Northumbria River Basin District
Mining pollution: catchment characterisation report

Date December 2015

Overall Summary:

Project details

Project name:	River Nent - Nenthead
Contact name:	Heather Wollaston
Contact team:	Land and Water, Northumberland and Tyne
Area Environment Manager:	Julie Brooker

Water body summary information

Water body name:	Nent from Source to South Tyne
Water body id:	GB103023075420
Water body type:	Surface Water
Catchment:	South Tyne / River Tyne
RBP Measure	Mine water treatment and sediment management
RFF database	Abandoned metal mines
Related catchments	• GB103023075531 – S Tyne, Black Burn to Tipalt • GB103023075532 – S Tyne Tipalt to Allen • GB103023075710 – S Tyne Allen to N Tyne

Water body classification

Surface water body classification	**Status (2009)**	**Status (2014)**	**Elements failing**
Ecological Status		Moderate	
Biological Status	Poor	Bad	Fish and Invertebrates
Specific Pollutants	Moderate	Moderate	Zinc
Chemical Status	High	Fail	Cadmium and Lead
Groundwater Body	**Name/ID**	**Status**	**Elements failing**
	Tyne Carboniferous Limestone and Coal Measures GB40302G701500	Poor	Chemical (GE) Status General Chemical Test

Comments

It should be noted that the EQS changed between cycle 1 and cycle 2, cycle 2 now uses a bioavailable measure as opposed to a hardness based assessment.

Summary of impacts from abandoned mines

NoCAM result River Nent from source to South Tyne	Impacted	**Score = 14 (2013)** **National rank = 4th** **RBD rank = 1st**
SWMI - Fail	At risk/Probably at risk	**At risk**

Mining Waste Directive

MWD inventory					
URN	**Site name**	**Mine type**	**Reason**	**Easting**	**Northing**
1005	Nenthead Mines	Metalliferous	Water Pollution	378420	543300
1137	Hudgill Burn	Metalliferous	Water Pollution	375180	545660
Potential MWD inventory					

Synopsis of catchment characterisation

	Details/Comments	
Summary of impacts	The Nent valley is one of the most intensively mined waterbodies in the country. Extensive spoil heaps exist throughout the valley as well as a number of significant point source discharges from mine adits, (Rampgill, Capelcleugh and Haggs). Metal loadings in the River Nent can be attributed to both point and diffuse sources. A number of studies have been carried put in recent years to try and understand the extent of the pollution from the abandoned metal mines in the North Pennines. • Feasibility of the amelioration of the metalliferous discharges in the Nent, East and West Allen catchments by Entec, 1997. This study confirmed the very wide spread nature of the problem. • Aquatic zinc pollution from abandoned mines. Assessment and passive treatment in the Nent valley. Charlotte Nuttall, 1997 PhD. • North Pennines Metal Mine Monitoring Report, River Nent, Atkins 2010. This confirmed the importance of the pollution from 3 main mine adits in the Nent valley. • Tyne Catchment Characterisation study P Aldred, 2012.	
# water bodies impacted	4	The River Nent is not the only source of metal loading in downstream water bodies however it contributes a significant source of metals to the downstream catchments. The River Nent contributes around 50% of the metal loading in the River Tyne.
Length of river impacted (km)	60 km (Including the River South Tyne)	

	100km (including the main River Tyne)	
Metals failing current EQS	Zn = Av:1274µg/l Max:2500µg/l Cu = Av:2.24µg/l Max:2.88µg/l Cd = Av: 3.69µg/l Max:7.43µg/l Pb = Av:35.2µg/l Max:91.1µg/l Ni = Av:4.08µg/l Max:5.92	The River Nent at Alston (43200231) is the WFD compliance point for the River Nent This sample point is within the catchment and was used in this catchment characterisation study.
Metals failing bioavailable EQS	**Nent at Alston -** Zn, Pb and Ni. **Min RCR:** Zn – 14.98 Pb – 1.41 Ni – 0.15 Cd – 19.6 **Annual average RCR:** Zn – 57.38 Pb – 3.20 Ni – 0.75 Cd – 28 **Max RCR:** Zn – 135.45 Pb – 10.34 Ni – 1.41 Cd – 43.73	Zn -12 out of 12 samples failed RCR Pb – 12 out of 12 samples failed RCR Ni – 4 out of 12 samples failed RCR Cd – 12 out of 12 samples failed RCR
Is there an outbreak risk?	None known	
# of sources	Point sources: 1. Rampgill adit 2. Capelcleugh adit 3. Haggs adit 4. Nent Force Level Diffuse sources 1. Nenthead spoil heaps 2. Nent tailings dam	Other point sources exist but have not been monitored. A significant number of spoil heaps are located throughout the River Nent catchment. Historic tailings dams and dressing floors also exist. Pollution from diffuse sources has not been specifically measured in this characterisation; however they have been incorporated in to the 'point source' discharges characterisation.

Metal loading – point sources (tonne/yr) ***(Q97 and Q20)*** ***(Q97 and Q20)*** ***(Q97 and Q20)***	**Capelcleugh:** Zn = 2.763 - 5.581 tons/yr Cu = 0 - 0.001 tons/yr Cd = 0 - 0.01 tons/yr Pb = 0 - 0.02 tons/yr Ni = 0.01 - 0.023 tons/yr **Rampgill:** Zn = 0.172 – 0.415 tons/yr Cu = 0 tons/yr Cd = 0.00024 – 0.00076 tons/yr Pb = 0 – 0.002 tons/yr Ni = 0.0008 – 0.002 tons/yr **Haggs:** Zn = 2.006 – 3.437 tons/yr Cu = 0 – 0.001 tons/yr Cd = 0.002 – 0.0033 tons/yr Pb = 0 – 0.001 tons/yr Ni = 0.0039 – 0.0085 tons/yr	**Sum of the point sources:** Zn = 4.941 – 9.433 tons/yr Cu = 0 - 0.011tons/yr Cd = 0.002 – 0.014 tons/yr Pb = 0 – 0.024 tons/yr Ni = 0.015 – 0.034 tons/yr
Metal loading – river (d/s) ***(Q97 and Q20)***	River Nent at Alston Zn = 2.31 – 34.78 tons/yr Cu = 0.04 – 0.053tons/yr Cd = 0.01 – 0.09 tons/yr Pb = 0.02 – 0.60 tons/yr Ni = 0.01 – 0.12 tons/yr	
How many sources need to be treated to achieve EQS (good status)	The data suggests limited EQS compliance can be achieved in the River Nent, even with treatment of point and diffuse sources of metal pollution.	This study only focuses on the River Nent catchment. Further characterisation of the River South Tyne and the River Tyne may better demonstrate the benefits and improvements that can be achieved in the downstream water bodies as a result of mine water treatment schemes on the River Nent.
Length of river improved by treatment (km)		Further characterisation of the River South Tyne and River Tyne.
NWEBS benefit (£m over 25 years)	Dealing with mine water pollution in the Nent catchment was considered to be cost-beneficial during the 2nd cycle economic appraisal work by the EA. The economic benefits of cleaning up metals in the South Tyne, particularly those impacting sediment qualities in	

	the estuary, have been estimated at £300m - £1,000m over 25 years (BAG assessment).	
Potential contribution from others?	Yes, eligible for the NE LEP Local Growth Fund budget.	

Recommendations

Options	**Comment**	
SWMI review		
Confirmed pollution from metal mines:	Recommend for source apportionment study, and identify monitoring locations.	
Pollution uncertain:	Spot samples at appropriate locations (2-3 rounds) and then: • If confirm polluted by mines, potential source apportionment study • If confirm NOT polluted by mines, recommend remove from SWMI list.	
Source apportionment study		
Monitor: **sources not defined, more monitoring needed**		
Feasibility: **sources defined, pass to Coal Authority for scoping stage**	1. The main sources of Zn and Cd are: **Zn** • Capelcleugh Adit • Haggs Adit • Rampgill Adit **Cd** • Haggs Adit • Capelcleugh Adit • Rampgill Adit 2. The contribution from the Nent Force Level has not been quantified although this discharges downstream of the main WFD compliance point in the River Nent. 3. Pb arises from diffuse sources throughout the catchment. 4. Scoping study should focus on: • Capelcleugh • Haggs • Rampgill • Diffuse lead	
Suspend: sources too complicated, not feasible with current technology/costs		
National delivery team decision		**Priority**

Introduction and site map(s)

The River Nent headwaters are sourced south of Nenthead town with the River Nent itself flowing for around 10km before joining the South Tyne at Alston. The Nent catchment has been heavily modified. There are significant areas of exposed mine spoil and tailings dams throughout the catchment resulting in varied metals loadings within the River Nent and associated downstream water bodies. Water quality data indicates pollution from abandoned metal mines in the Nent catchment is having a significant impact on the downstream water bodies.

During ‘normal’ flow conditions the main measured point sources of pollution, (Capelcleugh, Rampgill and Haggs) are the most important sources of pollution. However, during high flows the diffuse sources of metal pollution become more important. The Nent Force Level was not monitored during this study.

The River Nent forms a single water body for Water Framework Directive purposes. The Regional River Basin Management Plan states that the River Nent has an overall status of Moderate with an objective of Good ecological and overall status by 2027. It should be noted that it is not be technically feasible to achieve overall Good status in the River Nent by 2015.

Review of historical data and information

The Nent Valley is one of the most intensively mined catchments in the country. The Nenthead Mines are a Scheduled Ancient Monument. Mining in this area probably dates back to before the 1700s in the form of surface workings and shallow pits. During the 18th century most of the mines located around Nenthead were owned by the London Lead Company, with the exception of Browney Hill. By 1905 most of the leases were acquired by a Belgium company, Vieille Montgne who switched from lead to zinc mining. Mining of the Nenthead mines stopped just before the Second World War.

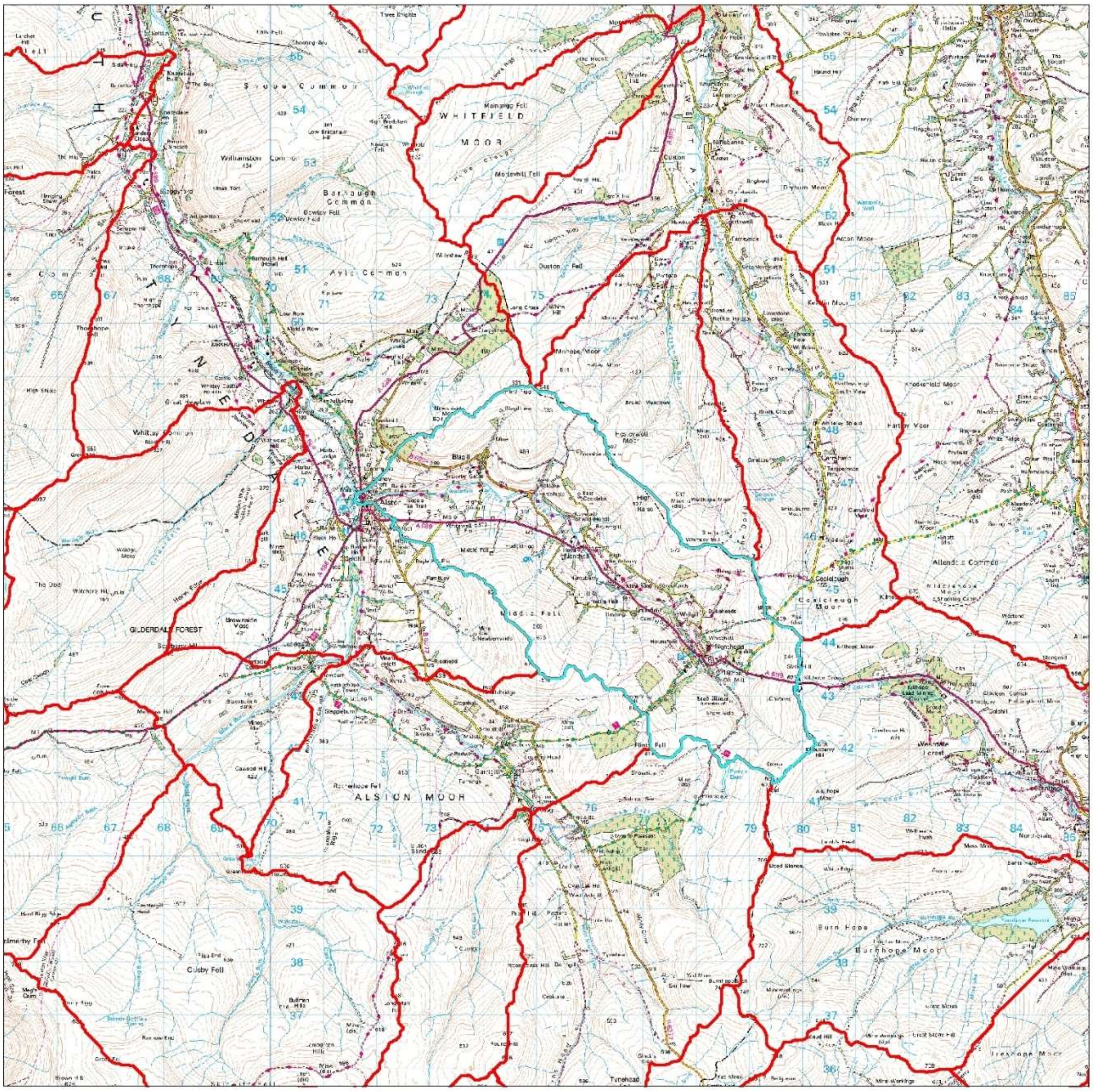
A monitoring program which involved gathering flow and water quality data was set up by the Environment Agency in late 2013. Information from the Atkins Report, 2010 indicated that 3 point sources, Capelcleugh, Rampgill and Haggs adits were significant and could lead to significant benefits to the River Nent if they were treated. These 3 adits, along with 4 river points were targeted for sampling. The seven sample points were sampled on a monthly basis on the same day. This ensured the results were consistent during varying conditions. Other small discharges were not included as it was assumed they could potentially be included in a larger treatment scheme.

Although the Nent Force Level is a major source of metals it was thought too difficult to monitor. Also, as there is very limited space for treatment in the vicinity of the Nent Force level it was left out of this study. Further investigations are been undertaken to look at the source of the flow within the Nent Force Level and whether it could be prevented or diverted to alternative sites.

The maps detailed below show the River Nent catchment, the sample points used for this characterisation, the designations in and around the River Nent catchment, the spoil heaps and MWD inventory sites and mineral veins in this area. Additional maps and photos detailing each sample point can be found in the appendix.

River Nent - WFD Catchment

ENVIRONMENT AGENCY



Legend

WFD River catchments. Cycle

0 0.4 0.8 1.2 1.6

Kilometers

N

River Nent - Sample Points

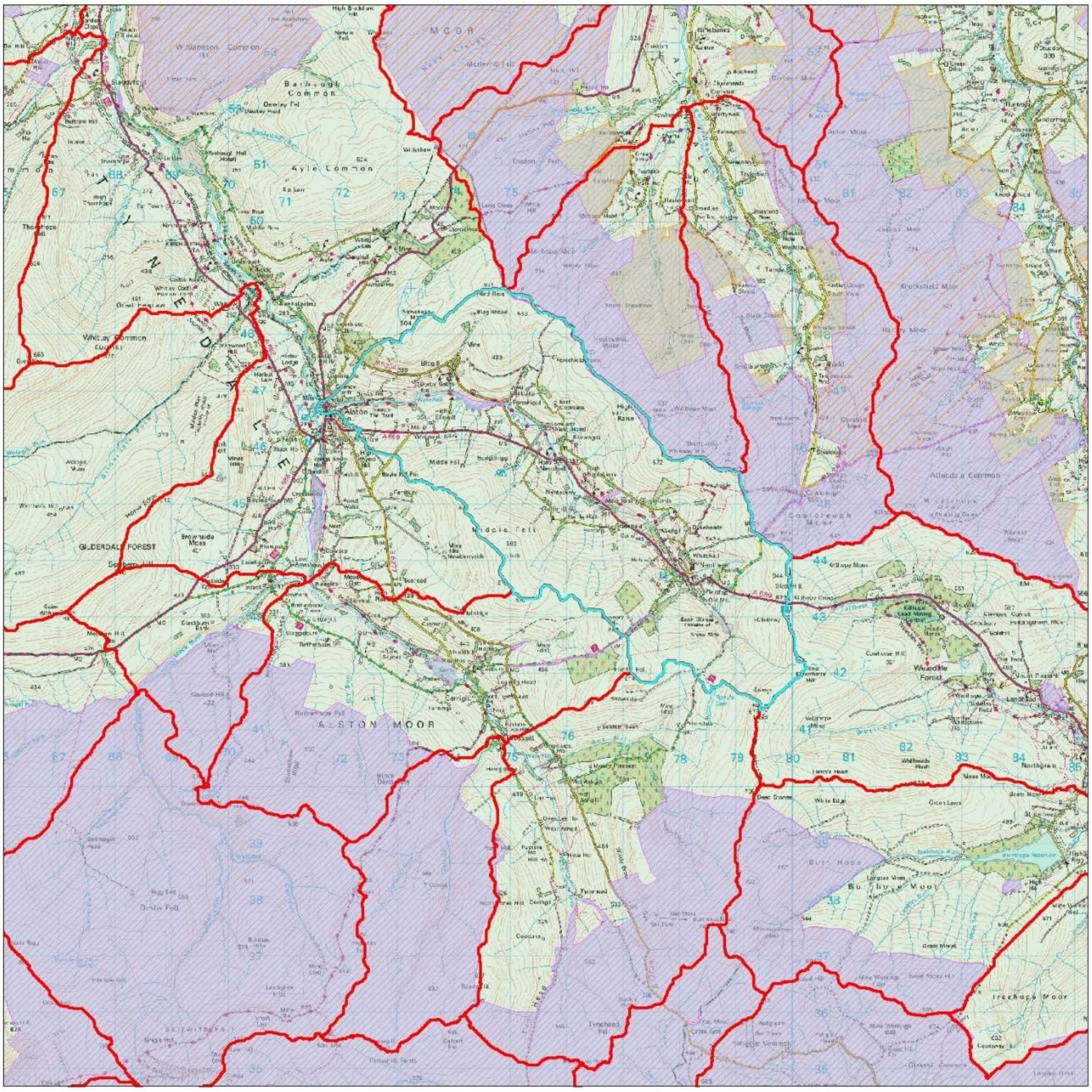
Legend

● Nent Sample Points

Kilometers

N

River Nent - Designations



Legend

- WFD River catchments. Cycle
- ramsar_10k
- World_Heritage_Sites
- sac_10k
- spa_10k
- aonb_50k
- **SSSI10k**

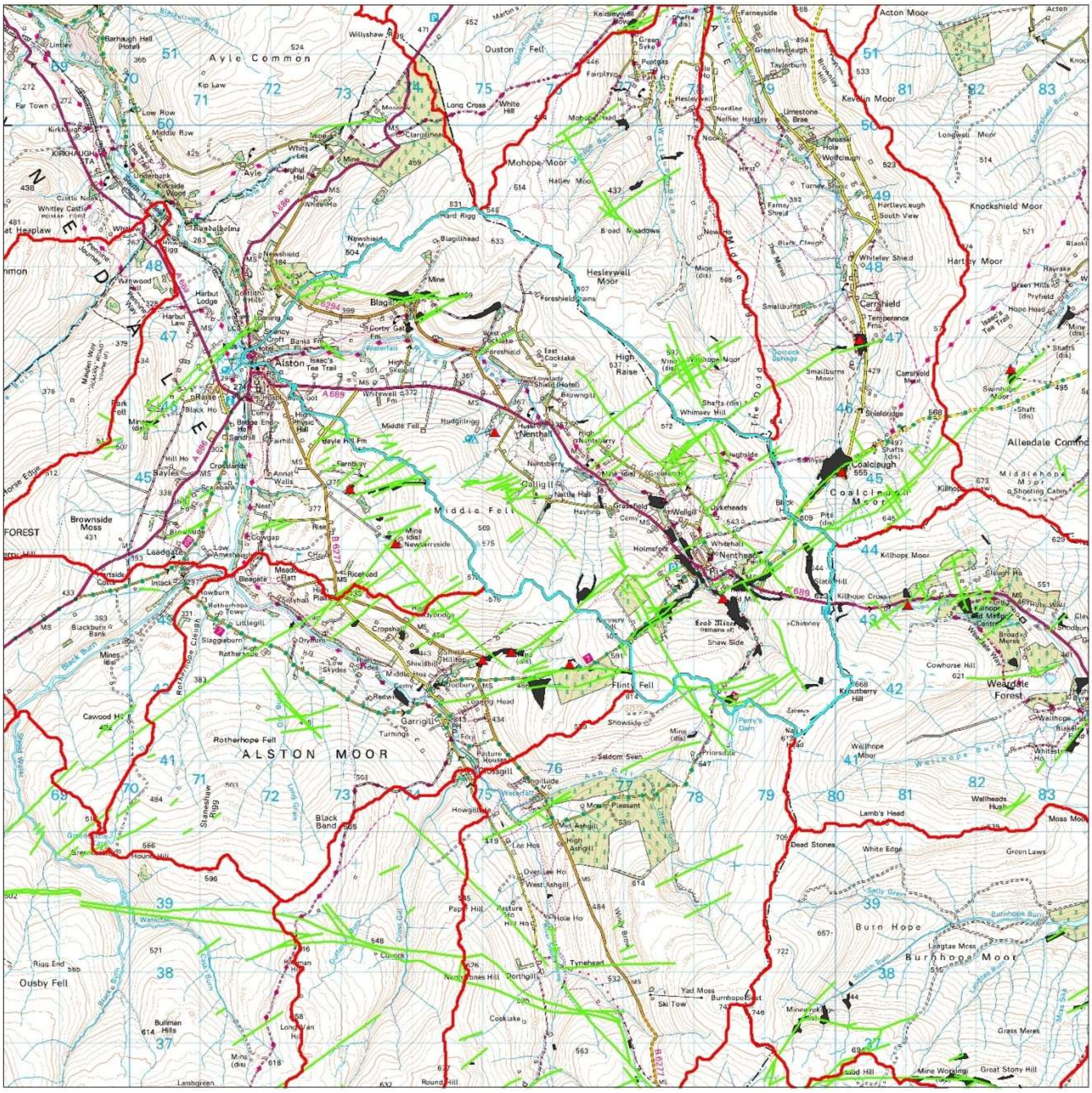
0 0.40.81.21.6

Kilometers

N

River Nent - Mineral Veins, MWD Invertory, Spoil

ENVIRONMENT AGENCY



Legend

WFD River catchments. Cycle

MWD Inventory Nov2013

Mineral Vein

Spoil layer

0 0.3 0.6 0.9 1.2

Kilometers

N

Geological setting and map

The Nent valley drains the Western side of the Alston Block mining area. This consists of a dome of ‘Weardale’ Granite overlain with thick limestone capped with sedimentary sandstone and mudstones. The limestone has fractures in multiple directions, allowing hot mineral rich water to flow and leave ore deposits in many of the veins as it cooled. The ore body has a number of zones radiating out from the central source of mineralisation. Zinc and lead are more prominent toward the centre with barium and fluorite towards the outer body. The town of Nenthead is located almost at the centre of this ore body resulting in particularly high zinc content in the ground surrounding Nenthead. This is reflected in the high zinc concentrations in the mine drainage in this area. The limestone geology buffers acid produced when sulphide minerals oxidise, resulting in the mine waters discharge being close to neutral pH. The main River Nent and its tributaries are deeply incised into the rock. This had exposed some of the veins and enabling historical mines to access the minerals.

Biological / ecological information

The River Nent joins the South Tyne at Alston. The South Tyne is considered environmentally significant in terms of fisheries and water resources. The concentrations of zinc in the River Nent waters and sediments restrict aquatic biodiversity. The elevated zinc concentrations cause both direct toxicity and reduction in the invertebrate community, reducing the food supply within the river.

	C1 2009	C1 2014	C2 2014
Fish	Poor	Good	Bad
Invertebrates	Moderate	Poor	Poor
Macrophytes	Moderate	Moderate	Bad

Landowners / occupiers

Landowners and occupiers have been contacted by the AONB and Coal Authority. Appendix 1 details land ownership, (owners and tenants) in the Nenthead area. Appendix 2 details land ownership in relation to estates. Appendix 3 provides a map of the historic sites, monuments and recorded scheduled monuments.

Stakeholders and discussions to date

To date:

- Environment Agency (EA)
- The Coal Authority (CA)
- The North Pennines Area of Outstanding natural Beauty (AONB) – Have not yet been formally consulted however it’s very likely they will have a view on the visual impacts of a mine water treatment scheme
- Natural England – Habitats Risk Assessment for Calaminarian Grasslands.
- English Heritage – have provided consent for flow gauges in mine adits

- Local Residents and Residents Groups – EA and AONB have attended Parish Council Meetings
- Land Owners – CA are consulting with local land owners
- Nent Hydro Scheme licence holder – EA
- Local Mine Explorer Groups, Peter Jackson

Monitoring program

The monthly sample regime set up to take flow gaugings and water quality samples from sample references N1-N7 are identified in Table 1 below. Flow data was collated from sample refs N1-N8. N8. The River South Tyne gauging station (N8) was used to calculate the Q value for flows on the River Nent as no flow level site existed on the River Nent at the time this data was collected.

Table 1: Sample points and flow data collection

Location	Sample Ref	NGR	Gauging method	Sample suite
Nent at Caplecleugh MW	N1	NY 78140 43450	EA Velocity gauge	METSTR
Caplecleugh MW at Nent	N2	NY 78140 43450	CA logger	METPR
Rampgill	N3	NY 78200 43500	CA logger	METPR
River Nent just u/s of STW	N4	NY 77700 44400	EA ADCP	METSTR
Haggs Adit	N5	NY 76620 45140	CA logger	METPR
River Nent at Nenthall	N6	NY 75800 45800	EA Velocity gauge	METSTR
River Nent at Alston	N7	NY 72332 46799	EA ADCP	METSTR
River South Tyne at Alston	N8		EA Gauging station	

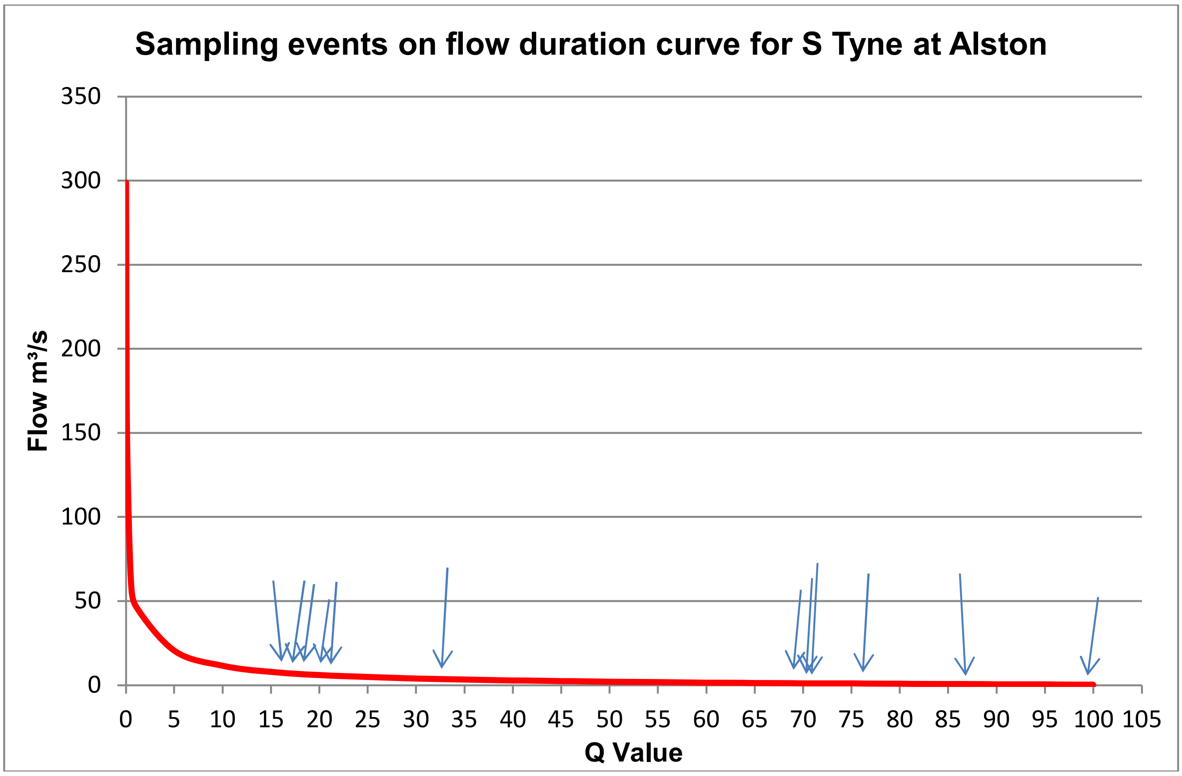
Table 2: Summery of analytical suites and water quality sample analysis

Analysis Suit	Field Determinants	Laboratory Determinants	Metals(Dissolved and Total
METSTR for surface waters	pH, EC, DO, Temp	Dissolved Organic Carbon Suspended Solids, Hardness as $CaCO_3$, pH, Alkalinity @ pH4.5, Cl, NO_2, NH_3, SiO_2, SO_4	Al, B, Ba, Ca, Cd, Cr, Cu, Fe, K, Li, Mg, Mn, Na, Ni, Pb, Sr, Zn
METPR for adits/levels	pH, EC, DO, Temp	EC, DO%, Hardness as $CaCO_3$, pH, Alkalinity @ pH4.5, Cl, NO_2, NH_3, SiO_2, SO_4	

Table 3: Q values for each sampling date.

Date	Q
23/06/2014	97
04/09/2014	86
17/07/2014	75
05/08/2014	69
15/04/2014	68
17/03/2014	67
18/02/2015	32
16/01/2014	20
13/01/2015	20
08/05/2014	18
19/02/2014	17
09/10/2014	16
12/11/2014	16
10/12/2014	15

Figure 1: Sampling events in relation to the River South Tyne flow duration curve.



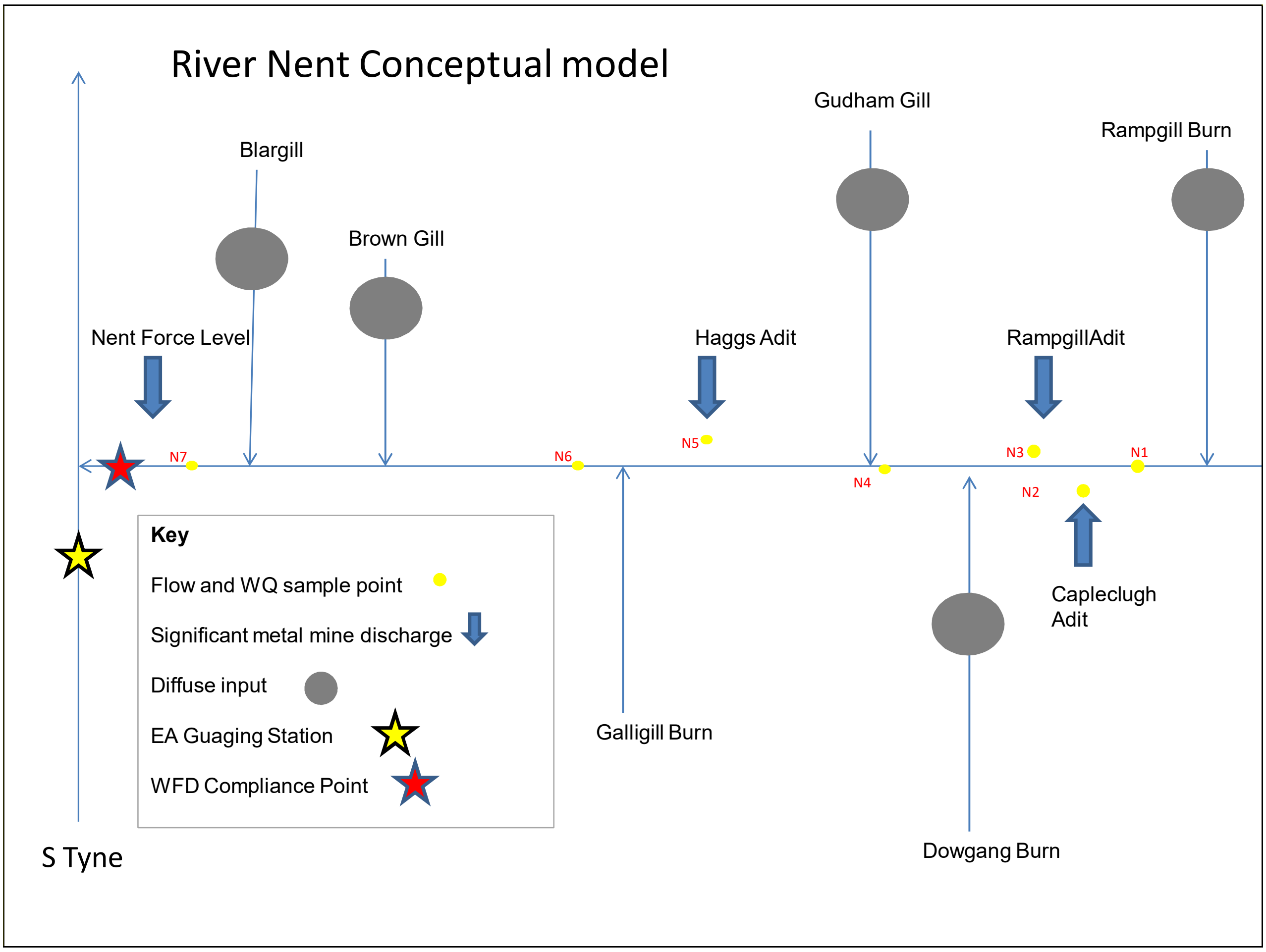
Samples were collected monthly on the same day. Samples were collected starting with the most upstream location first. As a result of the location and distance between each sample point it is unlikely the samples taken for the upstream sample points will have affected the downstream sample points.

When choosing the sample points for this characterisation existing research, information and date was considered. The 7 sample points used in the characterisation were chosen to best represent metal loadings in the River Nent. It is known that there are other point sources of metals in the catchment (for example the Nent Force Level and Blagill Level) but the sampling locations were chosen to reflect the key inputs upstream of the WFD compliance point (N7) based on previous data. Future work is likely to investigate other sources, particularly the Nent Force Level (once access and other issues have been resolved).

The data collected has enabled the comparison of metal loadings in the River Nent in relation to EQS compliance standards. This in turn informs the decision process with regards to treatment of point sources to achieve compliance with EQS standards.

Additional work and data collection is taking place in relation to diffuse sources of metals in the River Nent.

Conceptual model



The Water framework Directive (WFD) compliance point for the River Nent catchment is located on the River Nent just upstream of the Station Road Bridge, (N7).

Diffuse sources of pollution from mining spoil and tailings dams shown on the Conceptual Model, (CSM) indicates those areas of the catchment affected by diffuse inputs. It should be noted that the CSM is not so scale and therefore is not a true representation of the potential diffuse issue within the River Nent catchment. Also, point sources of pollution identified in the CSM do not accurately reflect the volume of these discharges.

Flow Balancing

N4 = N1+N2+N3

N6 = N4+N5

Table 4: Summary of flow data.

Date	**Q**	**Flow in l/s**							
		N8	**N7**	**N6**	**N5**	**N4**	**N3**	**N2**	**N1**
23/06/2014	97	289	61	92	3.8	27	2.4	9.1	62
04/09/2014	86	530	103	76		16	0.8	8.6	6
17/07/2014	75	849	82	52	3.4	34	1.8	9.2	4
05/08/2014	69	1080	81	67	3.4	110	1.8	8.5	4
15/04/2014	68	1100	340	284	4.0	164	4.1	12.0	114
17/03/2014	67	1170	223	239	12.0	121	3.5	9.5	109
18/02/2015	32	3960	987	455	6.0	300		10.2	158
16/01/2014	20	6360	1220	696	10.0	474	7.2	19.8	308
13/01/2015	20	6360		860	5.0	540	3.4	16.5	280
08/05/2014	18	7140		870	4.3	602	3.0	14.0	345
19/02/2014	17	14800			15.0	971	6.5	23.2	669
09/10/2014	16	7850		562		397	1.5	9.4	233
12/11/2014	16	7690		828	3.0	522		10.8	342
10/12/2014	15	8330			3.4	663	3.0	27.3	411
Average			379	400	6.1	339	3.3	13.440	203
Minimum			61	52	3.0	16	0.8	8.542	4
Maximum			1220	870	15	971	7.2	27.339	669

Table 5: Summary and flows and flows accounted for at each sample location during Q97, Q67 and Q20 flow conditions.

Q	**N1**	**N2**	**N3**	**N1+N2+N3=<N 4**	**N4**	**% accounted for at N4**	**N5**	**N6**	**N5+N6=<N7**	**N7**	**% accounted for at N7**
Q97 Flow l/s	62	9.1	2.4	73.5	27	272%	3.8	92	95.8	61	157%
Q67 Flow l/s	109	9.5	3.5	122	121	101%	12	239	251	223	113%
Q20 Flow l/s	308	19.8	7.2	335	474	71%	10	696	706	1220	58%

NOTE High flows at the Nent at Alston are un-measurable over 1220l/s as the site becomes dangerous. The Q 20 flows are therefore taken as a maximum measurable flow event.

Between monitoring points there are tributaries entering the River Nent that have not been gauged as part of this characterisation study. As a result it is expected that downstream flows will exceed the calculated flows. Also, gauging data should be considered as indicative rather than very accurate. This results from the methods used not being totally ideal given the nature of the water course being characterised in this study.

During low and medium flows over 100% of the flow in the River Nent at Alston can be accounted for. However during high flows, Q20 being the highest flow that data is available for, only 58% of the flow in the River Nent and Alston can be accounted for.

During the lower flow conditions, for example Q97 and Q67 calculated flows don’t agree with measured flows. Less accurate flow data can be expected during these conditions as a result of water flowing through the river gravels and not being captured in the gauging process.

Between March 2014 and April 2014 the flow monitoring at the Haggs adit (N5), was changed from a spot velocity gauge to an in pipe flow logger. It should be noted that there was a step change in the flow data between March 2014 and April 2014.

NOTE Q97 flow

During this particular flow condition the measured flow at N1 is 62 l/sec. The sum of N1, N2 and N3 equals 73.5 l/sec. The flow at N4 is 27 l/sec. 272% of the flow is accounted for at N4. Flow gaugings were taken upstream to downstream. It should be noted that there is a hydro scheme operating on the River Nent head waters. This scheme is known to ‘pulse’ water through the system. It is likely the inaccuracies in the flow balancing on this occasion are as a result of the hydro scheme operating. Analysis of the flow data for a Q86 scenario provides a more realistic representation of low flow conditions. At Q86 N1 is 6 l/sec. The sum of N1, N2 and N3 is 15.4 l/sec.

Results and interpretation

Table 6: Review of sample data taken over a 14 month period.

Sample point	Stats	Flow l/sec	pH	Zn µg/l (total)	Zn µg/l filtered)	Total Cd µg/l	Filtered Cd µg/l	Total Pb µg/l	Filtered Pb µg/l
N1	**Min**	4	6.960	262	246	0.69	0.57	12.0	11.4
N1	**Average**	204	7.532	613	614	1.79	1.69	34.9	22.6
N1	**Max**	669	8.160	1750	1850	5.14	5.00	87.4	46.5
N2	**Min**	9	7.430	4870	4790	8.67	8.61	13.9	12.3
N2	**Average**	13	7.904	7925	7974	13.2	12.96	37.4	27.6
N2	**Max**	27	8.150	10500	10000	16.10	15.50	83.4	54.8
N3	**Min**	0.8	7.900	1790	1580	3.2	2.85	12.0	0.0
N3	**Average**	3	8.109	2778	1909	4.43	3.14	272.2	8.3
N3	**Max**	7	8.350	6870	2290	11.50	3.55	1790.0	21.0
N4	**Min**	16	7.380	617	605	1.5	1.35	22.4	5.6
N4	**Average**	339	7.821	1502	1379	3.10	2.76	41.3	21.9
N4	**Max**	971	8.310	3480	3450	7.04	6.47	66.7	44.0
N5	**Min**	3	7.580	7180	7100	5.90	5.66	0.0	0.0
N5	**Average**	6	7.914	11195	11129	10.49	10.27	3.51	0.4
N5	**Max**	15	8.300	15800	16600	14.20	13.60	10.10	3.6
N6	**Min**	52	7.650	709	672	1.48	1.45	16.80	8.9
N6	**Average**	400	8.253	1367	1270	3.44	3.15	39.15	20.1
N6	**Max**	870	8.700	2230	2170	6.81	6.56	160.00	36.1
N7	**Min**	61	7.530	701	672	1.58	1.53	13.20	7.4
N7	**Average**	379	8.238	1248	1101	3.57	3.16	34.04	18.5
N7	**Max**	1220	8.750	2500	2150	7.43	6.08	91.10	33.4

Results and Interpretation

Section one of the results and interpretation details nine graphs which show the measured loadings of zinc, cadmium and lead in relation to the site specific EQS load at Q 97, Q67 and Q20 flow conditions, (Q values determine by the flow duration curve for the River South Tyne at Alston, see Figure 1). The site specific EQS is considered to be equivalent to The Predicted No Effect Concentration, (PNEC). PNEC have been calculated by using the BLM[1] and PbBLM Tools. These tools use ecotoxicological data and site specific water quality data to produce the PNEC values. PNEC loadings have been calculated by multiplying the metal PNEC by the measured flow. Therefore the "*PNEC load*" is the target metal loading (concentration multiplied by flow) required to achieve compliance with the EQS. The purpose of the graphs is to show the variation in the actual metal loadings in the River Nent in comparison to the EQS and illustrate the load of metal that needs to be removed to achieve EQS compliance.

Section two of the results and interpretation consists of a summary table displaying the bioavailable data results for zinc, cadmium and lead.

Also included in this section are nine tables showing the numeric loadings of zinc, cadmium and lead at all 7 sample points. The tables also indicate the percentage contribution of the individual metals from each sample point that are found in the River Nent at Alston, N7

The layout of the sampling locations relative to diffuse and measured point sources are summarised in the table below.

Table 7: Layout of sample locations in relation to diffuse and measured point sources.

SPT number	SPT name	Comment
N1	Nent at Caplecleugh MW	Downstream of diffuse sources only
N2	Caplecleugh MW at Nent	Point source
N3	Rampgill	Point source
N4	River Nent just u/s of STW	Downstream of diffuse sources, Caplecleugh and Rampgill
N5	Haggs Adit	Point source
N6	River Nent at Nenthall	Downstream of diffuse sources, Caplecleugh, Rampgill and Haggs
N7	River Nent at Alston	Downstream of all sources except Nent Force Level

[1] Also known as MBAT

Section One

Zinc

Figure 2 depicts zinc loadings during low flow conditions, Q97. The graph indicates EQS compliance is already breached prior to any point source discharges at N1. It can therefore be assumed that the EQS breach occurs as a result of diffuse inputs up stream of N1. The PNEC load is 0.3kg/day compared with a measured load of 1.9kg/day. Measured zinc loadings increase within the river water body as you move down stream. At N4 the measured load is 4.9kg/day compared with a PNEC of 0.2kg/day, this sample point is located downstream of 2 point source discharges, N2 and N3. At N6 the PNEC is 0.2kg/day compared with a measured load of 16.9kg/day. This river sample point takes into account the 3 point source discharges accounted for in this study N2, N3 and N5. After N6 zinc loadings decrease to 6.3kg/day at N7 with a PNEC load of 0.1kg/day.

Out of the three point source discharges to the River Nent that have been considered in this study N2 (downstream of N1, upstream of N4) is the most significant during Q97 flow conditions, contributing 7.6 kg/day of zinc. This is followed by N5 (downstream of N4, upstream of N6) which contributes 5.5kg/day then N3 (downstream of N1, upstream of N4) which discharges 0.5kg/day.

There are known areas where diffuse inputs are expected to be more significant, these are located upstream of N1 and downstream of both N4 and N6.

Figure 3 show how the relationship between the measured loads and PNEC loadings follow a very similar pattern during Q67, medium flow conditions as in Q97 flow conditions. Again, the measured load, 2.3kg/day at N1 is higher than the PNEC, 0.2kg/day, suggesting significant diffuse inputs upstream of N1. Measured zinc loadings increase within the river water body as you move down stream. At N4 the measured load is 12.03kg/day compared with a PNEC of 0.21kg/day, this sample point is located downstream of 2 point source discharges, N2 and N3. At N6 the PNEC is 0.35kg/day compared with a measured load of 44.81kg/day. This river sample point takes into account the 3 point source discharges accounted for in this study N2, N3 and N5. After N6 zinc loadings decrease to 27.94 kg/day at N7 with a PNEC load of 0.36kg/day.

Figure 4 below illustrates Q20 flow conditions. During high flow conditions the loadings of zinc in the River Nent steadily increase between N1 and N7. At N1 the zinc load is 15.84kg/day compared with a PNEC of 0.49kg/day. N4 shows a measured load of 34.24kg/day compared to a PNEC of 0.85kg/day. At N6 the measured load is 55.87kg/day with a PNEC of 1.28kg/day and at N7 the measured load is 95.29kg/day compared with the PNEC load of 2.14kg/day. This pattern in loadings differs from those seen at Q97 and Q67 flow conditions in that a continual rise in loadings occurs rather than a rise between N1 and N6 before seeing a dip at N7.

During Q20 flow conditions N2 continues to be the most significant point source followed by N5 then N3. During Q67 flow conditions N5 becomes the most significant point source followed by N1 then N3. However it should be noted that all three point sources retain their significance regardless of the flow conditions.

At very low flows (Q97), more than 16 kg/day needs to be removed from the river to achieve the EQS at N6 and over 6 kg/day at N7. The three measured point sources (N2, N3 and N5) contribute ~13.5 kg/day.

At low-medium flows (Q67), the three point sources discharge ~19 kg/day but over 44 kg/day needs to be removed at N6, and 27kg/day at N7.

At high flows (Q20), the measured point sources supply 25 kg/day whereas more than 55 kg/day needs to be removed at N6, and 93 kg/day at N7

Figure 2: Graph showing the measured zinc loading compared with the EQS loading at a Q97 flow.

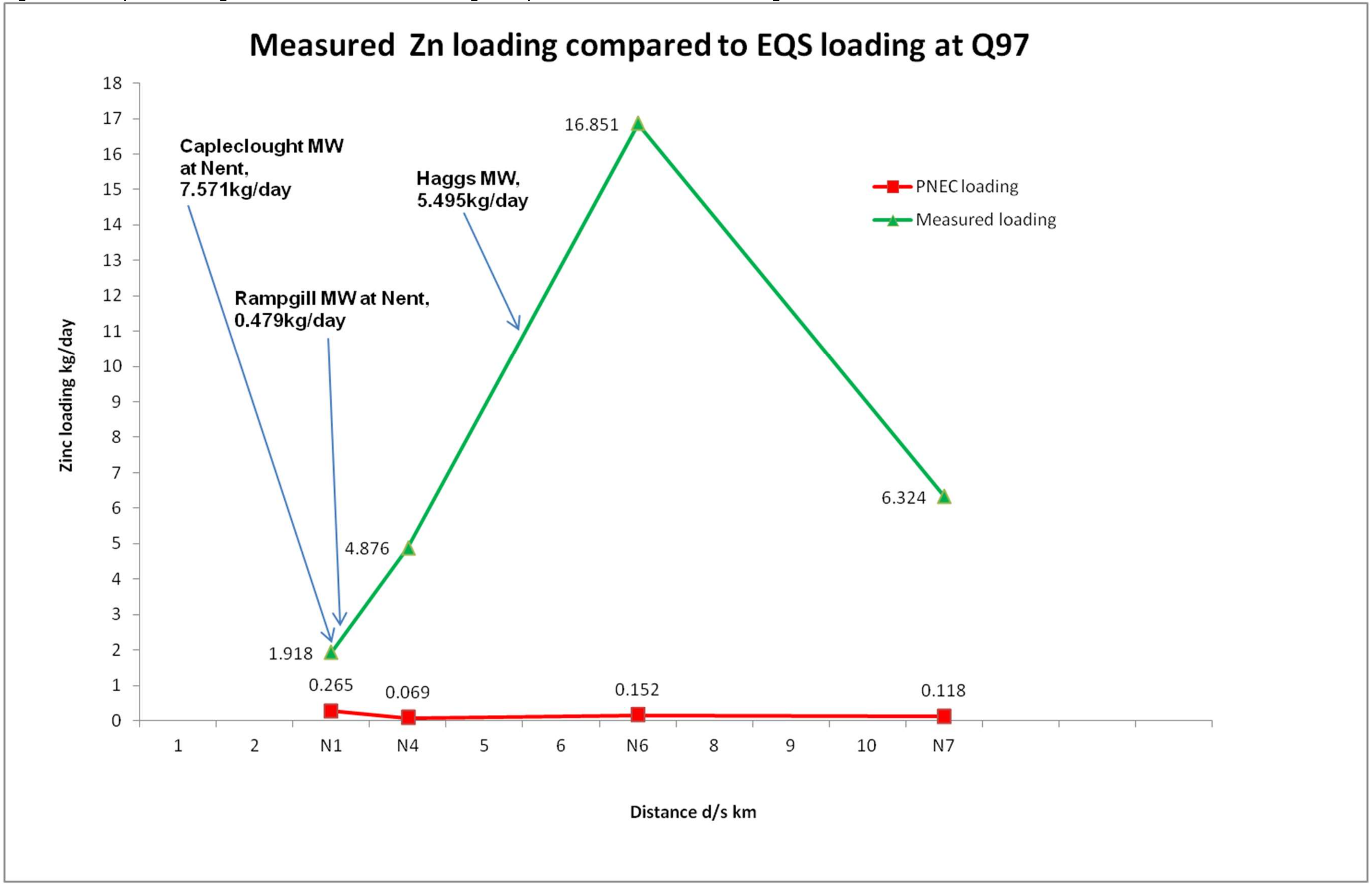


Figure 3: Graph showing the measured zinc loading compared with the EQS loading at a Q 67 flow.

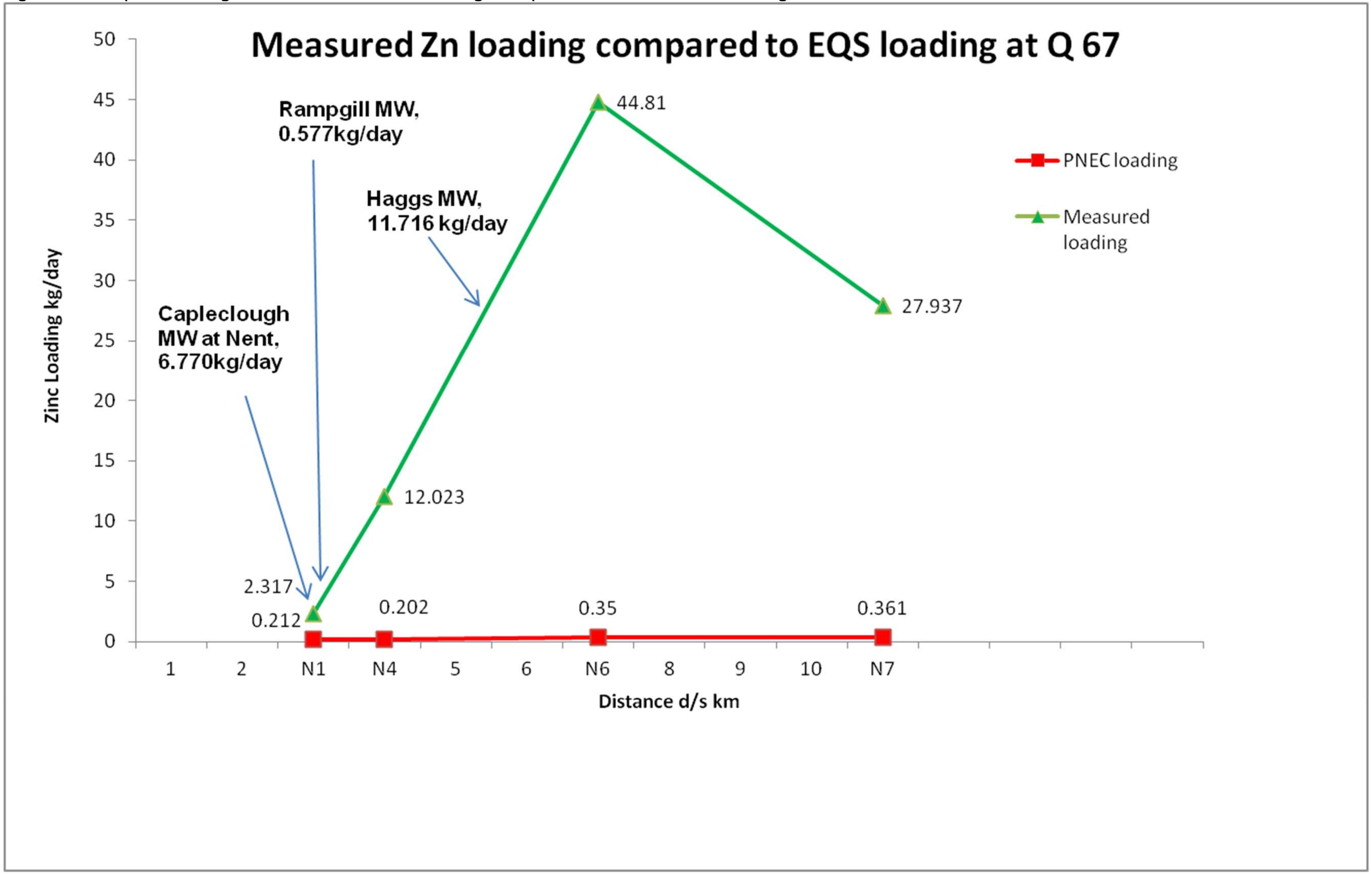
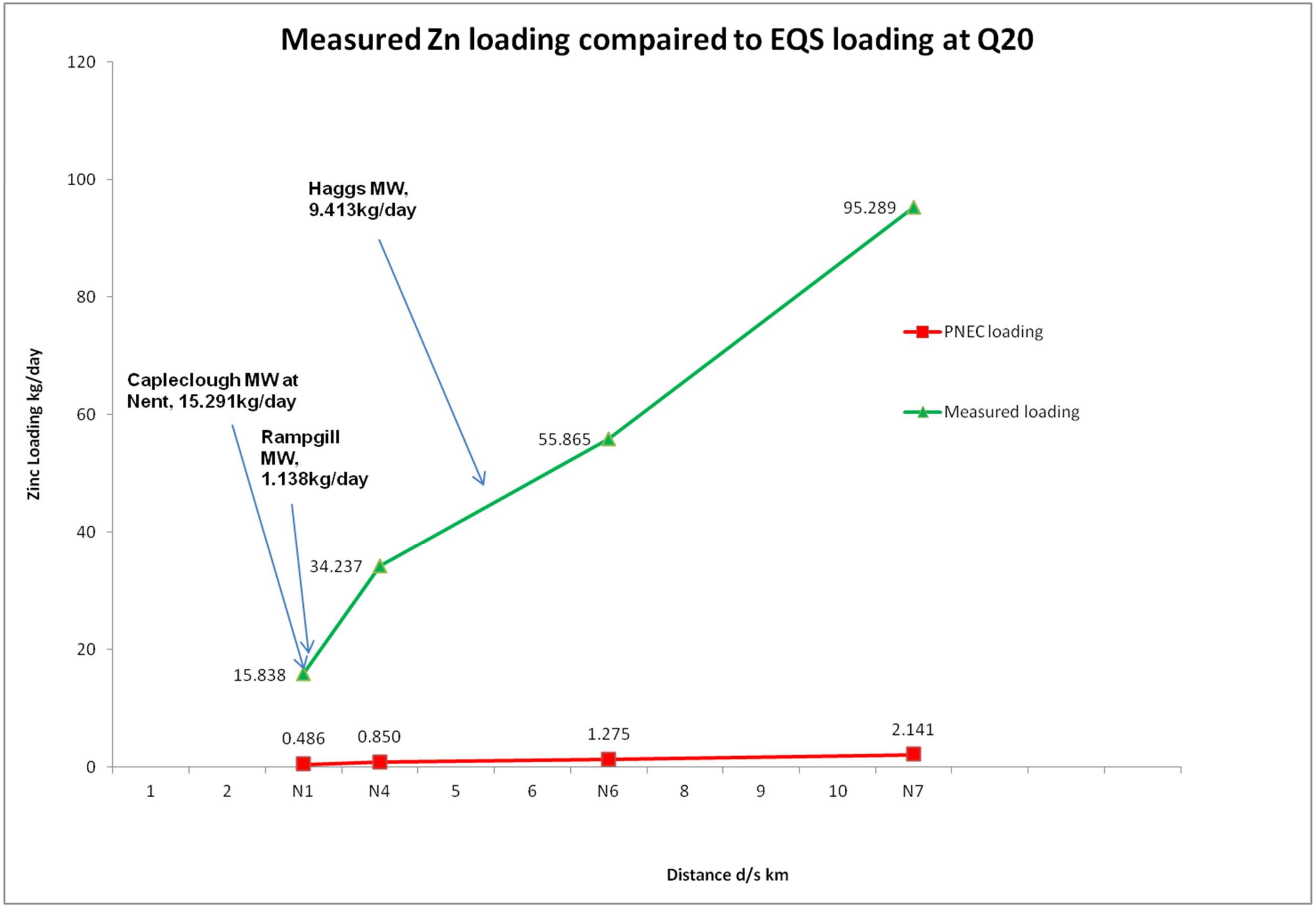


Figure 4: Graph showing the measured zinc loading compared with the EQS loading at a Q 20 flow.



Cadmium

Figures 5, 6 and 7 depict the cadmium loadings during Q97, Q67 and Q20 flow conditions. The relationship between cadmium loadings and flow conditions follow a similar pattern as that of zinc. EQS compliance is breached at N1 during all three flow conditions. At Q97 the PNEC is 0.48 g/day with a measured load of 6.32 g/day. At Q67 the PNEC is 0.75 g/day with a measured load of 5.37 g/day. At Q20 the PNEC is 2.13 g/day with a measured load of 18.71 g/day. As with zinc, cadmium loadings continue to rise up until N6, they then begin to drop. However, like zinc at no point do they drop below the PNEC.
With regards to point source significance, N2 is most significant followed by N5 then N3 during all three flow conditions. Table 8 below summarises the cadmium loading coming from the 3 point source discharges.

Table 8: Summary of cadmium loadings discharging to the River Nent from point sources.

Sample point	Q97 (g/day)	Q67 (g/day)	Q20 (g/day)
N2	11.28	11.87	25.37
N5	4.5	11.61	9.16
N3	0.67	0.9	2.1

At very low flows (Q97), more than 51 g/day needs to be removed from the river to achieve the EQS at N6 and over 29 g/day at N7. The three measured point sources (N2, N3 and N5) contribute ~16g/day.

At low-medium flows (Q67), the three point sources discharge ~ 24 g/day but over 94 g/day needs to be removed at N6, and over 71 g/day at N7.

At high flows (Q20), the measured point sources supply 37 g/day whereas more than 107 g/day needs to be removed at N6, and 243 g/day at N7.

Figure 5: Graph showing the measured cadmium loading compared with the EQS loading at a Q 97 flow.

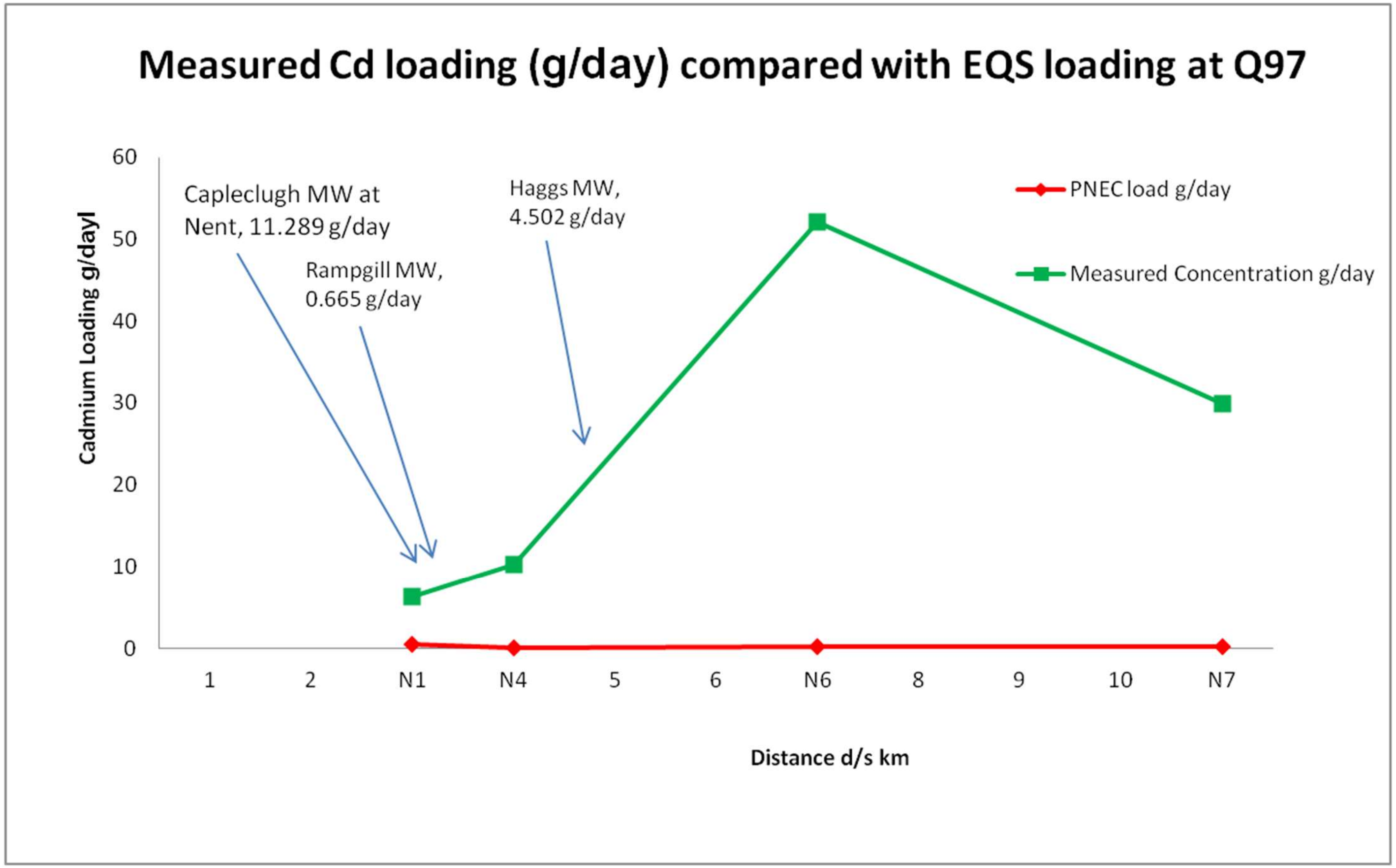


Figure 6: Graph showing the measured cadmium loading compared with the EQS loading at a Q 67 flow.

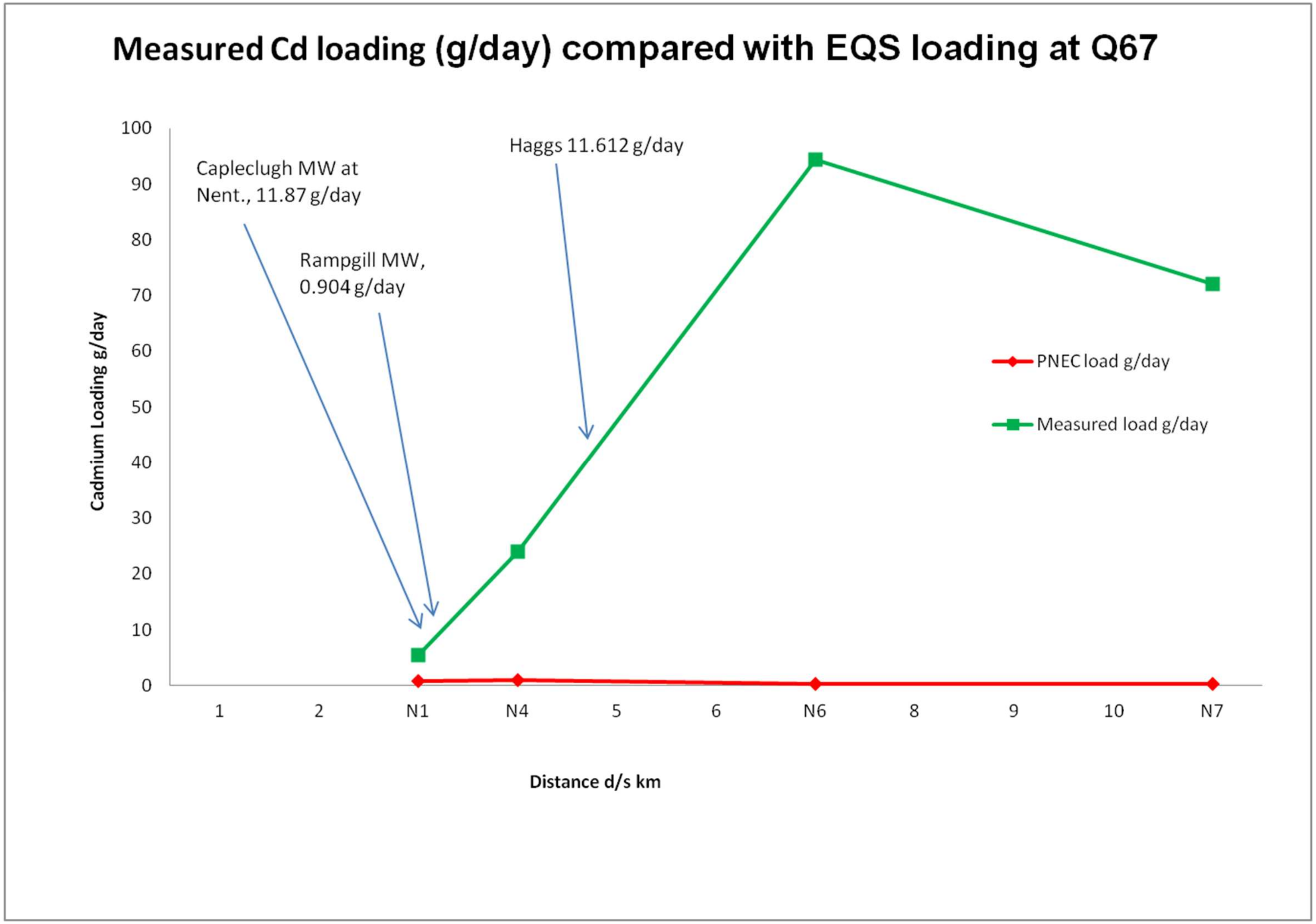
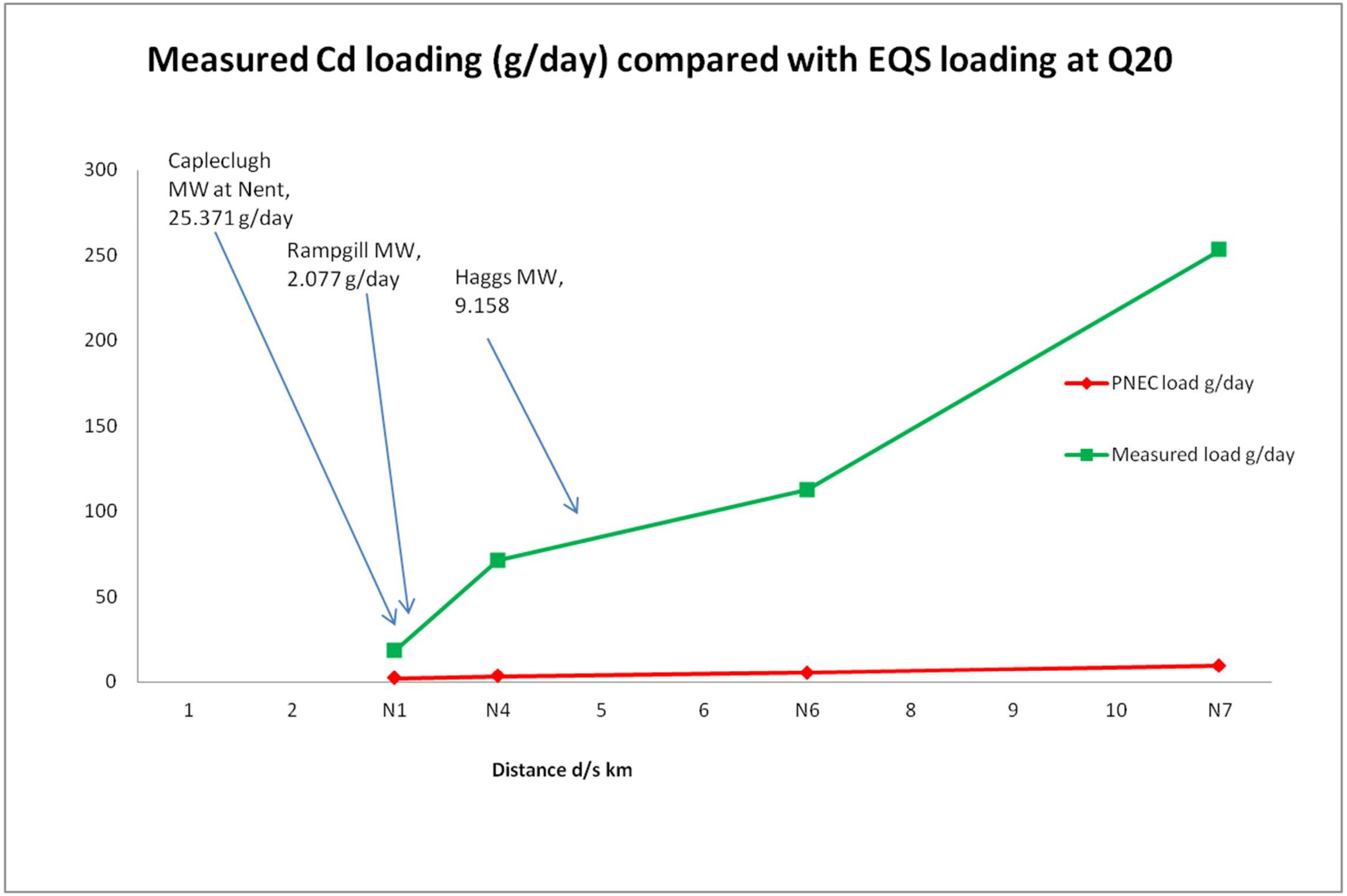


Figure 7: Graph showing the measured cadmium loading compared with the EQS loading at a Q 20 flow.



Lead

Figures 8, 9 and 10 depict the lead loadings during Q97, Q67 and Q20 flow conditions. Lead fails to meet EQS compliance at any of the designated sample points used in this study. As is to be expected, during high flow conditions, Q20 lead loadings are significantly higher than low, Q67 and medium, Q97 flow conditions. At Q20 the load at N1 is 1000 g/day, 786 g/day at N4, 1052 g/day at N6 and 1655 g/day at N7. The 3 graphs below illustrate how lead loadings vary in the River Nent across the 3 flow conditions. During low flow conditions lead loadings drop between N1 and N4 before rising between N4 and N6 then dropping again between N6 and N7. During medium flow conditions the River Nent experience a gradual increase in lead loadings between N1 and N7 with no peaks and troughs. High flow conditions result in a drop in lead loadings between N1 and N4 followed by a steady increase between N4 and N7.

With regards to the lead contribution from the point sources, these are arguably less significant than diffuse sources. The table below summarises the contributions of lead from the 3 point sources.

Table 9: Summary of lead loadings discharging to the River Nent from point sources

Sample point	Q97 (g/day)	Q67 (g/day)	Q20 (g/day)
N2	137	20.5	46
N3	0	1.3	5
N5	0	0	3.1

At very low flows (Q97), more than 100 g/day needs to be removed from the river to achieve the EQS at N6 and over 30g/day at N7. The three measured point sources (N2, N3 and N5) contribute ~137 g/day.

At low-medium flows (Q67), the three point sources discharge ~ 22 g/day but over 90 g/day needs to be removed at N6, and 490 g/day at N7.

At high flows (Q20), the measured point sources supply 54 g/day whereas more than 790 g/day needs to be removed at N6, and 1191 g/day at N7

Figure 8: Graph showing the measured lead loading compared with the EQS loading at a Q 97 flow

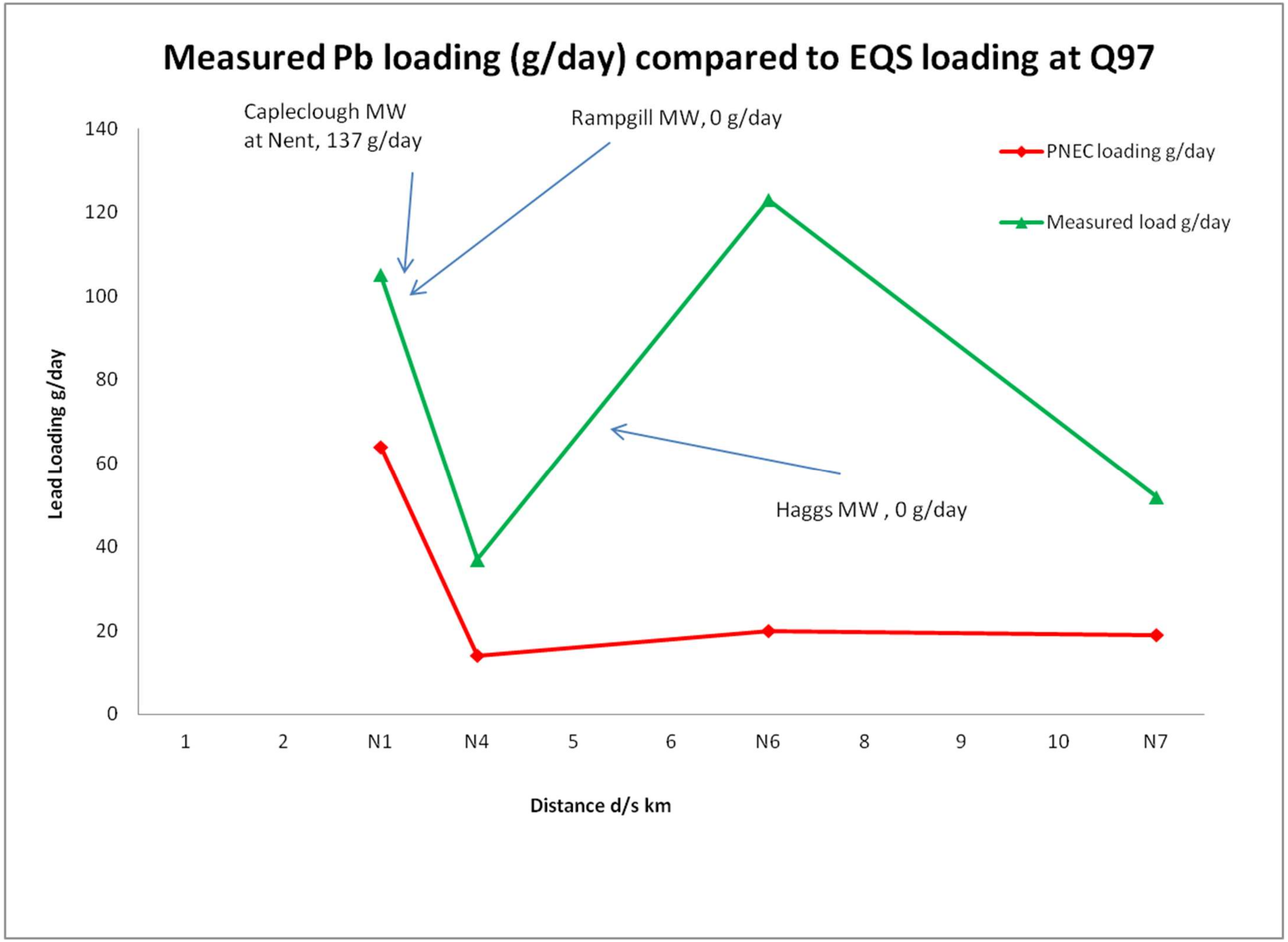


Figure 9: Graph showing the measured lead loading compared with the EQS loading at a Q 67 flow.

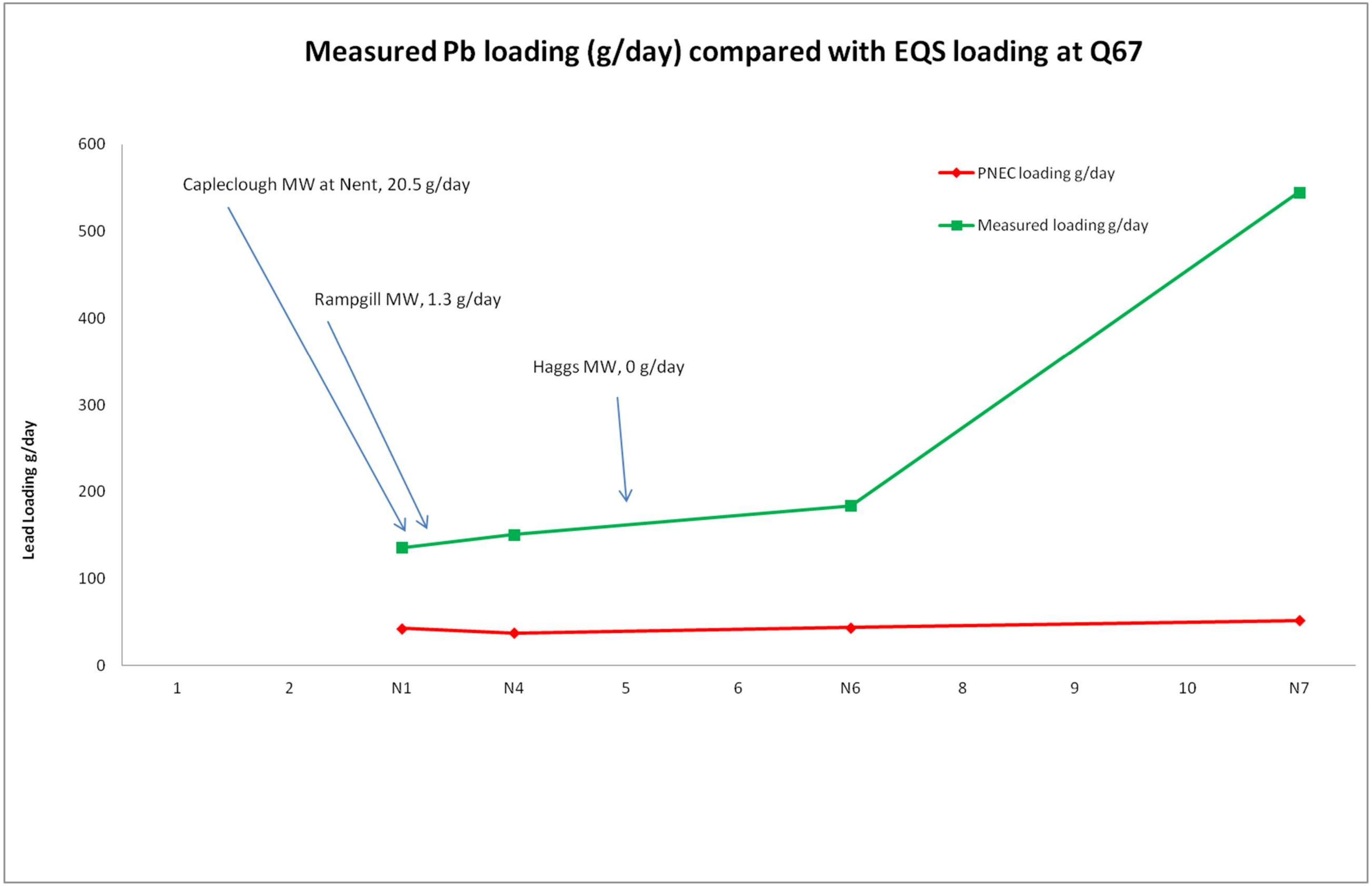
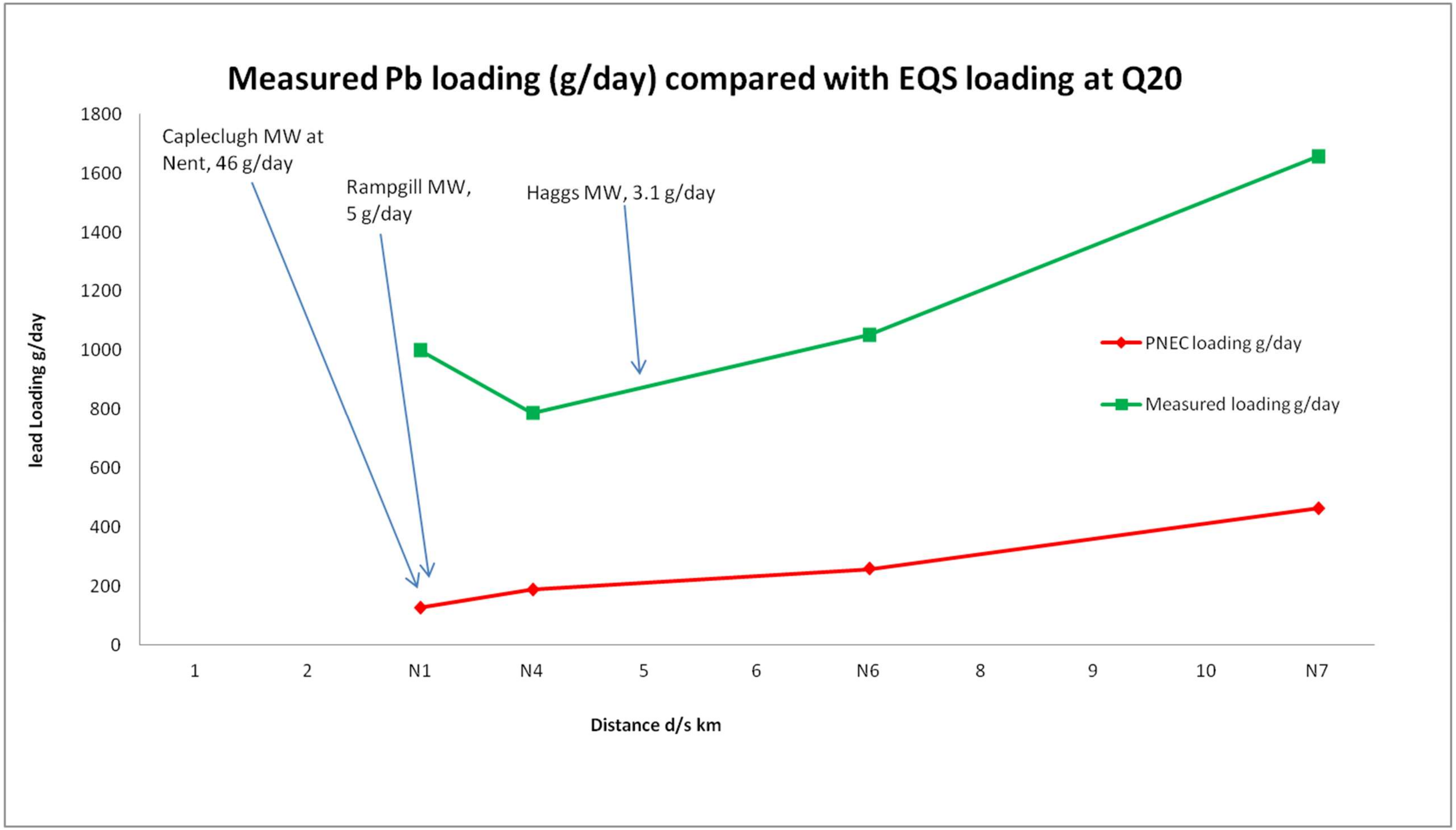


Figure 10: Graph showing the measured lead loading compared with the EQS loading at a Q 20 flow.



Section Two

Table 10: Summary of bioavailable data for the River Nent

Sample point	Zn (ug/l)[2]	Zn PNEC[3]	Zn RCR	Cd (ug/l)	Cd EQS	Cd RCR	Pb (ug/l)	Pb PNEC	Pb RCR
N1	613	30	28	1.7	0.08 – 0.25	15	22.6	7.4	3.5
N4	1,379	30	60	2.8	0.08 – 0.25	23	21.9	6.6	3.5
N6	1,245	26	64	3.1	0.08 – 0.25	21	19.9	6.3	3.7
N7	1,447	30	57	4.5	0.08 – 0.25	28	4.1	6.2	3.2
N8									

Zinc

The 3 tables below show the concentrations, loadings and percentage contributions of zinc to the River Nent at Alston in low, medium and high flow conditions (Q 97, Q67 and Q20).

Table 11: Concentrations, loadings and percentage contributions of zinc to the River Nent at Alston at Q97

Q 97	Flow (l/s)	Total Zn ug/l	Filtered Zn ug/l	Diss load ug/sec	Diss load kg/day	% at Alston
N1	62	425	358	22196	2	30%
N2	9.1	9240	9590	87623.8	7.6	120%
N3	2.4	3050	2240	5438.7	0.5	1%
N4	27	2780	2090	56430	4.9	77%
N5	3.8	15800	16600	63594.6	5.5	87%
N6	92	2230	2120	195040	16.9	266%
N7	61	1340	1200	73200	6.3	100%

Table 12: Concentrations, loadings and percentage contributions of zinc to the River Nent at Alston at Q67

Q 67	Flow (l/s)	Total Zn ug/l	Filtered Zn ug/l	Diss load ug/sec	Diss load kg/day	% at Alston
N1	109	262	246	26814	2.3	8%
N2	9.5	8000	8270	78358.3	6.8	24%
N3	3.5	3210	1910	6683.1	0.6	2%
N4	121	1280	1150	139150	12	43%
N5	12	11900	11300	135600	11.7	42%
N6	239	2140	2170	518630	44.8	160%
N7	223	1820	1450	323350	28	100%

[2] Average measured filtered concentration
[3] Target EQS (calculated with MBAT tool)

Table 13: Concentrations, loadings and percentage contributions of zinc to the River Nent at Alston at Q20

Q 20	Flow (l/s)	Total Zn ug/l	Filtered Zn ug/l	Diss load ug/sec	Diss load kg/day	% at Alston
N1	308	270	274	183306	16	17%
N2	19.8	8690	8920	176981.7	15	16%
N3	7.2	1860	1830	13170.5	1	1%
N4	474	830	836	396264	34	36%
N5	10	10900	10900	109000	9	10%
N6	696	931	929	646584	56	59%
N7	1220	853	904	1102880	95	100%

Cadmium

The 3 tables below show the concentrations, loadings and percentage contributions of cadmium to the River Nent at Alston in low, medium and high flow conditions (Q 97, Q67 and Q20).

Table 14: Concentrations, loadings and percentage contributions of cadmium to the River Nent at Alston at Q97

Q 97	Flow	Total Cd ug/l	Filtered Cd ug/l	Diss load ug/sec	Diss load g/day	% at Alston
N1	62	1.4	1.1	73.2	6.3	21%
N2	9.1	15	14.3	130.7	11.2	38%
N3	2.4	4	3.2	7.7	0.7	2%
N4	27	5	4.4	117.9	10.2	34%
N5	3.8	14	13.6	52.1	4.5	15%
N6	92	7	6.6	603.5	52.1	174%
N7	61	6	5.7	346.5	30	100%

Table 15: Concentrations, loadings and percentage contributions of cadmium to the River Nent at Alston at Q67

Q 67	Flow	Total Cd ug/l	Filtered Cd ug/l	Diss load ug/sec	Diss load g/day	% at Alston
N1	109	0.6	0.6	62.2	5.4	7%
N2	9.5	14.8	14.5	137.4	11.9	16%
N3	3.5	5	3	10.5	0.9	1%
N4	121	2.8	2.3	277.1	23.9	33%
N5	12	11.5	11.2	134.4	11.6	16%
N6	239	4.8	4.6	1092.2	94.4	131%
N7	223	4.8	3.7	834	72.1	100%

Table 16: Concentrations, loadings and percentage contributions of cadmium to the River Nent at Alston at Q20

Q 20	Flow	Total Cd ug/l	Filtered Cd ug/l	Diss load ug/sec	Diss load g/day	% at Alston
N1	308	0.709	0.703	216.5	18.7	7%
N2	19.8	14.7	14.8	293.647	25.4	10%
N3	7.2	3.5	3.34	24.038	2.1	1%
N4	474	1.8	1.74	824.760	71.3	28%
N5	10	10.5	10.6	106.000	9.2	4%
N6	696	1.94	1.87	1301.520	112.5	44%
N7	1220	2.54	2.4	2928.000	253	100%

Lead

The 3 tables below show the concentrations, loadings and percentage contributions of lead to the River Nent at Alston in low, medium and high flow conditions (Q 97, Q67 and Q20).

Table 17: Concentrations, loadings and percentage contributions of lead to the River Nent at Alston at Q97

Q 97	Flow	Total Pb ug/l	Filtered Pb ug/l	Diss load ug/sec	Diss load kg/day	% at Alston
N1	62	31.2	19.6	1215.2	0.1	201%
N2	9.1	17.8	15	137.1	0.01	23%
N3	2.4	36.6	0	0	0	0%
N4	27	66.7	16	432	0.03	72%
N5	3.8	0	0	0	0	0%
N6	92	17.5	15.5	1426	0.1	236%
N7	61	13.2	9.9	603.3	0.052	100%

Table 18: Concentrations, loadings and percentage contributions of lead to the River Nent at Alston at Q67

Q 67	Flow	Total Pb ug/l	Filtered Pb ug/l	Diss load ug/l	Diss load kg/day	% at Alston
N1	109	26.5	14.4	1569.6	0.1	25%
N2	9.5	29.3	25	236.9	0.02	4%
N3	3.5	419	4.36	15.3	0.001	0.2%
N4	121	50.9	14.4	1742.4	0.2	28%
N5	12	10.1	0	0	0	0%
N6	239	26.2	8.9	2127	0.2	34%
N7	223	91.1	28.3	6310.9	0.5	100%

Table 19: Concentrations, loadings and percentage contributions of lead to the River Nent at Alston at Q20

Q 20	Flow	Total Pb ug/l	Filtered Pb ug/l	Diss load ug/sec	Diss load kg/day	% at Alston
N1	308	20.6	17.3	11573.7	1	60%
N2	19.8	31.9	26.8	531.7	0.04	3%
N3	7.1	22	8.1	58.2	0.005	0.3%
N4	474	24.8	19.2	9100.8	0.8	48%
N5	10	4.7	3.6	35.7	0.003	0.2%
N6	696	26.2	17.5	12180	1.1	64%
N7	1220	21.2	15.7	19154	1.7	100%

Discussion

The data detailed in this report confirms the River Nent currently fails to meet EQS for zinc, cadmium and lead on an annual basis at all four river sample points used in this characterisation study, including N7, the WFD compliance point for the River Nent. As annual average data is used for WFD classification purposes the date presented in this report clearly demonstrates the River Nent currently fails to meet WFD compliance standards.

The EQS failures are significant. For example, when looking at the bioavailable zinc data for N7, the Risk Characterisation Ratio, (RCR) ranges between 16.08 and 135.45. The RCR is calculated by dividing the Predicted Environmental Concentration by the Predicted No Effect Concentration. A RCR greater than 1 presents a potential risk to the environment. These figures clear indicate a significant breach of the site specific EQS limit. The figures for cadmium and lead also illustrate the extent of the EQS breaches with the RCR and N7. For cadmium the RCR range between 19.8 and 427.3 and for lead between 1.41 and 10.34. The full bioavailable data set it available in the appendix.

Both zinc and cadmium follows very similar patterns with regards to their loadings as you move down the river from N1 to N7. At Q97 and Q67 flow conditions the data suggests a peak in the metal loadings at N6. However at Q20 flow conditions you see a gradual increase in the metal loadings from N1 through to N7. At no point is EQS compliance achieved.

Lead loadings follow a different pattern. During Q97 flow conditions, between N1 and N4 there is a drop in the loadings, followed by a peak at N6 before a decrease at N7. During Q67 flow conditions there is a gradual increase in the loadings between N1 and N7. At Q20 flow conditions, again there is a drop between N1 and N4 followed by a steady increase between N4 and N7. At no point is EQS compliance achieved

Predicted improvements with treatment of various point and diffuse sources

A number of scenarios exploring the potential improvements that could be made to the River Nent if treatment were to be incorporated on the identified significant point sources and measures taken to reduce diffuse sources of metal pollutant have been considered using the Source Apportionment Tool (SAT) (Newcastle and Hull Universities).

Taking into consideration the current performance of the Force Crag mine water scheme (VFP) which is operating in Cumbria, a 90% removal of metals from point sources has been applied in the SAT. With regards to the removal of diffuse sources, placing a quantifiable numeric figure on this is rather difficult as currently there is no supporting data. Therefore a figure of 50% has been applied in the SAT.

As the bioavailable EQS is for dissolved metals the removal scenarios have focused on dissolved metal concentrations and the dissolved PNEC value.

It should be noted that data from only seven out of the twelve sampling events used in this study have been included when looking at potential improvement scenarios for the River Nent at Alston. This results from missing flow data for the N7 sample site on 5 occasions as a result of high flows. During high flows, anything >12000 l/sec in the River Nent at Alston is ungaugable due to the health and safety risks associated with the measurement method used in this study.
The 6 tables below show the results from the SAT for the current and predicted RCR.

NOTE
The same pH, DOC, Ca and water hardness have been assumed when calculating the ''predicted RCR'' as when the ''current RCR'' was calculated for the River Nent at Alston during Q97, Q67 and Q 20 flow conditions.

During Q97 flow conditions 90% removal of zinc from Capelcleugh in the SAT gives a figure of -92.81µg/l. Therefore 5µg/l was entered into the BLMTool as this is the analysis detection limit.

Table 20: River Nent at Alston, current and predicted RCR at Q97

Treatment scenarios	Zinc		Cadmium		Lead	
	Current RCR	Predicted RCR	Current RCR	Predicted RCR	Current RCR	Predicted RCR
Caplecleugh 90%	53.68	0.22	24.24	15	2.81	2.24
Haggs 90%	53.68	11.71	24.24	19.64	2.81	2.81
Caplecleugh and Haggs 90%	53.68	0.22	24.24	11.92	2.81	2.24
Caplecleugh, Haggs and Rampgill 90%	53.68	0.22	24.24	11.48	2.81	2.24
Caplecleugh, Haggs and Rampgill 90% and 50% removal of diffuse upstream of N1, N4, N6 and N7	53.68	0.22	24.24	2.28	2.81	1.15

Table 21: River Nent at Alston, current and predicted RCR at Q67

Treatment scenarios	Zinc		Cadmium		Lead	
	Current RCR	Predicted RCR	Current RCR	Predicted RCR	Current RCR	Predicted RCR
Caplecleugh 90%	77.36	60.49	32.2	21.27	10.34	9.99
Haggs 90%	77.36	48.17	32.2	21.33	10.34	10.34
Caplecleugh and Haggs 90%	77.36	31.29	32.2	17.67	10.34	9.99
Caplecleugh, Haggs and Rampgill 90%	77.36	30.06	32.2	17.40	10.34	9.97
Caplecleugh, Haggs and Rampgill 90% and 50% removal of diffuse upstream of N1, N4, N6 and N7	77.36	17.66	32.2	2.47	10.34	5.01

Table 22: River Nent at Alston, current and predicted RCR at Q20

Treatment scenarios	Zinc		Cadmium		Lead	
	Current RCR	Predicted RCR	Current RCR	Predicted RCR	Current RCR	Predicted RCR
Caplecleugh 90%	40.52	34.50	28.22	24.22	3.56	3.48
Haggs 90%	40.52	45.95	28.22	24.67	3.56	3.56
Caplecleugh and Haggs 90%	40.52	30.92	28.22	23.44	3.56	3.47
Caplecleugh, Haggs and Rampgill 90%	40.52	30.48	28.22	23.22	3.56	3.46
Caplecleugh, Haggs and Rampgill 90% and 50% removal of diffuse upstream of N1, N4, N6 and N7	40.52	15.79	28.22	2.67	3.56	1.73

It should be noted that data from only ten out of the twelve sampling events used in this study have been included when looking at potential improvement scenarios for the River Nent at Nenthall. This results from missing flow data for the N6 sample site. 870 l/sec is the highest flow gauged at this site.

NOTE
The same pH, DOC, Ca and water hardness have been assumed when calculating the ''predicted RCR'' as when the ''current RCR'' was calculated for the River Nent at Nenthall during Q97, Q67 and Q 20 flow conditions.

Table 23: River Nent at Nenthall, current and predicted RCR at Q97

Treatment scenarios	Zinc		Cadmium		Lead	
	Current RCR	Predicted RCR	Current RCR	Predicted RCR	Current RCR	Predicted RCR
Caplecleugh 90%	111.24	66.26	262.4	21	6.06	5.71
Haggs 90%	111.24	78.59	262.4	24.2	6.06	6.06
Caplecleugh and Haggs 90%	111.24	33.62	262.4	19.08	6.06	5.54
Caplecleugh, Haggs and Rampgill 90%	111.24	30.82	262.4	18.8	6.06	5.54
Caplecleugh, Haggs and Rampgill 90% and 50% removal of diffuse upstream of N1, N4, N6 and N7	111.24	19.88	262.4	9.8	6.06	2.80

Table 24: River Nent at Nenthall, current and predicted RCR at Q67

Treatment scenarios	Zinc		Cadmium		Lead	
	Current RCR	Predicted RCR	Current RCR	Predicted RCR	Current RCR	Predicted RCR
Caplecleugh 90%	127.94	110.55	30.46	27.07	4.12	3.71
Haggs 90%	127.94	97.84	30.46	27.07	4.12	4.12
Caplecleugh and Haggs 90%	127.94	80.44	30.46	23.67	4.12	3.71
Caplecleugh, Haggs and Rampgill 90%	127.94	79.17	30.46	23.47	4.12	3.56
Caplecleugh, Haggs and Rampgill 90% and 50% removal of diffuse upstream of N1, N4, N6 and N7	127.94	42.29	30.46	12.13	4.12	1.87

Table25: River Nent at Nenthall, current and predicted RCR at Q20

Treatment scenarios	Zinc		Cadmium		Lead	
	Current RCR	Predicted RCR	Current RCR	Predicted RCR	Current RCR	Predicted RCR
Caplecleugh 90%	43.83	33.03	20.77	16.56	4.07	3.91
Haggs 90%	43.83	37.18	20.77	19.22	4.07	4.06
Caplecleugh and Haggs 90%	43.83	26.38	20.77	15	4.07	3.90
Caplecleugh, Haggs and Rampgill 90%	43.83	25.58	20.77	14.67	4.07	3.89
Caplecleugh, Haggs and Rampgill 90% and 50% removal of diffuse upstream of N1, N4, N6 and N7	43.83	13.80	20.77	7.67	4.07	1.95

Table 20 shows the results for low flow conditions, (Q97) a RCR of <1 for zinc is achievable for the River Nent at Alston (N7) with treatment of the point sources and work to reduce diffuse inputs. However, treating N5 alone will not achieve a RCR <1. With regards to cadmium and lead, the results suggest that a RCR < 1 will not be achieved, even with both point source and diffuse treatment.

Tables 21 and 22 shows the results for both medium (Q67) and high flow (Q20) conditions a RCR < 1 cannot be achieved in the River Nent at Alston for zinc, cadmium or lead with both point and diffuse source treatment.

At the River Nent at Nent Hall, (N6) a RCR of <1 cannot be achieved for zinc, cadmium and lead during any of the three flow conditions, (Q97, Q67 and Q20) with the treatment of both point and diffuse sources, see tables 23, 24 and 25.

However, it should be noted that the ''current RCR'' is either reduced or equal to the ''predicted RCR'' for all treatment scenarios considered at both N6 and N7. This indicates that the proposed treatment schemes and works to reduce diffuse inputs within the River Nent catchment will result in a positive effect on water quality as the degree of the EQS failures would substantially improve.

Constraints

There are a number of constrains that have resulted in limitations within this study of the River Nent catchment.

- As a result of time limitations only 7 monitoring points were included in this study. This resulted in a number of point source discharges and tributaries of the River Nent been left out of the study. There is also uncertainty surrounding the accuracy of the flow measurements used in this study, particularly during low and higher flows. This results from the nature of the water courses being gauged and the methods used to gauge the flows. This has resulted in some limitations within the data set and scope of the characterisation study.
- As mentioned in an earlier section of this study, the Nent Force Level, which is a significant contributor of metals to the River Nent was not included in this study as it was felt too dangerous to access. The Nent Force Level enters the River Nent downstream of the WFD compliance point (N7).
- During high flow conditions the 2 downstream river monitoring points were as time ungaugable as a result of health and safely constraints. Since this study has been completed a River Level Site has been installed on the River Nent at Alston. This will enable flow data during high flow conditions to be calculated.
- As the full range of flow conditions for the River Nent at Alston were not available for this study, the Q values used in the study were taken from flow data from the long-established gauging station on the River South Tyne at Alston. Therefore Q values may not be a true representation of the flows experience at the sample points used in this study.
- The lack of flow data during high flow conditions for the 2 downstream river sample sites has hindered the calculation of some metals loadings.
- There are also some further anomalies in the flow data as a result of the hydroelectric scheme that operates on the old mine site at Nenthead. The

scheme utilises some of the River Nent headwaters. The scheme is known to 'pulse' water through the system at times when there is not enough water available to constantly operate the turbines efficiently. This can significantly affect flows in the River Nent downstream of where the hydroelectric scheme discharges back to the Rampgill Burn, (which then flows into the River Nent).

- On a number of occasions flow data is unavailable for some of the point source discharges. This occurred as a result of issues with the logging equipment being used to collate the flow data.
- In more recent months issues have occurred with regards to the diversion of mine waters within the historic mine workings. These diversions have result in changes in the flows of mine water discharging to the River Nent at a given location and resulted in increased flow discharge from other point sourced that were not being monitored as part of this characterisation study.
- Monitoring of the River South Tyne was not incorporated into this study. This has limited the extent of the impacts of any proposed treatment scheme on the River South Tyne.

Summary and conclusions

This study has enabled a better conceptual understanding of the River Nent and how it is impacted by historic metal mining activities. It is impacted by both point and diffuse sources with the point sources being more important during in low flows conditions.

During low flow conditions, Q97 sources of zinc can be accounted for via the point source discharges, with Capelcleugh, (120%) and Haggs, (87%) contributing a significantly higher loading than the Rampgill discharge, (1%) to the River Nent at Alston. The three point source discharges contribute ~13.5 kg/day of zinc to the River Nent compared with the following zinc loadings at the four river sample points, 1.9 kg/day at N1, 4.9 kg/day at N4, 16.85 kg/day at N5 and 6.32 kg/day at N7. This is also the case for cadmium; Capelcleugh contributes 38% of the load at Alston, Haggs contributes 15% and Rampgill contributes only 2%.

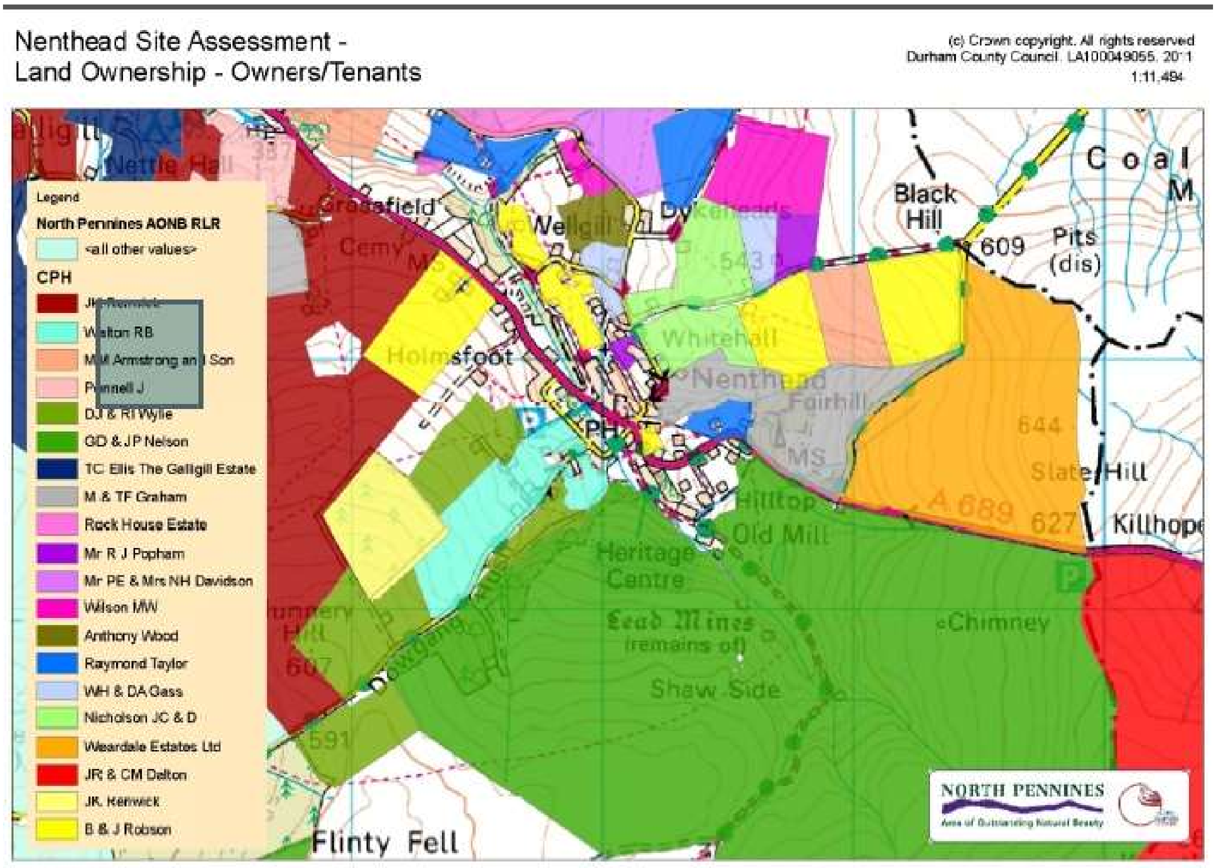
During high flows, Q20 zinc loadings accounted for in the River Nent at Alston from the point sources are reduced, 16% from Capelcleugh, 10% from Haggs and 1% from Rampgill, with a cumulative contribution of 25 kg/day from the three point source discharges.

The zinc loading accounted for at Alston from N1 is 16.62% during high flows. There is a similar picture for the cadmium loadings accounted for at Alston during high flows. 10% comes from Capelcleugh, 4% comes from Haggs, 1% from Rampgill and 7.39% being accounted for from N1.

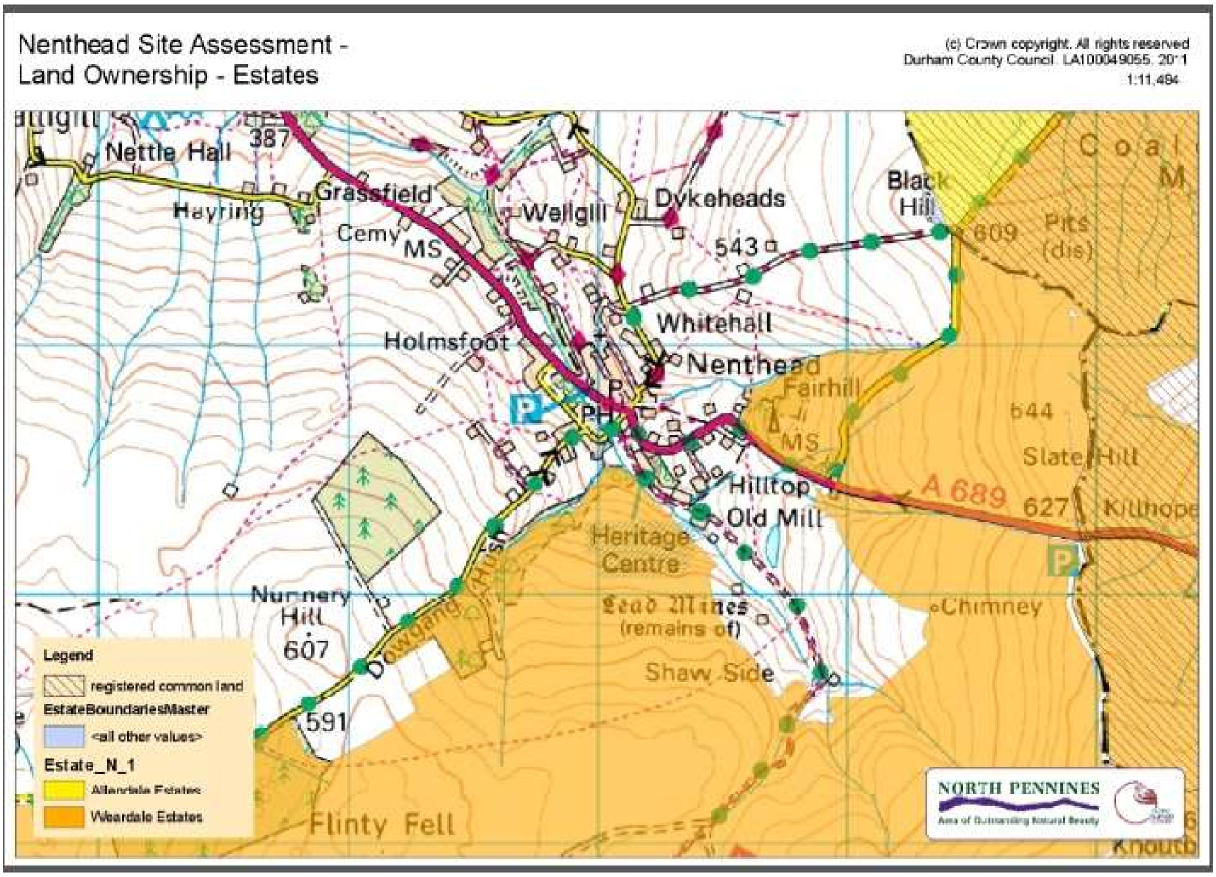
With regards to lead contributions, as would be expected the point sources contribute significantly less than diffuse sources. Even in low flow conditions the contribution of lead from the point sources is significantly lower than the diffuse sources. For example, N1 contributes 201% of the lead load at Alston in comparison with 23% from Capelcleugh and 0% for both the Rampgill and Haggs adits. During high flow conditions the diffuse sources are still the most significant source of lead with 60% of the lead at Alston being accounted for at N1. The situation regarding point sources changes slightly during high flows in that all three point sources contribute to the lead loading at Alston, Capelcleugh 3%, Rampgill 0.3% and Haggs 0.19% but this is still a tiny contribution to the lead flux in the river.

With the implantation of treatment schemes to address the input of metals to the River Nent from the point sources EQS compliance in the River Nent at Alston is unlikely to be achieved. This is also the case if measures are taken to reduce diffuse inputs. Given the geology and extent historic metal mining activities that have taken place in the River Nent Catchment it is important to understand that achieving overall EQS compliance in the River Nent is unlikely. However, work in the River Nent catchment to reduce metal inputs into the water body is important as a result of the impact on the downstream water bodies. EQS improvements are likely to be seen in the River South Tyne and the main Tyne.

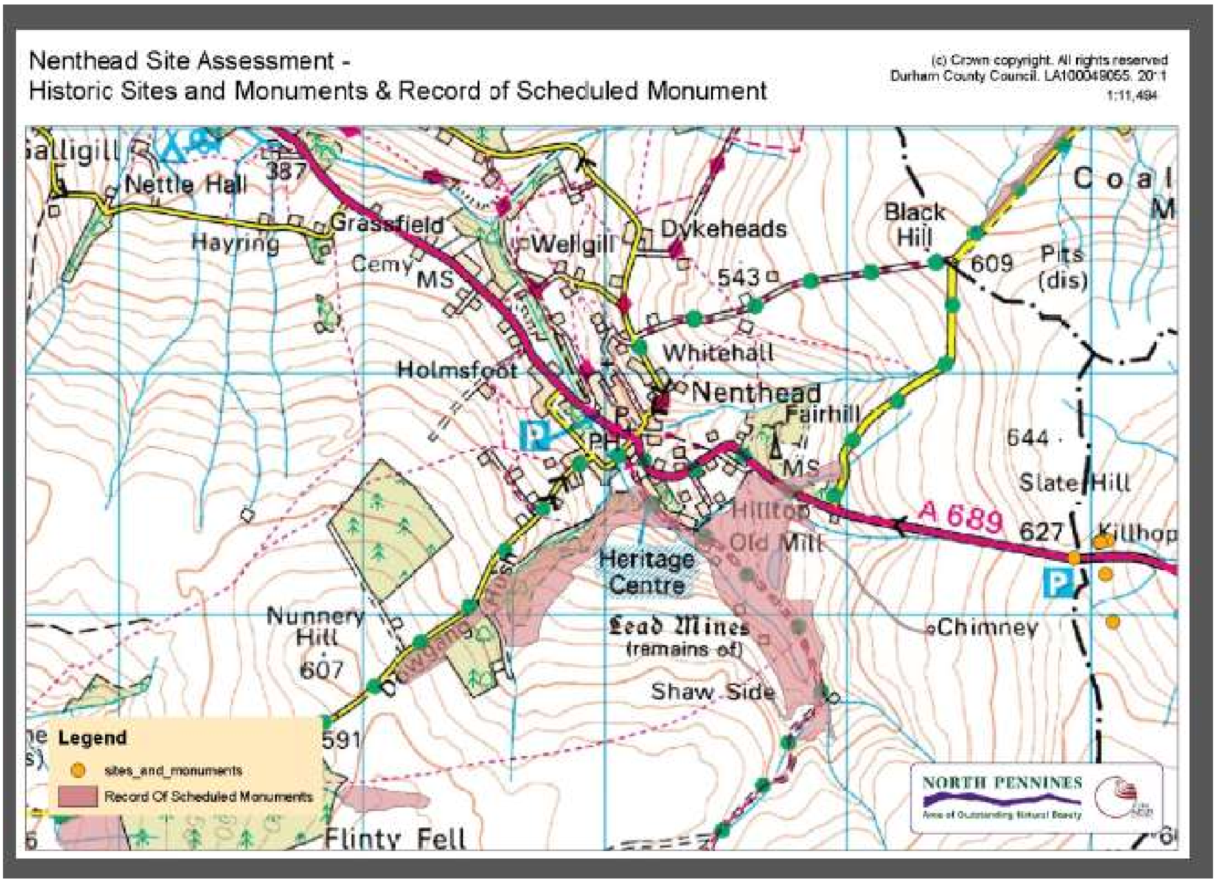
Appendix 1: Nenthead Land Ownership – Owners/Tenants



Appendix 2: Nenthead Land Ownership – Estates.



Appendix 3: Historic Sites and Monuments and Record of Scheduled Monument



Appendix 4: Bioavailable data

Nent at Capelcleugh

Date	Estimated PNEC Dissolved Zinc (µg l-1)	BioF	Bioavailable Zinc Concentration (µg l-1)	Risk Characterisation Ratio	Pb PNEC (µg l-1)	BioF	Risk Characterisation Ratio	Cd (filtered)	Hardness	Cd (EQS)	Risk Characterisation Ratio
16/01/2014	18.26	0.60	163.59	15.01	4.81	0.21	3.60	0.703	15.8	0.08	8.788
19/02/2014	18.05	0.60	179.36	16.45	4.56	0.22	5.50	0.765	13.7	0.08	9.563
17/03/2014	21.42	0.51	125.20	11.49	4.66	0.21	3.09	0.571	40	0.08	7.138
15/04/2014	27.75	0.39	105.64	9.69	6.59	0.15	2.00	0.669	33.6	0.08	8.363
08/05/2014	49.55	0.22	58.96	5.41	13.56	0.07	2.58	0.736	18	0.08	9.200
23/06/2014	49.41	0.22	78.97	7.25	11.96	0.08	1.64	1.18	68	0.09	13.111
17/07/2014	17.42	0.63	982.54	90.14	2.42	0.41	6.02	4.61	143	0.15	30.733
05/08/2014	18.35	0.59	1015.79	93.19	2.66	0.38	4.28	4.99	155	0.15	33.267
04/09/2014	20.73	0.53	972.54	89.22	3.54	0.28	3.31	5	124	0.15	33.333
09/10/2014	54.35	0.20	57.15	5.24	15.12	0.07	1.66	0.758	19.8	0.08	9.475
12/11/2014	46.20	0.24	86.82	7.97	13.08	0.08	3.56	1.01	19.4	0.08	12.625
10/12/2014	34.32	0.32	123.87	11.36	9.46	0.11	4.00	0.965	19.5	0.08	12.063
13/01/2015	22.15	0.49	179.63	16.48	6.35	0.16	4.08	0.933	17	0.08	11.663
18/02/2015	20.68	0.53	181.35	16.64	5.28	0.19	3.47	0.852	20.5	0.08	10.650

Nent upstream of Nenthead Sewage Treatment Works

Date	Estimated PNEC Dissolved Zinc (µg l-1)	BioF	Bioavailable Zinc Concentration (µg l-1)	Risk Characterisation Ratio	Pb PNEC (µg l-1)	BioF	Risk Characterisation Ratio	Cd (filtered)	Hardness	Cd (EQS)	Risk Characterisation Ratio
16/01/2014	20.76	0.52	438.84	40.26	4.58	0.22	4.19	1.74	41.7	0.08	21.750
19/02/2014	21.65	0.50	316.62	29.05	4.79	0.21	5.97	1.47	27.8	0.08	18.375
17/03/2014	20.25	0.54	619.11	56.80	3.67	0.27	3.92	2.29	89.6	0.09	25.444
15/04/2014	26.93	0.40	433.14	39.74	6.04	0.17	2.50	2.1	75.7	0.09	23.333
08/05/2014	47.18	0.23	140.22	12.86	12.72	0.08	2.87	1.42	37	0.08	17.750
23/06/2014	29.46	0.37	773.38	70.95	5.94	0.17	2.69	4.37	178	0.15	29.133
17/07/2014	16.04	0.68	2344.86	215.13	1.64	0.61	4.35	6.47	276	0.25	25.880
05/08/2014	24.31	0.45	1103.10	101.20	4.38	0.23	2.65	4.46	188	0.15	29.733
04/09/2014	19.51	0.56	1720.35	157.83	2.78	0.36	2.00	5.75	244	0.25	23.000
09/10/2014	52.40	0.21	125.85	11.55	13.80	0.07	2.00	1.35	39	0.08	16.875
12/11/2014	45.04	0.24	157.78	14.48	12.12	0.08	3.63	1.52	35.1	0.08	19.000
10/12/2014	39.06	0.28	271.82	24.94	8.52	0.12	4.12	1.96	46.5	0.08	24.500
13/01/2015	27.51	0.40	334.77	30.71	6.05	0.17	4.27	1.89	39.9	0.08	23.625
18/02/2015	25.14	0.43	373.34	34.25	5.10	0.20	4.04	1.81	46.3	0.08	22.625

River Nent at Nenthall

Date	Estimated PNEC Dissolved Zinc (µg l-1)	BioF	Bioavailable Zinc Concentration (µg l-1)	Risk Characterisation Ratio	Pb PNEC (µg l-1)	BioF	Risk Characterisation Ratio	Cd (filtered)	Hardness	Cd (EQS)	Risk Characterisation Ratio
16/01/2014	21.20	0.51	477.71	43.83	4.30	0.23	4.07	1.87	55.3	0.09	20.778
19/02/2014	22.04	0.49	332.42	30.50	4.63	0.22	4.75	1.45	37	0.08	18.125
17/03/2014	16.96	0.64	1394.60	127.94	2.16	0.46	4.12	4.57	186	0.15	30.467
15/04/2014	19.32	0.56	1111.68	101.99	2.96	0.34	4.08	4	161	0.15	26.667
08/05/2014	53.06	0.21	147.29	13.51	13.80	0.07	2.62	1.67	46.9	0.08	20.875
23/06/2014	19.06	0.57	1212.47	111.24	2.56	0.39	6.06	6.56	279	0.25	26.240
17/07/2014	18.85	0.58	1115.73	102.36	2.54	0.39	5.86	5.7	263	0.25	22.800
05/08/2014	25.18	0.43	601.74	55.21	4.26	0.23	3.00	4.02	229	0.25	16.080
04/09/2014	24.93	0.44	629.56	57.76	4.20	0.24	2.50	4.2	220	0.25	16.800
09/10/2014	52.00	0.21	181.11	16.62	12.48	0.08	2.38	1.81	56.2	0.09	20.111
12/11/2014	50.47	0.22	154.86	14.21	13.20	0.08	2.63	1.51	45.5	0.08	18.875
10/12/2014	10.90	1.00	785.00	72.02	9.34	0.11	3.02	1.72	53.5	0.09	19.111
13/01/2015	10.90	1.00	823.00	75.50	6.11	0.16	3.00	1.77	50.6	0.09	19.667
18/02/2015	12.15	0.90	818.89	75.13	5.02	0.20	3.39	1.92	64.5	0.09	21.333

River Nent at Alston

Date	Estimated PNEC Dissolved Zinc (µg l-1)	BioF	Bioavailable Zinc Concentration (µg l-1)	Risk Characterisation Ratio	Pb PNEC (µg l-1)	BioF	Risk Characterisation Ratio	Cd (filtered)	Hardness	Cd (EQS)	Risk Characterisation Ratio
16/01/2014	22.31	0.49	441.72	40.52	4.40	0.23	3.56	2.54	62	0.09	28.222
19/02/2014	22.24	0.49	329.42	30.22	4.93	0.20	3.83	1.58	41.7	0.08	19.750
17/03/2014	18.74	0.58	843.27	77.36	2.74	0.37	10.34	4.83	158	0.15	32.200
18/03/2014	20.12	0.54	1018.27	93.42	3.18	0.31	2.67	5.09	146	0.15	33.933
15/04/2014	22.31	0.49	644.84	59.16	3.86	0.26	2.90	3.61	130	0.15	24.067
08/05/2014	53.35	0.20	163.26	14.98	13.68	0.07	2.44	2.08	49.8	0.08	26.000
20/06/2014	27.30	0.40	1181.92	108.43	5.04	0.20	2.12	8.66	221	0.25	34.640
23/06/2014	22.35	0.49	585.17	53.68	3.52	0.28	2.81	6.06	227	0.25	24.240
17/07/2014	19.94	0.55	798.03	73.21	2.87	0.35	3.84	7.43	241	0.25	29.720
05/08/2014	27.07	0.40	865.81	79.43	4.90	0.20	2.51	6.41	184	0.15	42.733
04/09/2014	29.12	0.37	415.49	38.12	5.23	0.19	1.41	5.15	204	0.25	20.600
05/09/2014	23.11	0.47	1476.43	135.45	3.89	0.26	2.15	7.85	219	0.25	31.400
09/10/2014	52.53	0.21	213.73	19.61	13.20	0.08	2.05	2.44	62.1	0.09	27.111
12/11/2014	50.24	0.22	175.31	16.08	12.72	0.08	2.54	2.14	52.6	0.09	23.778
10/12/2014	39.37	0.28	228.39	20.95	8.48	0.12	2.82	1.95	59.2	0.09	21.667
13/01/2015	30.00	0.36	286.28	26.26	6.17	0.16	2.29	2.06			
18/02/2015	26.16	0.42	375.40	34.44	5.02	0.20	2.79				

Appendix 5: Photographs of sampling points and other mining features

Capelcleugh Adit (N2)

Rampgill Adit N3

Dowgang Hush, lower section

Unnamed Adit, Dowgang Burn

River Nent down stream of Nenthead Town (N4), weirs and gabions.

Brownley Hill tailings dam

Brownley Hill mine entrance

Haggs Adit (N5)

Croft Mine entrance and discharge

Adit at Nent Hall

Worked land/Hush and spoil at Haggs Mine

Nent Force Level (2009)