Summer dredging campaigns and their effect on water quality

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Abstract The Canal & River Trust was established in July 2012 within England and Wales, to manage inland waterways, docks, reservoirs and estates that had previously been the responsibility of British Waterways. The key purpose of the new Trust is to "*act as guardian for the canals and rivers of England and Wales – ensuring that history, nature and communities are central to everything we do*". As part of this remit, the Trust is responsible for maintaining navigation for approx. 2000 miles of waterways. In order to achieve this, the Trust needs to dredge sediment out of its waterways to maintain a minimum depth of ~1.5 m. In the past, dredging was only conducted over the winter months from October through to March, but due to contractual changes and a backlog of identified problems, a "year round" dredging programme has been operating since 2011. In September 2011, dredging on the Aylesbury Arm contributed to a fish kill in the area. On investigation, mean ammoniacal nitrogen in the sediment was 181 mg kg^{-1}, coupled with water pH 8.0 and temperature of 15.1°C, led to ammoniacal nitrogen concentrations >4 mg L^{-1} in the water column. A second fish kill, in the Tame Valley canal during a dredging project in July 2012, appeared to be attributed to high water temperatures, BOD and COD in the sediment leachate samples taken after the event. Parallels were drawn between the two cases and questions were raised about the sediment sampling regime, which historically has been based on determining a safe and cost-effective re-use or disposal routes. This paper discusses the events over the last two years and the proposed new approaches to future sediment testing and water quality monitoring as well as reinstating on-site emergency remedial measures.

Key words dredge; sediment; water quality; fish kill; Aylesbury Arm, UK; Tame Valley, UK; canal

INTRODUCTION

Between 2002 and 2011, the Canal & River Trust (and its predecessor British Waterways) summer dredging campaigns were reduced in number or stopped completely due to concerns over environmental impacts. Minutes of a meeting reviewing a dredging campaign for the Grand Union Canal in 2002 concluded that environmentally there was little support for summer dredging due to fish kills and it was only conducted as a result of Contractor pressure on the Client for obtaining "best value" (British Waterways, 2002). In 2011, driven by financial constraints, British Waterways moved from a position of having two dredging contractors working from September to April to one contractor working through the year, saving approx. two million GBP (£) per annum. Decisions regarding which lengths of waterway are dredged are based on the number of customer complaints of poor navigation and the result of channel profiling surveys. Since summer dredging campaigns were reintroduced in 2011, fish kills have occurred on three campaigns. Typically, sediment samples are obtained prior to dredging works taking place to determine the most sustainable disposal route for the waste sediment and determine the health and safety risks posed to the Contractor, and not for the potential impact on the water column.

This purpose of this paper is twofold: firstly, to consider whether additional analysis of the sediment could have identified risks to aquatic life at the sampling stage and, secondly, to consider whether a more robust sampling regime can be developed to try and reduce the possibility of future fish mortalities during dredging.

DREDGING SITES

This paper will review two dredging campaigns which suffered substantial fish mortalities. The fish kill on the Aylesbury Arm in 2011 and the fish kill on the Tame Valley Canal in 2012. This paper only considers the parameters that potentially contributed to the fish kills and therefore the sediment data in Tables 1 and 3 do not report hexavalent chromium, boron, cyanide or molybdenum; these parameters have been shown not to be a problem in canal sediments (Beckwith, 2010). Aqueous chloride, fluoride extract and monohydric phenol have also been excluded as these were present below detection levels and only tested on the Aylesbury Arm sediments as part of the requirements to spread waste sediments to agricultural land. Speciated polycyclic aromatic hydrocarbons (PAH) values have also been omitted as this is used for sediment disposal and total PAH will be sufficient to determine a presence. Available magnesium, available potassium, nitrate and kjeldahl nitrogen have also been omitted as these were sampled to determine benefit to agricultural land and are not perceived to contribute towards the fish kills.

AYLESBURY ARM, GRAND UNION CANAL

The Aylesbury Arm is ~10 km long and was completed in 1815 to link the town of Aylesbury to the Grand Union Canal. Located on the border of Hertfordshire and Buckinghamshire in the south-east of England, the canal rises ~20 m over 14 locks from Aylesbury town to the junction with the Grand Union Canal. The canal is thought to be lined with puddle-quality Kimmeridge clay, which overlies Cretaceous Lower Chalk and Gault (English Heritage, 2009). The surrounding catchment is predominantly arable (80%), but becomes urbanised (20%) in the west at Aylesbury (Canal & River Trust ArcGIS, 2012).

The canal is fed by three sources of water: a feed from the Grand Union canal, an overflow feed at high flow from the Bear brook (at AA2 on Fig. 1) and a gravity feed from Wilstone Reservoir into the canal pound below Lock 9. Wilstone Reservoir is one of four reservoirs called the Tringford Group, used to feed the Grand Union Canal system. The Tringford Group are recharged by both groundwater and surface water and are interconnected by a series of pipes and pumps, so water supply to the Grand Union and the Aylesbury Arm are essentially the same.

The water quality of the Aylesbury Arm and the Grand Union Canal are currently classified as "moderate ecological potential", under the Water Framework Directive (DIRECTIVE 2000/60/EC) (Environment Agency, 2012), but only due to their hydromorphological constraints. The feed from Wilstone reservoir is classed as "good ecological potential" for all elements of the classification. The Bear brook is classed as "moderate status" due to macroinvertebrates and phosphates (Environment Agency, 2012).

There are currently no permitted sewage or trade effluent discharges into Wilstone Reservoir or to the Aylesbury Arm. Historically this has not always been the case. Tring Sewage Treatment Works (STW) used to discharge directly into Marsworth Reservoir, one of the Tringford Group; this practice was stopped about 15 years ago. The storm tanks from the Tring STW are still permitted to discharge to the reservoir today; the last discharge event occurred in 2007 (Atkins, 2012). As a result of past discharges to the reservoirs and continued diffuse inputs, the Tringford Group reservoirs have become nutrient rich and suffer from annual algal blooms. In mid-August 2001 a fish kill occurred in the terminus basin due to deoxygenation; in addition there were also bird deaths from botulism.

The dredging campaign aimed to remove ~9500 m^3 sediment from a 9 km section from Lock 6, 1 km east from the junction with the Grand Union Canal, to the terminus at Aylesbury, to return the canal to a depth of 1.35 m (Littler, 2011). The location of the Aylesbury Arm, the locks and sediment sampling are given in Fig. 1. Sediment samples were taken at roughly 500 m intervals along the canal prior to dredging from point AA1 (Aylesbury) to point AA8 (the junction with the Grand Union Canal). The results of the sediment sample analysis are presented in Table 1 and identified that sediment between the terminus (sample AA1) and Lock 15 (sample AA4) was suitable for land disposal, but large amounts of debris prevented this and so the material was taken to landfill. The remaining material, from AA5 west towards the Grand Union Canal, was identified as suitable for spreading to agricultural land and for use as backfilling material in bank strengthening works. Perceived environmental project risks were: dredging in the autumn to avoid seasonality, turbid water loss from the canal to adjacent watercourses, low dissolved oxygen from increased turbidity trapping fish against lock gates (Littler, 2011).

The dredging project commenced on the 28 September 2011, in an unseasonably warm September. Maximum air temperatures increased from ~23°C between 12th and 18th September to ~29°C on 29 September. Mean water temperatures were recorded as 15.1°C by the dredging contractor. The local catchment was in drought; water levels in the dredging pounds were lower

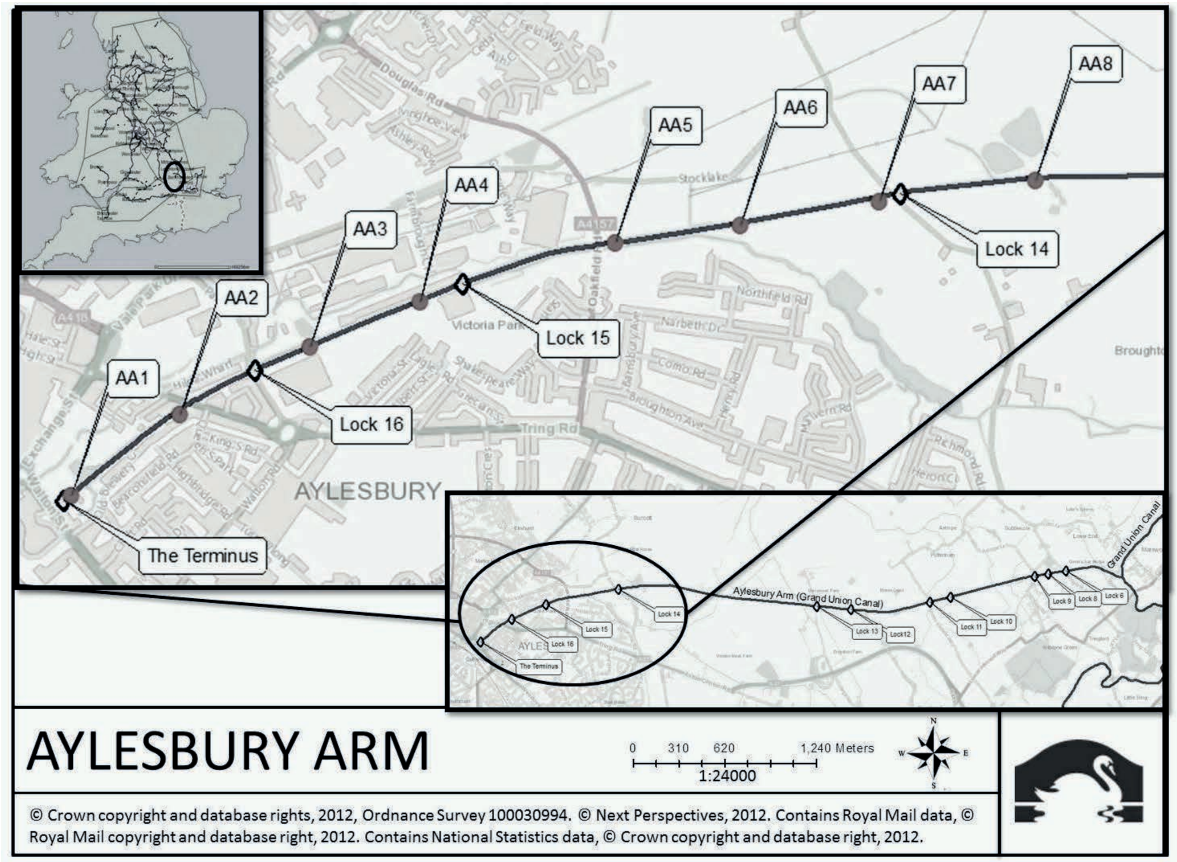

Fig. 1 Aylesbury Arm and location of sediment sample locations and locks.

Table 1 Sediment results for the Aylesbury Arm.

Test	Units	AA1	AA2	AA3	AA4	AA5	AA6	AA7	AA8
Arsenic	mg/kg	8.8	6.4	8.5	7.1	7.9	5.1	9.3	2.9
Barium	mg/kg	120	160	91	72	73	68	63	63
Cadmium	mg/kg	1.3	1.4	0.5	0.3	0.3	0.2	0.4	0.2
Chromium	mg/kg	32	23	26	23	28	25	43	9
Copper	mg/kg	61	64	24	21	13	10	15	12
Lead	mg/kg	160	180	40	23	17	15	35	15
Mercury	mg/kg	0.4	0.4	0.2	0.1	0.1	0.1	0.3	0.1
Nickel	mg/kg	24	27	21	20	23	18	26	22
Available phosphorus	mg/kg	190	140	80	110	55	69	75	67
Selenium	mg/kg	<0.5	<0.5	0.8	0.7	<0.5	<0.5	<0.5	<0.5
Zinc	mg/kg	340	420	160	250	130	91	92	82
Ammoniacal nitrogen as N	mg/kg	180	190	240	160	160	260	200	96
Organic matter content	%	12	13	7.0	6.5	5.9	5.1	4.3	4.3
Total sulphate as SO_4	%	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Total organic carbon	%	6.9	7.5	4.0	3.8	3.4	2.9	2.5	2.5
pH		8.9	8.7	8.6	8.4	8.5	8.6	8.6	8.4
PAH	mg/kg	<1.6	11	<1.6	<1.6	<1.6	<1.6	<0.1	<0.1
EPH (C5-C10)	mg/kg	<10	<10	<10	<10	<10	<10	< 1.6	<1.6
EPH (C10-C25)	mg/kg	23	340	<10	30	<10	<10	<10	<10
EPH (C25-C40)	mg/kg	21	280	<10	<10	<10	<10	<10	<10
EPH (C10-C40)	mg/kg	45	610	<10	39	<10	<10	<10	<10

than normal, but this was not perceived as a problem as pounds are often lowered during dredging campaigns to prevent weirage into adjacent watercourses. The first fish kill occurred at 14:14 BST on 29 September at the terminus where dissolved oxygen (DO) was recorded at 76% saturation. Dead fish were also observed between locks 15 and 16 where DOs of 3% were recorded. It is possible that the three dead fish observed at the terminus had floated down from locks 15 and 16. Dredging was suspended.

On 30 September aerators were installed in the Aylesbury basin at the terminus, and pumps installed between locks 15 and 16 to facilitate further aeration. As no further distressed fish were observed, dredging continued at 14:00 BST. Despite the mitigation measures, more dead fish were reported on 3 October and dredging was suspended until further notice (Copleston, 2011). The Environment Agency (EA) attended the site as part of their incident response. The results of the EA samples are summarised in Table 2. Sample 7744969 was taken from the terminus and sample 7744970 was taken above Lock 15. The results show that Environment Quality Standards (EQS) were breached within the terminus for ammoniacal nitrogen (EQS 1.0 mg L^{-1}) and nitrite (EQS 0.03 mg L^{-1}) for sample 744969, suspended solids (EQS 25 mg L^{-1}), DO (EQS >40% sat) and DEHP (1.3 mg L^{-1}) for both samples and these concentrations are likely to have been higher at the time of the fish kill, three days previously (Environment Agency, 2012a). Combined with the water temperatures of 16.7°C, fish kills were inevitable. The remaining parameters either have no standards or were within their respective EQS (Environment Agency, 2012a). Parameters such as cyclohexanone and caffeine would have been taken by the EA to confirm that the source of the incident was not from either an industrial or sewage related source.

Table 2 Water sampling by the Environment Agency on 3 October 2011.

Test/Sample ID		744969	744970	Test/Sample ID		744969	744970
Temperature	°C	16.7	16.8	Cyclohexanone	µg L^{-1}	2.9	15.6
Ammoniacal nitrogen	mg L^{-1}	4.16	0.26	N,N-diethyl-m-toluamide	µg L^{-1}	<0.5	<0.5
Unionised ammonia	mg L^{-1}	0.019	0.0037	Caffeine	µg L^{-1}	<0.5	<0.5
Nitrite	mg L^{-1}	0.11	0.0045	DEHP	µg L^{-1}	12.3	5.3
Total oxidised nitrogen as N	mg L^{-1}	1.14	<0.2	Sodium	mg L^{-1}	15.0	15.0
Ortho Phosphate as P	mg L^{-1}	<0.02	<0.02	Magnesium	mg L^{-1}	2.9	2.30
Total BOD_{atu}	mg L^{-1}	<3.9	<2.9	Aluminium	mg L^{-1}	0.89	0.27
Total COD	mg L^{-1}	50.0	33.0	Potassium	mg L^{-1}	4.2	3.20
Suspended solids	mg L^{-1}	82.2	33.1	Calcium	mg L^{-1}	74.0	59.0
Conductivity	µScm^{-1}	553.0	419.0	Manganese	mg L^{-1}	0.18	0.05
Sulphur	µg L^{-1}	0.6	<0.5	Iron	mg L^{-1}	1.94	0.58
pH		7.2	7.7	Zinc	mg L^{-1}	0.04	0.02
Dissolved oxygen	%sat	16.5	61.3	Strontium	mg L^{-1}	0.56	0.43
Salinity	µg L^{-1}	0.27	0.2	Barium	mg L^{-1}	0.05	0.03
Chloride	mg L^{-1}	32.3	32.1	Oil and grease		Not found	Not found

TAME VALLEY CANAL, BIRMINGHAM CANAL NETWORK

The Tame Valley Canal is ~14 km long and was completed in 1844 to alleviate congestion on the Birmingham Canal Network. Located within the West Midlands region of England, the canal descends 32 m over 13 locks, from the junction with the Walsall Canal to the junction of the Tame Valley Canal and the Birmingham & Warwick Junction Canal. The canal follows the line of the River Tame which divides the Birmingham plateau west to east. Much of the Tame Valley Canal is elevated above the River Tame and surrounding area. The canal is lined by puddle clay, which overlies Mercia mudstone. The surrounding catchment is urbanised with no rural sections along its length.

The canal has two sources of water; the primary source is from the Wolverhampton Level via the Wyrley & Essington Canal and the secondary source from the Birmingham Level via the Walsall Canal. The water quality of the Wolverhampton Level and Tame Valley Canal is currently classified as "good ecological potential", but the Birmingham Level is classified as "moderate ecological potential" due to the zinc content of the water (Environment Agency, 2012).

The Tame Valley Canal accepts one discharge of sewage effluent from a private dwelling at Lock 13 (Perry Barr), although there are many trade, sewage, surface water and misconnections into the Birmingham and Wolverhampton Levels.

In July 2012, a dredging campaign was designed to dredge the length of the Tame Valley Canal, starting at TV1, to restore the canal dimensions to a minimum open channel of 5.3 m width by 1.1 m depth and reduce customer complaints. This involved the removal of ~2700 m^3 sediment from the entire length of the canal. Only 300 m^3 of sediment was removed during the summer campaign, with the remaining sediment removed during the winter when the risk of deoxygenation was thought to be lower. The results of the sediment sample analysis are presented in Table 3. The dredging contractor identified that the dredged sediment was to be disposed to landfill due to the hazard from its PAH content. Project risks were perceived to be from turbid water causing low DO and also suspended solids from the canal weiring over canal spill weirs into adjacent watercourses (Wetherall, 2012).

The dredging project commenced on 26 July 2012. Mean air temperatures were 16.3°C, ~1°C below the seasonal norm in July; rainfall was 108.1 mm in July (178% above the norm) and 83.2 mm in August (123% above the norm) (Met Office, 2012a,b). Mean water temperatures were 18.0°C and mean DO saturation was 19.8% throughout the day.

On 31 July 2012, at 08:00 BST ~600 dead fish were reported in the canal around sample location TV2 and dredging was stopped. The water was reported to be "murky and oily black" (Land & Water Services, 2012) and the decision was taken to undertake leachate analysis on fresh

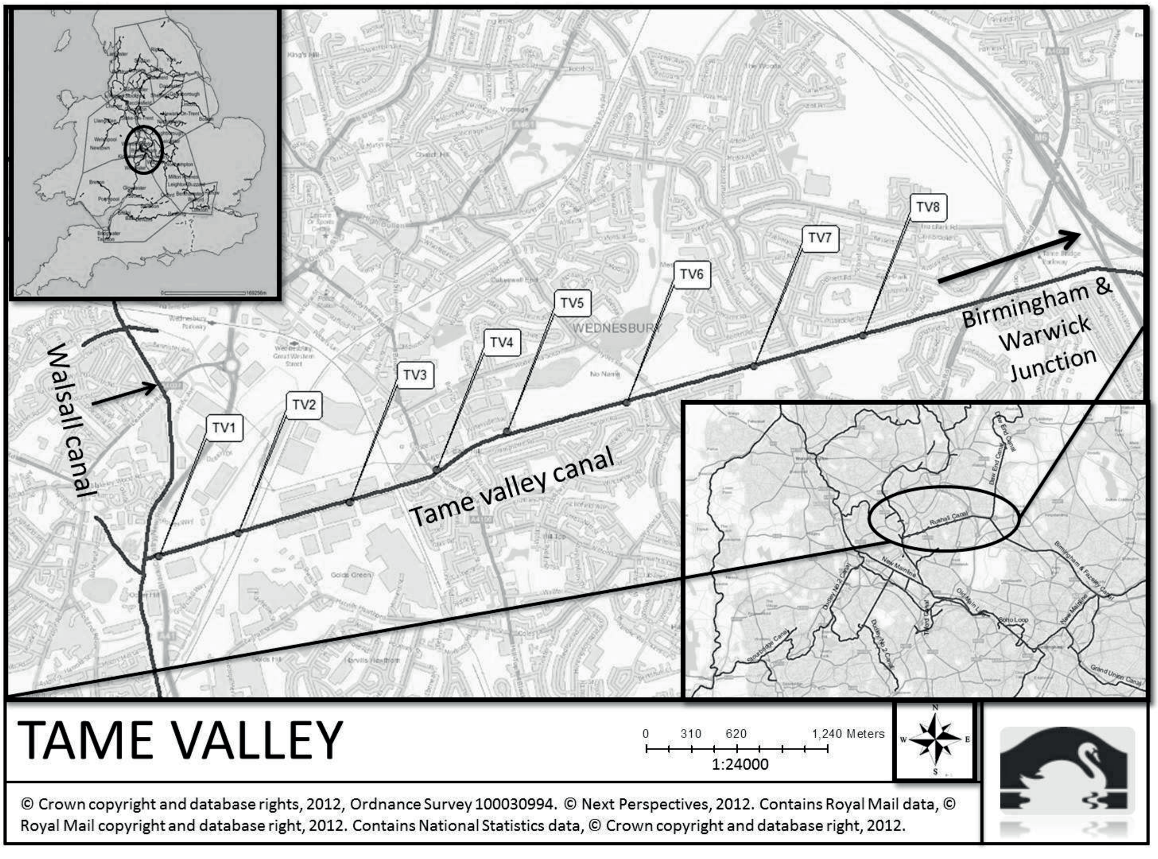

Fig. 2 Location of the Tame Valley Canal and sediment samples.

Table 3 Sediment results for the Tame Valley Canal.

Sample ID		TV1	TV2	TV3	TV4	TV5	TV6	TV7	TV8
Test	Units								
Arsenic	mg/kg	95	140	90	76	180	150	18	15
Barium	mg/kg	47	65	57	64	44	35	200	130
Cadmium	mg/kg	39	83	31	26	54	89	6	5
Chromium	mg/kg	260	230	160	110	200	230	65	33
Copper	mg/kg	1600	1600	1200	800	1200	1200	190	170
Lead	mg/kg	540	490	590	520	590	570	99	100
Mercury	mg/kg	1.3	0.8	0.7	0.7	1.0	1.1	0.1	0.1
Nickel	mg/kg	130	170	170	130	220	220	51	46
Selenium	mg/kg	4.6	3.8	2.5	2.0	5.6	5.9	0.6	<0.5
Zinc	mg/kg	8100	11000	7900	6700	14000	16000	1200	1100
Organic matter content	%	25	17	22	22	22	23	11	5.9
Sulphide	mg/kg	720	660	710	660	2200	1400	390	290
Total sulphate	%	0.5	0.5	0.6	0.7	0.9	0.8	0.2	0.2
Total sulphur as S	%	2.4	2.4	3.2	3.1	4.5	3.3	0.7	0.6
Total organic carbon	%	14	10	13	13	13	14	6	3
pH		7.4	7.6	7.6	7.5	7.6	7.7	8.0	7.6
PAH	mg/kg	18	47	160	69	58	87	43	8

Table 4 Leachate test results.

Sample ID		TV1w	TV2w	TV3w	TV4w	TV5w	TV6w	TV7w	TV8w
Test	Units								
Arsenic, dissolved	$\mu g\ L^{-1}$	5.0	3.8	2.1	5.6	3.3	2.9	3.4	6.6
Barium, dissolved	$\mu g\ L^{-1}$	31	70	44	33	26	19	12	18
Cadmium, dissolved	$\mu g\ L^{-1}$	0.05	< 0.03	0.05	0.03	0.05	0.05	0.06	0.05
Chromium, dissolved	$\mu g\ L^{-1}$	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25	<0.25
Copper, dissolved	$\mu g\ L^{-1}$	<0.4	<0.4	1.5	<0.4	<0.4	0.5	0.7	0.5
Lead, dissolved	$\mu g\ L^{-1}$	0.7	0.1	1.3	0.3	0.1	0.2	0.2	0.3
Mercury, dissolved	$\mu g\ L^{-1}$	0.03	0.04	0.03	0.04	0.04	0.04	0.05	0.04
Nickel, dissolved	$\mu g\ L^{-1}$	9.1	9.2	4.4	5.8	3.7	3.9	4.8	7.0
Selenium, dissolved	$\mu g\ L^{-1}$	0.5	0.4	0.5	0.5	0.5	0.5	0.5	0.5
Zinc, dissolved	$\mu g\ L^{-1}$	32	7	14	26	16	13	14	27
Chloride	$mg\ L^{-1}$	4.0	4.4	3.5	3.3	3.1	4.0	4.3	4.3
Ortho phosphate as P	$mg\ L^{-1}$	< 0.01	< 0.01	< 0.01	< 0.01	0.02	0.07	0.02	0.03
Total BOD	$mg\ L^{-1}$	59	84	26	290	230	6	7	24
Total COD	$mg\ L^{-1}$	77	110	160	37	< 10.0	19	58	120
Conductivity	$\mu S\ cm^{-1}$	99	269	132	114	123	143	106	97
Total oxidised nitrogen as N	$mg\ L^{-1}$	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7	<0.7
pH		7.9	7.6	7.8	7.9	7.9	7.9	7.9	8.1
PAH	$\mu g\ L^{-1}$	0.42	0.34	<0.20	0.36	<0.20	<0.20	<0.20	0.22

samples taken at the original sample points. The purpose of this was to determine whether the source of the problem could be identified and to investigate why the original analysis had not identified anything of concern. The leachate test results are presented in Table 4.

Dredging resumed on 15 August as fish had been herded away from the dredging area using nets. On 16 August more dead fish were observed and the dredging project was suspended until 21 November when cooler water temperatures were expected to reduce the risk of fish kills. The leachate results have been compared against statutory and guidance EQS (Environment Agency, 2012a). The results show that all of the dissolved metal concentrations were within their respective EQS. In TV1w there is elevated zinc (59 mg L^{-1}), concurring with the ecological classification for the Birmingham Level. As this is the norm for this area, it is thought that elevated zinc would not have contributed to the fish kill. No EQS exists for orthophosphate, but samples TV5w to TV8w show orthophosphate levels above the limit of detection, showing that nutrients had been released into the water column. As orthophosphate provides a food source to algae and bacteria, this may have contributed to significantly elevated BOD concentrations at TV6w (290 mg L^{-1}) and TV7w (230 mg L^{-1}), as these are effectively "downstream" samples. For comparison, the Freshwater Fisheries Directive (DIRECTIVE 2006/44/EC) gives a guidance BOD value of 6 mg L^{-1}. The COD is normally expected to be between 30–80% greater than the BOD, but the leachate from the Tame Valley shows that COD values were 37 mg L^{-1} at TV4w and <10.0 mg L^{-1} at TV5w. As COD is the complete digestion of organic matter, it is not clear why at these sites the BOD value is significantly greater than the COD value. The DO and temperature recording log (Land & Water Services, 2012) refers to black oily residues and Table 3 shows that PAHs are present within the sediments, but it is not clear whether the presence of oily residues restricted the oxygen absorption across the water surface.

DISCUSSION AND CONCLUSIONS

The sediment analysis suite on the Tame Valley Canal (Table 3) was a reduced suite compared to the Aylesbury Arm, consisting of arsenic, barium, cadmium, chromium, copper, lead, mercury, nickel, selenium, zinc, organic matter content (OMC), total organic carbon (TOC), pH and PAH, as landfilling was the expected disposal route for the waste. The suite should have included total petroleum hydrocarbons (TPH) to cover all of the risk ratings for the carcinogenic hydrocarbons. Two further parameters, sulphide and total sulphur were analysed in the Tame Valley suite, to give an indication of the oxic conditions of the sediment. These were not tested along the Aylesbury Arm (Table 1). In addition to the standard sediment analysis, the sediment suite of the Aylesbury Arm also included available phosphorus, available magnesium, available potassium, nitrate, kjeldahl nitrogen, ammoniacal nitrogen to determine the level of benefit for agricultural benefit and extractable petroleum hydrocarbons (EPH) to determine the hydrocarbon content.

The Trust and its Contractors assessed the sediment analysis results for disposal purposes only and, by doing this, they failed to identify in sample results AA1 and AA2 (Table 1) that elevated available phosphorus, ammoniacal nitrogen, OMC, TOC and high sediment pH had the potential to have an adverse impact on water quality of the Aylesbury Arm. Coupled with a past history of industrial discharges of an organic nature, fish kills from past dredging jobs and records of bird deaths due to botulism, this dredging project should have been scheduled for a winter dredging campaign. On the Tame Valley Canal, the sediment results (Table 3) showed high sulphide, OMC and TOC from TV1 to TV6; these elevated results provided an indication of a potential impact on the BOD/COD; which was confirmed in practice as fish kills continued until the summer dredging was concluded on 16 August. The leachate tests (Table 4) indicated that the low DO was the cause of the fish mortalities from the high BOD values. One explanation for the BOD/COD concentrations at TV4w and TV5w may be that the sediment disturbance caused a sudden increase in available nutrients and bacteria. This assumption cannot be proved, but on any subsequent dredging projects where fish kills occur, bacteria populations should be investigated.

To reduce the possibility of future fish mortalities during summer dredging, sediment testing still needs to be conducted to determine disposal routes, but the Trust should also:

(a) Ensure that the standard dredging suite includes TPH and sulphide. Sediment analysis should provide characterisation for disposal but also to evaluate water quality impacts. More research is required to determine sediment warning thresholds where sediment concentrations are thought to pose a risk to the aquatic environment. These should trigger leachate testing and a review of whether the proposed project is suitable for "summer" dredging (end of March to end of September).

(b) Ensure that there is sufficient water resource available prior to commencement of a dredging project should there be need to provide a fresh supply of water to an area affected by fish kills.

(c) Review the OMC and TOC and investigate their relationship with COD.
(d) More research is needed to determine the most appropriate leachate test, which simulates the dredging environment. The NRA leachate test tested the sample “as received”, but did not agitate the sample, which would resemble dredging conditions. The second problem with this method is that it is no longer recognised by environmental regulators. The BS EN method 12457 does not resemble dredging conditions, as the requirements are to dry and crush the sample before re-wetting, which is more representative of landfill or bankside disposal.
(e) Ensure that any water sampling and leachate tests include water hardness ($CaCO_3$/L) for the complete analysis of dissolved cadmium, copper and zinc.
(f) The BOD/COD tests do not truly represent the dredging environment and so further research into the method proposed by Beckwith & Newman back in the 1990s, to assess the impact of dredging on the DO by obtaining a combined sediment and water sample, letting it stand until the water clears, measure DO, seal, shake and re-measure the DO when sediment settles and water clears. There is no proof that this method works, so field trials are required to prove whether it is an effective indicator of potential risk to the aquatic environment.
(g) Any fish kill should trigger leachate testing for the remainder of the dredging area, where none was carried out at the project design stage. Field testing should include DO, temperature, pH and ammonia using test kits. Laboratory testing should include BOD, COD, pH, un-ionised and ionised ammonia, soluble reactive phosphorus and bacteria as a minimum. Dissolved metal analysis should be reviewed on a case by case basis, dependent on the sediment results.
(h) Ensure on-site provision for emergency aeration during dredging in warm dry conditions where sediment has an OMC content over 6% (precautionary approach to landfill waste criteria limit of TOC) or 11% (average OMC from 1992 National Sediment Survey).

Acknowledgements The authors would like to thank Alex May, Sally Grainger, Ian Marmont, John Kearsey, Mark Wetherall, Paul Fox, Karen Jackson and Danen Appasamy at the Canal & River Trust for geological, historical, GIS support and project records. Thanks also to Ameeta Parekh-Pross at ESG and Grahame Newman for their valuable knowledge which contributed to this paper.

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