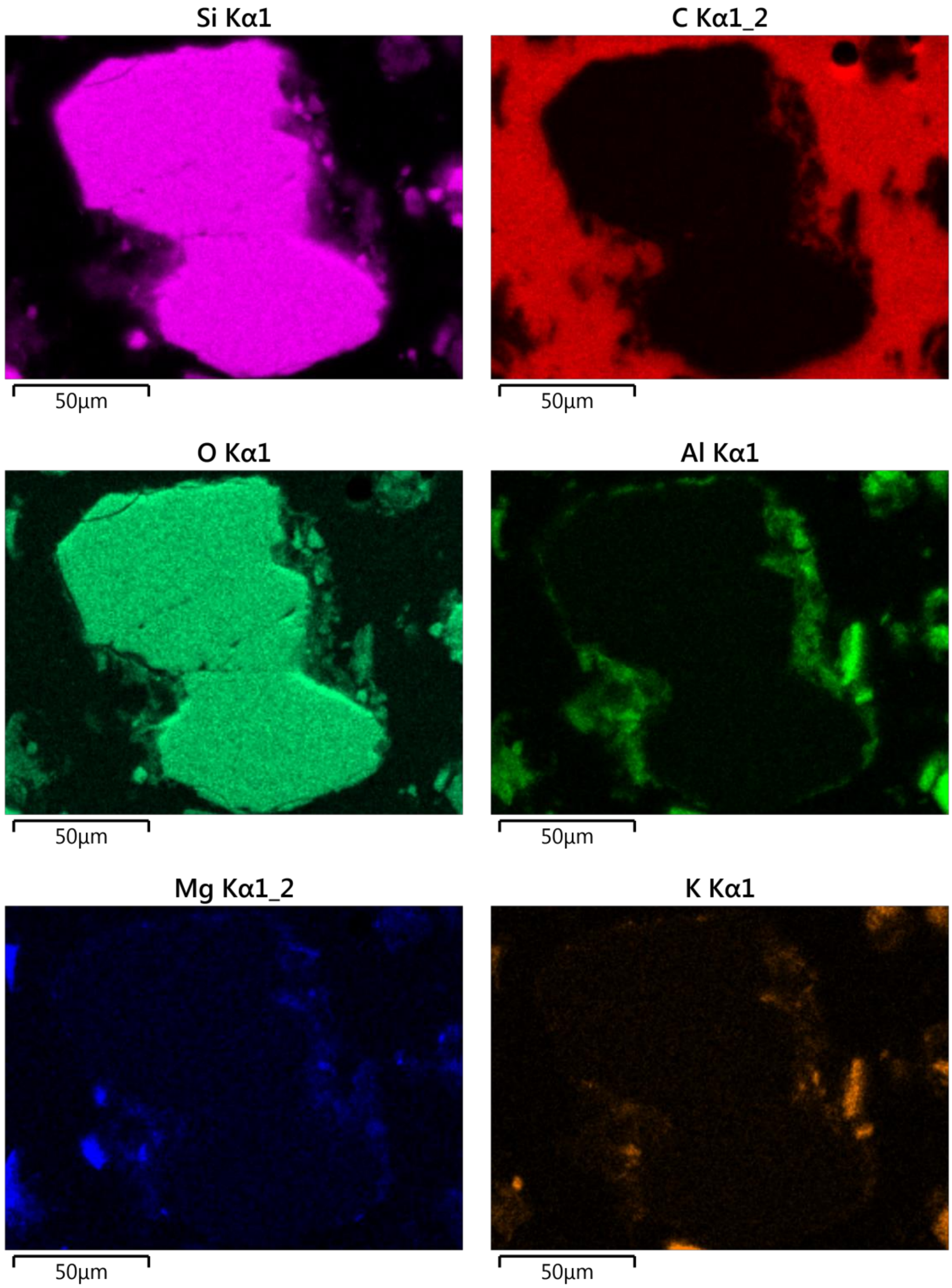
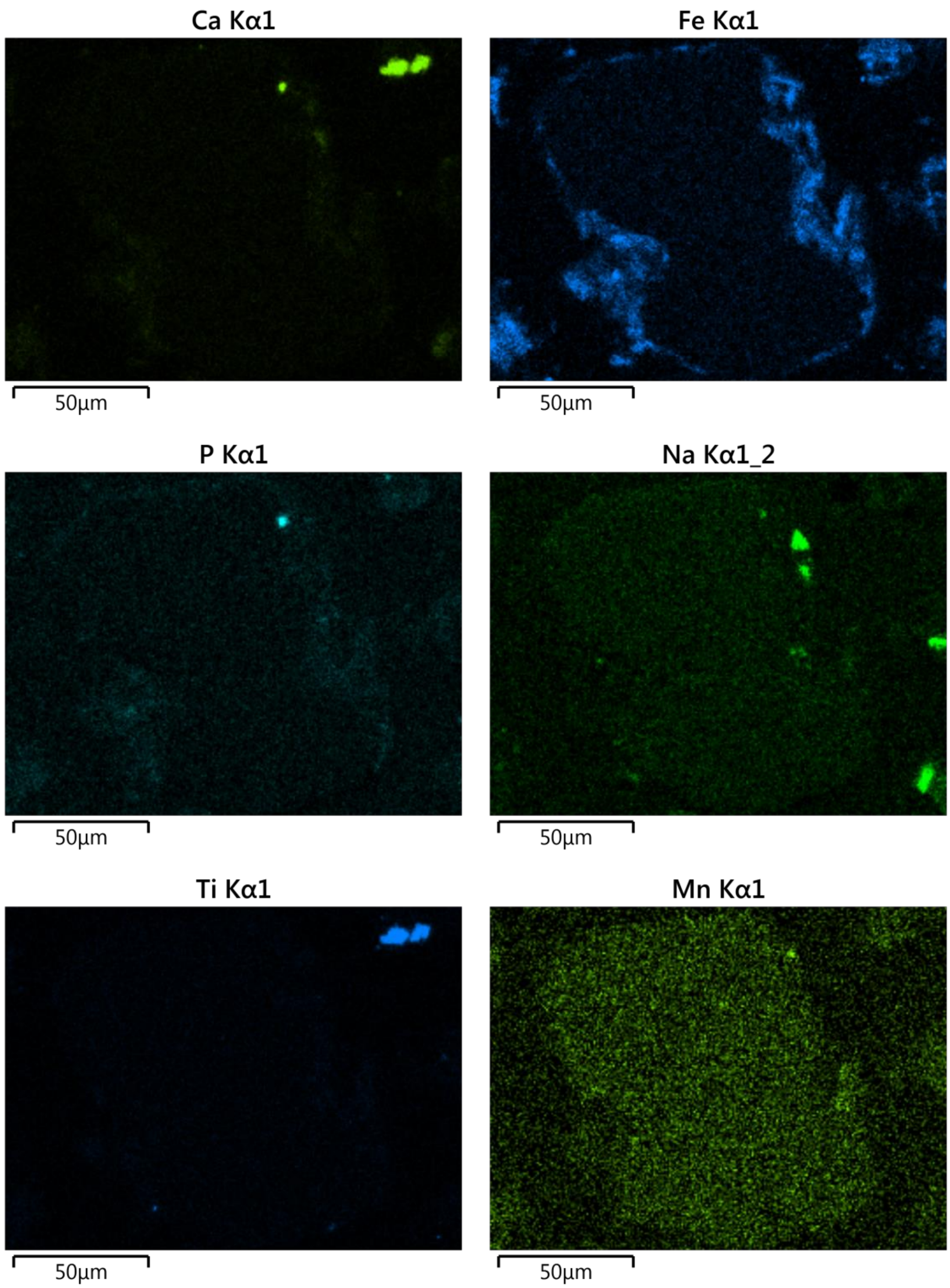


Fig. A16. Drainfield sample NL1-1.5’ depth, grain 2.



Fig, A16. Continued.

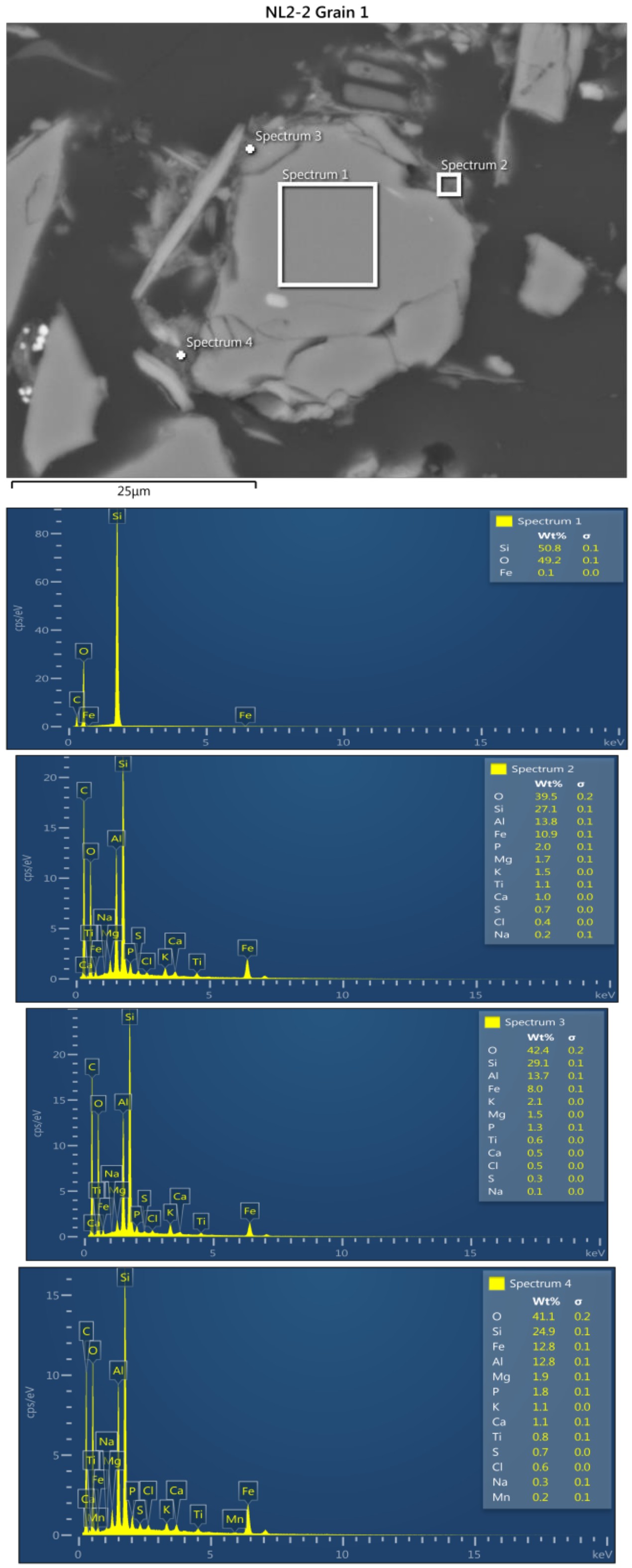


Fig. A17. Drainfield sample NL2-2.0’ depth, grain 1.

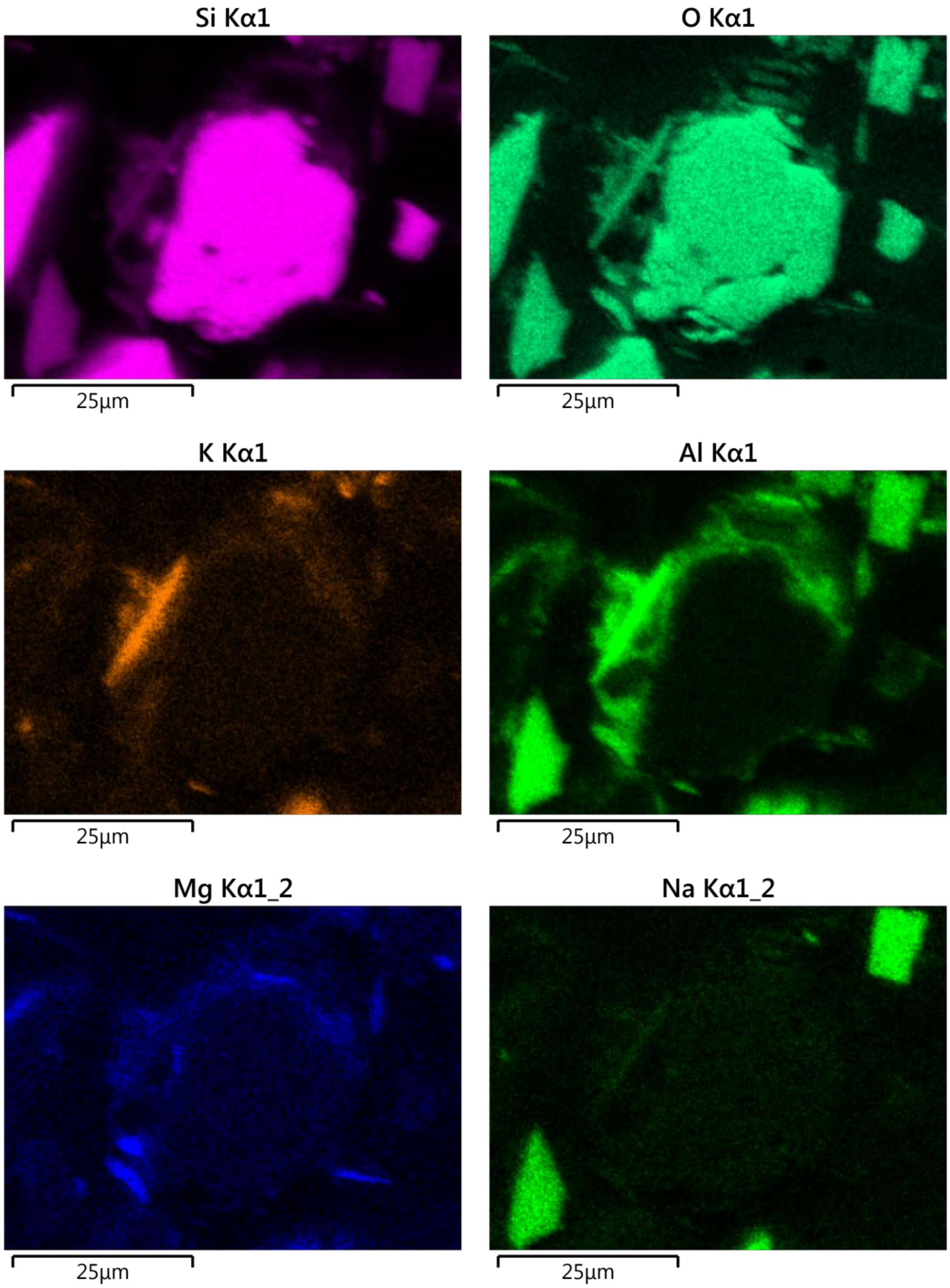


Fig. A17. Continued.

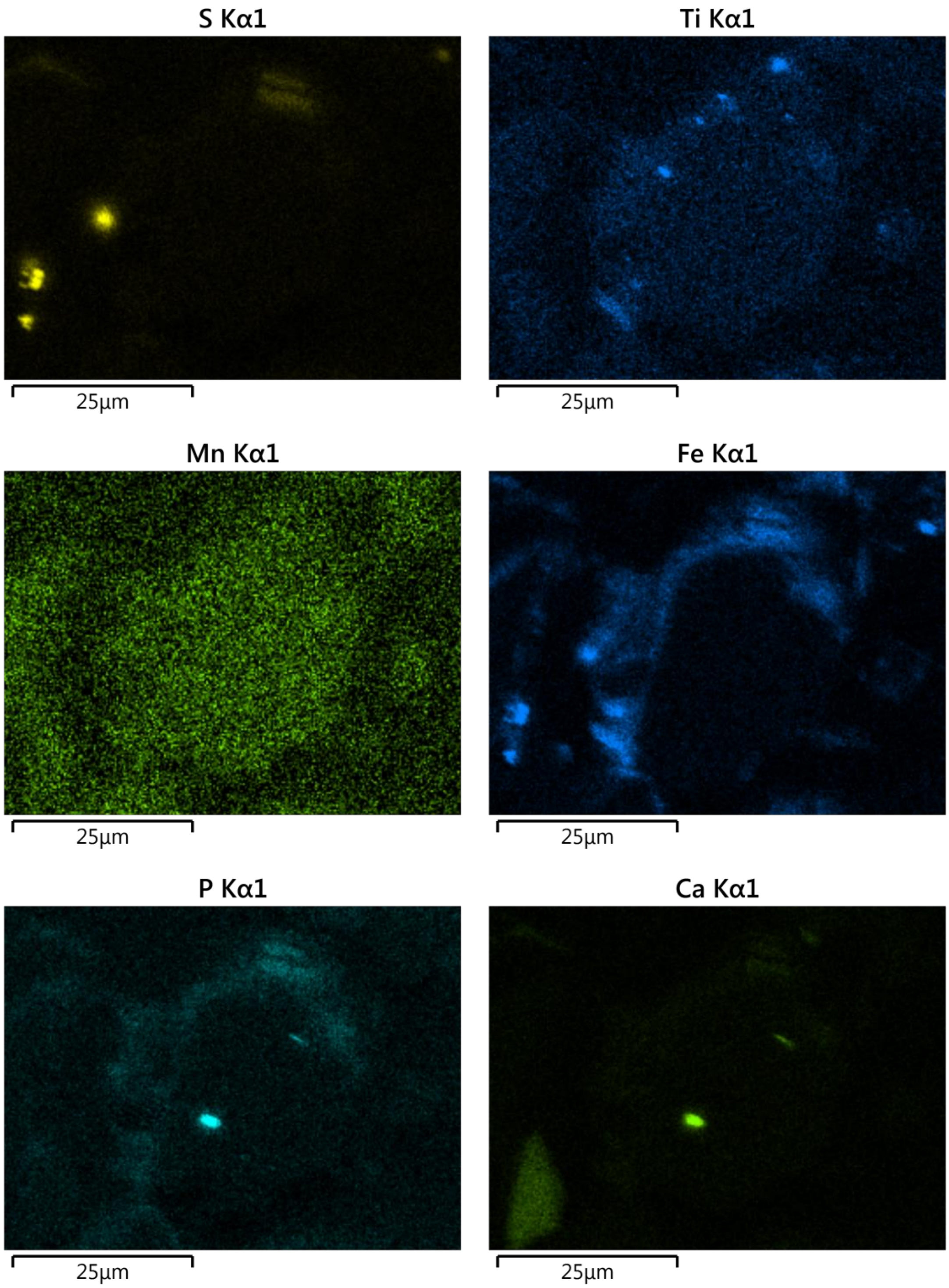


Fig. A17. Continued.

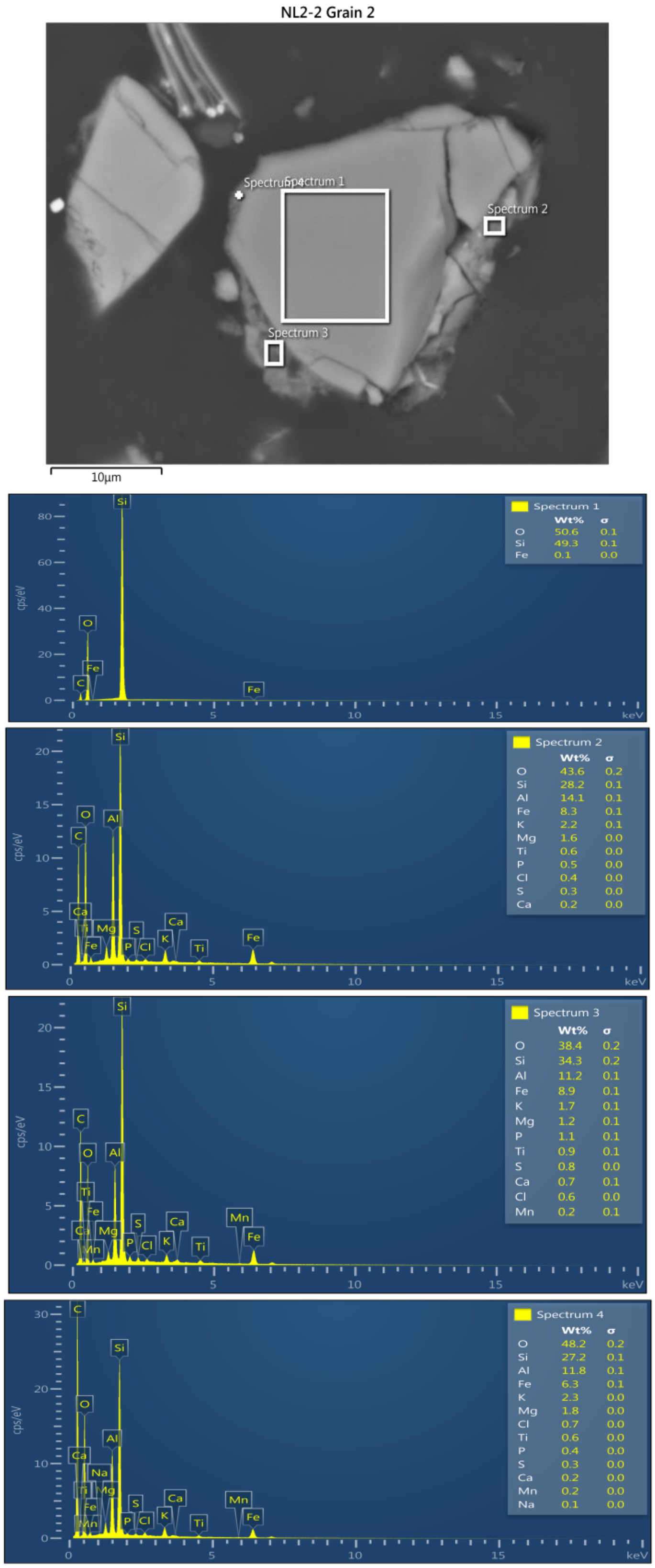


Fig. A18. Drainfield sample NL2-2.0’ depth, grain 2.

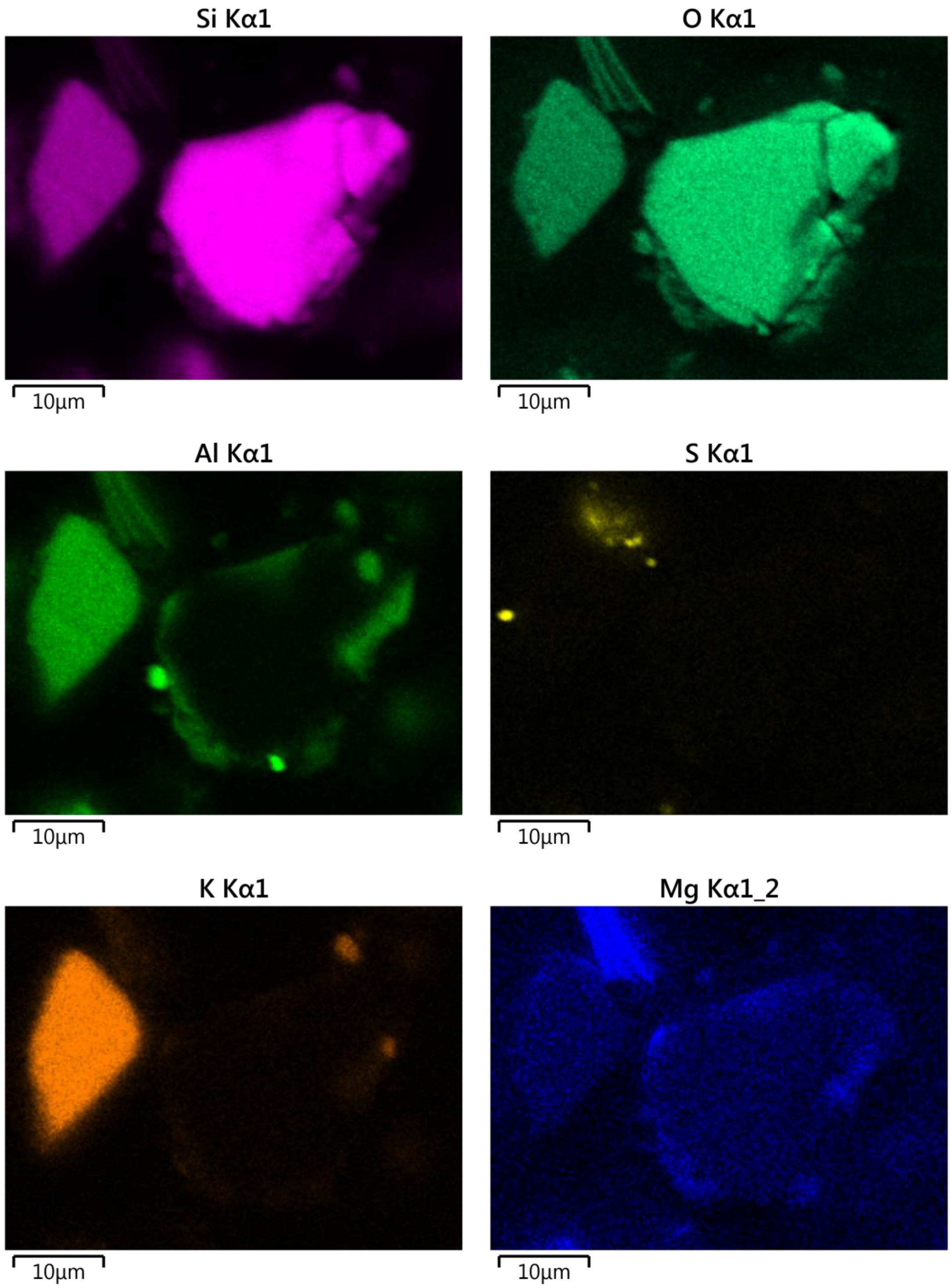


Fig. A18. Continued.

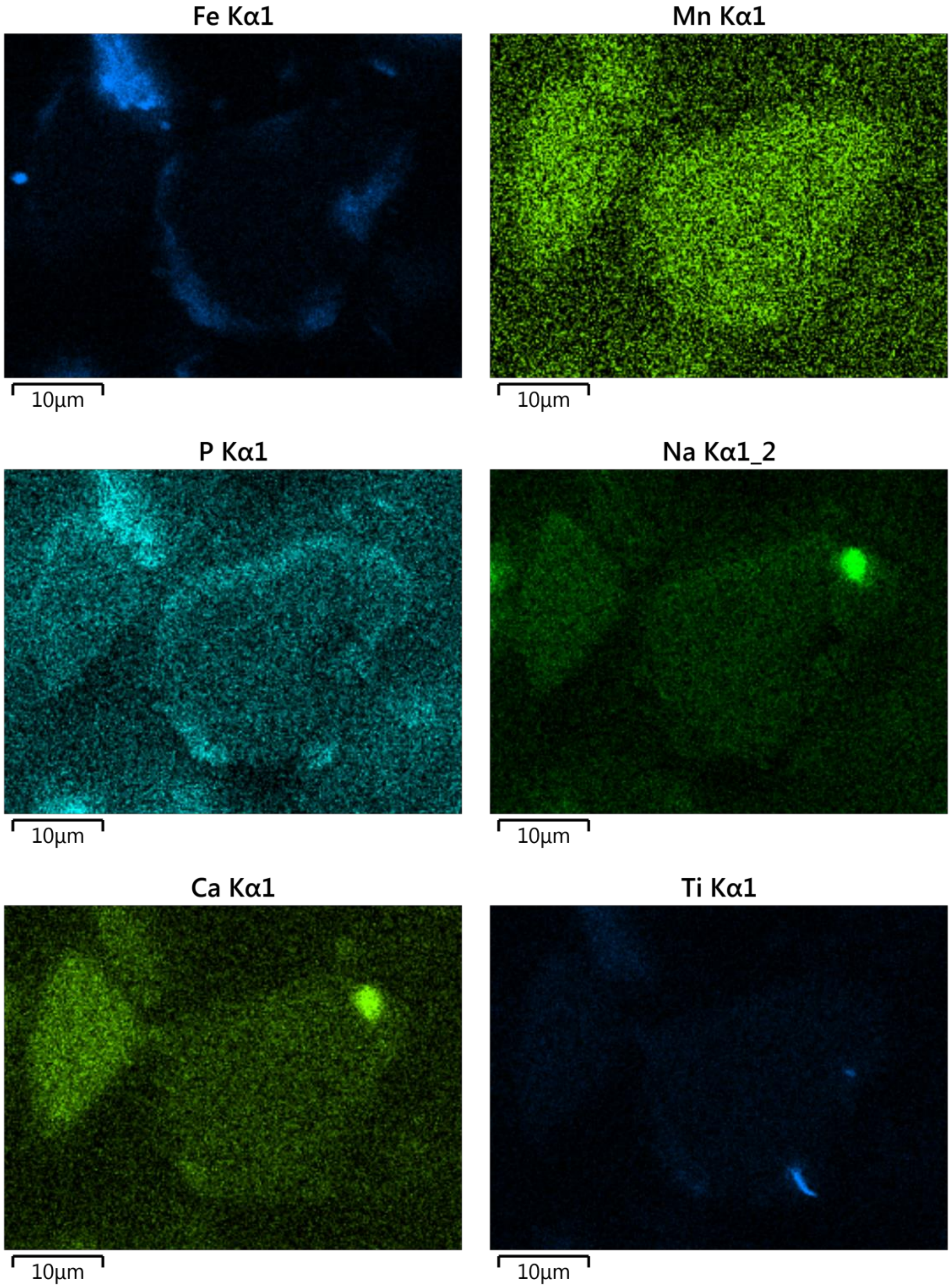


Fig. A18. Continued.

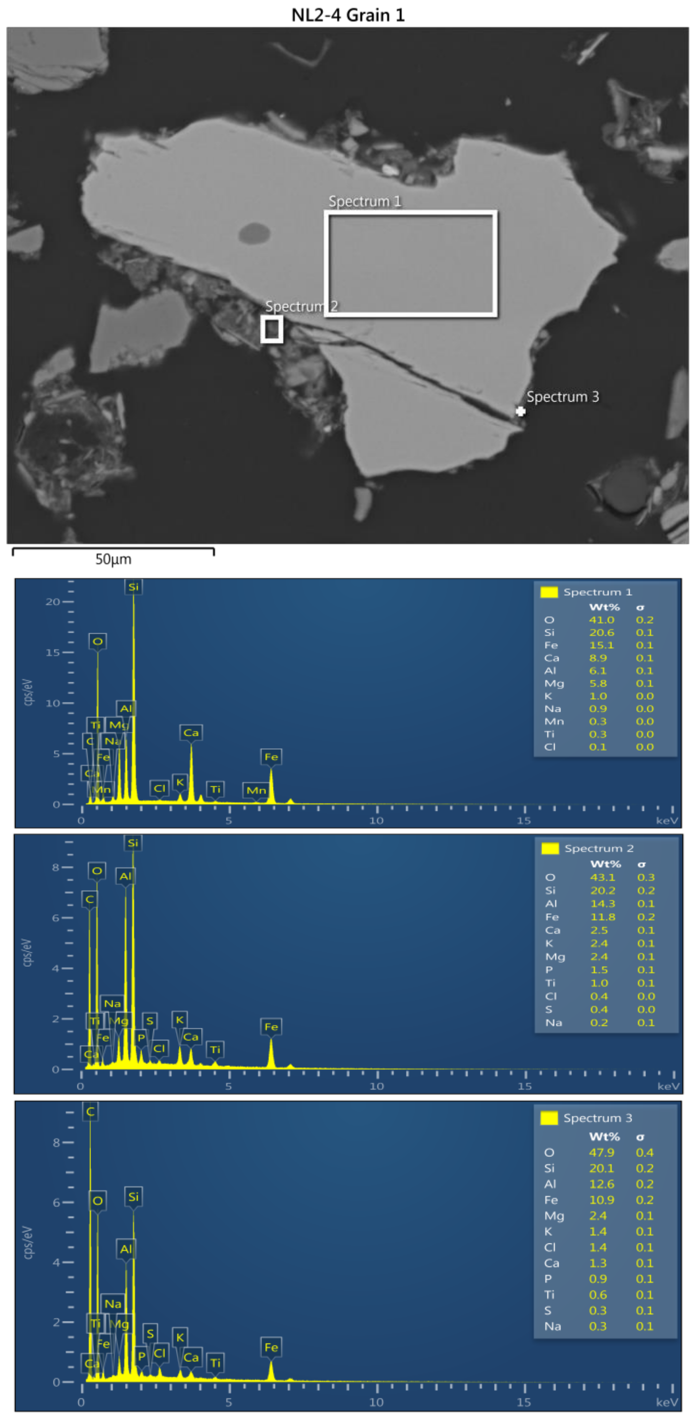


Fig. A19. Drainfield sample NL2-4.0’ depth, grain 1.

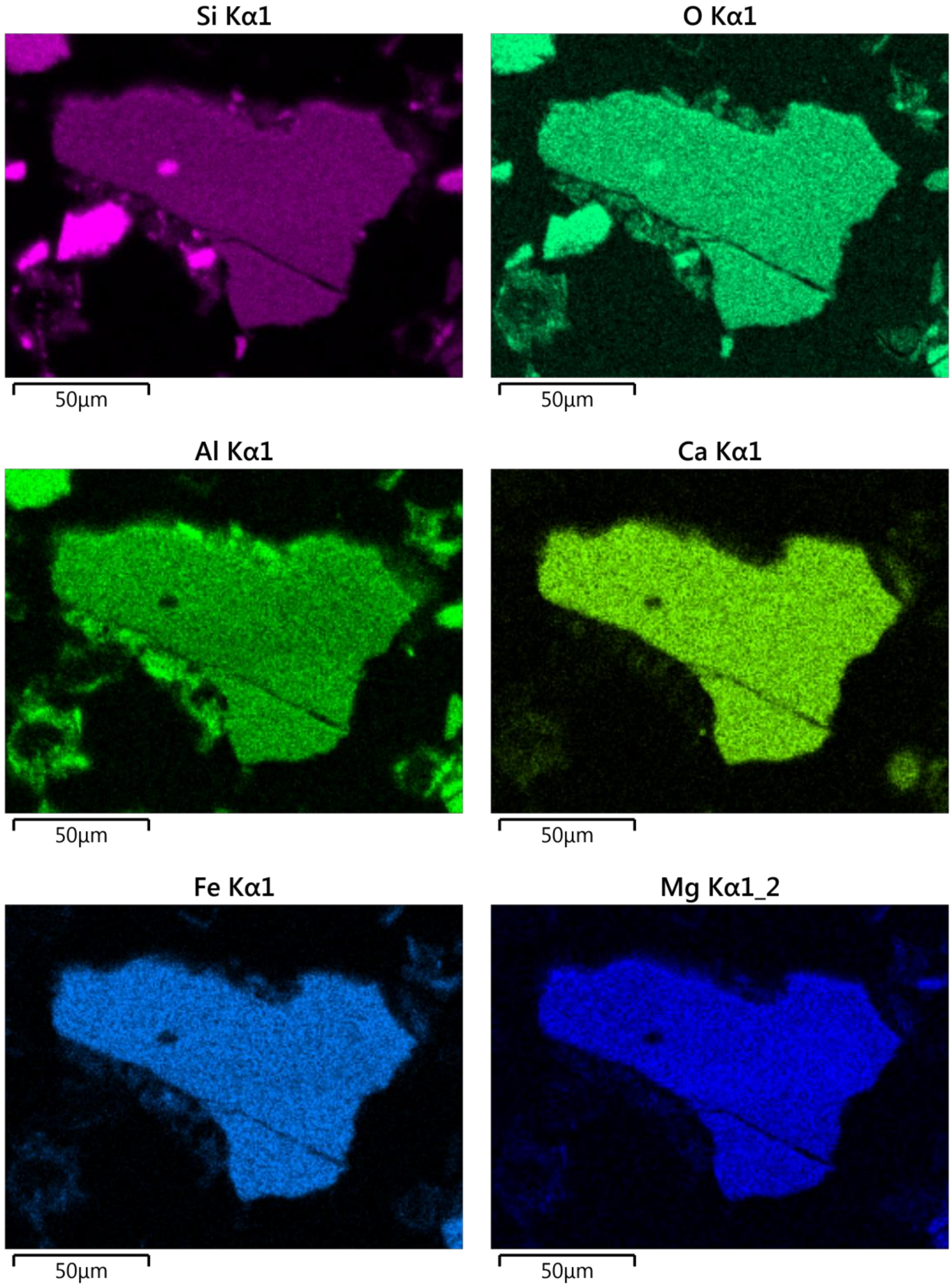


Fig. A19. Continued.

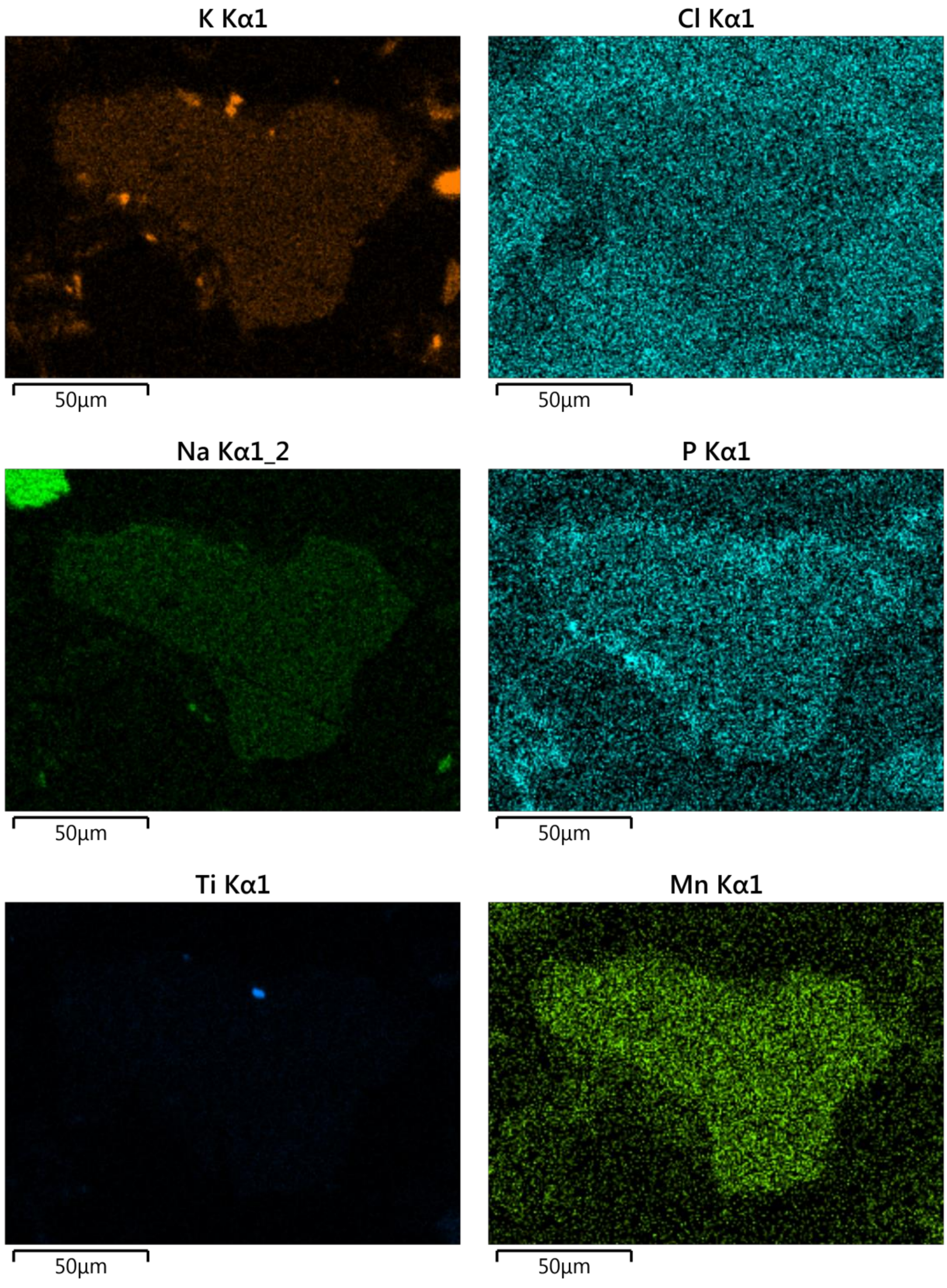


Fig. A19. Continued.

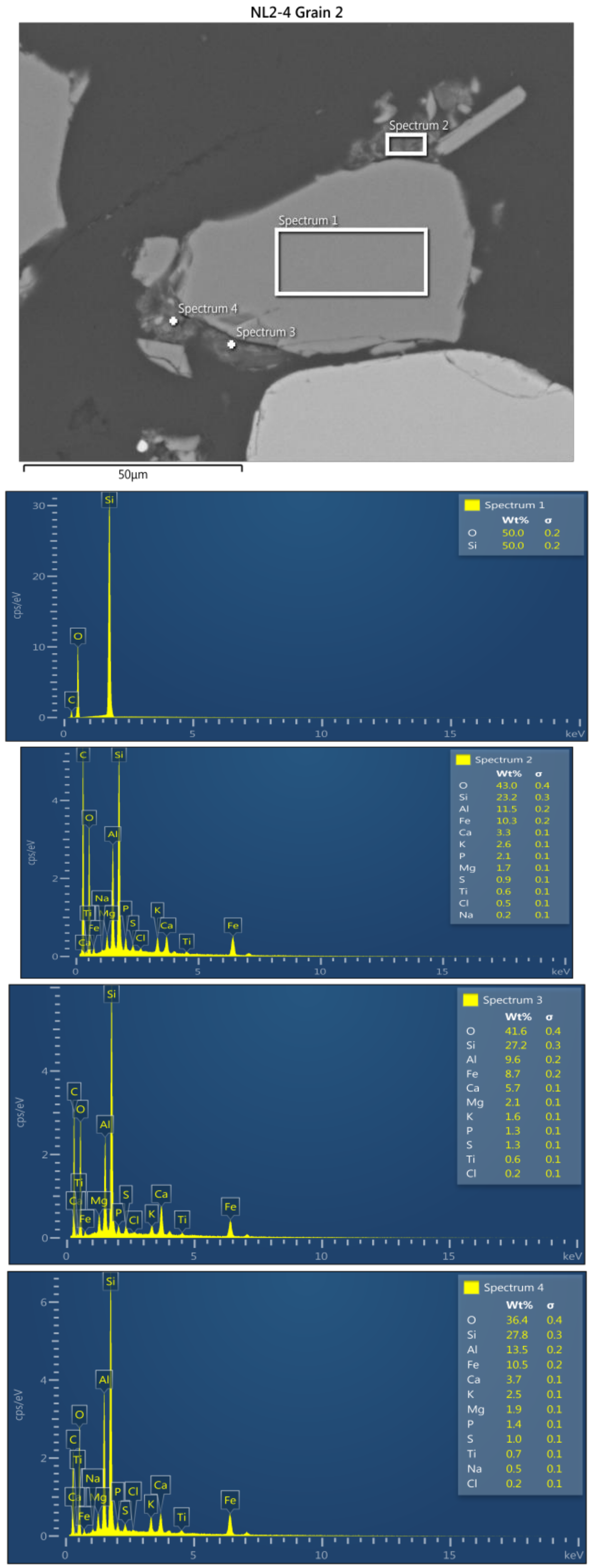


Fig. A20. Drainfield sample NL2-4.0' depth, grain 2. Also shown is a primary apatite grain (bottom right).

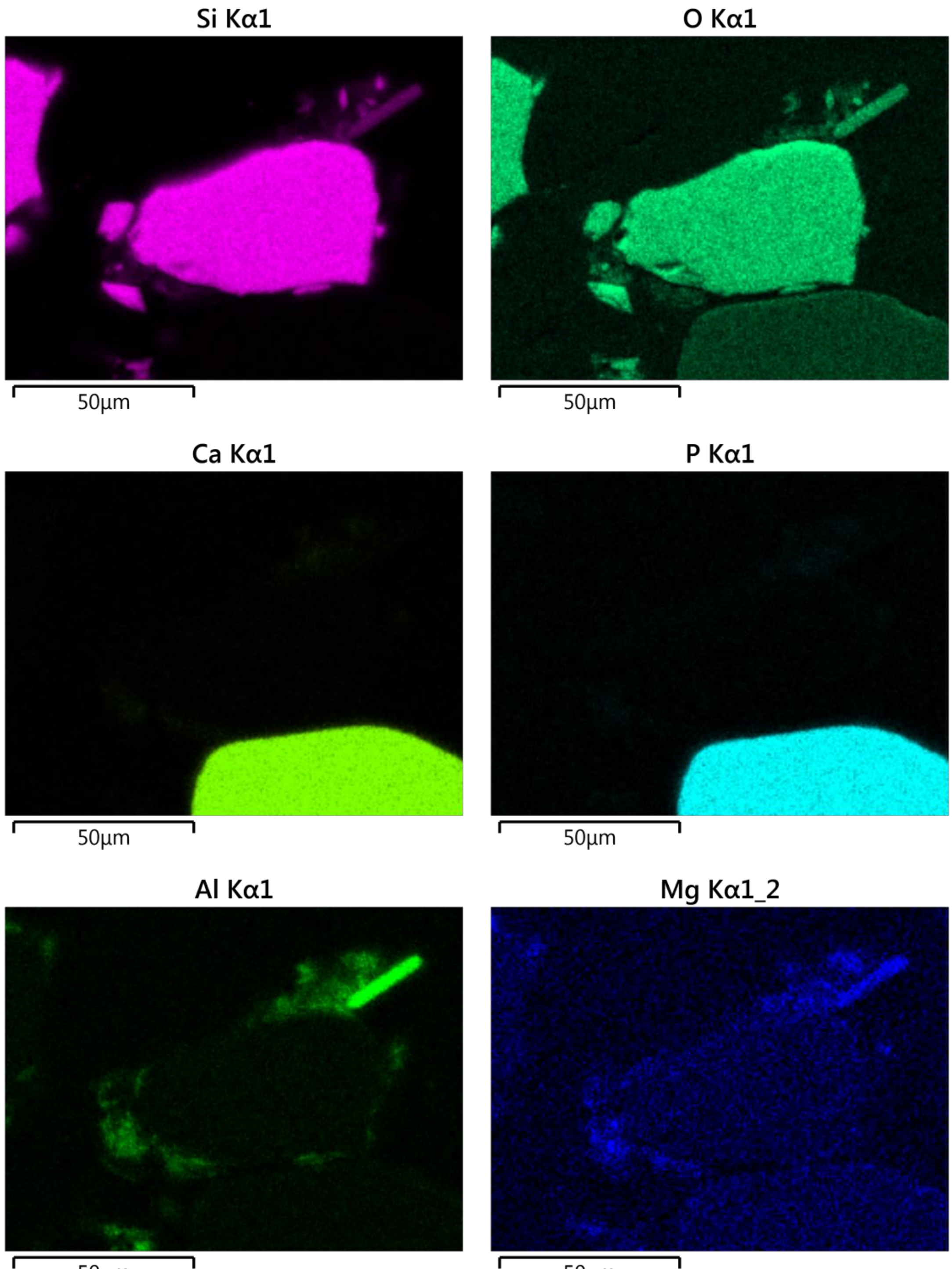
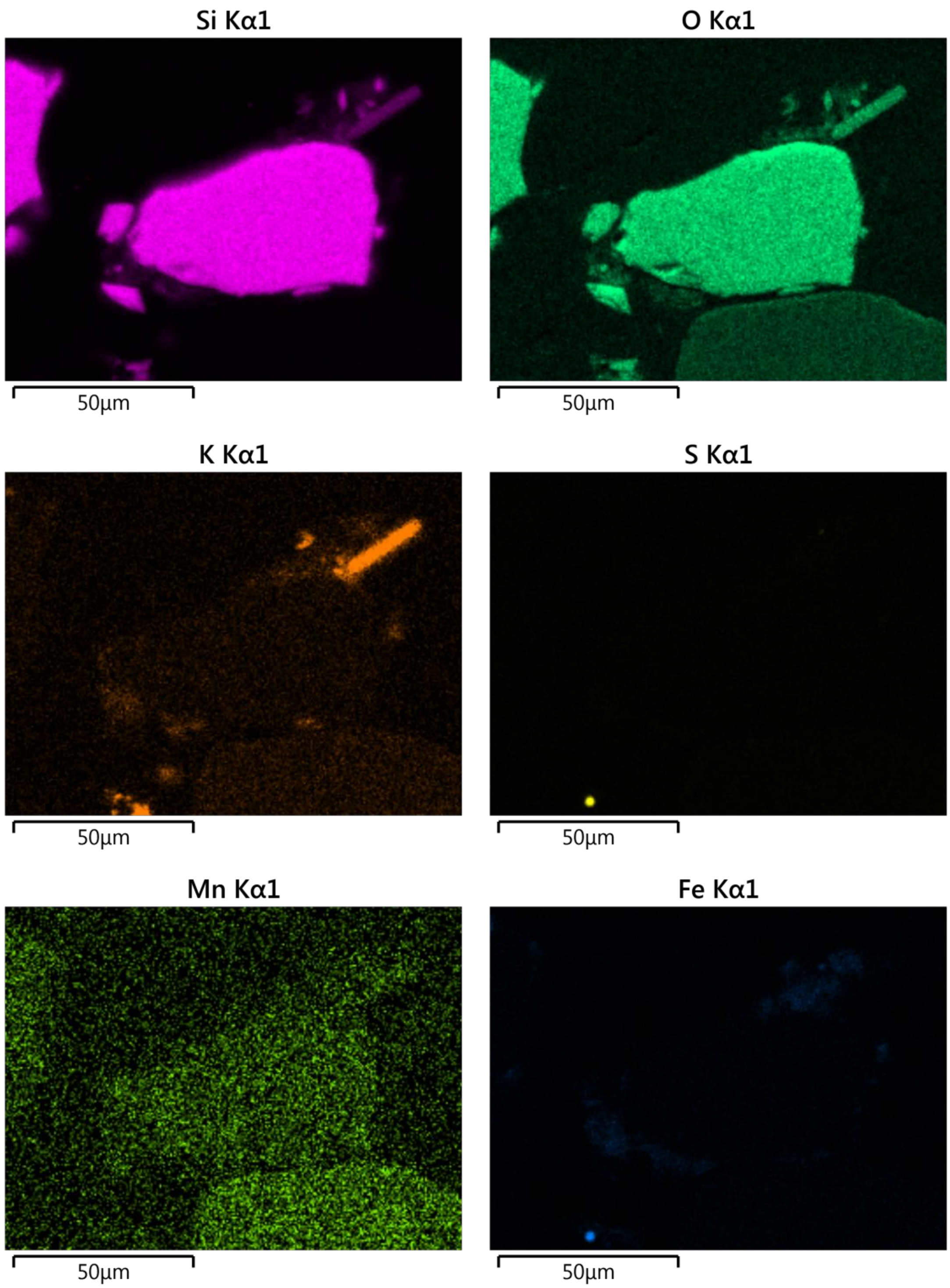


Fig. A20. Continued. Also shown is a primary apatite grain (bottom right)


Si Kα1
O Kα1
50µm
50µm
K Kα1
S Kα1
50µm
50µm
Mn Kα1
Fe Kα1
50µm
50µm

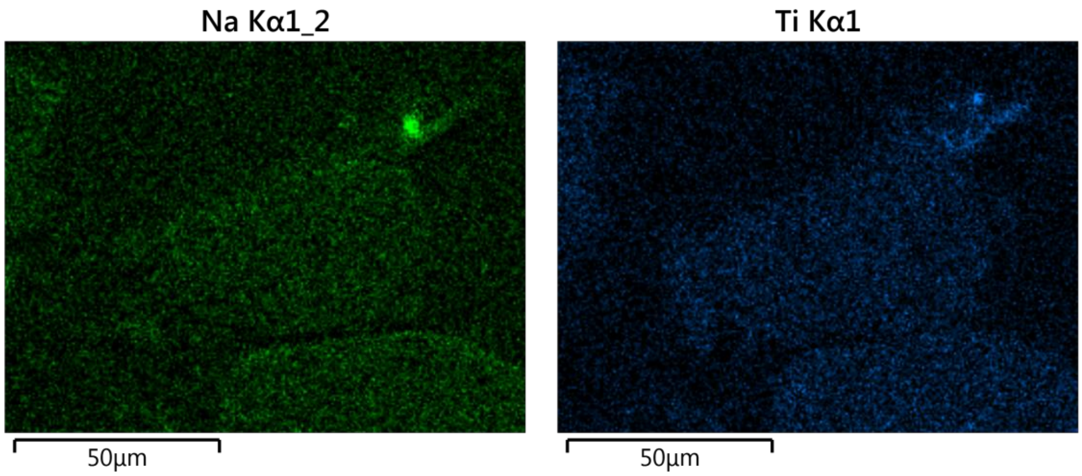


Fig. A20. Continued.

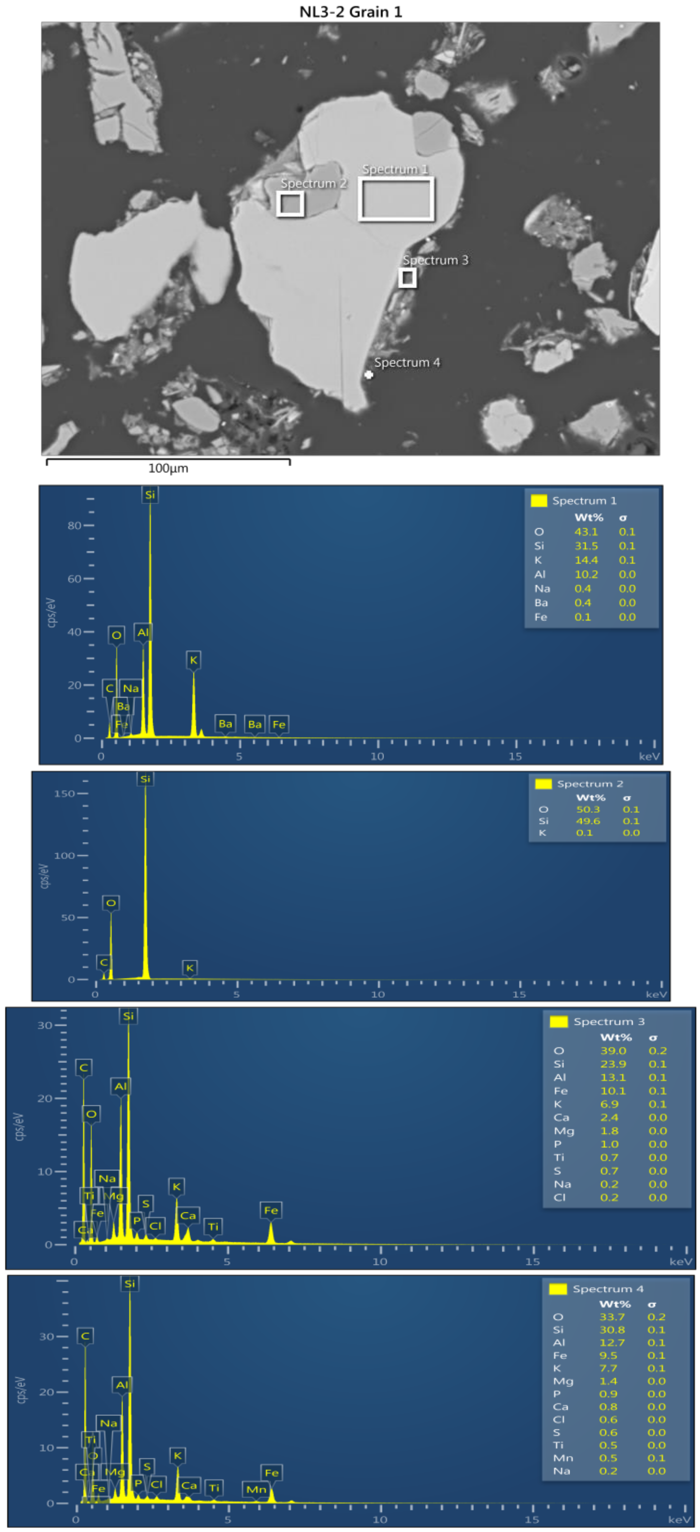


Fig. A21. Drainfield sample NL3-2’depth, grain 1.

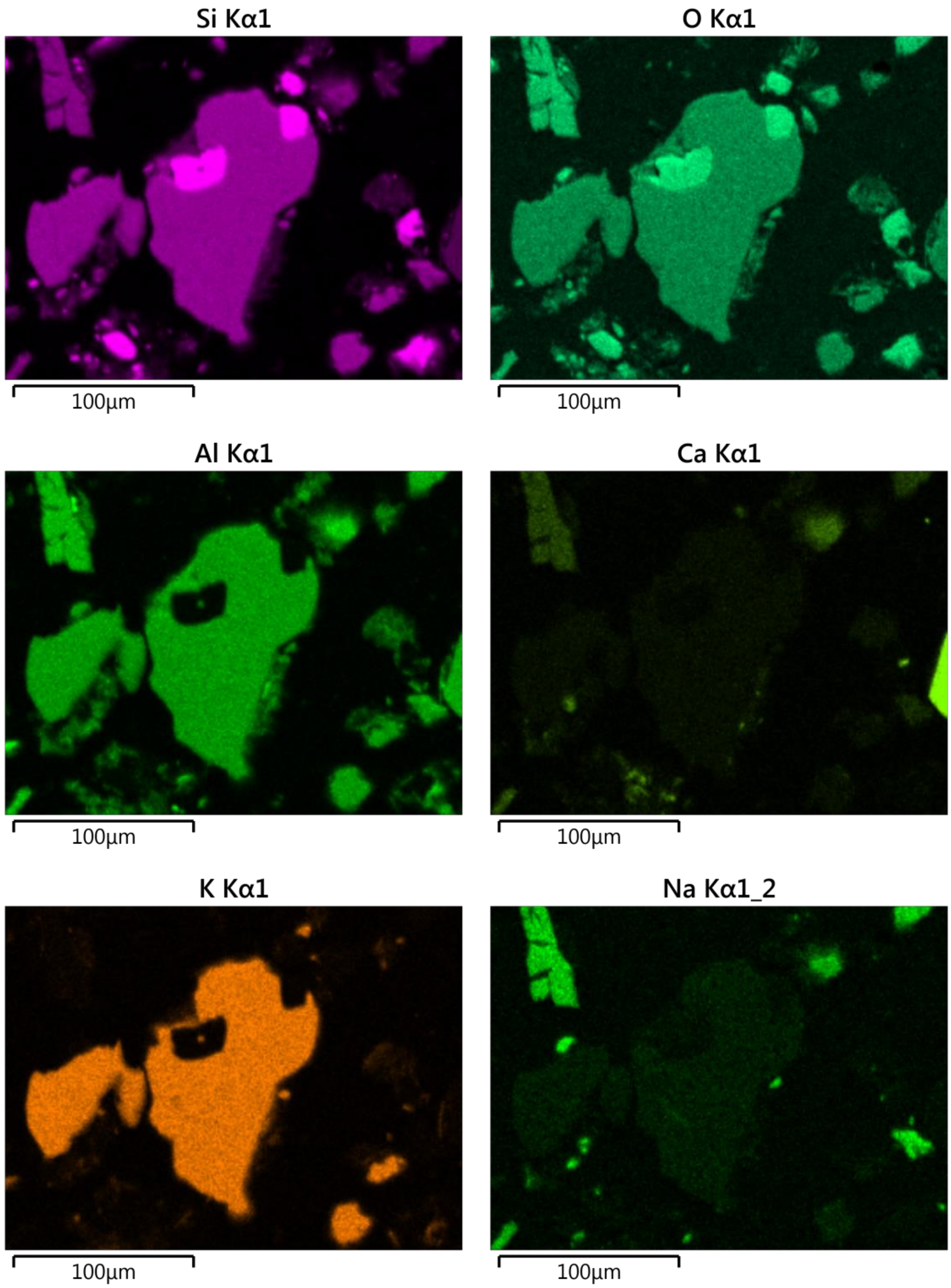


Fig. A21. Continued.

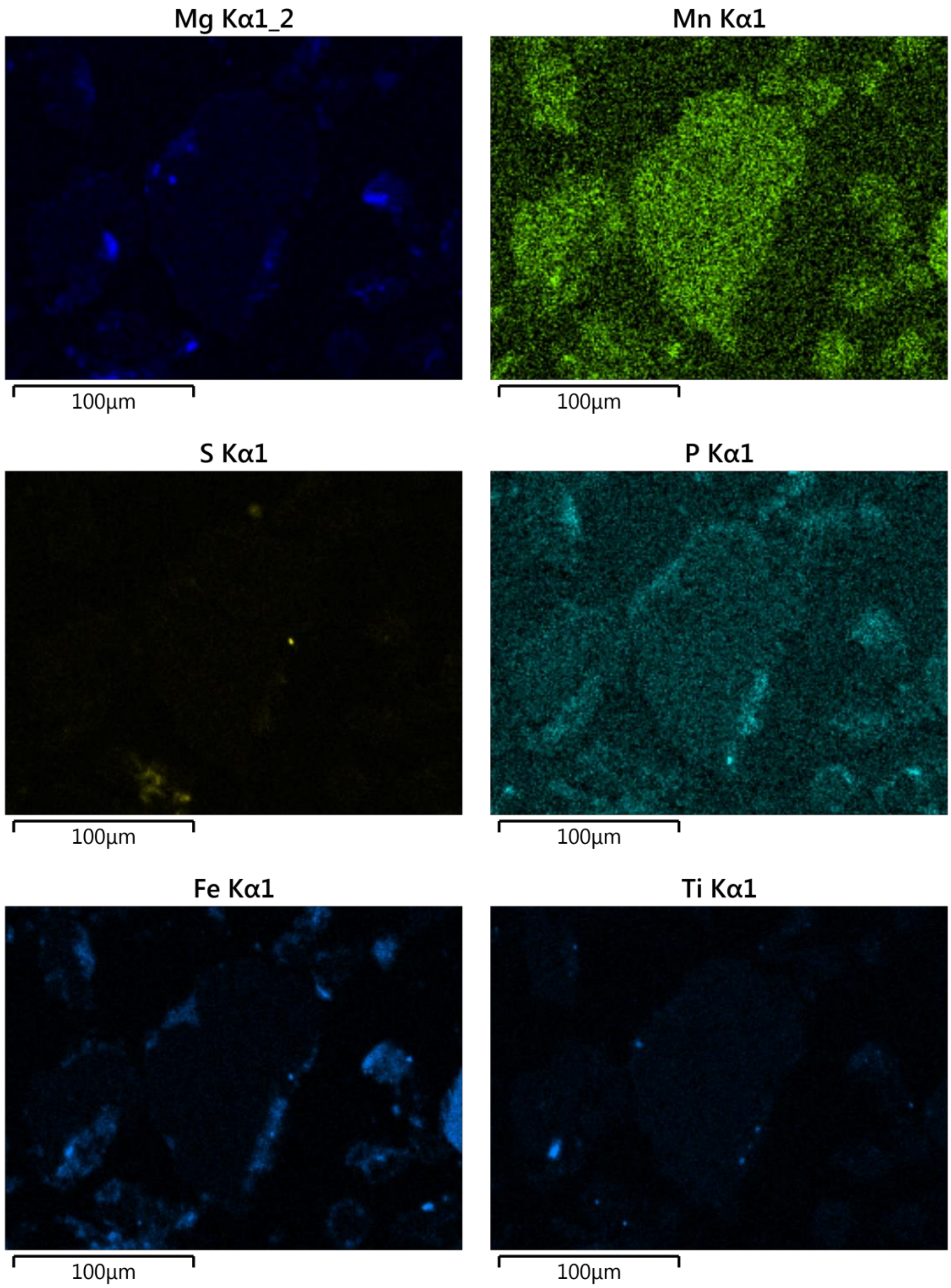


Fig. A21. Continued.

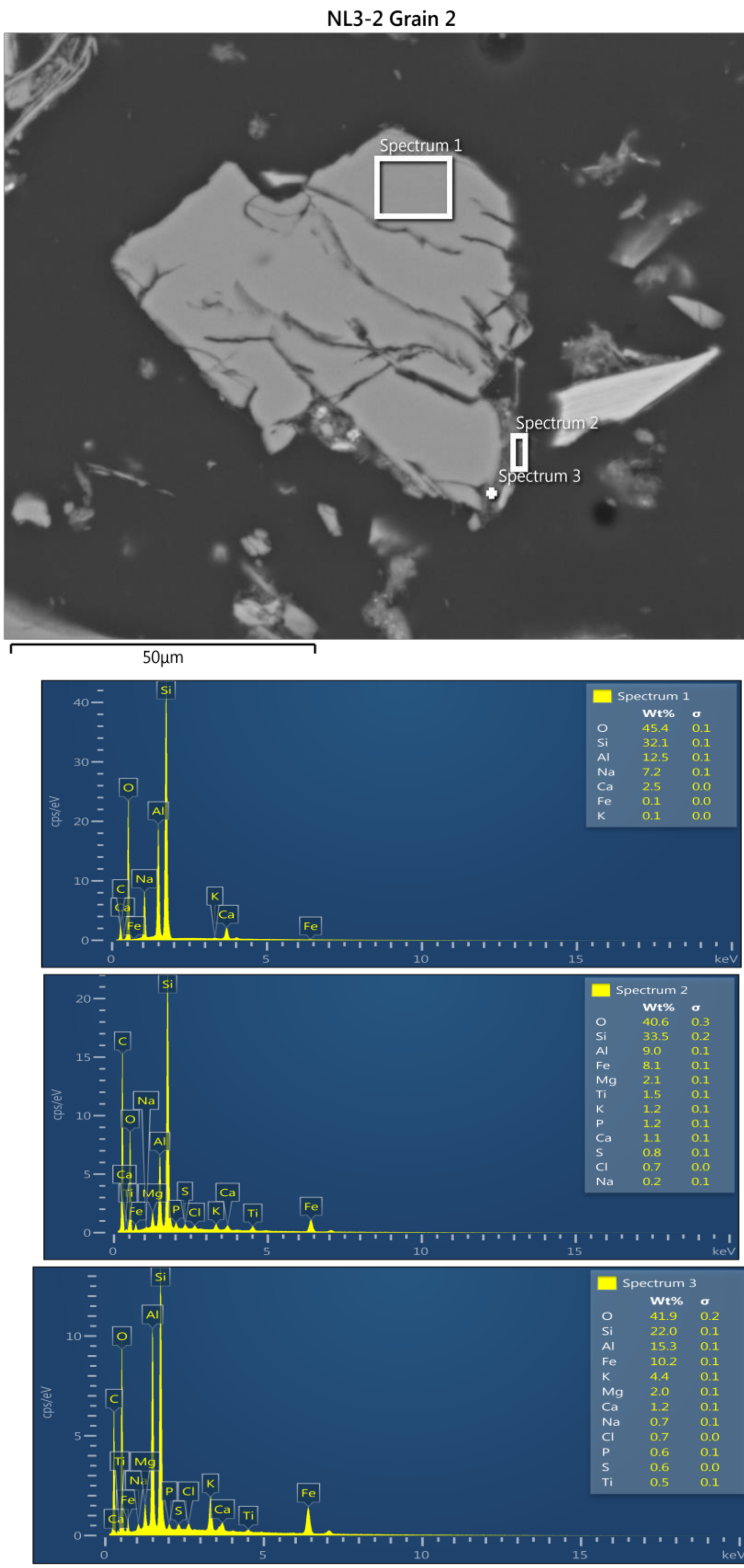


Fig. A22. Drainfield sample NL3-2.0 ft depth, grain 2.

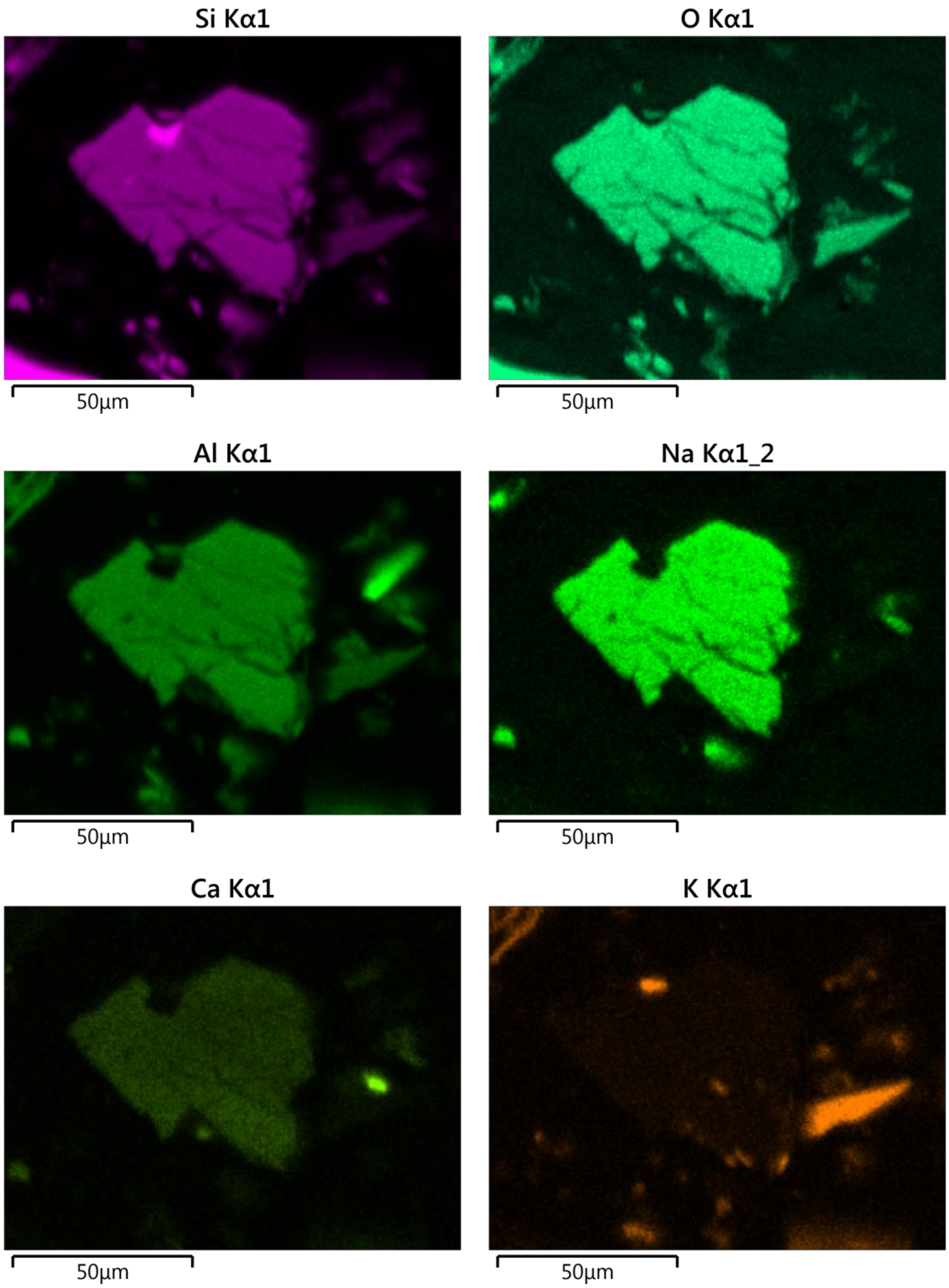


Fig. A22. Continued.

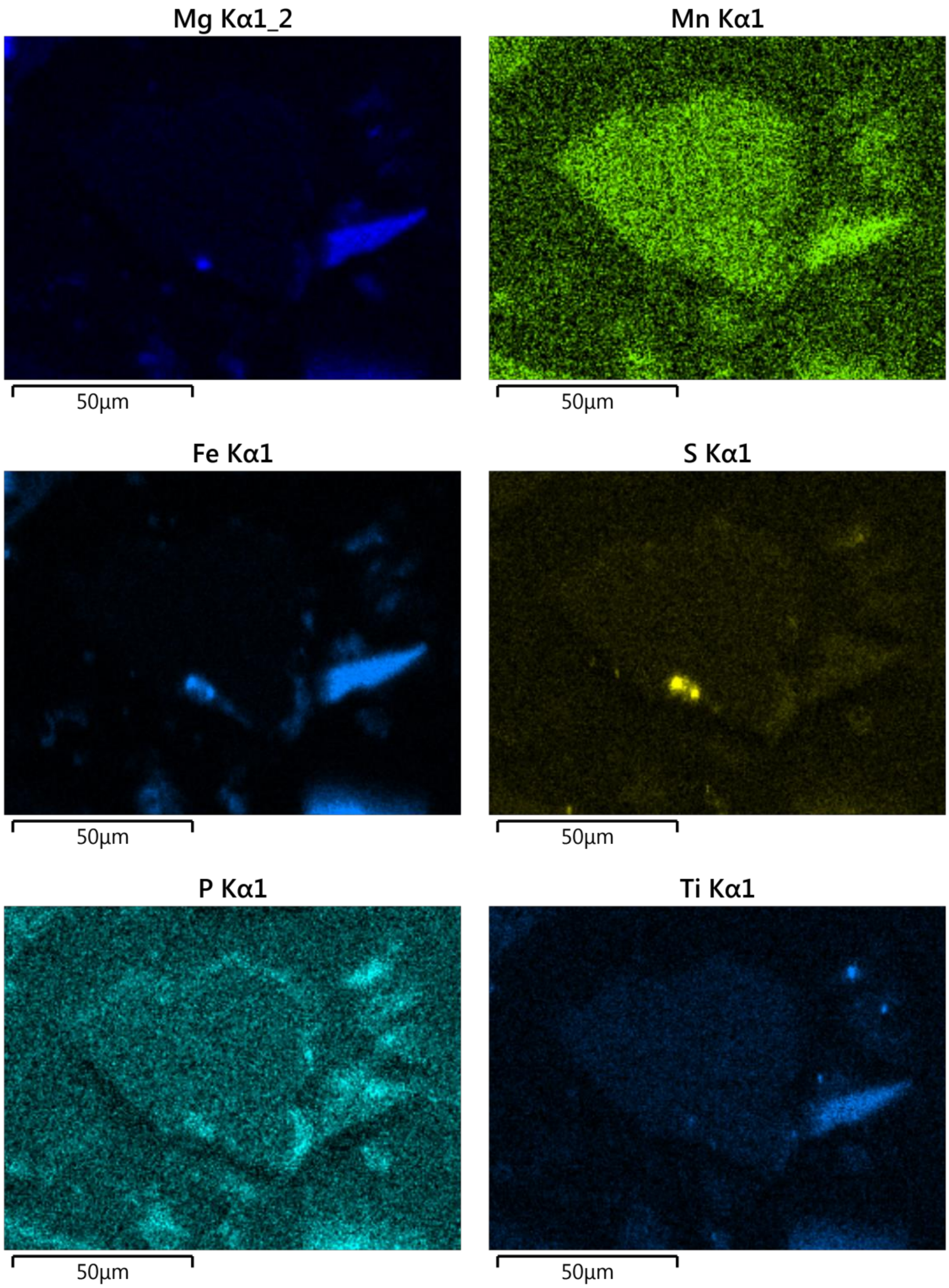


Fig. A22. Continued.

Appendix B

Drainfield Sediment Desorbable phosphorus analyses

Analyses completed at;

Agriculture and Food Laboratory
University of Guelph, ON

UNIVERSITY of GUELPH

LABORATORY SERVICES
Agriculture and Food Laboratory

FINAL Report
Submission# **19-083864**
Reported: 2019-Nov-06

Submitted By:
Client ID: **1060552**
UNIV WATERLOO EARTH SCIENCE
UNIV OF WATERLOO
WILL ROBERTSON
200 UNIVERSITY AVE W
BFG BLDG
WATERLOO, ON N2L 3G1

Owner:
WILL ROBERTSON

Phone: 705 352-3554
Sampling Date: 2019-Oct-17
Received Date: 2019-Oct-24

Phosphorus, Soil (mass) **Method ID:SNL-026**
Date Authorized: 2019-Nov-06 16:52

Sample ID	Client Sample ID	Specimen type	Sampling date / time	Test	Result	Units	Note
0001	76-1-1.5	Soil	19-Oct-17	Phosphorus (Extractable)	39.3	mg/kg dry	
0002	76-1-2.5	Soil	19-Oct-17	Phosphorus (Extractable)	74.6	mg/kg dry	
0003	76-1-3	Soil	19-Oct-17	Phosphorus (Extractable)	139	mg/kg dry	
0004	76-1-3.5	Soil	19-Oct-17	Phosphorus (Extractable)	56.7	mg/kg dry	
0005	76-1-4	Soil	19-Oct-17	Phosphorus (Extractable)	93.4	mg/kg dry	
0006	76-1-5	Soil	19-Oct-17	Phosphorus (Extractable)	56.3	mg/kg dry	
0007	76-2-1.5	Soil	19-Oct-17	Phosphorus (Extractable)	38.2	mg/kg dry	
0008	76-2-2	Soil	19-Oct-17	Phosphorus (Extractable)	38.9	mg/kg dry	
0009	76-2-2.5	Soil	19-Oct-17	Phosphorus (Extractable)	38.8	mg/kg dry	
0010	76-2-3	Soil	19-Oct-17	Phosphorus (Extractable)	40.0	mg/kg dry	
0011	76-2-3.5	Soil	19-Oct-17	Phosphorus (Extractable)	46.1	mg/kg dry	
0012	76-3-1.5	Soil	19-Oct-17	Phosphorus (Extractable)	26.0	mg/kg dry	
0013	76-3-2	Soil	19-Oct-17	Phosphorus (Extractable)	30.4	mg/kg dry	
0014	76-3-2.5	Soil	19-Oct-17	Phosphorus (Extractable)	24.5	mg/kg dry	

Phosphorus, Soil (mass) Method ID:SNL-026
Date Authorized: 2019-Nov-06 16:52

0015	76-3-3	Soil	19-Oct-17	Phosphorus (Extractable)	41.9	mg/kg dry
0016	LV1-1.5	Soil	19-Oct-17	Phosphorus (Extractable)	3.80	mg/kg dry
0017	LV1-2.5	Soil	19-Oct-17	Phosphorus (Extractable)	20.5	mg/kg dry
0018	LV1-3	Soil	19-Oct-17	Phosphorus (Extractable)	20.7	mg/kg dry
0019	LV1-3.5	Soil	19-Oct-17	Phosphorus (Extractable)	20.4	mg/kg dry
0020	LV1-4	Soil	19-Oct-17	Phosphorus (Extractable)	20.2	mg/kg dry
0021	LV2-1.5	Soil	19-Oct-17	Phosphorus (Extractable)	3.56	mg/kg dry
0022	LV2-2	Soil	19-Oct-17	Phosphorus (Extractable)	5.11	mg/kg dry
0023	LV2-2.5	Soil	19-Oct-17	Phosphorus (Extractable)	4.30	mg/kg dry
0024	LV2-3	Soil	19-Oct-17	Phosphorus (Extractable)	4.31	mg/kg dry
0025	LV3-1	Soil	19-Oct-17	Phosphorus (Extractable)	3.80	mg/kg dry
0026	LV3-1.5	Soil	19-Oct-17	Phosphorus (Extractable)	5.56	mg/kg dry
0027	LV3-2	Soil	19-Oct-17	Phosphorus (Extractable)	11.3	mg/kg dry
0028	LV3-2.5	Soil	19-Oct-17	Phosphorus (Extractable)	11.2	mg/kg dry
0029	LV3-3.5	Soil	19-Oct-17	Phosphorus (Extractable)	11.1	mg/kg dry
0030	LV3-4	Soil	19-Oct-17	Phosphorus (Extractable)	11.3	mg/kg dry
0031	NL1-1.5	Soil	19-Oct-17	Phosphorus (Extractable)	35.5	mg/kg dry
0032	NL1-2	Soil	19-Oct-17	Phosphorus (Extractable)	14.9	mg/kg dry
0033	NL1-2.5	Soil	19-Oct-17	Phosphorus (Extractable)	18.3	mg/kg dry
0034	NL1-3.5	Soil	19-Oct-17	Phosphorus (Extractable)	5.71	mg/kg dry
0035	NL1-4	Soil	19-Oct-17	Phosphorus (Extractable)	5.66	mg/kg dry
0036	NL2-1.5	Soil	19-Oct-17	Phosphorus (Extractable)	7.56	mg/kg dry

Phosphorus, Soil (mass) **Method ID:SNL-026**

Date Authorized: 2019-Nov-06 16:52

0037	NL2-2	Soil	19-Oct-17	Phosphorus (Extractable)	47.1	mg/kg dry
0038	NL2-2.5	Soil	19-Oct-17	Phosphorus (Extractable)	34.5	mg/kg dry
0039	NL2-3.5	Soil	19-Oct-17	Phosphorus (Extractable)	34.8	mg/kg dry
0040	NL2-4	Soil	19-Oct-17	Phosphorus (Extractable)	57.5	mg/kg dry
0041	NL3-1	Soil	19-Oct-17	Phosphorus (Extractable)	17.8	mg/kg dry
0042	NL3-1.5	Soil	19-Oct-17	Phosphorus (Extractable)	16.7	mg/kg dry
0043	NL3-2	Soil	19-Oct-17	Phosphorus (Extractable)	70.9	mg/kg dry
0044	NL3-2.5	Soil	19-Oct-17	Phosphorus (Extractable)	39.9	mg/kg dry
0045	NL3-3	Soil	19-Oct-17	Phosphorus (Extractable)	35.7	mg/kg dry

Supervisor: Nicolaas Schrier MSc, Agriculture and Food Laboratory 519 823 1268 ext. 57215 nschrier@uoguelph.ca

Appendix C

Drainfield Sediment Acid Extractable Cation Analyses

Analyses completed at;
Activation Laboratories,
Ancaster, ON

Results **Activation Laboratories Ltd.** **Report:**

Analyte Symbol	Na	P	S	Sb	Sc	Sr	Ti	Th	Te	Tl	U	V	W	Y	Zr
Unit Symbol	%	%	%	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
Lower Limit	0.001	0.001	0.01	2	1	1	0.01	20	1	2	10	1	10	1	1
Method Code	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP
76-1- 1.5	0.057	0.138	0.03	< 2	5	12	0.14	< 20	< 1	< 2	< 10	47	< 10	22	< 1
76-1- 2.5	0.070	0.182	0.02	< 2	5	14	0.14	< 20	< 1	< 2	< 10	47	< 10	20	< 1
76-1- 3	0.076	0.232	0.02	< 2	4	18	0.14	< 20	< 1	< 2	< 10	46	< 10	20	< 1
76-1- 3.5	0.045	0.150	0.02	< 2	5	12	0.14	< 20	< 1	< 2	< 10	47	< 10	20	< 1
76-1- 4	0.062	0.186	0.03	< 2	5	15	0.14	< 20	< 1	< 2	< 10	48	< 10	21	4
76-1- 5	0.095	0.121	0.06	< 2	9	14	0.23	< 20	< 1	< 2	< 10	63	< 10	17	4
LV-1- 1.0	0.023	0.078	0.02	< 2	5	13	0.17	< 20	2	< 2	< 10	42	< 10	16	2
LV-1- 1.5	0.021	0.074	0.01	< 2	4	12	0.17	< 20	< 1	< 2	< 10	40	< 10	16	2
LV-1- 2.5	0.026	0.077	0.01	< 2	5	10	0.16	< 20	3	< 2	< 10	44	< 10	15	2
LV-1- 3	0.028	0.093	0.02	< 2	5	12	0.18	< 20	< 1	< 2	< 10	48	< 10	17	2
LV-1- 3.5	0.028	0.121	0.03	< 2	6	17	0.22	< 20	1	< 2	< 10	75	< 10	21	1
LV-1- 4	0.026	0.093	0.02	< 2	7	18	0.27	< 20	3	< 2	< 10	79	< 10	12	2
NL 3- 1	0.027	0.102	0.01	< 2	4	21	0.12	< 20	< 1	< 2	< 10	36	< 10	14	1
NL 3- 1.5	0.034	0.103	0.02	< 2	3	31	0.11	< 20	< 1	< 2	< 10	28	< 10	12	1
NL 3- 2	0.048	0.133	0.12	< 2	3	17	0.12	< 20	< 1	< 2	< 10	41	< 10	13	< 1
NL 3- 2.5	0.036	0.122	0.61	< 2	5	14	0.15	< 20	< 1	< 2	< 10	46	< 10	15	2
NL 3- 3	0.040	0.125	0.39	< 2	4	22	0.13	< 20	< 1	< 2	< 10	41	< 10	14	1

Results **Activation Laboratories Ltd.** **Report: A19-15476**

Analyte Symbol	Ag	Cd	Cu	Mn	Mo	Ni	Pb	Zn	Al	As	B
Unit Symbol	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm
Lower Limit	0.2	0.5	1	5	1	1	2	2	0.01	2	10
Method Code	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP
76-1- 1.5	< 0.2	< 0.5	24	646	< 1	16	18	86	2.47	3	< 10
76-1- 2.5	< 0.2	< 0.5	35	510	< 1	18	17	103	2.31	< 2	< 10
76-1- 3	< 0.2	< 0.5	44	479	1	21	15	97	2.21	< 2	< 10
76-1- 3.5	< 0.2	< 0.5	25	598	< 1	17	18	91	2.30	3	< 10
76-1- 4	< 0.2	< 0.5	33	580	< 1	16	18	99	2.46	4	< 10
76-1- 5	< 0.2	< 0.5	38	361	< 1	24	7	67	2.87	< 2	< 10
LV-1- 1.0	0.6	< 0.5	18	499	< 1	16	28	127	2.71	< 2	< 10
LV-1- 1.5	0.5	< 0.5	14	520	< 1	14	26	141	2.75	< 2	< 10
LV-1- 2.5	< 0.2	< 0.5	18	507	< 1	18	43	88	2.18	< 2	< 10
LV-1- 3	< 0.2	< 0.5	22	535	< 1	16	24	74	2.36	< 2	< 10
LV-1- 3.5	< 0.2	< 0.5	34	584	1	19	16	96	3.04	< 2	< 10
LV-1- 4	< 0.2	< 0.5	38	398	3	29	10	87	2.97	< 2	< 10
NL 3- 1	< 0.2	< 0.5	17	485	< 1	16	11	64	1.59	< 2	< 10
NL 3- 1.5	< 0.2	< 0.5	21	334	< 1	15	9	57	1.31	< 2	< 10
NL 3- 2	< 0.2	< 0.5	44	383	1	16	16	79	1.97	< 2	< 10
NL 3- 2.5	< 0.2	< 0.5	25	353	3	29	8	64	1.88	< 2	< 10
NL 3- 3	< 0.2	< 0.5	151	448	5	37	19	133	1.76	< 2	< 10

Analyte Symbol	Ba	Be	Bi	Ca	Co	Cr	Fe	Ga	Hg	K	La	Mg
Unit Symbol	ppm	ppm	ppm	%	ppm	ppm	%	ppm	ppm	%	ppm	%
Lower Limit	10	0.5	2	0.01	1	1	0.01	10	1	0.01	10	0.01
Method Code	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP	AR-ICP
76-1- 1.5	103	1.0	< 2	0.21	10	31	2.84	< 10	< 1	0.20	43	0.57
76-1- 2.5	89	0.9	< 2	0.24	9	33	2.81	< 10	< 1	0.21	42	0.56
76-1- 3	91	0.9	< 2	0.31	9	39	2.85	< 10	< 1	0.23	41	0.55
76-1- 3.5	94	0.9	< 2	0.23	10	35	2.78	< 10	< 1	0.20	41	0.55
76-1- 4	100	1.0	< 2	0.25	10	34	2.89	< 10	< 1	0.21	42	0.58
76-1- 5	135	1.1	< 2	0.23	13	37	3.85	< 10	< 1	0.51	45	0.79
LV-1- 1.0	53	1.1	< 2	0.93	7	31	2.33	< 10	< 1	0.17	28	4.08
LV-1- 1.5	46	1.1	< 2	1.12	7	29	2.28	< 10	< 1	0.12	29	4.54
LV-1- 2.5	82	0.8	< 2	0.46	9	31	2.63	< 10	< 1	0.25	36	1.54
LV-1- 3	90	0.9	< 2	0.42	11	29	2.95	< 10	< 1	0.28	39	1.24
LV-1- 3.5	145	1.1	< 2	0.36	11	44	3.65	< 10	< 1	0.26	41	0.82
LV-1- 4	118	0.8	< 2	0.33	12	55	3.72	< 10	< 1	0.31	37	1.11
NL 3- 1	83	0.6	< 2	1.63	8	25	2.30	< 10	< 1	0.21	37	1.33
NL 3- 1.5	67	0.5	< 2	3.37	8	20	2.12	< 10	< 1	0.24	32	2.36
NL 3- 2	106	0.8	< 2	0.35	9	29	2.15	< 10	< 1	0.15	41	0.50
NL 3- 2.5	91	0.7	< 2	0.32	10	49	2.82	< 10	< 1	0.28	34	0.63
NL 3- 3	124	0.7	< 2	1.16	10	59	2.79	< 10	< 1	0.29	34	1.00

Quality Analysis ... **Actlabs** *Innovative Technologies*

Report No.:	**A19-15476**
Report Date:	**25-Nov-19**
Date Submitted:	**13-Nov-19**
Your Reference:	

University of Waterloo
200 University Ave. W.
Waterloo Ontario N2L 3G1
Canada

ATTN: Will Robertson

CERTIFICATE OF ANALYSIS

17 Soil samples were submitted for analysis.

The following analytical package(s) were requested:		Testing Date:
1E3	QOP AquaGeo (Aqua Regia ICPOES)	2019-11-21 08:57:22

REPORT A19-15476

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Notes:

Values which exceed the upper limit should be assayed for accurate numbers.

CERTIFIED BY:

Emmanuel Eseme , Ph.D.
Quality Control Coordinator

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