Influence of Water Quality and Sediment Transport on Biological Recovery Downstream of Lime Dosers

Comparative Study of Four Lime Doser Systems

Presented by

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Athens, OH

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Dr. Kelly Johnson, College of Arts and Sciences, Biological Sciences;
Dr. Dina Lopez, College of Arts and Sciences, Geological Sciences

Introduction

- Acid Mine Drainage (AMD) is the legacy of pre-regulation mining in southeastern Ohio.
- Lime Dosers - Active Remediation strategy when space limitation exists and where passive system would not be effective .
- Used in high acid loading streams.

Objectives of Study

The purpose of this study is to investigate the factors that contribute to biological recovery in the downstream reaches of lime doser systems.

Specific Objectives

- To explore differences in biological recovery downstream of dosers systems.
- To examine the aqueous water chemistry trends to identify correlations with biological recovery.
- To assess the influence of precipitation of dissolved metals and additional alkalinity loads downstream of the doser treatment on biological improvement.

Summary of Lime Dosers installed in the Southeast Ohio watersheds.

Doser Location	Year Installed	Stream Remediated	Sub-Watershed	Watershed
Carbondale	2004	Carbondale Seeps	Hewett Fork	Raccoon Creek
Job's Hollow	2004	Job's Hollow Seeps	N/A	Monday Creek
Pine Run	2012	Pine Run Seeps	West Branch Sunday Creek	Sunday Creek
Thomas Fork	2012	Thomas Fork Seeps	Thomas Fork	Leading Creek

Methods

- Total study duration was 12 months.
- Study commenced in February 2014 and continued until January 2015.
- Eight to eleven miles downstream of dosers were sampled for analysis.

Physical / Chemical Analysis

- Field Parameters and Flow
- Alkalinity – Acidity Budget
- Water Quality Analysis

Biological Recovery

- MAIS

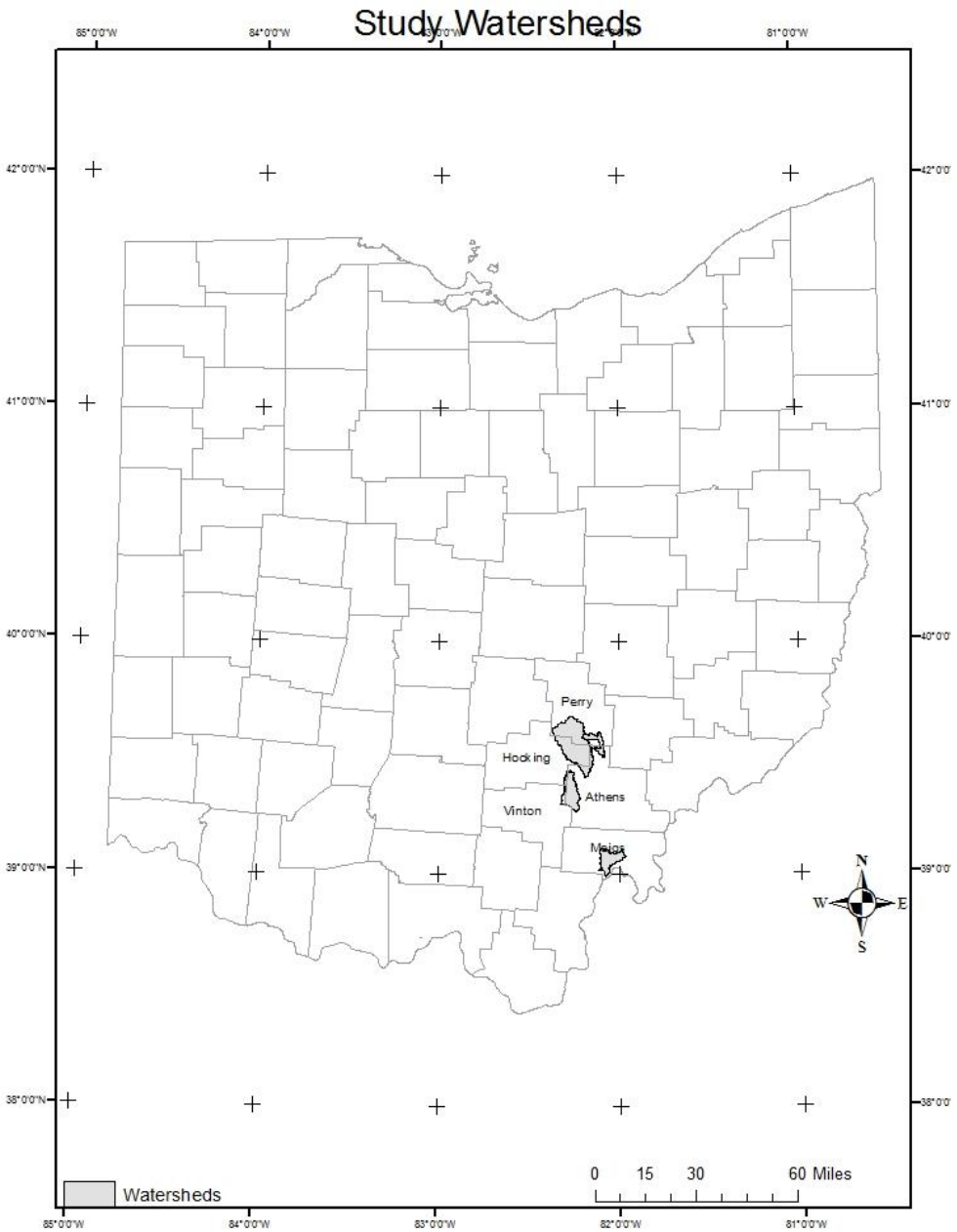
Preliminary Macroinvertebrate Identification and Enumeration

Breakdown of sampling sites and volume

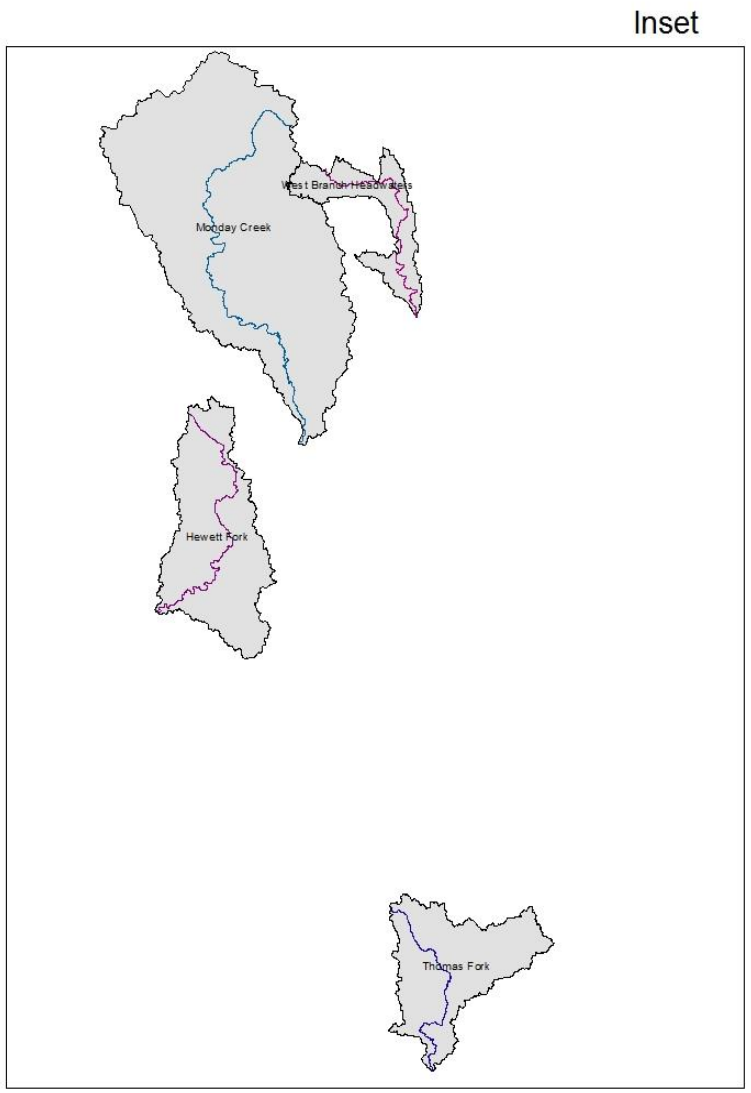
			Location/ No of Sites			
Activity		Total No of Sites	Monday Creek / Downstream Jobs Hollow Doser	West BranchSunday Creek / Downstream Pine Run Doser	Thomas Fork / DownstreamThomas Fork Doser	Hewett Fork / Downstream Carbondale Doser
Water Quality / Field Parameters/Flow		37	7	9	11	11
Field Parameters / Flow or Velocity		37	7	9	11	11
Alkalinity Budget		80	21	20	21	18
MAIS		25	6	7	5	7

Statistical Analysis

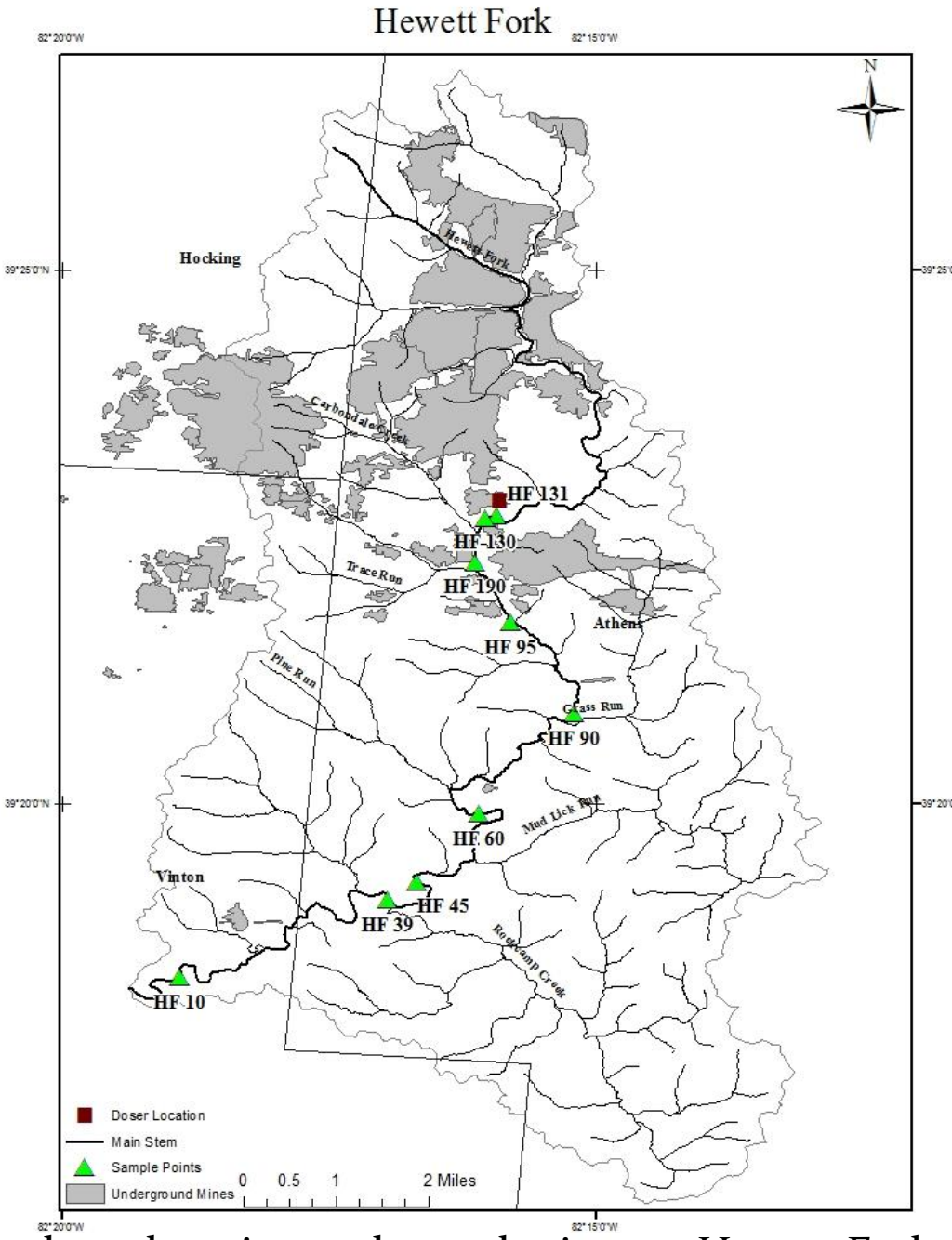
- Correlation and Regression analysis of data were conducted using R and Excel employing parametric and non-parametric approaches.
- Sampling results were compared to MAIS results to find the best correlation that describes the factors that enhance biological recovery.
- Downstream reaches field parameters and water quality profile for the dosers were analyzed and compared to assess differences in biological recovery.



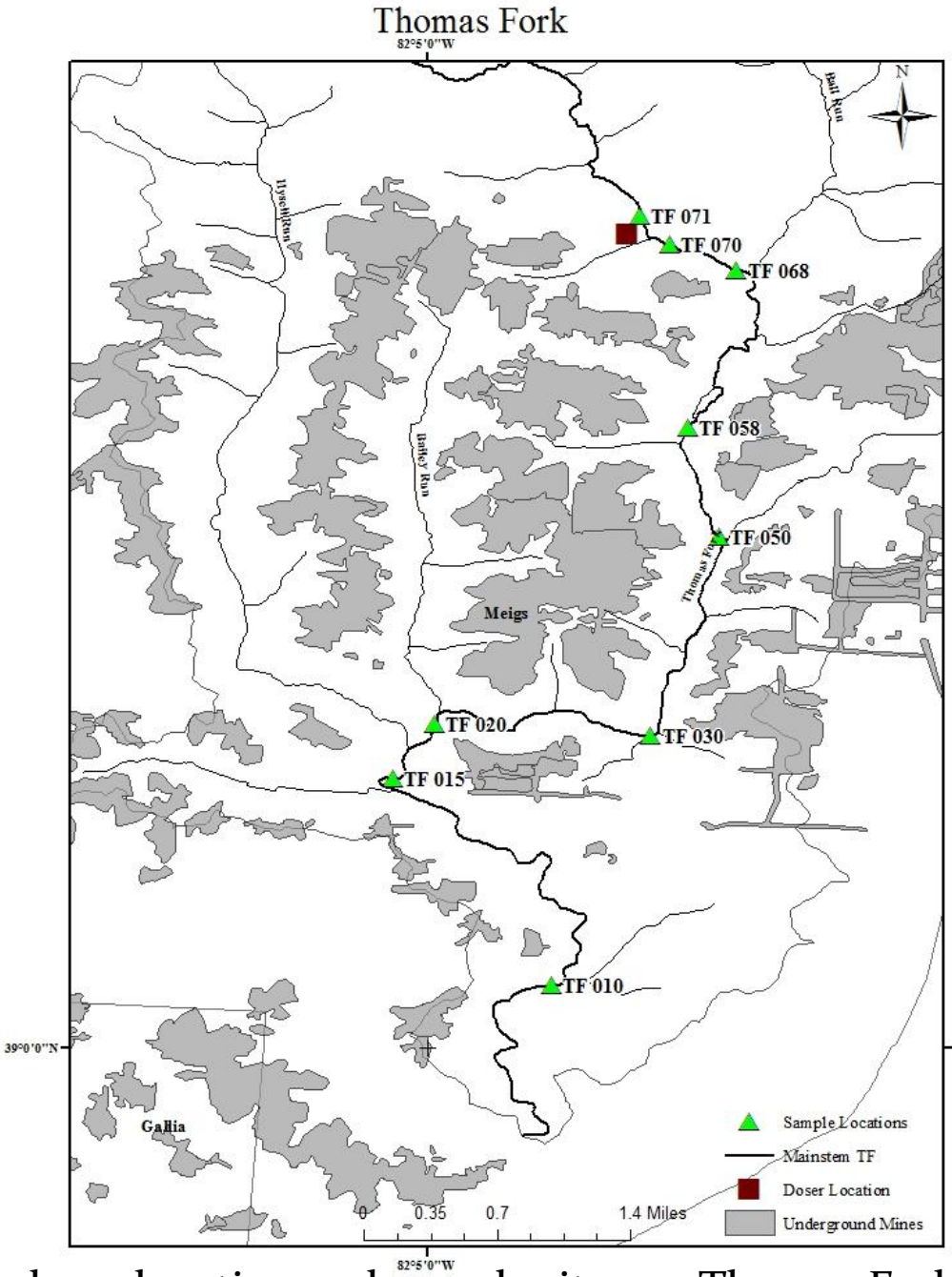
Study Watersheds



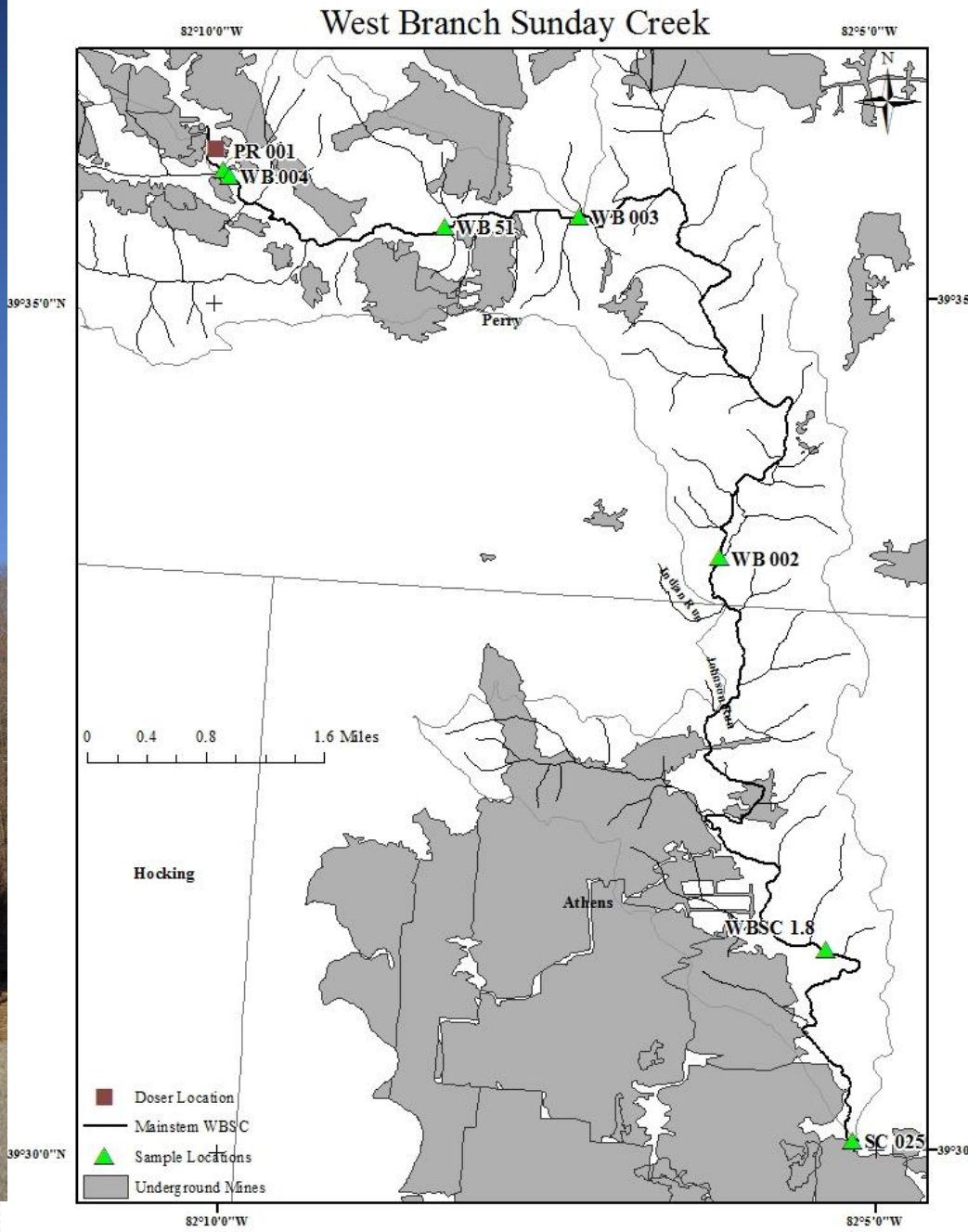
Inset of Study Watersheds



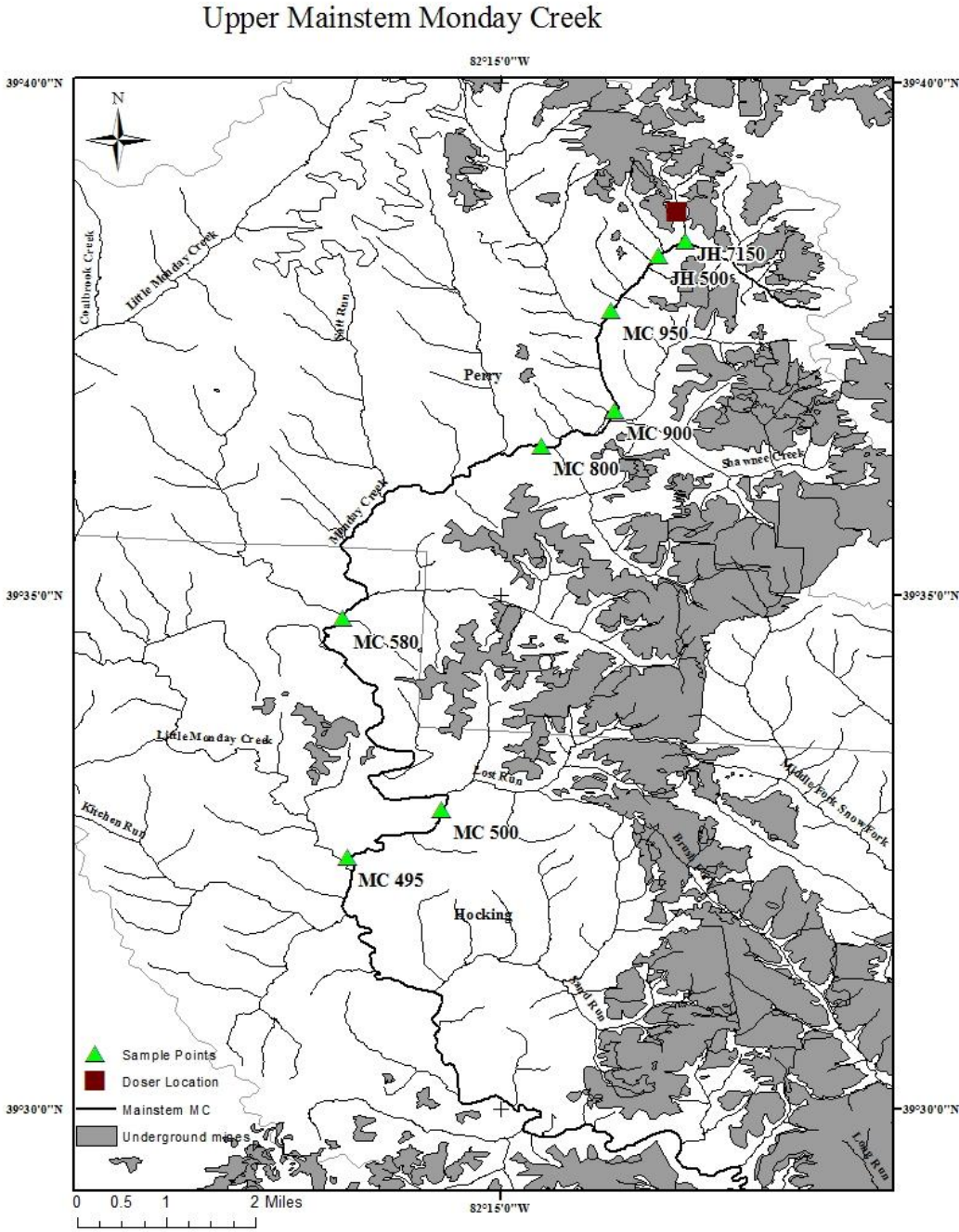
Map showing doser location and sample sites on Hewett Fork



Map showing doser location and sample sites on Thomas Fork



Map showing doser location and sample sites on West Branch Sunday Creek



Map showing doser location and sample sites on Upper Mainstem Monday Creek

Results and Discussion

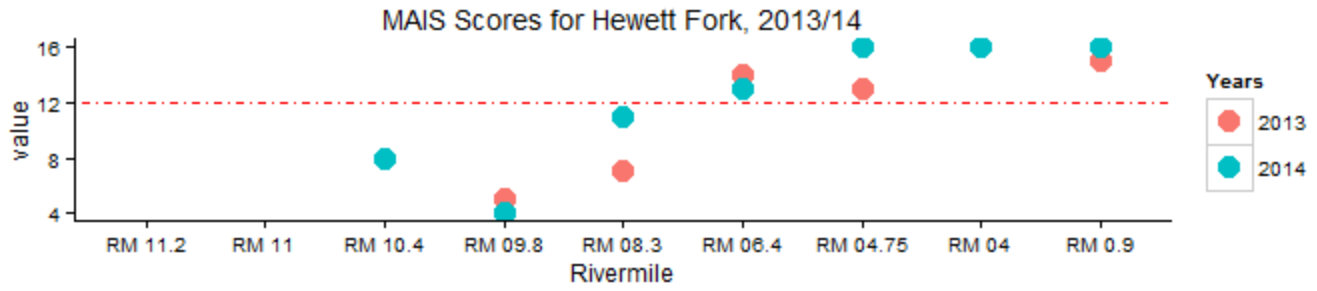
Influential Factors

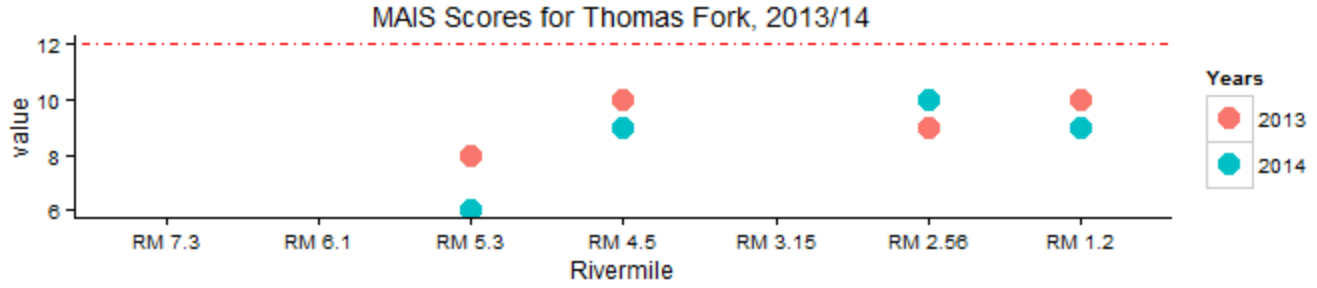
- Net Alkalinity
- Water Column Metal Concentration
- Fe Concentration

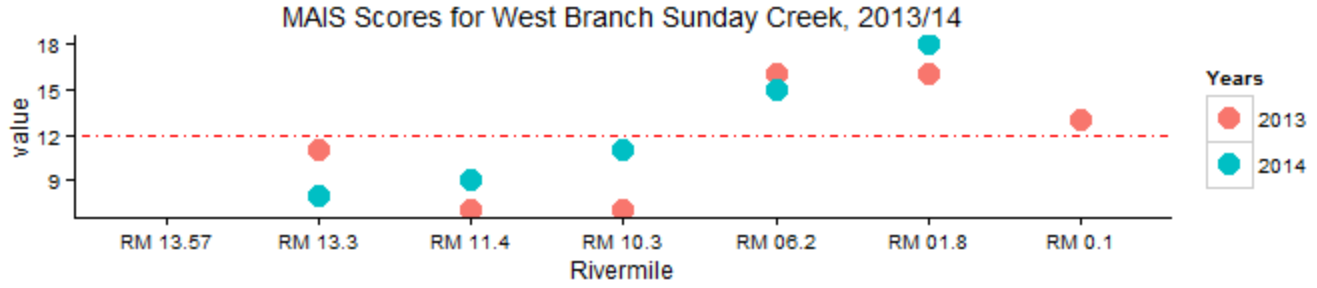
Water Quality criteria limits of an AMD impacted stream, FWPCA (1968)

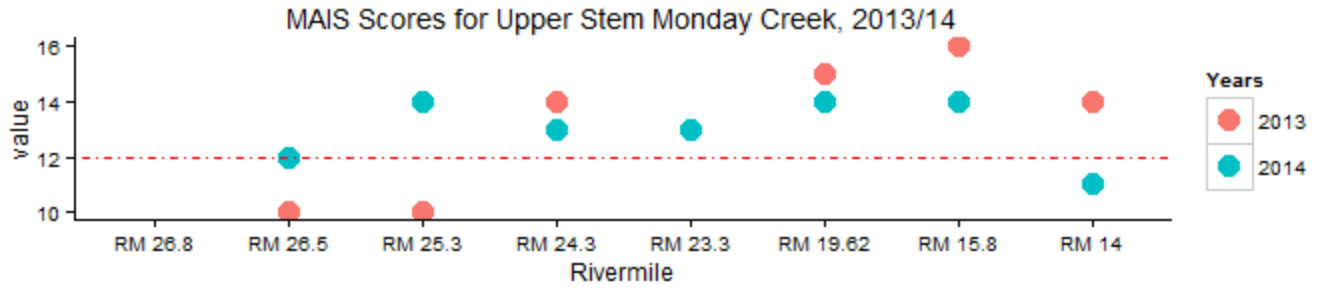
Parameter	Criteria Limit
pH	< 6.5 S.I.*
Conductivity	< 800 uS/cm
Alkalinity	< 20 mg/L
Sulfate	> 74 mg/L
Iron	> 0.5 mg/L
Manganese	> 0.5 mg/L
Aluminum	> 0.3 mg/L
Zinc	> 5 mg/L

* Ohio Non-Point Source Criteria Limit

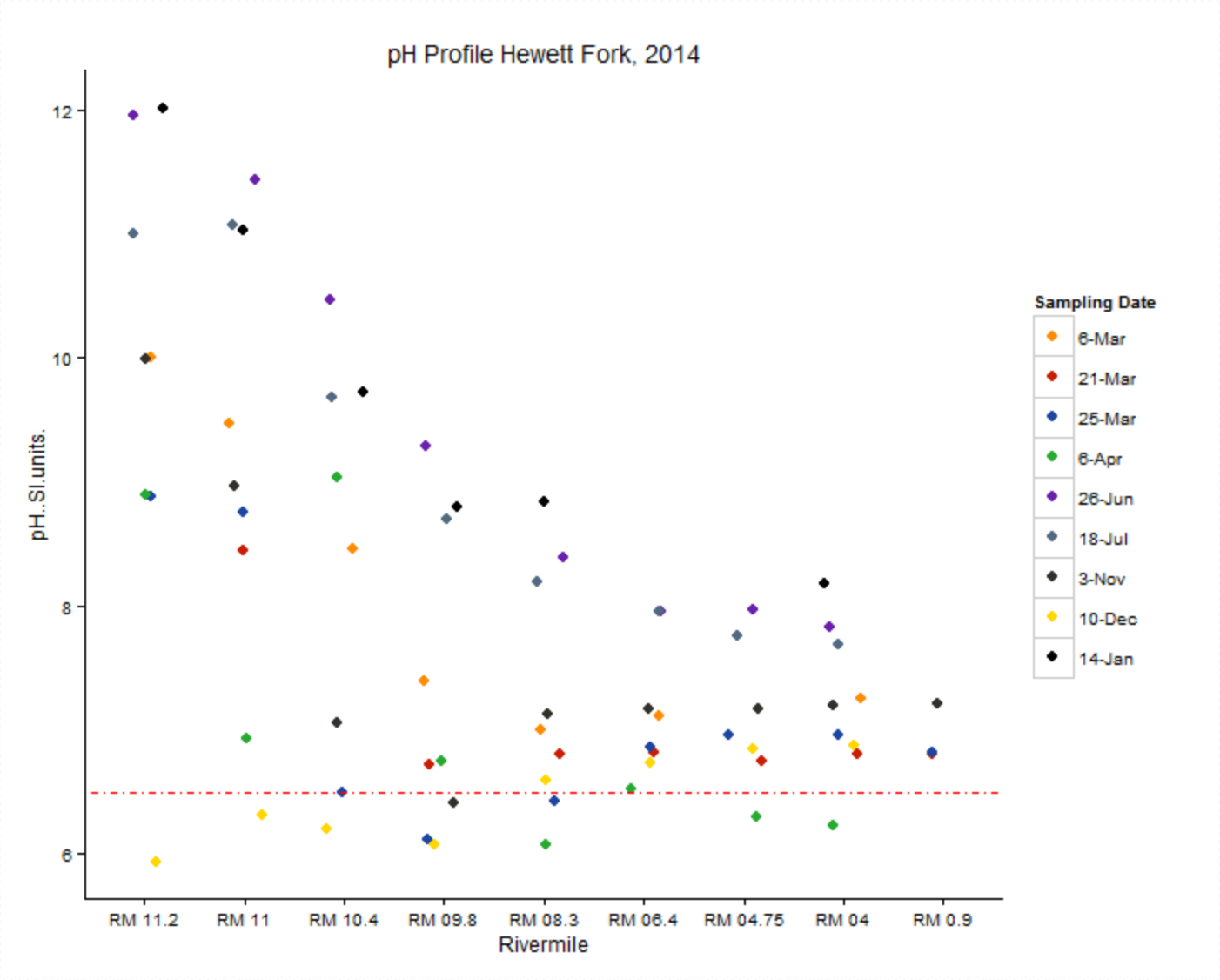

MAIS Scores for Hewett Fork, 2013/14
value
16
12
8
4
RM 11.2
RM 11
RM 10.4
RM 09.8
RM 08.3
RM 06.4
RM 04.75
RM 04
RM 0.9
Rivermile
Years
2013
2014

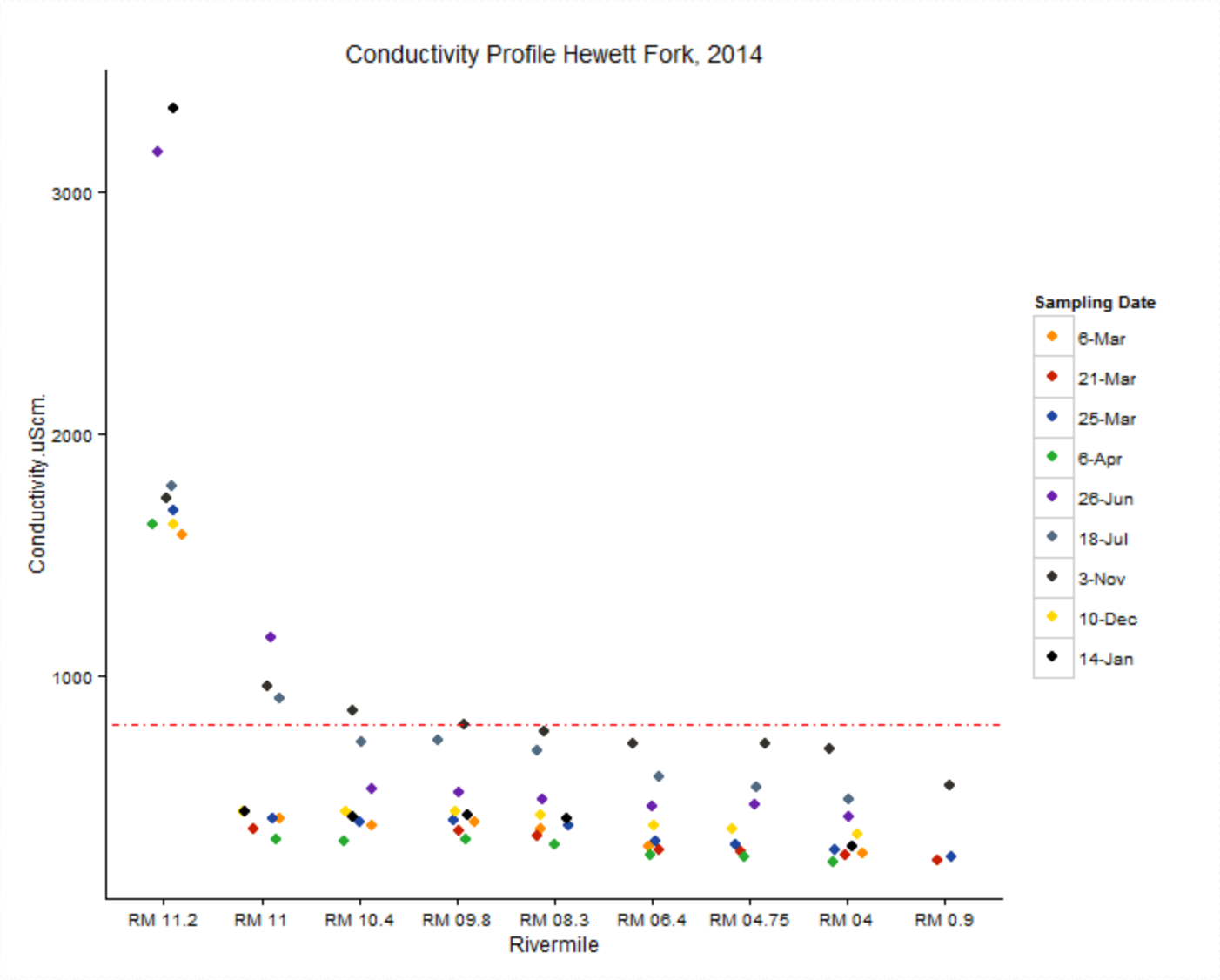

MAIS Scores for Thomas Fork, 2013/14
value
12
10
8
6
RM 7.3
RM 6.1
RM 5.3
RM 4.5
RM 3.15
RM 2.56
RM 1.2
Rivermile
Years
2013
2014


MAIS Scores for West Branch Sunday Creek, 2013/14
value
18
15
12
9
RM 13.57
RM 13.3
RM 11.4
RM 10.3
RM 06.2
RM 01.8
RM 0.1
Rivermile
Years
2013
2014


MAIS Scores for Upper Stem Monday Creek, 2013/14
value
16
14
12
10
RM 26.8
RM 26.5
RM 25.3
RM 24.3
RM 23.3
RM 19.62
RM 15.8
RM 14
Rivermile
Years
2013
2014

Hewett Fork


pH Profile Hewett Fork, 2014
pH..SI.units.
12
10
8
6
RM 11.2
RM 11
RM 10.4
RM 09.8
RM 08.3
RM 06.4
RM 04.75
RM 04
RM 0.9
Rivermile
Sampling Date
6-Mar
21-Mar
25-Mar
6-Apr
26-Jun
18-Jul
3-Nov
10-Dec
14-Jan


Conductivity Profile Hewett Fork, 2014
Conductivity.uScm.
3000
2000
1000
RM 11.2
RM 11
RM 10.4
RM 09.8
RM 08.3
RM 06.4
RM 04.75
RM 04
RM 0.9
Rivermile
Sampling Date
6-Mar
21-Mar
25-Mar
6-Apr
26-Jun
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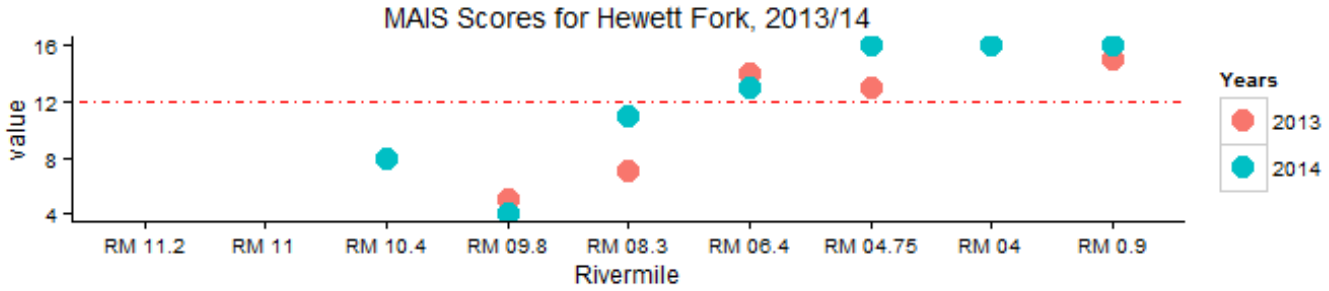
10-Dec
14-Jan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16
12
8
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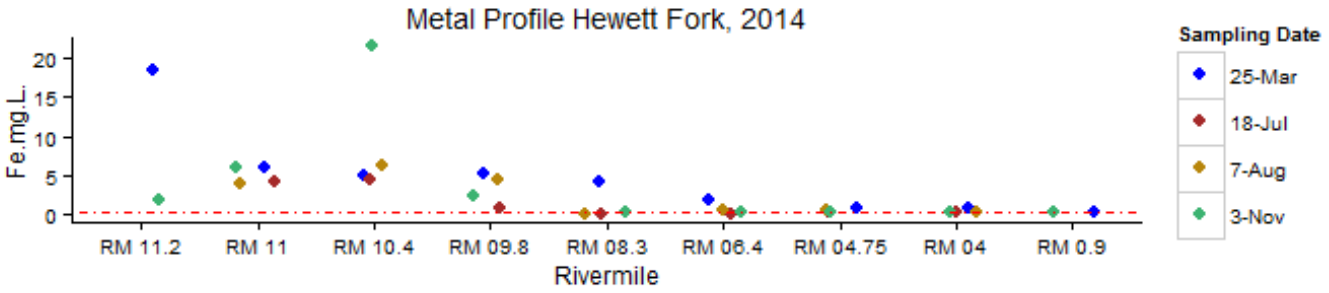
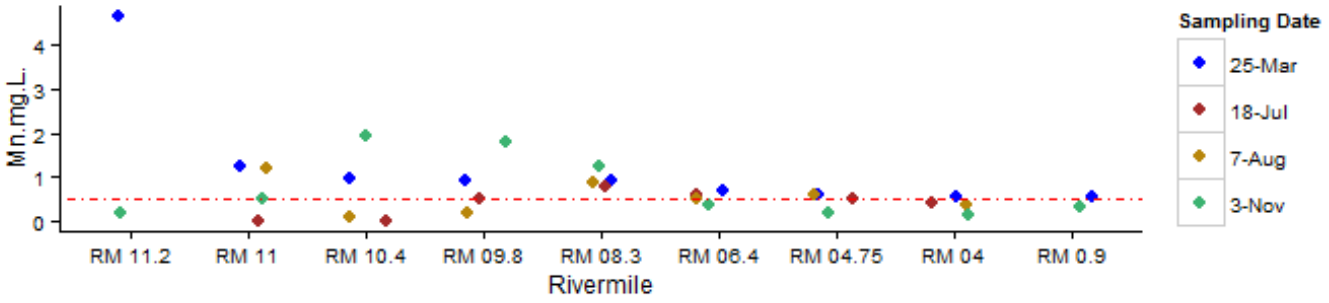
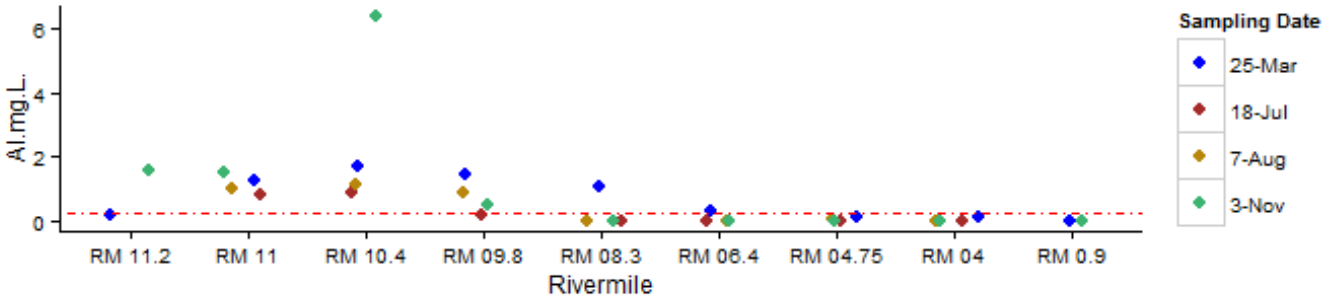

Metal Profile Hewett Fork, 2014
Fe.mg.L.
20
15
10
5
0
RM 11.2
RM 11
RM 10.4
RM 09.8
RM 08.3
RM 06.4
RM 04.75
RM 04
RM 0.9
Rivermile
Sampling Date
25-Mar
18-Jul
7-Aug
3-Nov


Mn.mg.L.
4
3
2
1
0
RM 11.2
RM 11
RM 10.4
RM 09.8
RM 08.3
RM 06.4
RM 04.75
RM 04
RM 0.9
Rivermile
Sampling Date
25-Mar
18-Jul
7-Aug
3-Nov


Al.mg.L.
6
4
2
0
RM 11.2
RM 11
RM 10.4
RM 09.8
RM 08.3
RM 06.4
RM 04.75
RM 04
RM 0.9
Rivermile
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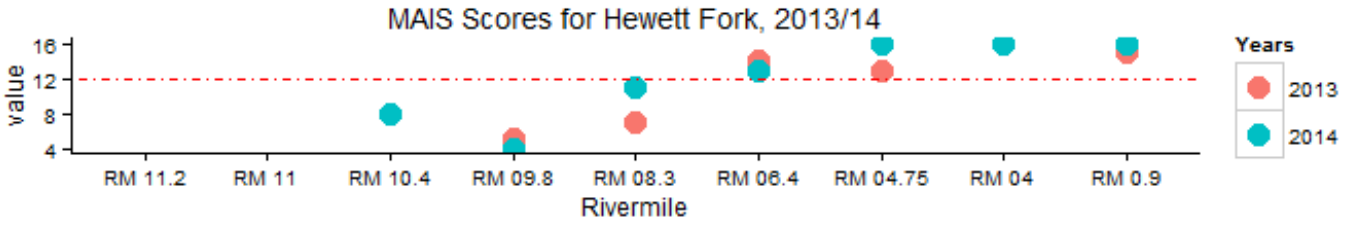
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16
12
8
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Rivermile
Years
2013
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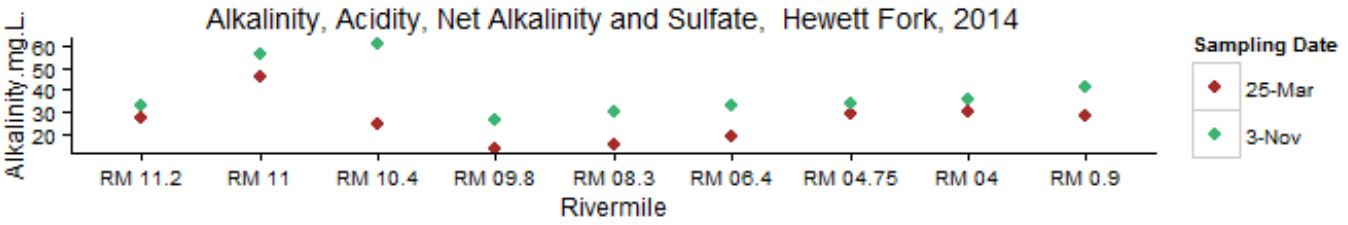
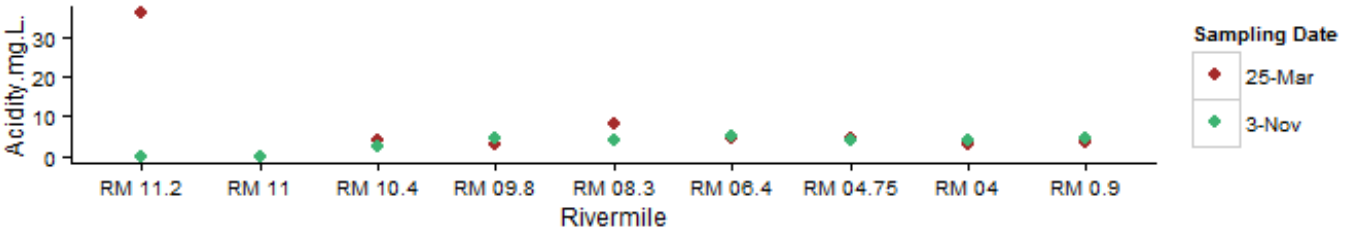
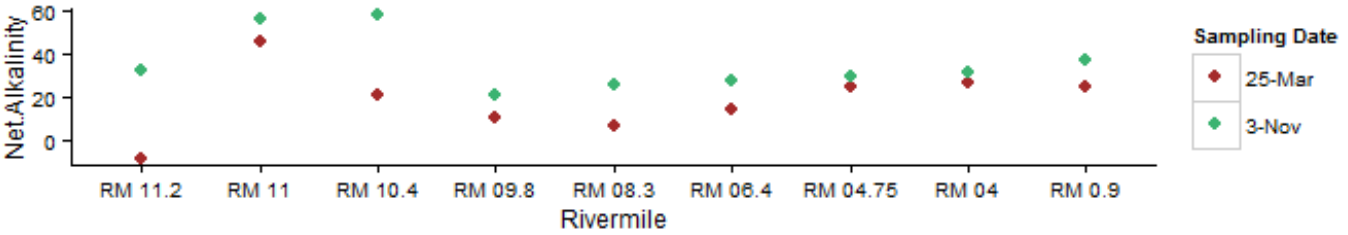
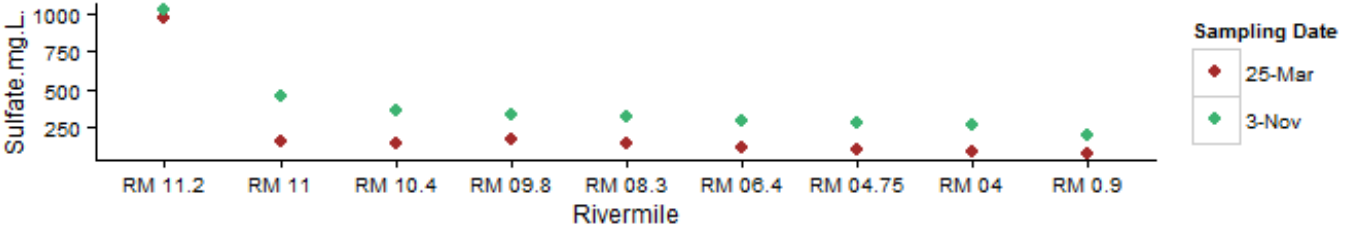
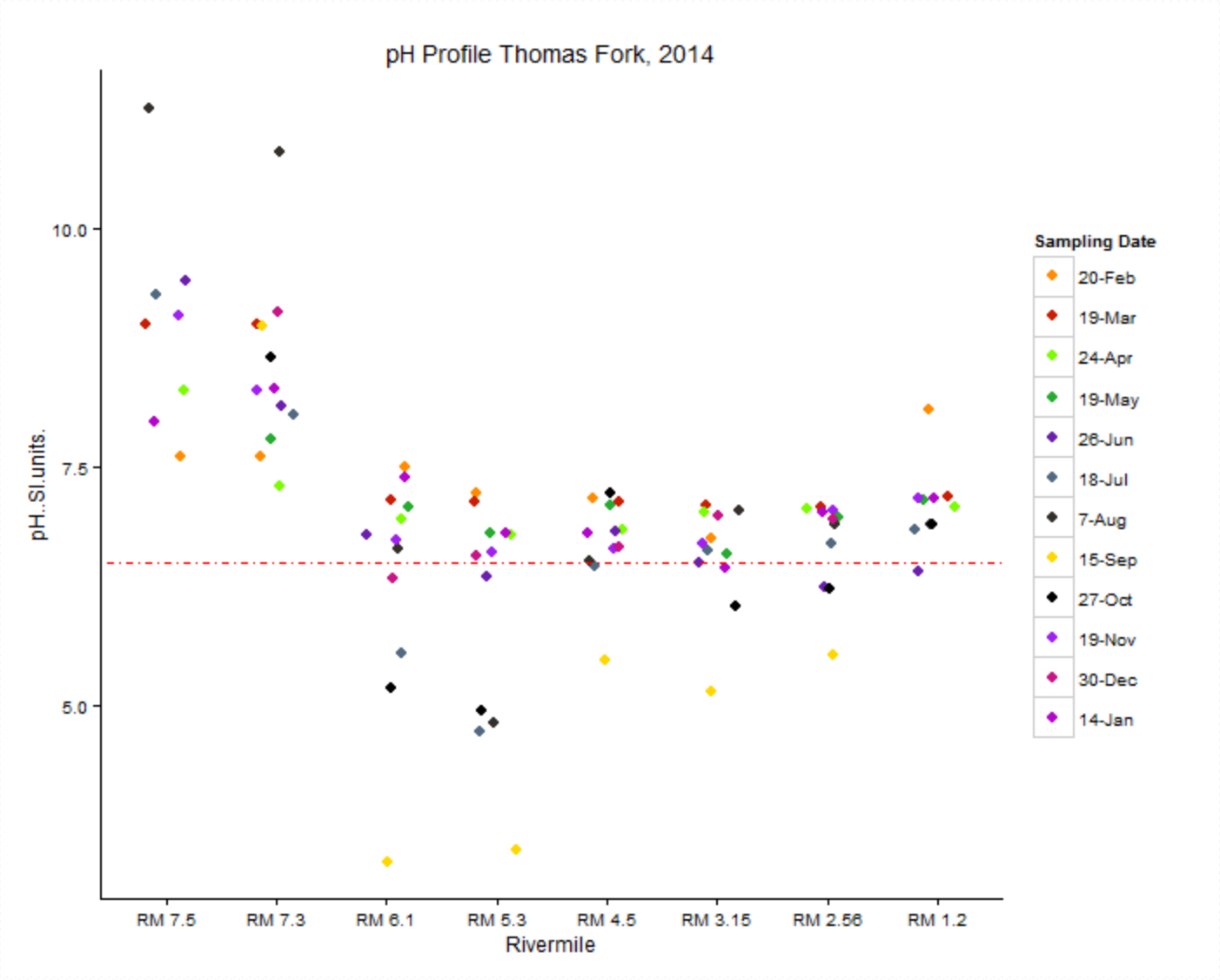

Alkalinity, Acidity, Net Alkalinity and Sulfate, Hewett Fork, 2014
Alkalinity.mg.L.
60
50
40
30
20
RM 11.2
RM 11
RM 10.4
RM 09.8
RM 08.3
RM 06.4
RM 04.75
RM 04
RM 0.9
Rivermile
Sampling Date
25-Mar
3-Nov

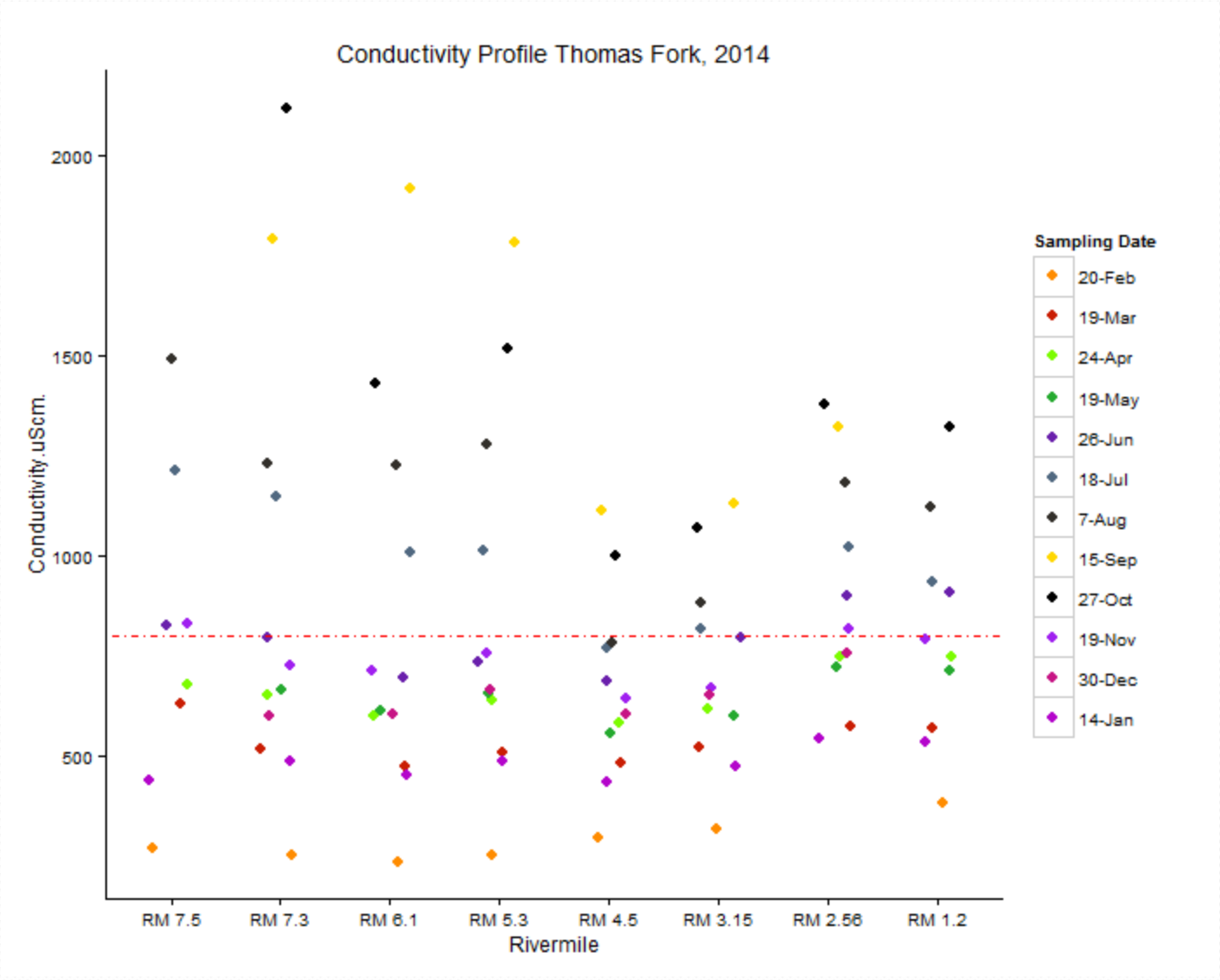

Acidity.mg.L.
30
20
10
0
RM 11.2
RM 11
RM 10.4
RM 09.8
RM 08.3
RM 06.4
RM 04.75
RM 04
RM 0.9
Rivermile
Sampling Date
25-Mar
3-Nov


Net.Alkalinity
60
40
20
0
RM 11.2
RM 11
RM 10.4
RM 09.8
RM 08.3
RM 06.4
RM 04.75
RM 04
RM 0.9
Rivermile
Sampling Date
25-Mar
3-Nov


Sulfate.mg.L.
1000
750
500
250
RM 11.2
RM 11
RM 10.4
RM 09.8
RM 08.3
RM 06.4
RM 04.75
RM 04
RM 0.9
Rivermile
Sampling Date
25-Mar
3-Nov

Thomas Fork


pH Profile Thomas Fork, 2014
pH..SI.units.
10.0
7.5
5.0
RM 7.5
RM 7.3
RM 6.1
RM 5.3
RM 4.5
RM 3.15
RM 2.56
RM 1.2
Rivermile
Sampling Date
20-Feb
19-Mar
24-Apr
19-May
26-Jun
18-Jul
7-Aug
15-Sep
27-Oct
19-Nov
30-Dec
14-Jan


Conductivity Profile Thomas Fork, 2014
Conductivity.uScm.
2000
1500
1000
500
RM 7.5
RM 7.3
RM 6.1
RM 5.3
RM 4.5
RM 3.15
RM 2.56
RM 1.2
Rivermile
Sampling Date
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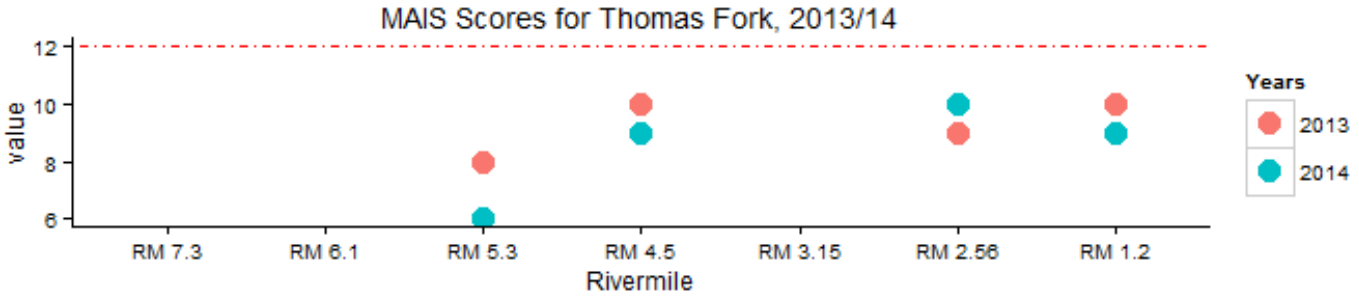
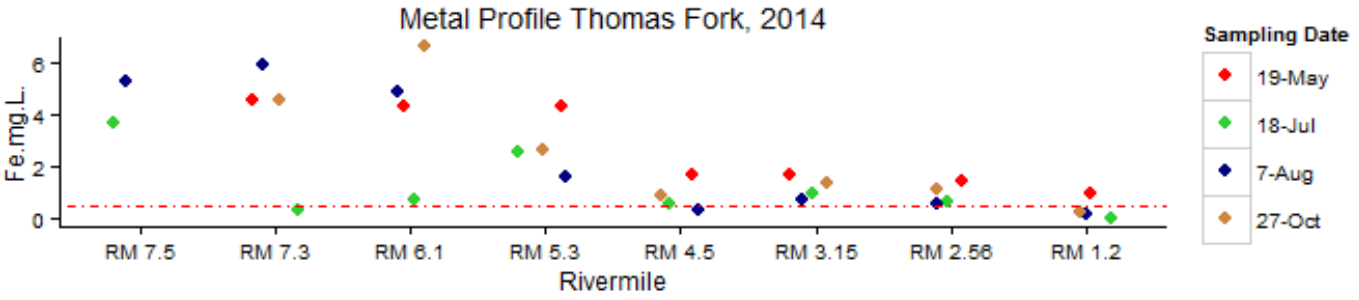
14-Jan


MAIS Scores for Thomas Fork, 2013/14
value
12
10
8
6
RM 7.3
RM 6.1
RM 5.3
RM 4.5
RM 3.15
RM 2.56
RM 1.2
Rivermile
Years
2013
2014


Metal Profile Thomas Fork, 2014
Fe.mg.L.
6
4
2
0
RM 7.5
RM 7.3
RM 6.1
RM 5.3
RM 4.5
RM 3.15
RM 2.56
RM 1.2
Rivermile
Sampling Date
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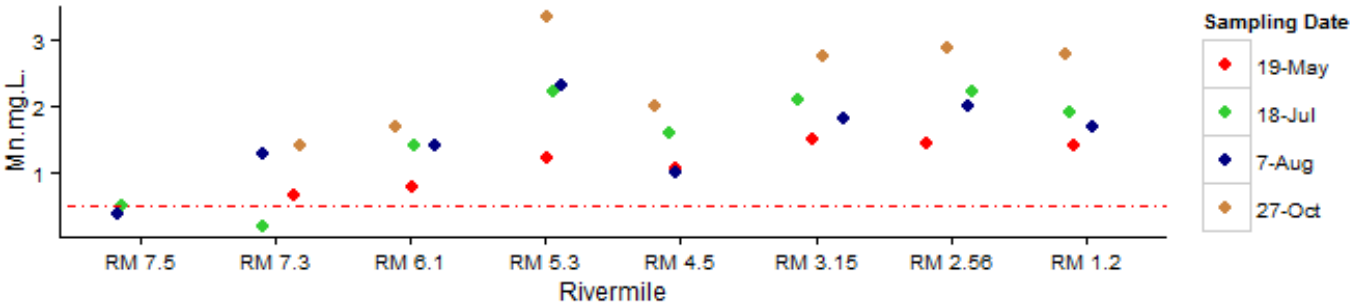
Mn.mg.L.
3
2
1
RM 7.5
RM 7.3
RM 6.1
RM 5.3
RM 4.5
RM 3.15
RM 2.56
RM 1.2
Rivermile
Sampling Date
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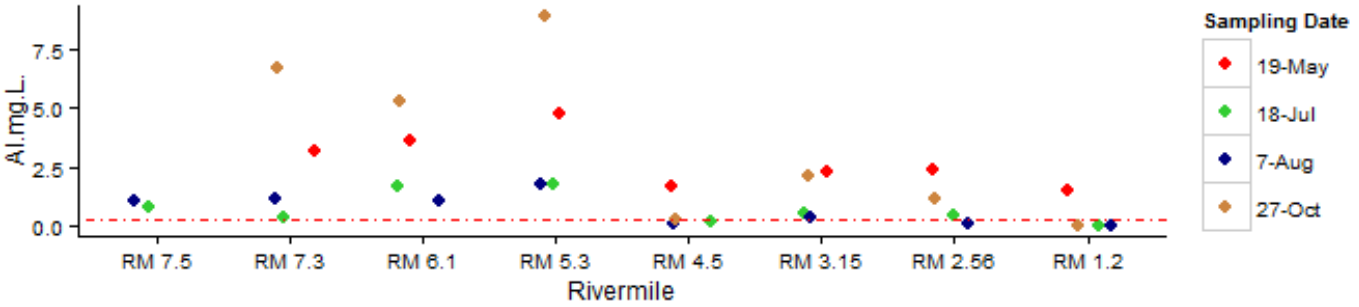
27-Oct


Al.mg.L.
7.5
5.0
2.5
0.0
RM 7.5
RM 7.3
RM 6.1
RM 5.3
RM 4.5
RM 3.15
RM 2.56
RM 1.2
Rivermile
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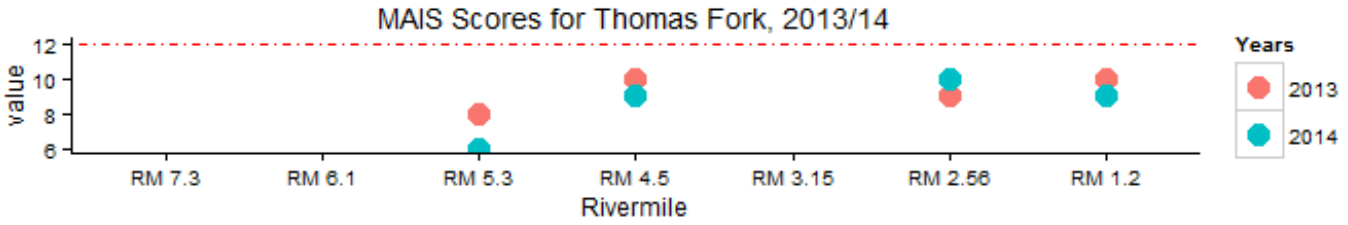
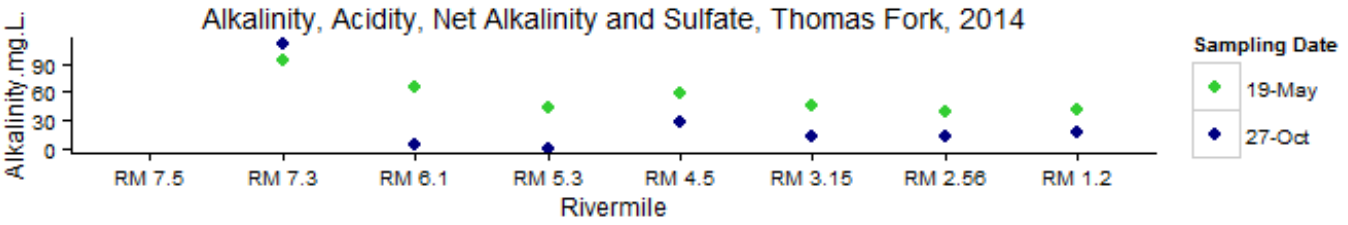
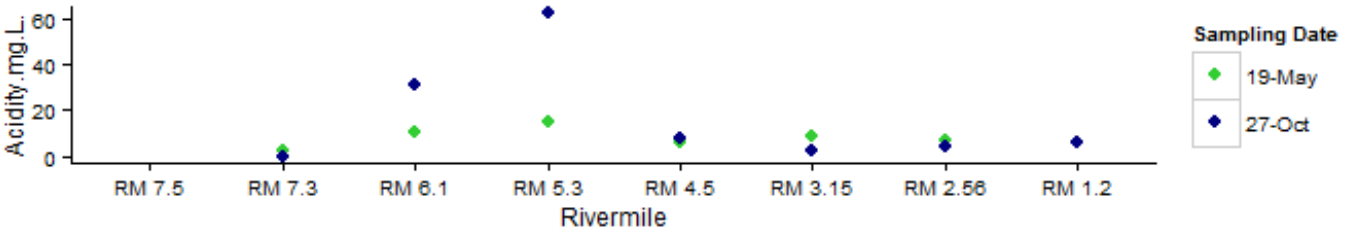

MAIS Scores for Thomas Fork, 2013/14
value
12
10
8
6
RM 7.3
RM 6.1
RM 5.3
RM 4.5
RM 3.15
RM 2.56
RM 1.2
Rivermile
Years
2013
2014


Alkalinity, Acidity, Net Alkalinity and Sulfate, Thomas Fork, 2014
Alkalinity.mg.L.
90
60
30
0
RM 7.5
RM 7.3
RM 6.1
RM 5.3
RM 4.5
RM 3.15
RM 2.56
RM 1.2
Rivermile
Sampling Date
19-May
27-Oct


Acidity.mg.L.
60
40
20
0
RM 7.5
RM 7.3
RM 6.1
RM 5.3
RM 4.5
RM 3.15
RM 2.56
RM 1.2
Rivermile
Sampling Date
19-May
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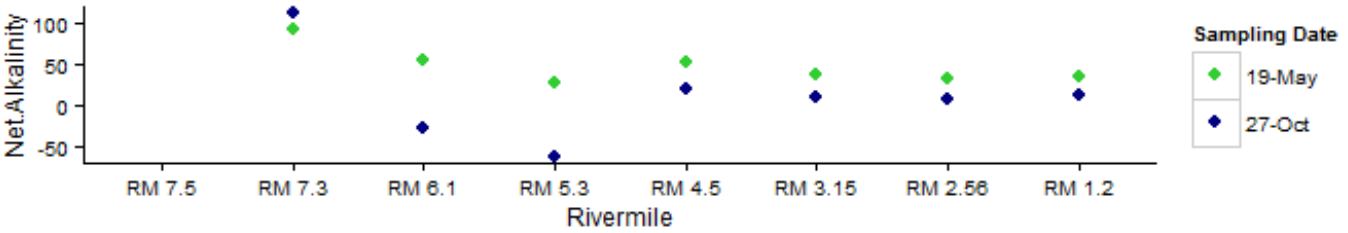
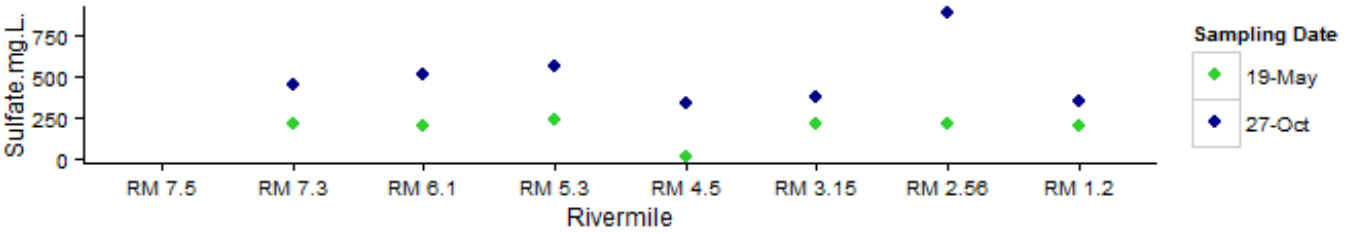

Net.Alkalinity
100
50
0
-50
RM 7.5
RM 7.3
RM 6.1
RM 5.3
RM 4.5
RM 3.15
RM 2.56
RM 1.2
Rivermile
Sampling Date
19-May
27-Oct


Sulfate.mg.L.
750
500
250
0
RM 7.5
RM 7.3
RM 6.1
RM 5.3
RM 4.5
RM 3.15
RM 2.56
RM 1.2
Rivermile
Sampling Date
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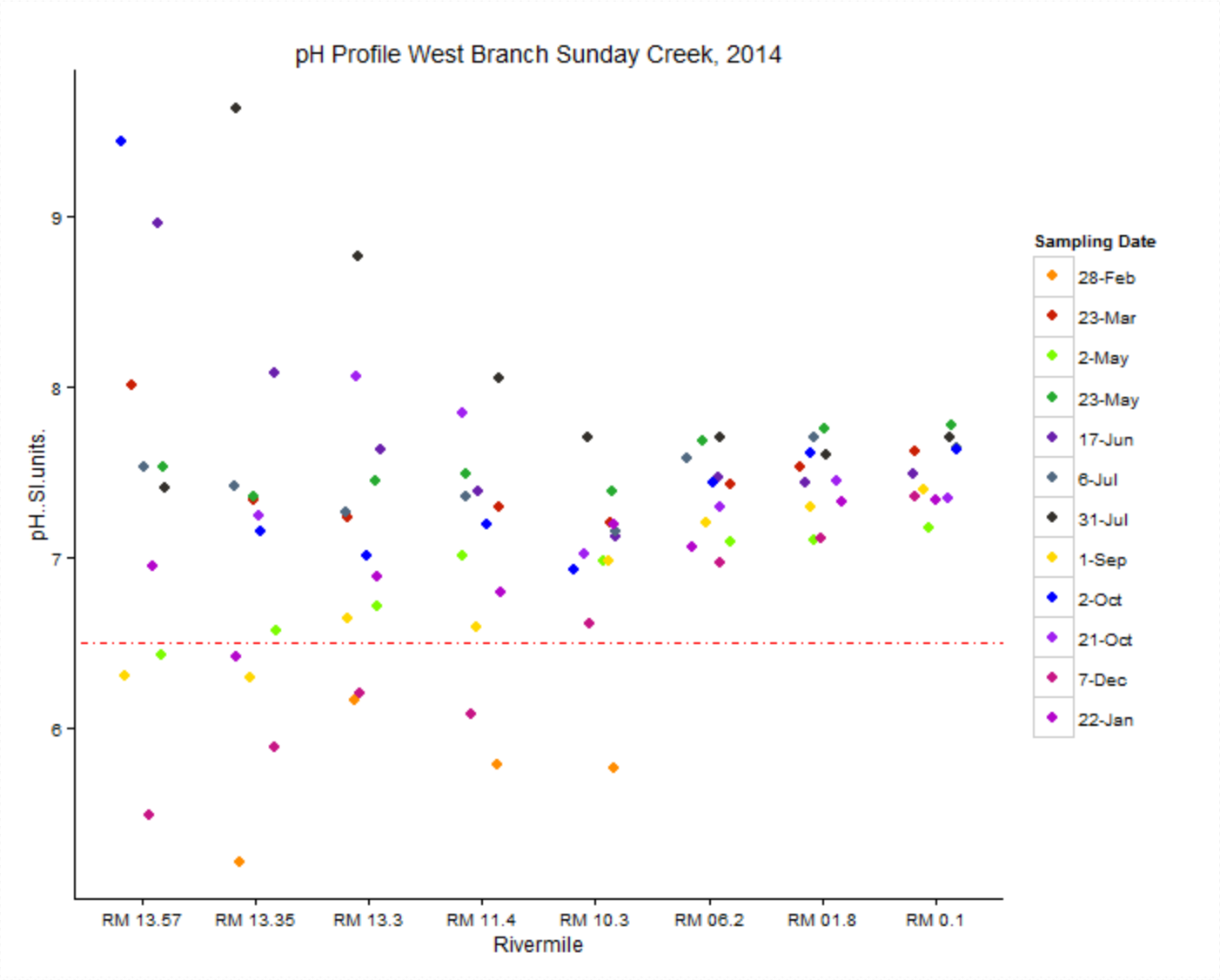
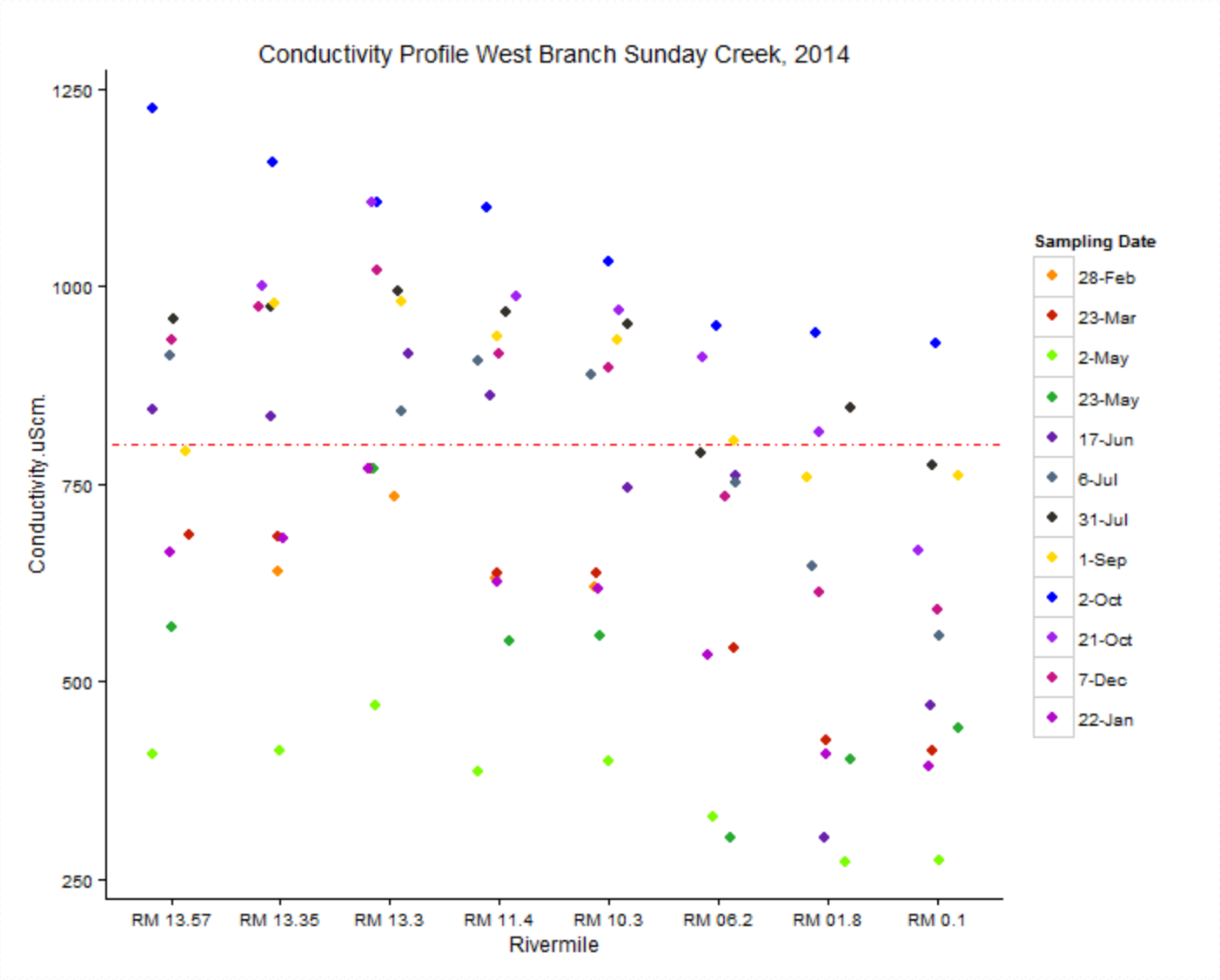
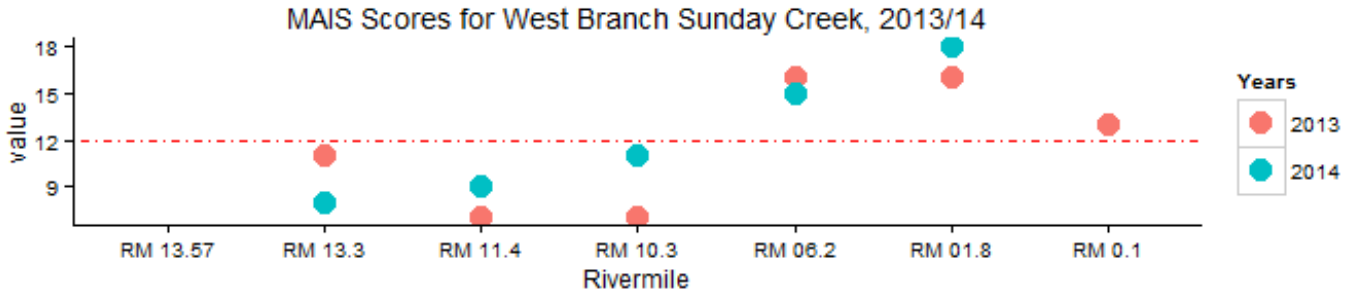
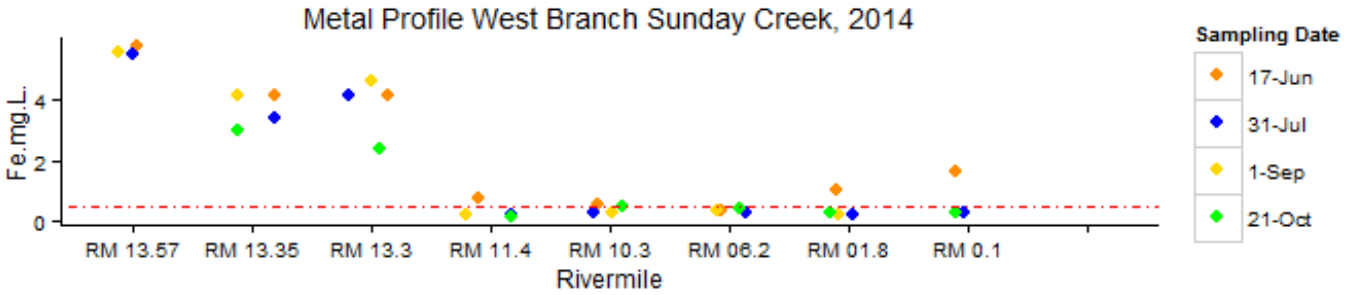
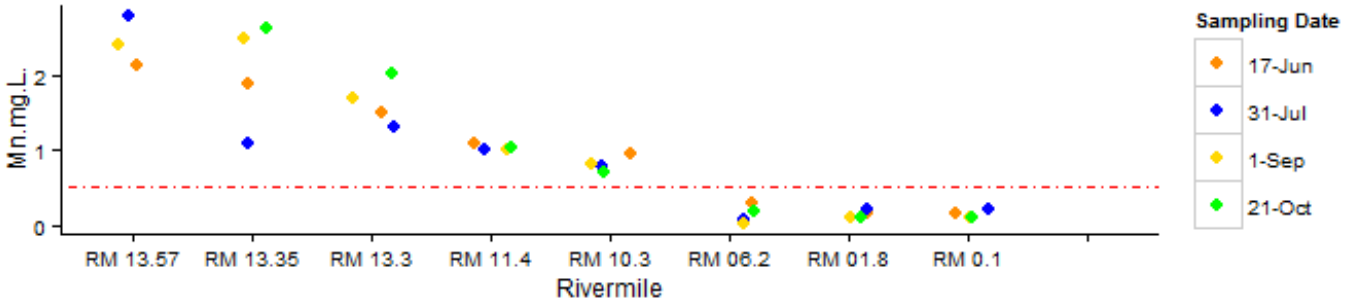
West Branch Sunday Creek

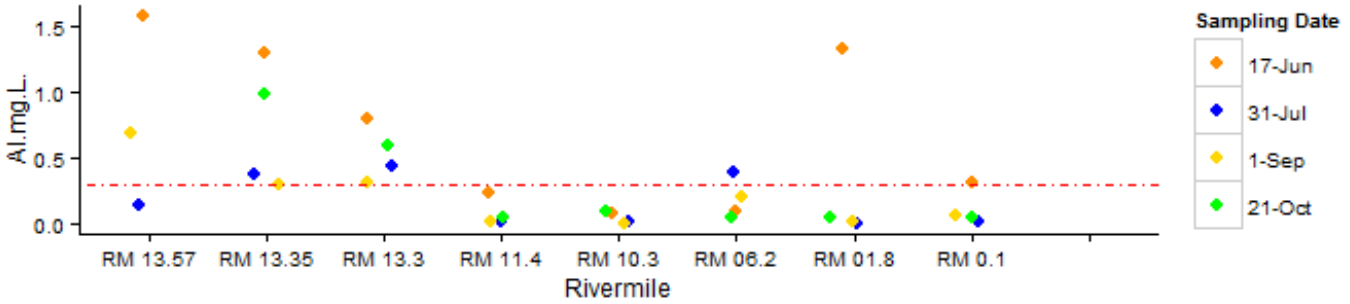


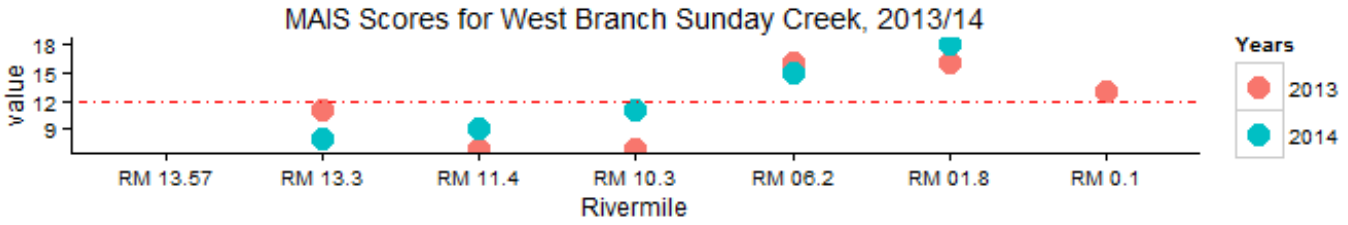

Conductivity Profile West Branch Sunday Creek, 2014
Conductivity.uScm.
1250
1000
750
500
250
RM 13.57
RM 13.35
RM 13.3
RM 11.4
RM 10.3
RM 06.2
RM 01.8
RM 0.1
Rivermile
Sampling Date
28-Feb
23-Mar
2-May
23-May
17-Jun
6-Jul
31-Jul
1-Sep
2-Oct
21-Oct
7-Dec
22-Jan

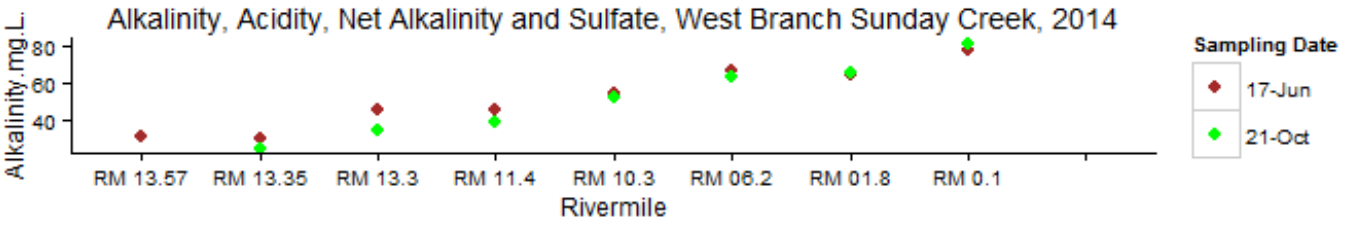

MAIS Scores for West Branch Sunday Creek, 2013/14
value
18
15
12
9
RM 13.57
RM 13.3
RM 11.4
RM 10.3
RM 06.2
RM 01.8
RM 0.1
Rivermile
Years
2013
2014

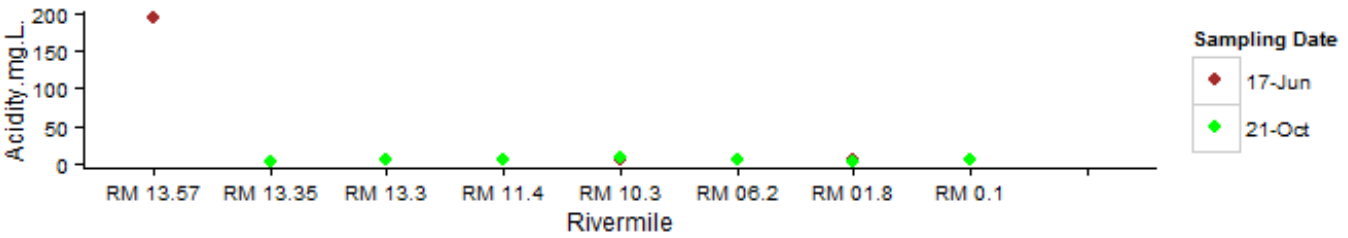

Metal Profile West Branch Sunday Creek, 2014
Fe.mg.L.
4
2
0
RM 13.57
RM 13.35
RM 13.3
RM 11.4
RM 10.3
RM 06.2
RM 01.8
RM 0.1
Rivermile
Sampling Date
17-Jun
31-Jul
1-Sep
21-Oct

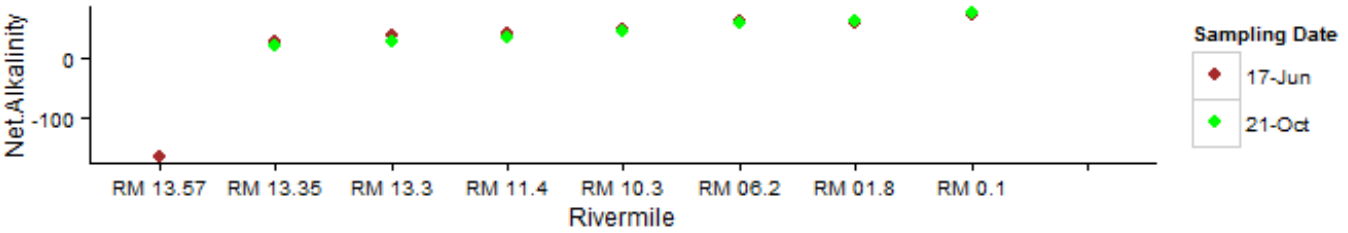

Mn.mg.L.
2
1
0
RM 13.57
RM 13.35
RM 13.3
RM 11.4
RM 10.3
RM 06.2
RM 01.8
RM 0.1
Rivermile
Sampling Date
17-Jun
31-Jul
1-Sep
21-Oct

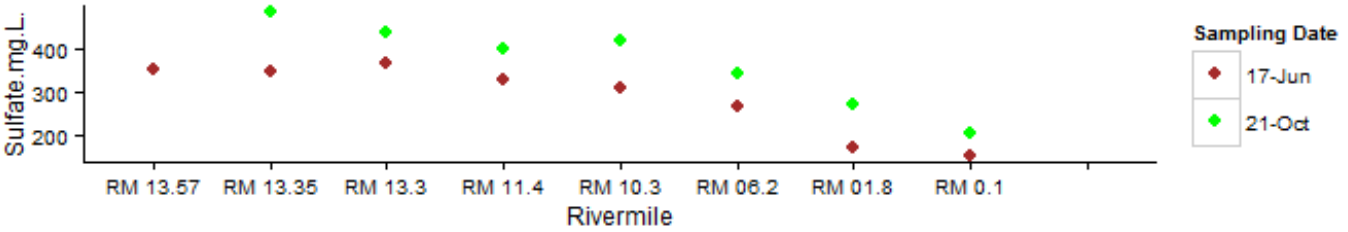

Al.mg.L.
1.5
1.0
0.5
0.0
RM 13.57
RM 13.35
RM 13.3
RM 11.4
RM 10.3
RM 06.2
RM 01.8
RM 0.1
Rivermile
Sampling Date
17-Jun
31-Jul
1-Sep
21-Oct


MAIS Scores for West Branch Sunday Creek, 2013/14
value
18
15
12
9
RM 13.57
RM 13.3
RM 11.4
RM 10.3
RM 06.2
RM 01.8
RM 0.1
Rivermile
Years
2013
2014

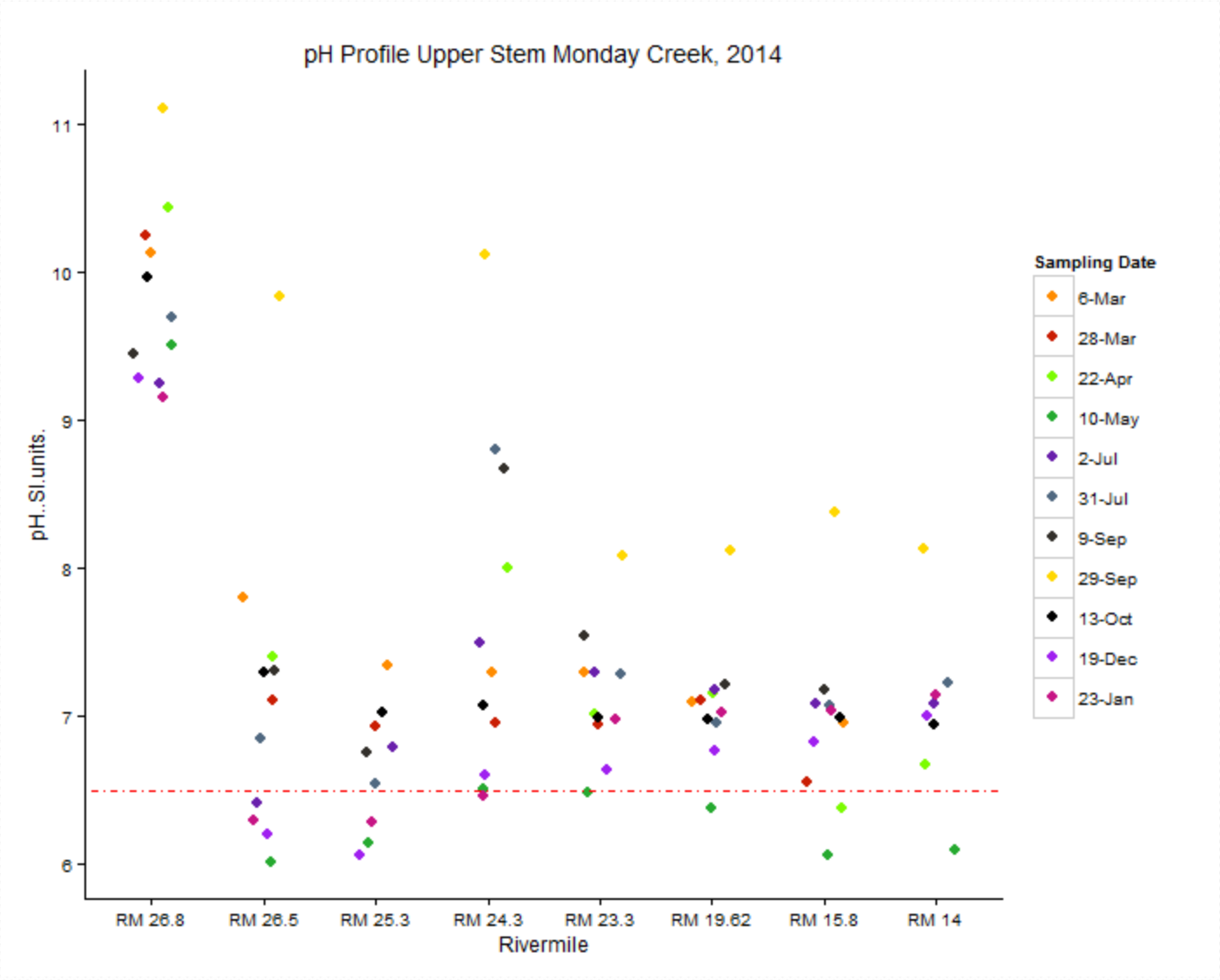

Alkalinity, Acidity, Net Alkalinity and Sulfate, West Branch Sunday Creek, 2014
Alkalinity.mg.L.
80
60
40
RM 13.57
RM 13.35
RM 13.3
RM 11.4
RM 10.3
RM 06.2
RM 01.8
RM 0.1
Rivermile
Sampling Date
17-Jun
21-Oct

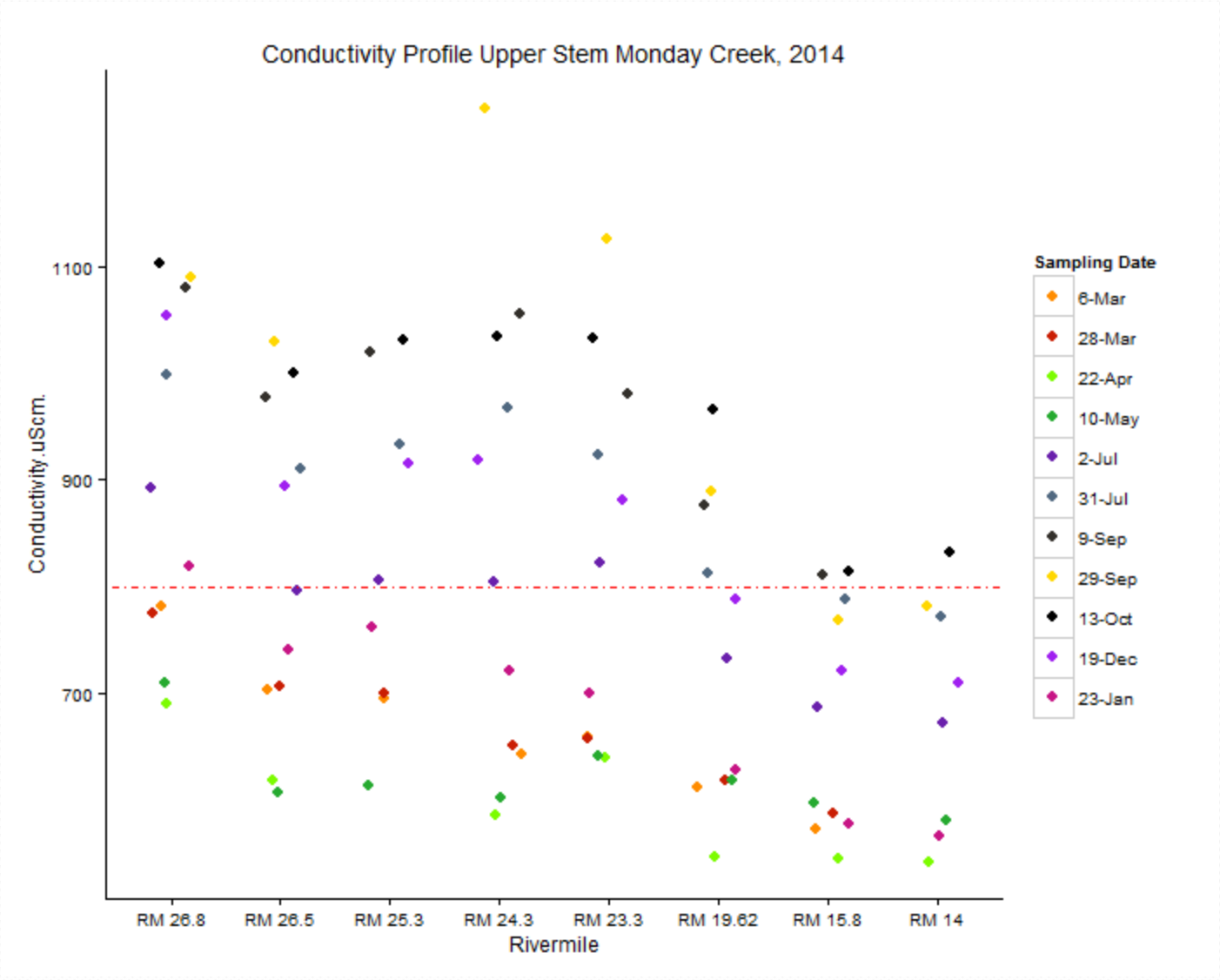

Acidity.mg.L.
200
150
100
50
0
RM 13.57
RM 13.35
RM 13.3
RM 11.4
RM 10.3
RM 06.2
RM 01.8
RM 0.1
Rivermile
Sampling Date
17-Jun
21-Oct

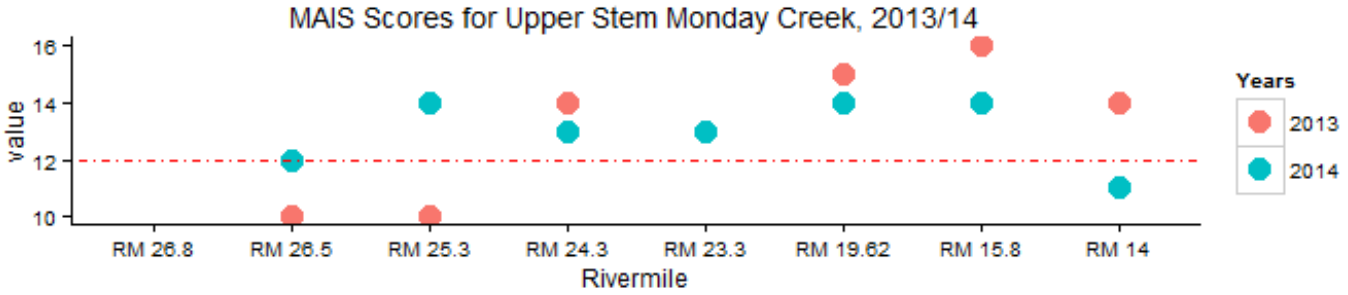

Net.Alkalinity
0
-100
RM 13.57
RM 13.35
RM 13.3
RM 11.4
RM 10.3
RM 06.2
RM 01.8
RM 0.1
Rivermile
Sampling Date
17-Jun
21-Oct

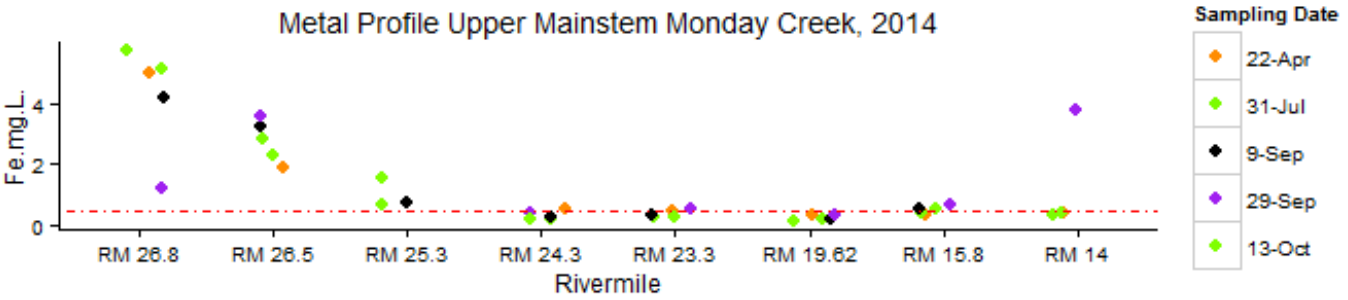

Sulfate.mg.L.
400
300
200
RM 13.57
RM 13.35
RM 13.3
RM 11.4
RM 10.3
RM 06.2
RM 01.8
RM 0.1
Rivermile
Sampling Date
17-Jun
21-Oct

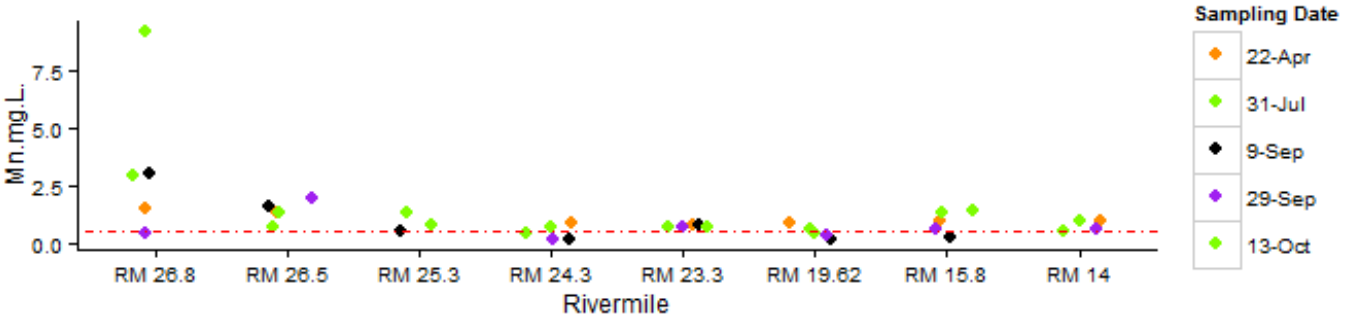
Monday Creek

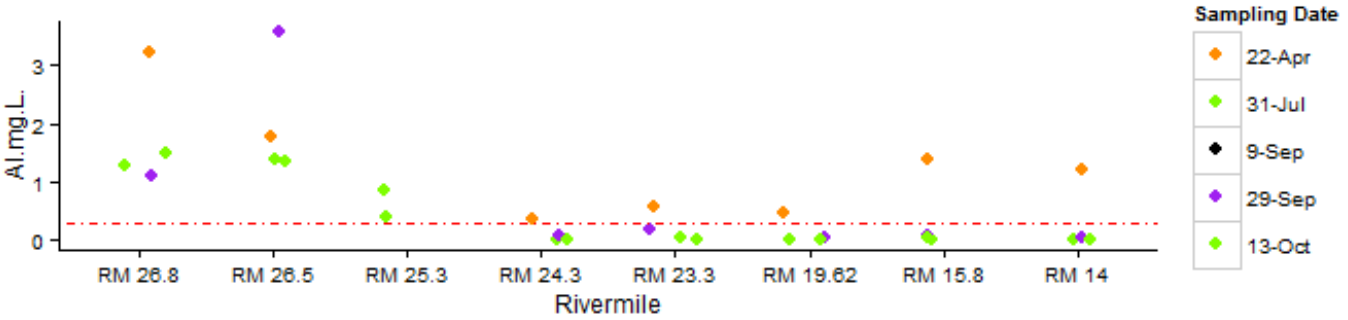


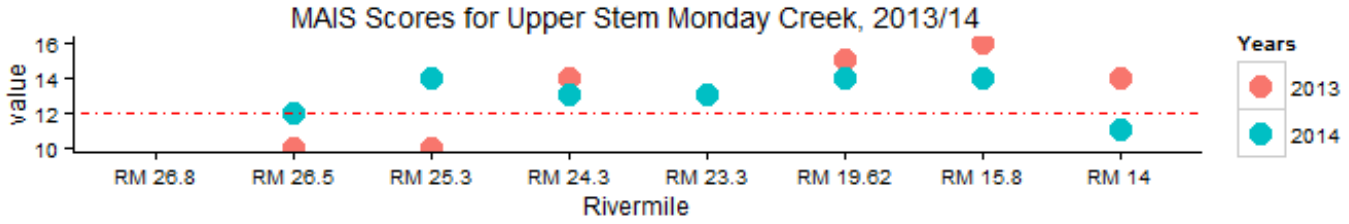

Conductivity Profile Upper Stem Monday Creek, 2014
Conductivity.uScm.
1100
900
700
RM 26.8
RM 26.5
RM 25.3
RM 24.3
RM 23.3
RM 19.62
RM 15.8
RM 14
Rivermile
Sampling Date
6-Mar
28-Mar
22-Apr
10-May
2-Jul
31-Jul
9-Sep
29-Sep
13-Oct
19-Dec
23-Jan

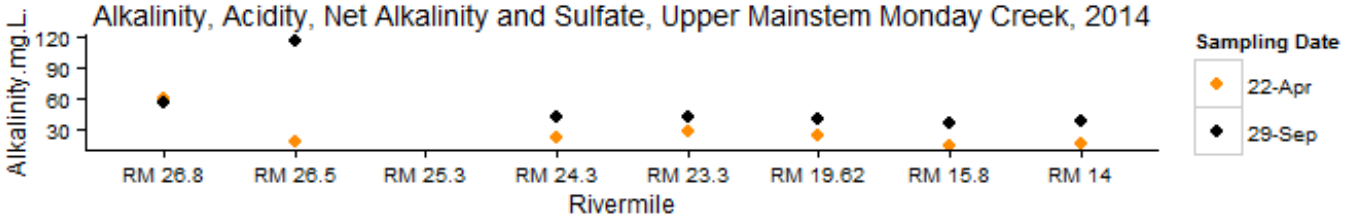

MAIS Scores for Upper Stem Monday Creek, 2013/14
value
16
14
12
10
RM 26.8
RM 26.5
RM 25.3
RM 24.3
RM 23.3
RM 19.62
RM 15.8
RM 14
Rivermile
Years
2013
2014

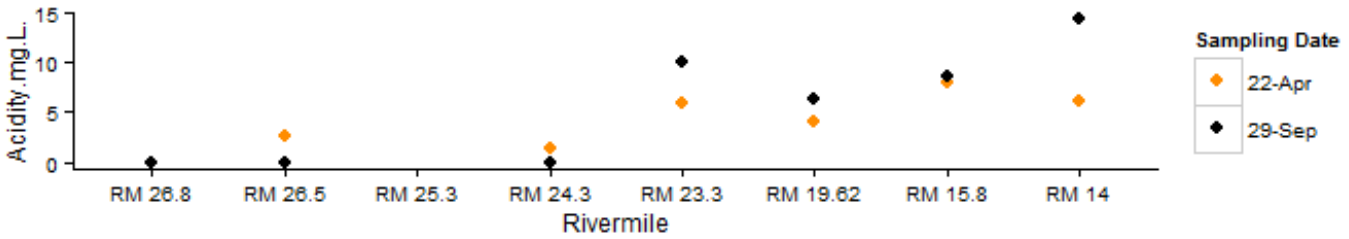

Metal Profile Upper Mainstem Monday Creek, 2014
Fe.mg.L.
4
2
0
RM 26.8
RM 26.5
RM 25.3
RM 24.3
RM 23.3
RM 19.62
RM 15.8
RM 14
Rivermile
Sampling Date
22-Apr
31-Jul
9-Sep
29-Sep
13-Oct

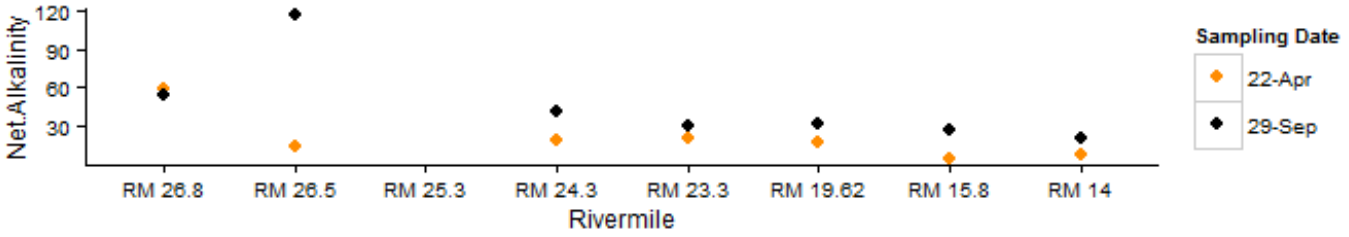

Mn.mg.L.
7.5
5.0
2.5
0.0
RM 26.8
RM 26.5
RM 25.3
RM 24.3
RM 23.3
RM 19.62
RM 15.8
RM 14
Rivermile
Sampling Date
22-Apr
31-Jul
9-Sep
29-Sep
13-Oct

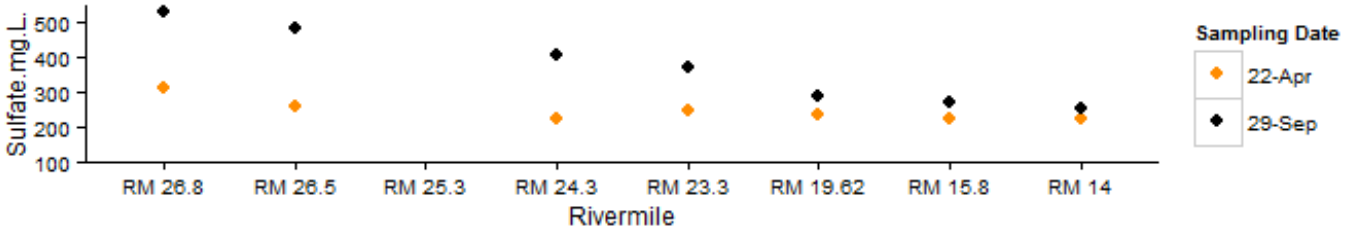

Al.mg.L.
3
2
1
0
RM 26.8
RM 26.5
RM 25.3
RM 24.3
RM 23.3
RM 19.62
RM 15.8
RM 14
Rivermile
Sampling Date
22-Apr
31-Jul
9-Sep
29-Sep
13-Oct


MAIS Scores for Upper Stem Monday Creek, 2013/14
value
16
14
12
10
RM 26.8
RM 26.5
RM 25.3
RM 24.3
RM 23.3
RM 19.62
RM 15.8
RM 14
Rivermile
Years
2013
2014


Alkalinity, Acidity, Net Alkalinity and Sulfate, Upper Mainstem Monday Creek, 2014
Alkalinity.mg.L.
120
90
60
30
RM 26.8
RM 26.5
RM 25.3
RM 24.3
RM 23.3
RM 19.62
RM 15.8
RM 14
Rivermile
Sampling Date
22-Apr
29-Sep


Acidity.mg.L.
15
10
5
0
RM 26.8
RM 26.5
RM 25.3
RM 24.3
RM 23.3
RM 19.62
RM 15.8
RM 14
Rivermile
Sampling Date
22-Apr
29-Sep


Net.Alkalinity
120
90
60
30
RM 26.8
RM 26.5
RM 25.3
RM 24.3
RM 23.3
RM 19.62
RM 15.8
RM 14
Rivermile
Sampling Date
22-Apr
29-Sep


Sulfate.mg.L.
500
400
300
200
100
RM 26.8
RM 26.5
RM 25.3
RM 24.3
RM 23.3
RM 19.62
RM 15.8
RM 14
Rivermile
Sampling Date
22-Apr
29-Sep

Correlations of Water Column Chemistry

Spearman correlations coefficient (r) matrix of MAIS scores, field parameters and stream chemistry

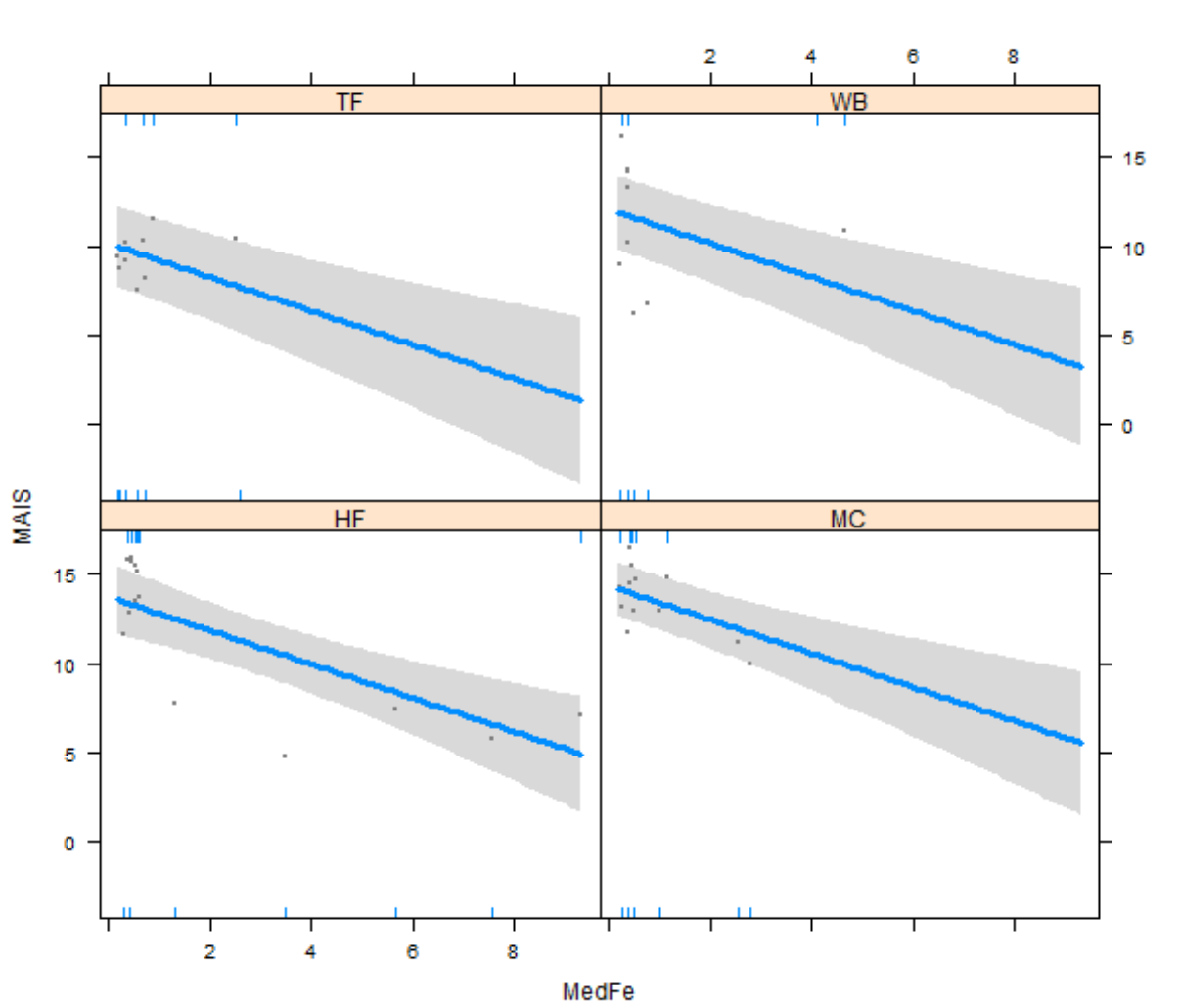
(Shaded boxes indicate significant correlations)

	MAIS	pH	Conductivity	Sulfate	Acidity	Alkalinity	Fe	Mn	Al
MAIS	.								
pH	0.232	.							
Conductivity	-0.307	0.151	.						
Sulfate	-0.452	0.034	0.765	.					
Acidity	-0.374	-0.458	0.177	0.195	.				
Alkalinity	0.24	0.504	0.069	-0.201	-0.415	.			
Fe	-0.511	0.041	0.093	0.307	0.019	-0.181	.		
Mn	-0.682	-0.204	0.424	0.589	0.356	-0.473	0.571	.	
Al	0.463	0.015	0.256	0.425	0.037	-0.149	0.809	0.581	.

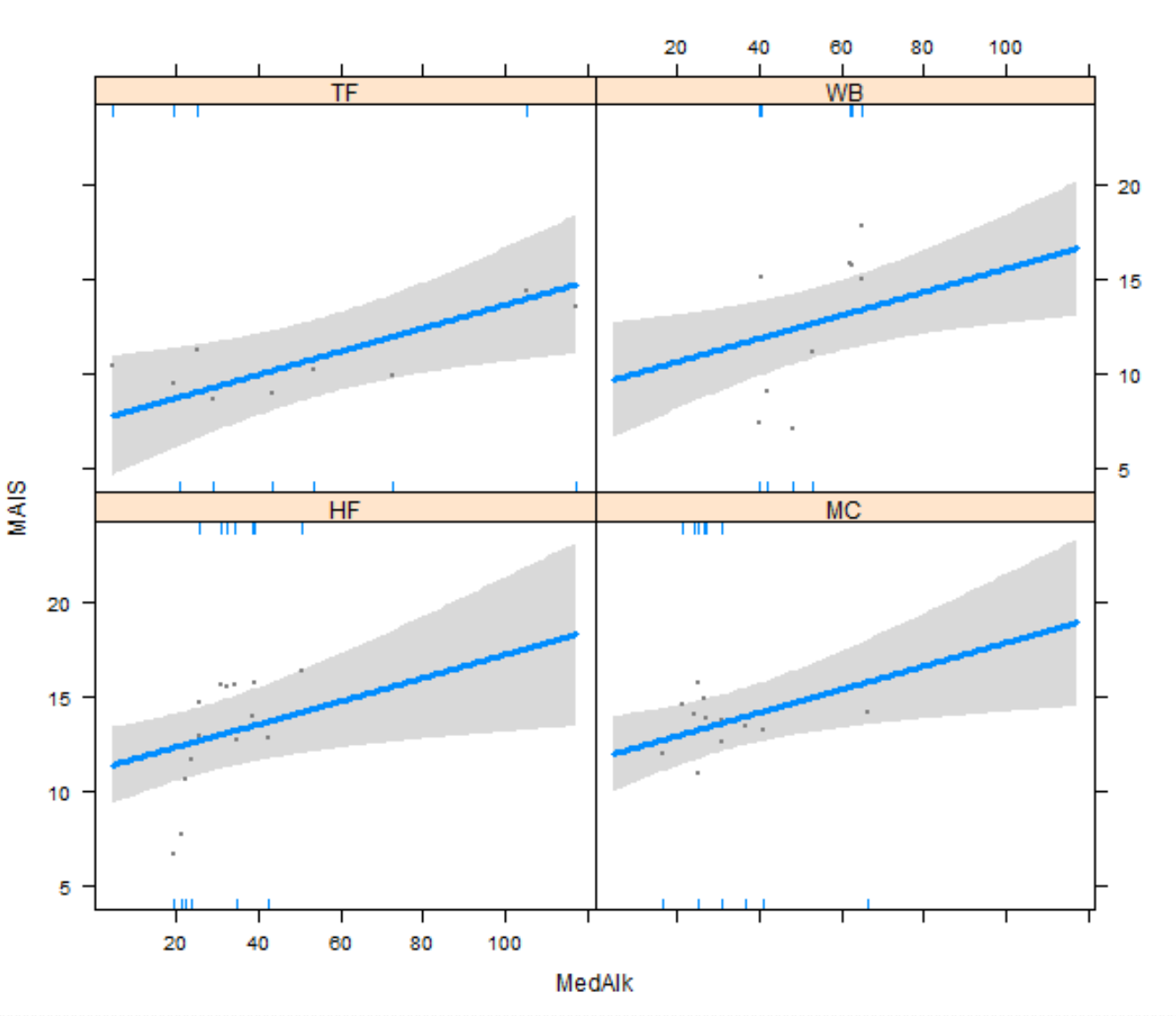
Multivariate Regression Model Output

	Dependent Variable: MAIS	
Independent Variables	Coefficient	Standard Error
Constant	13.102	80.071
pH	-0.112	1.129
Sulfate	-0.003	0.006
Alkalinity	0.062**	0.059
Acidity	-0.022	0.059
Fe	-0.948***	0.217
Wshed MC	0.61	1.163
Wshed TF	-3.586**	1.609
Wshed WB	-1.693	1.522
Observations		46
R2		0.561
Adjusted R2		0.466
Residual Std. Error		2.549 (df=37)
F-Statistic		5.913*** (df=8; 37)
*p<0.1; **p<0.05, ***p<0.01		

Model Simulations



Model Simulation with Fe (all variables constant)



Model Simulation with Alkalinity (all variables constant)

Conclusions

- pH above 6.5 is important to achieve biological target.
- The combination effect of net alkalinity, and water chemistry and Fe concentrations are important complement of pH target to enhance biological recovery.
- The model proved reliable to relate MAIS scores to water chemistry in the four watersheds

Acknowledgement

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Godfrey Ogallo
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Thank You!