Citizen Crane at 5:
Project Update, Key Findings and Plans for the Future

Executive Summary

The Citizen Crane project has shown that the data collected by teams of dedicated Citizen Scientists can support key investment decisions at a catchment scale.

Whilst this reflects very positively on the many volunteers who have contributed large amounts of time to regularly collect water and biodiversity data over a 5-year period, the data itself makes for less positive reading.

Despite significant investment from Thames Water in their Surface Water Outfalls Programme to remove misconnections, and the efforts of the Environment Agency and others in responding to pollution incidents, the data strongly suggests that an approximate status quo exists in the River Crane with regards to water quality and biodiversity.

The project continues to show that the river ecosystem is constrained by poor water quality, poor flow diversity, siltation and contaminated road run off.

As the Citizen Crane project evolves and the prospect of further investment from Thames Water via their Smarter Water Catchments program becomes a reality, there are several key questions that remain unanswered.

There are significant sources of Ammonia (NH_3) and Phosphorus (P) in the upper and middle catchment which have not been sufficiently identified or removed. There may be (a) further misconnections not yet identified through the SWOP - or new ones being added at an unknown rate; (b) the negative impact of other factors such as low rainfall and reduced flows counteracting any improvements or (c) other pollutant sources - including from sewerage system inadequacies and blockages linking sewage sources to the surface water drainage system.

The report identifies eleven variables that are thought to be influencing the condition of the river ecosystem and sets out the current understanding of the relative importance and impact of each of these variables.

The report proposes an approach to the next five to ten years of investigation and investment through the Smarter Water Catchments programme included in Thames Water's Asset Management Plan from April 2020 onwards.

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Abbreviations used:
AMP: Asset Management Plan
AN: Ammoniacal Nitrogen (NH_3-N) - *used as a measure of organic pollution e.g. related to wastewater*
CPiL: Catchment Partnership in London
CVP: Crane Valley Partnership
EA: Environment Agency
EHO: Environmental Health Officer
FORCE: Friends of the River Crane Environment
P: Phosphate. P is the chemical symbol for 'phosphorus'. For the purposes of this report we will be examining phosphate, the fraction of phosphorus that is inorganic, soluble and reactive and therefore bioavailable. P will be used to denote 'phosphate' in the text unless otherwise noted
RMI: Riverfly Monitoring Initiative
SWOP: Surface Water Outfall Programme
TW: Thames Water
WFD: Water Framework Directive
WHPT: Whalley, Hawkes, Paisley, Trigg (invertebrate monitoring system)
ZSL: Zoological Society of London

Acknowledgements:
All of the Citizen Scientists who after five years of hard work continue to work towards a cleaner River Crane.
Steering Group members and their colleagues from Thames Water, The Environment Agency and Crane Valley Partnership.
Other partners and volunteers for their engagement and interest.

1. Introduction

This document sets out the findings and questions raised by five years of data collection by the Citizen Crane project. The report provides an update on the findings of the Year Four report and needs to be read in conjunction with other reports for a full understanding of the project findings. All project reports can be viewed, along with the base data, at: http://www.cranevalley.org.uk/projects/citizen-crane.html

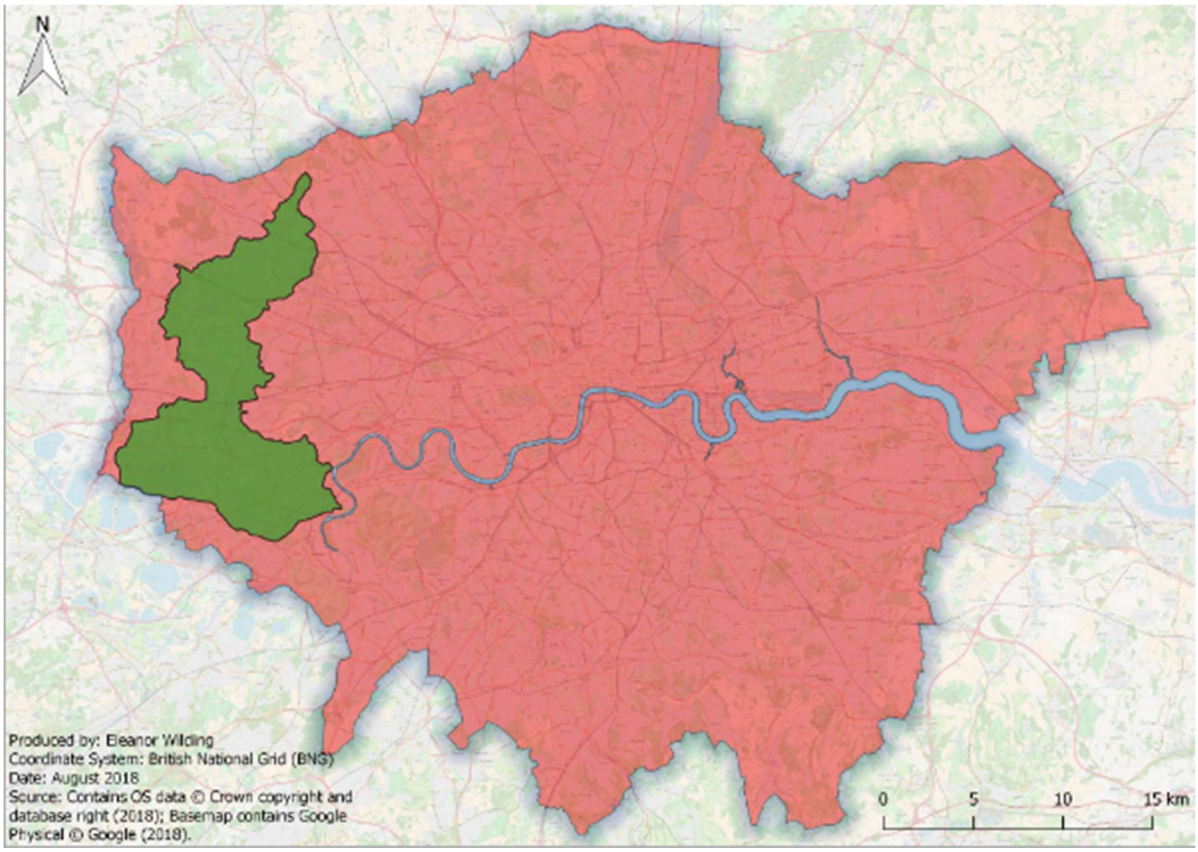

Fig. 1 Location of the Crane Catchment

2. Project Overview

The River Crane is a small urban tributary of the River Thames, running for around 35km through five boroughs in west London, with a total catchment area of 120 sq km. The Crane Valley Partnership (CVP) was formed in 2005, and now has 26 partners, with objectives to protect and enhance the value of the River Crane and its tributaries.

A major pollution incident in 2011 decimated the middle and lower Crane, killing around 10,000 fish and leaving only a few aquatic snails surviving. The Citizen Crane project was devised by CVP members in response to this incident, with the intention of investigating the basic condition of the river, identifying and quantifying pollution risks and sources, and working with key partners - the Environment Agency and Thames Water - to reduce these risks and sources.

The project management team comprises frog environmental (a small private consultancy), Zoological Society of London (ZSL – a major conservation charity) and Friends of the River Crane Environment (FORCE – a small local charity). This team is supported by a network of volunteer groups and individuals, with over 60 volunteers trained during the five years, operating 16 monitoring sites. A project steering group meets every quarter.

Eleven monitoring sites were initially set up at regular intervals (every 3 to 4 km) throughout the river system, each with a team of volunteers. The project undertakes monthly monitoring at these sites for:

- invertebrates, using the River Monitoring Initiative (RMI) methodology
- water samples, analysed in TW's UKAS accredited laboratory for ammoniacal nitrogen (AN) and phosphate (P) concentrations
- flow measurement (river section alongside depth and velocity measurement) – used to calculate loadings from concentration data.

A further five sites were added in the upper reaches of the catchment in early 2019. These allow a more detailed assessment of the sub-catchments and processes in these upper reaches.

These data provide the basic inputs for the Citizen Crane project, the scope of which also includes:

1. Engagement with TW and their Environmental Protection Team, investigating and resolving misconnections
2. Delivery of the UK's first Outfall Safari in 2016, using citizen scientists to visit and evaluate the condition of all 230 surface water outfalls across the catchment
3. Identification and monitoring of pollution incidents, in support of the EA and other stakeholders
4. Engagement with Universities and other researchers to use and develop the data sets
5. Development of a conceptual model of the chemical and ecological characteristics of the river system, including a first mass balance of AN and P for the river
6. Preliminary investigation of the impact of road run-off on the river system
7. Preliminary assessment of the impacts of river improvement measures
8. Engagement with local stakeholders, the general public and the wider world about the project and its findings. This includes support for the extension of the project approach to other catchments within London and elsewhere
9. Supporting TW in the development of the UK's first urban "Smarter Water Catchment" initiative on the River Crane – due to start in April 2020.

This report provides an update on all these project elements.

3. Project support

The following project support elements have been delivered over the last year:

- Continued maintenance of all the site gauging stations
- Training provided for new volunteers. ZSL provide training across London for potential recruits on the Crane and other rivers. Over 60 River Crane volunteers have gone through this training programme to date
- Overhaul of the data management system – with all data available to the volunteers and other interested parties on the Citizen Crane pages of the CVP website
- The fourth annual Citizen Crane Forum was held in October 2018 (with a fifth forum planned for October 2019). The forum is an opportunity to review progress to date and discuss future plans with all interested parties
- Visits and other events for volunteers – including to Heathrow Airport's new treatment system and to Middlesex University's laboratories during the last year
- A volunteers' social event in summer 2019.

The project continues to seek means of better encouraging and supporting volunteers and would welcome suggestions from all interested parties.

4. Water Quality

Background

The purpose of taking water samples is to:

- Create a detailed and reliable baseline of water quality across the catchment
- Track changes to water quality over time
- Assess the impact of interventions and remedial works; e.g. SWOP and new SuDS schemes
- Identify pollution 'hotspots' and inform the prioritisation of resources for interventions across the catchment.

The water quality data consist of monthly concentration and loadings data for ammoniacal nitrogen (AN) and phosphate (P) for each monitoring site. These two parameters are measured because they are generally considered to provide the best assessment of organic pollution in the river.

Flow rates are recorded at each site using a standard gauging board and flow velocity measurement system along with a pre-measured cross section. Flows are then used to calculate pollution loadings from the quality data.

Between May 2014 and April 2019, a total of 623 samples have been collected by citizen scientists and analysed in Thames Water's laboratories as follows:

- Year 1: 108
- Year 2: 122
- Year 3: 124
- Year 4: 120
- Year 5: 149

Samples have been collected from eleven monitoring sites over the last five years. In early 2019 a further five sites were added, in order to enhance the information available from the upper reaches of the catchment, where the most pollution problems have been identified. These latter data have not been included in the plots in this part of the report but are considered further in a subsequent section.

The data have been reviewed and quality checked. Any data of concern have either been removed or flagged as unreliable. Full data sets were not always available due to the following reasons:

- Volunteers unavailable
- Very occasional issues with sample bottles (not available or leaking en route)
- River too deep to undertake RMI (and therefore not visited)
- Concerns about data reliability (see Table 1, page 12)
- Loss of water level gauging boards (such that loadings cannot be calculated).

However, given the project is entirely reliant on volunteers, the overall return of reliable data (at around 90 per cent of potential data points) is considered very satisfactory. It is also very encouraging to note that this return has remained constant over the five years of the project.

Tables showing median year-on-year records for water quality and flow are presented in Appendix B.

Water Quality Concentration Data

Data are presented as median concentration and loading values at each site for each of the five years, measured from April to March (e.g. median 2017 = Year 4 = April 2017 to March 2018). Median data are used as these reduce the impact of individual outlier data points.

Data are plotted in terms of the distance from the river source in Headstone Manor, creating a line plot between all the points on the main channel. Data points for Newton Park (Site 4, near the source of the Roxbourne arm of the river) and the Upper Duke's River (Site 10, where the Duke's River enters the Crane at Donkey Wood) are shown individually as floating points.

The five-year data set for phosphate concentration is shown in Figure 2 below:

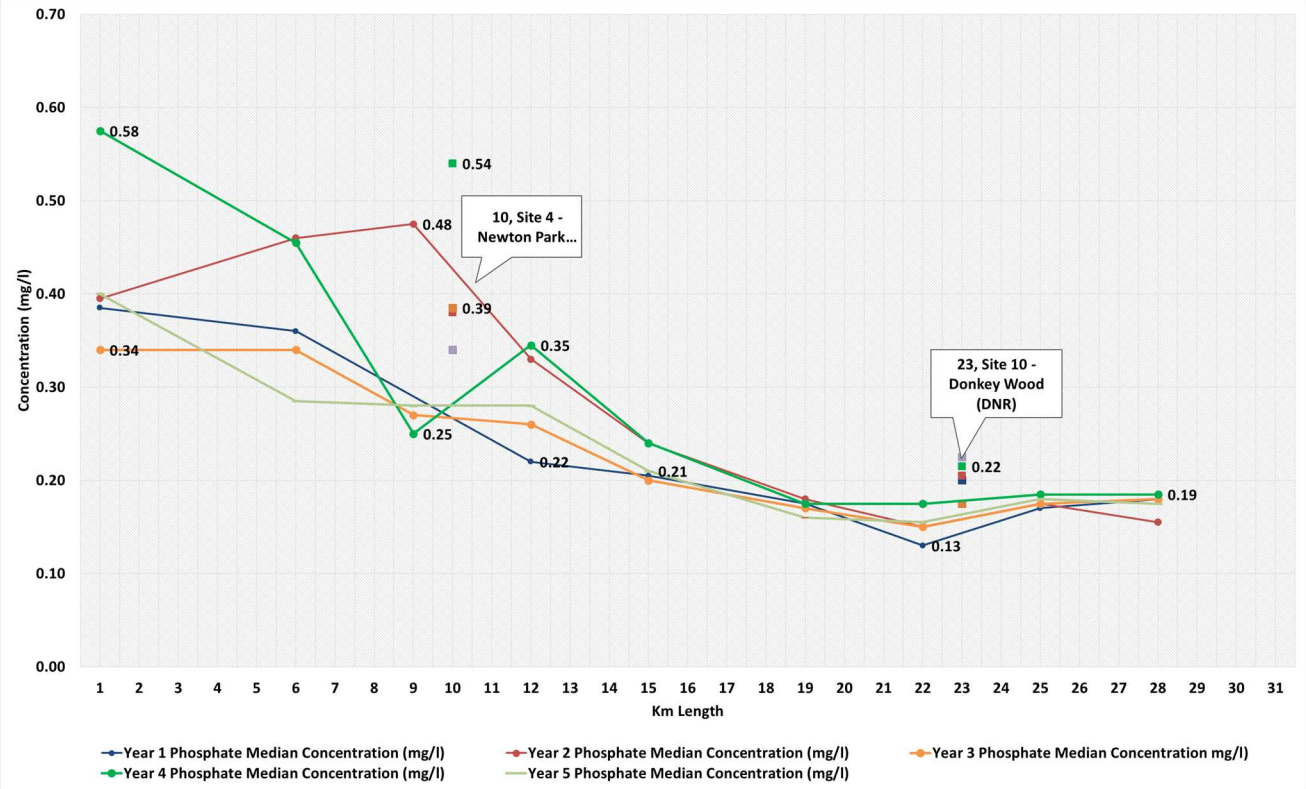

Fig. 2 Median Phosphate Concentration over km lengths for years 1 - 5

Note that the Water Framework Directive (WFD) standards for Phosphate (P) are calculated through a complex metric. However, in broad terms the boundary between poor and moderate status is around 0.2 mg/l whilst the boundary between moderate and good is around 0.1 mg/l.

Initial conclusions drawn from these data are as follows:

- The data show a reasonably consistent pattern of median annual P concentrations over the last five years. The most variation in P concentrations has been in the upper catchment
- The highest concentration of P is consistently recorded in the two upper tributaries of the catchment, with concentration generally reducing with distance downstream
- The data for Year 4 were a concern, showing at or close to the highest concentrations recorded. In contrast, these data for Year 5 are at the lower end of the range recorded over the five years. However, overall there is no clear trend in the data over the five year period
- Median levels from middle and lower reaches, from Site 7 downstream, remain consistent

- The water quality (WFD with respect to phosphate) remains poor in the upper and middle reaches to around Site 7. Water quality remains moderate throughout the middle and lower reaches and at no point does the river reach Good Ecological Status with respect to P
- The input from the Upper Duke's River continues to have a higher P than the receiving water in the Crane – the median concentration in Year 5 was the highest yet recorded and was indicative of 'poor' quality according to WFD standards.

The concentration data for ammoniacal nitrogen (AN) are plotted using the same approach in Figure 3

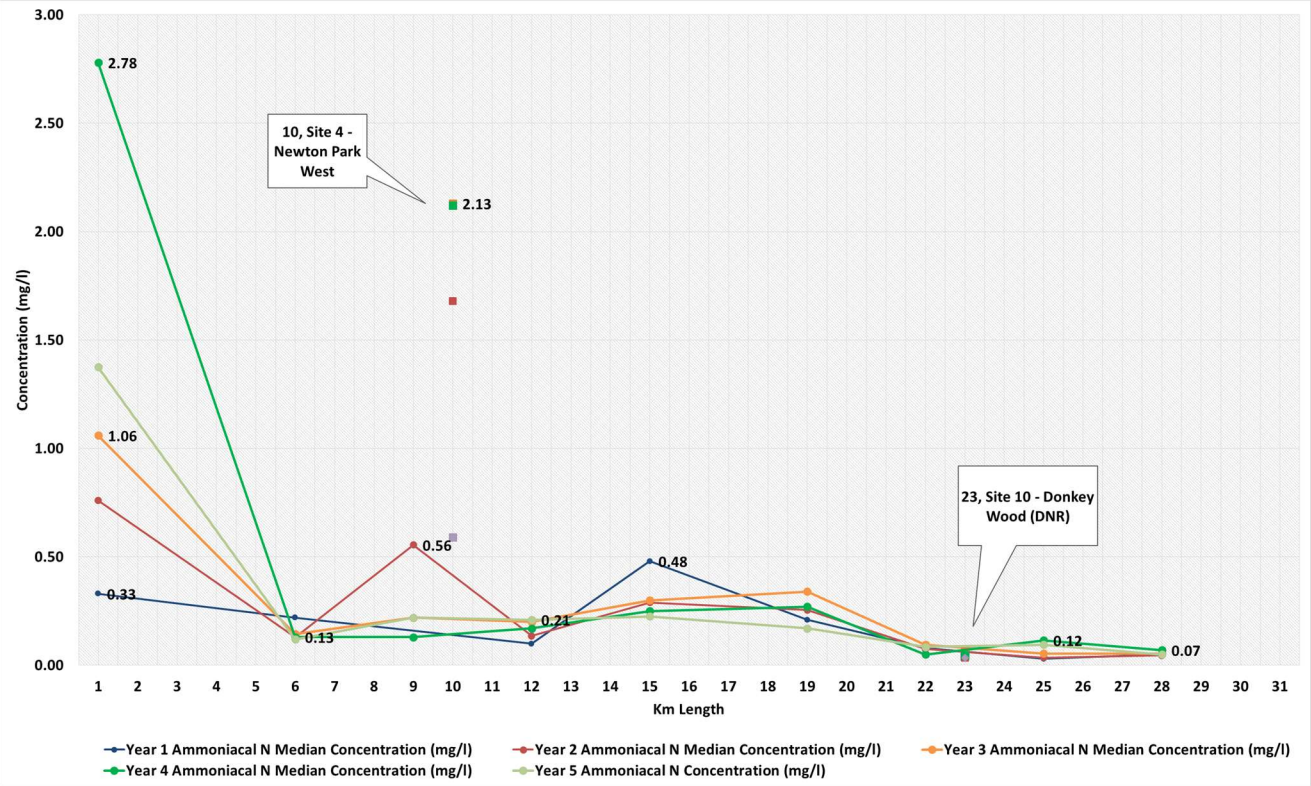

Fig. 3 Median Ammoniacal Nitrogen Concentration over km lengths for years 1 to 5

Initial conclusions drawn from these data are as follows:

- As with P, there is a reasonably consistent pattern in AN concentrations recorded over the last five years. By far the highest levels are recorded in the two upper catchment sites and concentrations are generally lower from Site 2 onwards – although there are other spikes in the middle catchment before levels fall to at or below 0.1 mg/l for Sites 9 through 12
- Also in common with the P data there has been a fall in concentrations at the top of the catchment for Year 5 from the peak levels shown in Year 4. A decrease in median AN has been recorded in both headwaters (Headstone Manor and Newton Park) in Year 5
- Concentrations vary in the middle reaches. Higher median concentrations are recorded at Site 3 and Site 7.

There is further consideration of these data – and in particular the water quality at the top of the catchment – in further sections of this report.

Flow Data

Flow estimates are made at each site every month using a flow gauging section and measurements of flow velocity and water depth. These data are used to calculate the loadings of P and AN at each site and thereby gain an insight into how the loadings change along the river corridor.

The method used for gauging flow in the Citizen Crane project has been developed with the support of the Environment Agency, who also provided training for volunteers. It should be noted that the accuracy of results from flow gauging can be impeded by the following:

- Robustness of gauging boards at flow monitoring stations. Damage to gauging boards can arise from debris during flood flows, tampering by members of public, fly tipping and general wear. This can directly lead to missing or compromised flow data
- Seasonal issues such as aquatic weed growth. This can result in the river flow becoming funneled into a tighter channel at the gauging station and the transect data becoming compromised. This may result in an artificially high flow rate being recorded by the volunteer
- Debris (natural or fly-tipped) reducing the even distribution of flow through the gauging station and compromising the accuracy of the transect
- Shifting sediments/gravels following high flow conditions may lead to the gauging station transect being changed
- Access can be impeded to the gauging stations from terrestrial plant growth. Plants have also been known to obscure gauging markers
- Occasionally flood flows can prohibit access or even submerge a gauging station. In these circumstances accurate measurements cannot be recorded.

Water quality returns for the Citizen Crane project run at a respectable 90%, whilst flow data, which is used to calculate loading, runs at a more modest 65% .Some of the issues cited above come into play when considering the validity of flow data and the loading data it produces. Note that all the gauging stations were visited, new sections measured and gauging boards replaced where necessary during late 2018.

Table 1. An overview of different issues encountered at each gauging station

Monitoring Site	Board Issues	Access issues	Aquatic weed growth	Storm damage	New material deposits/debris in channel
1				X	
2		X	X	X	
3	X		X	X	
	X				X
6			X	X	X
7	X	X		X	X
8	X	X		X	
9	X			X	
10	X			X	
11					
12					X

It should be noted that even Environment Agency flow monitoring stations frequently encounter problems (such as debris) which sometimes reduce confidence in the official flow record.

As part of the data review in 2018 two key changes were implemented:

- Where flow data has been compromised due to a combination of the aforementioned issues, flow data has been excluded for the purpose of calculating loading
- Where there is a data return of less than 50%, or where there is a known issue impacting the confidence in flow data, these data have been excluded from calculations

The decision to exclude certain data sets should not be viewed as a comment on the dedication of the Citizen Scientists involved with the Citizen Crane project. The factors that affect the usability of data are often beyond the control of volunteers.

Whilst flows in the upper and middle reaches are broadly comparable over the 5 years of the project, the four sites that are used for monitoring flow in the lower reaches all show a reduction over the first 4 years of the project. Year 5 data show a further reduction in flow recorded at sites 10 and 12 (Donkey Wood, upper DNR and Mill Road, with broadly comparable flows recorded at sites 9 and 11.

Table 2. Annual median cumec record for lower catchment gauging stations

Site reference	**Year 1 median cumec**	**Year 2 median cumec**	**Year 3 median cumec**	**Year 4 median cumec**	**Year 5 median cumec**
Site 9 Donkey Wood (Crane above DNR)	0.55	0.35	0.28	0.29	0.27
Site 10 Donkey Wood (upper DNR)	0.53	0.46	0.29	0.20	0.26
Site 11 Crane Park island (below confluence)	1.15	0.76	089	0.60	0.59
Site 12 Mill Road (furthest site downstream)	0.90	0.83	0.82	0.76	0.60

Annual rainfall data for the five years from the gauging station at Heathrow are as follows:

- Year 1: 663 mm
- Year 2: 652 mm
- Year 3: 476 mm
- Year 4: 674 mm
- Year 5: 409 mm

The summer of 2018 was notably hot and dry, and there were also reduced rainfall totals in the winter period, all leading to an annual total that was only around 60 per cent of the long term average. This is reflected in flow rates in the lower reaches which are close to half of those recorded in Year 1 of the project. This is a major difference in flow which also has the effect of significantly increasing the concentrations recorded when compared to the earlier years of the record. It is therefore of particular value to have the capability to generate loading data whereby this effect is removed.

The inflow along the Upper DNR is sourced from the River Colne to the west. It is not actively controlled and the offtake is prone to siltation. FORCE has reported the problem of siltation at this offtake to the EA and other interested parties and it is currently being investigated. It can be seen that flows along this channel have reduced in Years 3 to 5 compared to Years 1 and 2. This is a particular concern as the inflow from the Upper DNR has a beneficial effect on the ecological value of the Crane downstream (see later sections of this report).

Loading Data

Loadings are calculated by combining the water quality concentration data with the flow data. Loadings data provide an insight into the bulk amounts of P and AN in the river system at a sampling point. These bulk amounts are a function of the inputs and the outputs from the system at any particular time. Figures 4 and 5 below set out the median annual loading data for P and AN over the five years of the project along with initial conclusions from an analysis of these data.

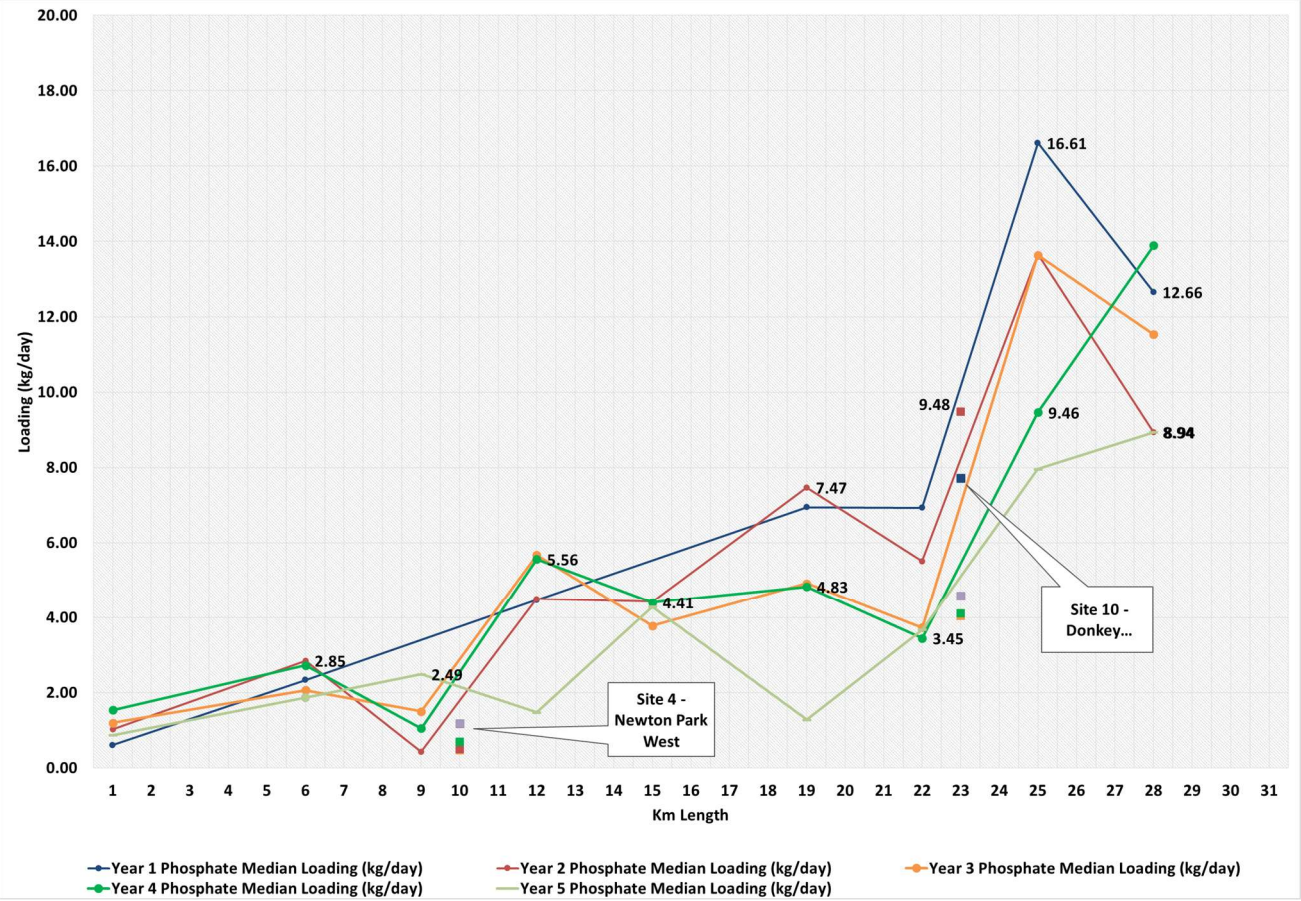

Fig. 4 Median Phosphate Loading over km lengths for years 1 to 5

Initial conclusions drawn from these data are as follows:

- The overall pattern of loadings is reasonably consistent across the catchment and between the five years
- The two exceptions for Year 5 are Site 8 and Site 6 which show a lower loading than in previous years.
- In the case of Site 6 the accuracy of the gauging station was assessed as being compromised by seasonal weed growth, funneling water down a thinner section of channel thus increasing the flow

rate record and leading to an artificially high loading record. A new gauging station position has now been set up which is intended to eliminate the influence of seasonal weed growth.

- For site 8, EA data has been used for the last two years from the nearby Cranford Countryside Park flow gauging station. The average cumec was used for all data points recorded for each sampling weekend. The Year 5 cumec record shows approximately 35% of the flows recorded in year 4 over the relevant sampling weekend. For both Site 6 & 8 in Year 5 the lower phosphate loading is predominantly driven by flow as opposed to concentration
- Across the catchment the actual loadings in Year 5 are at the lower end of the five year data record. The only exception to this is Newton Park, on the eastern tributary of the river, which posts the highest loading
- For the first time the actual loading remains broadly consistent (at between 1 and 4kg/day) from Site 1 at the top of the catchment to Site 9 around 22 km downstream
- There continues to be a large additional input of phosphate from the Upper Duke's River, directly below Site 9, amounting to around half the downstream in-river total
- The lowest reach of the catchment, between Sites 11 and 12, record (in 3 years out of 5) a reduction in phosphate loading in the water column

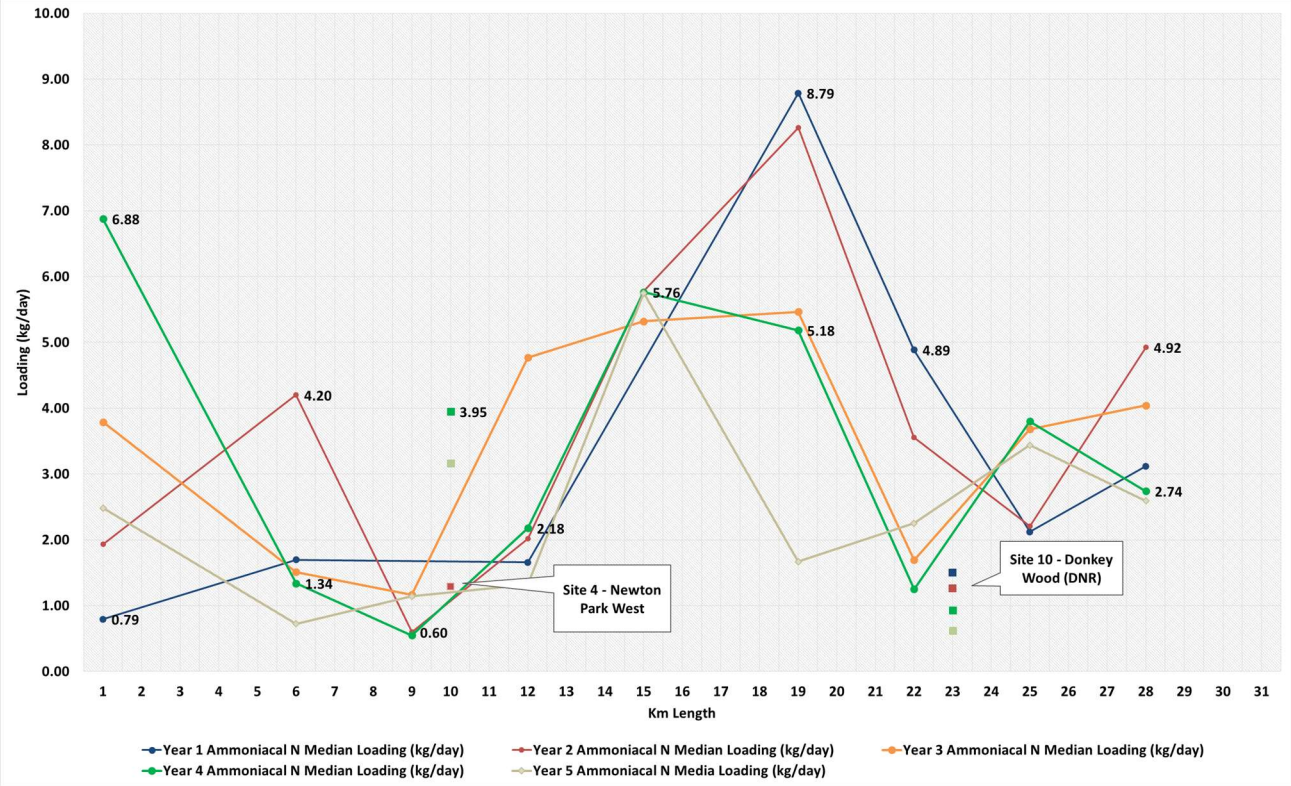

Fig. 5 Median Ammoniacal Nitrogen loading over km lengths for years 1 to 5

Initial conclusions drawn from these data are as follows:

- The overall pattern of loadings is broadly consistent across the catchment and between the five years. Site 8 has a lower Year 5 loading, largely driven by reduction in flow. Whilst Site 6 also showed a significant reduction in flow this was compensated for by the AN concentration rising from 0.18 mg/l in Year 4 to 0.33 mg/l in Year 5, almost doubling.
- The loading at the top of the catchment in Headstone Manor has dropped back from the peak of almost 7 kg/day in Year 4 to a longer-term average of around 2.5 kg/day. The loading at Newton Park at the top of the eastern tributary is also reduced compared to Year 4 (4kg to 3kg/day). Both though remain significant inputs to the top of the two arms of the catchment
- The pattern shows a river system which includes two zones of significant ammonia input - several kg/day at the top of the catchment and 7 to 8 kg/day around Sites 7 and 8 in the middle reaches.

The river also exhibits two reaches – in the upper middle around Sites 2 to 6 and in the lower reaches around Sites 9 to 12 – where it appears capable of self-cleaning, exhibiting a net reduction in ammonia of several kg/day

- The loadings recorded in Year 5 are broadly speaking towards the lower end of the five year record. This tallies with the findings for phosphate

Further consideration of these data are provided below.

Further Investigations in the Upper Catchment

The upper reaches of the Crane catchment have become a focal point for the project due to the poor water quality and low ecological value (from the RMI data) recorded in the two tributary sources (Headstone Manor and Newton Park) during the first two years of the project. LB Harrow is investing a considerable amount in improving the environmental and aesthetic value of these sites and this further increases the importance of resolving the pollution issues here. As a result Thames Water shifted (from 2017) the focus of their Surface Water Outfall Programme to these reaches.

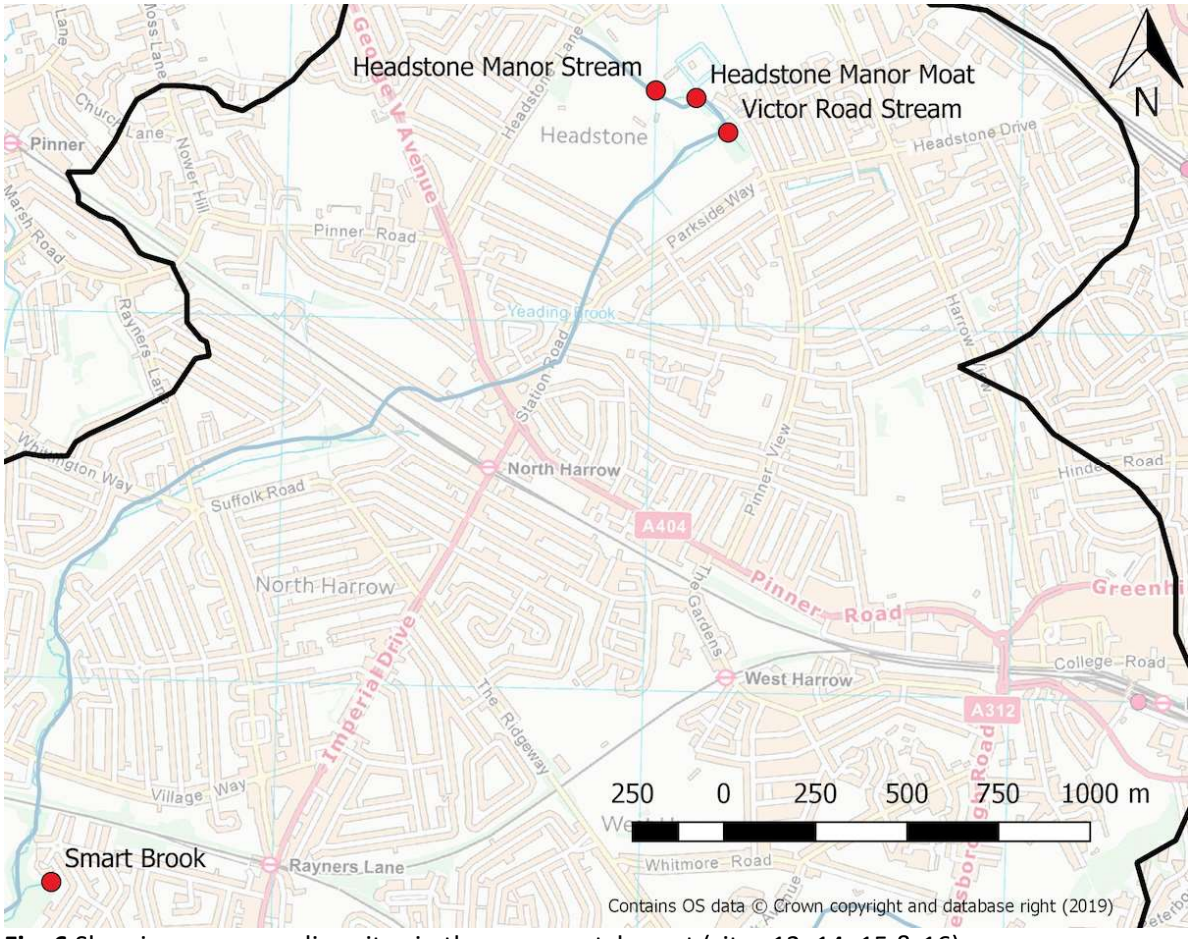

Fig. 6 Showing new sampling sites in the upper catchment (sites 13, 14, 15 & 16)

At Headstone Manor:

- The main stream source is considered to be the moat around the manor house, fed by one stream at its north eastern corner. The build-up of polluted sediment in the moat has been a problem over many years. In early 2019 LB Harrow dredged the moat to remove much of this sediment. LB Harrow has a scheme (with funding in place) to create a new wetland upstream of the moat which will enhance the local habitat and should further help improve water quality downstream. A new monitoring site was added at the outfall from the moat (Site 13) in January 2019

- There is a second stream that feeds into the main channel just downstream of the moat. LB Harrow has a scheme to remove this stream from culvert as it flows through the park. A new monitoring site was added where this stream meets the main channel (Site 14) in January 2019
- There is a third stream that feeds into the main channel where it turns through a right angle bend, just above Site 1. This stream drains the catchment where the new housing development is taking place on the old Kodak site. A new monitoring site was added where this stream meets the main channel (Site 15) in January 2019

The main conclusions to date from the Headstone Manor area are:

- There was a major increase in organic pollution load from the moat immediately following the dredging. This was a temporary effect and initial data indicate an improvement compared to the pre-dredging baseline in the following months
- There is some evidence that water quality is slowly improving in these channels – following intensive SWOP work by Thames Water. It is too early to be definitive about this though. Pollutant concentrations in each of the input sources monitored indicate that the water quality is still classified as poor under WFD.
- The proposed stream de-culverting and wetland schemes proposed for the area should provide further aesthetic and environmental enhancements. The monitoring scheme now in place should help to help verify this

At Newton Park:

- A series of three large wetlands were installed by LB Harrow and opened in summer 2018. These take the incoming stream flow and pass it through a network of channels and marginal plants
- In August 2018 the Citizen Crane project started to sample the water quality both upstream (Site 4) and downstream (Site 5) of this new wetland feature. These data are shown in Table 3 below. Note: they also include data from Year 6

Table 3. Water quality data upstream and downstream of Newton Park wetland

	Site 4												Site 5											
	Upstream of ponds (site 4)												**Downstream (Site 5)**											
mg/l	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May	July	Aug	Mean	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	May	July	Aug	Mean
P Total	0.6	0.8	0.4	0.4	0.6	0.7	0.4	0.4	0.7	0.3	0.5	0.5	0.4	0.6	0.3	0.4	0.4	0.5	0.3	0.3	0.4	0.4	0.4	0.4
P (dis)	0.4	0.6	0.3	0.3	0.5	0.6	0.4	0.3	0.6	0.2	0.3	0.4	0.2	0.5	0.2	0.4	0.3	0.4	0.3	0.2	0.4	0.3	0.3	0.3
AN	1.2	0.3	0.4	0.6	1.5	2.8	1.2	0.5	1.9	0.4	0.4	1.1	0.5	0.5	0.2	0.4	1.0	1.3	0.1	0.3	0.8	0.6	0.4	0.6

The main conclusions to date from the Newton Park area are:

- There is some evidence of recent reductions in the incoming organic loads at Newton Park. More data are needed to be confident of this. Nevertheless, pollutant concentrations in the incoming stream water mean this is still classified as poor under WFD
- Whilst data collected upstream and downstream of the Newton Park wetland at the same time are not directly comparable there is a strong indication from the full data set that water leaving the wetland and re-joining the channel has a lower nutrient and organic pollution concentration than water entering the wetland. The mean P level has reduced by around 25 per cent and AN by around 50 per cent
- These data are comparable to the data presented at a recent workshop for a comparable wetland area at Pymms Park on the River Lea in LB Enfield (report by Natalie Gilbert of T21, 2016). These were summarised as: P 1.6 to 1 and AN 1.4 to 0.4

- Other data from the same project report showed BOD reduced from 7 to 5; coliforms 600 to 200 and nitrate 5 to 3.5

At Smart Brook:

- This culverted stream has been identified as being a source of pollution. A monthly sample has been taken here since February 2019 and is known as Site 16
- The data so far indicates that this small catchment is significantly polluted – comparable to the other culverted streams in the LB Harrow area – with ammonia levels in the order of 0.5 to 2 mg/l

There are ongoing discussions between the project team, Thames Water and LB Harrow about the potential causes of the pollution issues in the upper catchment. There is some encouragement from recent data that pollution levels may be falling, although conditions are generally still described as poor. Investigations by Thames Water and the SWOP team in the adjacent Brent catchment have identified long term infrastructure issues in the LB Harrow area including:

- Network cross connections – as part of the infrastructure
- Network cross connections made many years ago to resolve local urban drainage flooding issues
- Missing and broken caps in dual manholes that allow cross connections between the surface and sewerage networks
- blockages in the sewer network that lead to the activation of cross-connections or local sewer flooding into the drainage network by overland flow.

The extent of these issues and their implications for the water quality in the upper Crane catchment are still to be properly investigated and understood. We anticipate this will be a major task of the new Smarter Water Catchments initiative.

Key Findings

1. The water quality data follow a reasonably consistent pattern
2. The data from Year 5 have shown an improvement compared to Year 4 – despite low rainfall in Year 5
3. There are ongoing significant water quality issues in the upper catchment – and the river remains in poor condition here
4. There is a second area with significant pollution sources in the middle reaches of the river around Sites 7 and 8
5. Outside of these more heavily polluted areas there is evidence that the river has the capacity to self-cleanse
6. In the lower reaches the river is moderate status and may have the potential to consistently achieve good status in the future.

5. River Monitoring Initiative (RMI)

RMI Approach

A full description of the RMI methodology is available in the Citizen Crane Year Two report. The primary purpose of the RMI is to allow for the detection of pollution issues and gathering of evidence by trained volunteers to supply to the Environment Agency (EA) if further investigation is required. Trigger levels were originally set in discussion with EA staff in Year One of the project and represent levels at which a pollution incident was considered to have occurred.

Between May 2014 and April 2019, RMI samples have been conducted on a monthly basis at the 11 sites along the river. There have been the occasional gaps in sampling at some sites, caused by factors such as the unavailability of volunteers, or heavy rain in the catchment causing unsafe river conditions. At Newton Park sampling was suspended in 2018 due to the inaccessibility of the site during the construction of new wetland area. Our RMI volunteer at Cranford Countryside Park left the project in winter 2018 and the project team have struggled to find a long-term replacement since.

RMI Data Sets

Mean annual RMI scores at each site for each of the five years are set out in Figure 6 below. As with the water quality data these run from April to March, such that Year 5 runs from April 2018 to March 2019. This plot also shows the trigger level set for each site.

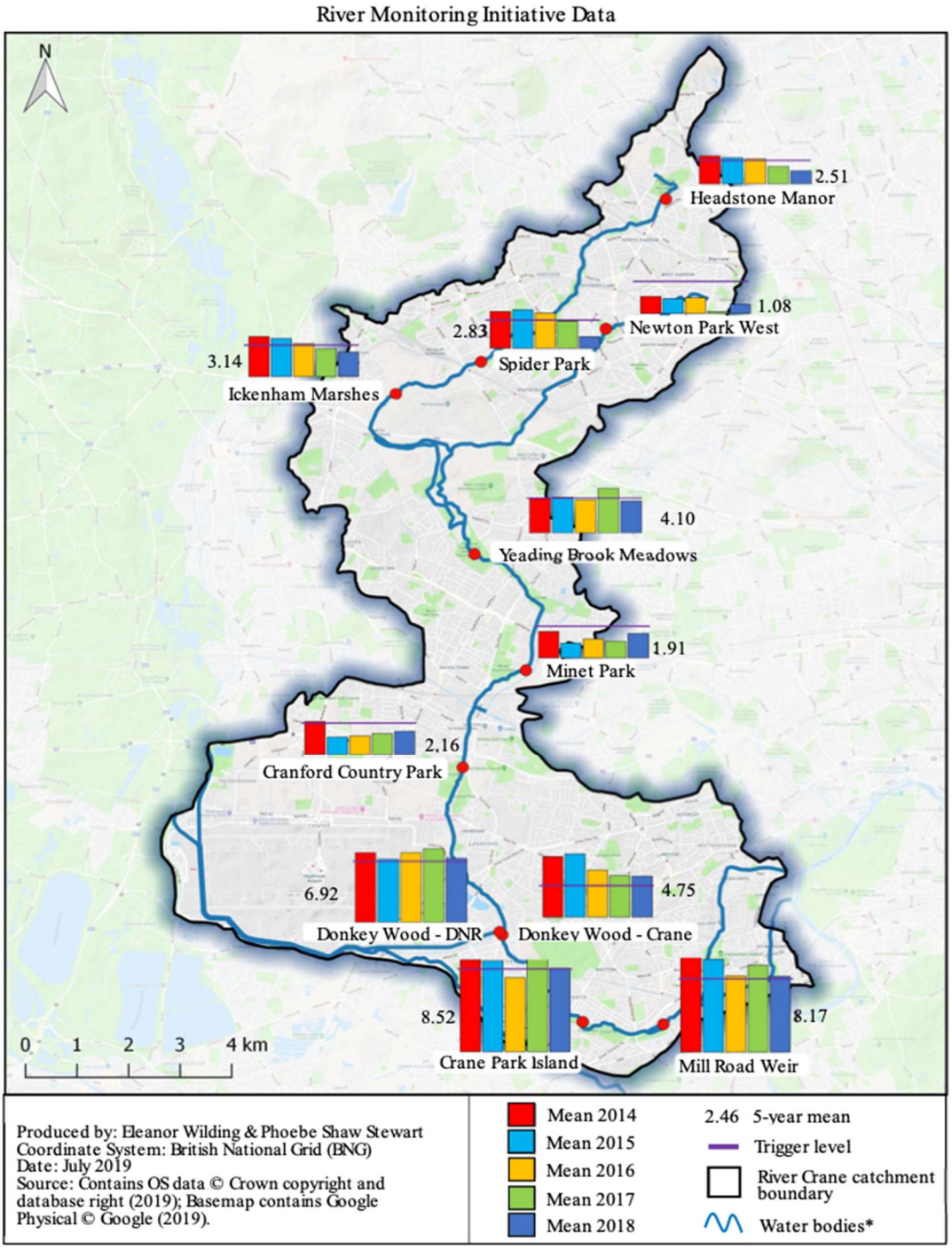

Fig. 7 Mean annual RMI scores for each year of the 5 years of monitoring for all sites

The RMI invertebrate groups recorded at least once at each site over the five-year period of the project are shown in Table 4 below.

Table 4 RMI invertebrate groups recorded at each monitoring site

	Headstone Manor	Newton Park West	Spider Park	Ickenham Marshes	Yeading Brook Meadows	Minet Country Park	Cranford Country park	Donkey Wood-Crane	Crane Park Island	Mill Road Weir
Flat bodied mayfly (Heptageniidae)					✓				✓	✓
Mayfly (Ephemeridae)									✓	✓
Blue Winged Olive Mayfly (Ephemerellidae)				✓	✓		✓	✓	✓	✓
Olives (Baetidae)	✓		✓	✓	✓	✓		✓	✓	✓
Stoneflies										
Caseless caddis							✓	✓	✓	✓
Cased caddis	✓		✓		✓		✓	✓	✓	✓
Gammarus	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Total number of RMI groups found	3	1	3	3	5	2	4	5	7	7

Figure 7 shows five years of RMI scores over time for the three sites downstream of the Heathrow Eastern Balancing reservoir outfall on the main river (Donkey Wood, Crane Park Island and Mill Road). The data show regular monthly variation and some trigger breaches outside of winter. These plots were produced in order to investigate further issues of fungal blooms and reduced RMI scores during and following cold winter events.

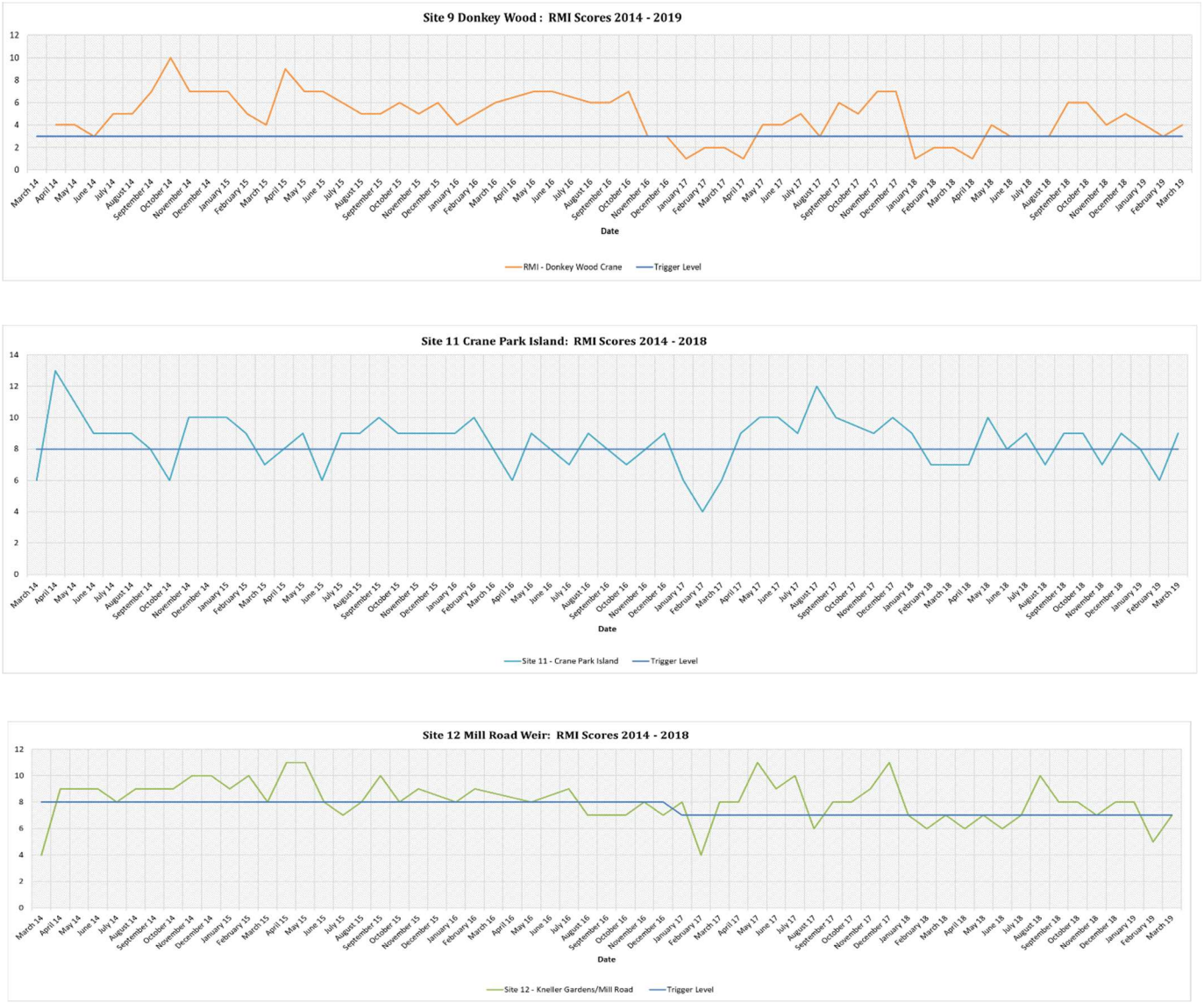

Fig. 8 Five years of RMI scores over time for sites downstream of the Heathrow Eastern Balancing reservoir outfall.

Note: the straight blue line on the charts shows the site trigger level

RMI Data Review

Over 1000 volunteer hours have been spent RMI sampling the river during the five years of the Citizen Crane Project. Considerable value has been derived from a) the significantly increased frequency of monitoring by trained volunteers who, after five years with the project have honed their identification skills and b) an enhanced synergy with the Environment Agency (EA) ecologists and pollution team. The increased monitoring by the Citizen Crane network, for instance, has led to the early detection of specific pollution events that have in turn allowed the EA to respond quickly to problems.

In addition, the RMI data collected by volunteers provide a valuable baseline on which to build an increasingly detailed picture of the ecological quality of the river. The RMI methodology is a simplified, citizen science version of the monitoring method used by the EA to check the ecological quality of rivers for Water Framework Directive classification.

When reviewing RMI data it is important to keep in mind that complex relationships exist in rivers. Invertebrate communities are not only impacted by water quality but also geomorphology, water quantity and flow, shading, sediment quantity and quality. The RMI scores are an indicative guide to the overall ecological condition at each sample site.

The RMI data show a reasonably consistent distribution pattern over the last five years, with low values in the upper catchment, some recovery in the upper-middle reaches before reducing again at Minet Park and Cranford Park. Scores have increased again to around 5 just above the confluence of the Upper Duke's River in Donkey Wood whilst the Upper Duke's has a higher score than the receiving waters (at around 7). Downstream of this point the scores increase further to between 8 and 9 (at Crane Park Island and Mill Road).

Whilst scores at each site have been reasonably consistent at each site over the last five years there is some evidence of scores reducing in recent years – and no evidence to suggest any catchment wide improvement in ecological value over time.

RMI scores continue to be low in the upper catchment, particularly at Headstone Manor and Newton Park. This is unsurprising given the poor water quality recorded at these two sites. Note however that in recent months (post April 2019) invertebrate species have been recorded at Newton park that have not been seen there before – providing early indications of benefits from the new wetland system and/or SWOP pollution reduction programme.

Minet Country Park and Cranford Countryside Park, in the middle reaches, consistently score below trigger levels agreed with the EA. Volunteers at Minet Country Park report that 'about 50% of the time there is an unhealthy smell from the river, and sometimes a sheen or it is slightly milky'. The site is also becoming progressively more shaded which may have an impact on the invertebrate community. The site at Cranford Countryside Park is both over-shaded and over-wide – resulting in a heavy sediment load and poor geomorphological character.

The most obvious change in RMI score from Year 4 to 5 has been seen at Spider Park with a 60% drop in the mean annual score at the site. Volunteer observations from this site are:

1. Spider Park has had a step change in results from Nov 2017, since when the scores have mostly failed the trigger point of 3. Only single numbers of Gammarus and/or Olives being found
2. Prior to this date, although the results were variable, they were generally above the trigger point of 3. Gammarus and usually Olives were found along with occasional Cased Caddis and a single Caseless Caddis
3. The downstream site at Ickenham Marsh is showing a similar trend. There is a reported polluted outfall at Ruislip Gardens between the 2 sites
4. The upstream site at Roxbourne Park never fails the trigger point and there are sometimes hundreds of Olives and Gammarus, so the WQ deteriorates downstream of here
5. The polluted outfall just downstream of Roxbourne Park at Field End Road was polluting but has been resolved by the Thames Water SWOP team
6. The site at Spider Park never looks polluted but there are a number of outfalls between the upstream site at Roxbourne Park and Spider Park
7. Low rainfall and poor flow may well be a factor perhaps concentrating any chronic pollution load

8. Spider Park does suffer from some sedimentation and scouring away of gravel but this has always been the case
9. Spider Park does suffer from growth of river weed and in the past this has choked the channel but it has always been here

In summary, the site has always been vulnerable to outfall pollution, periodic sedimentation and invasive weed growth. In the past, the stream has always had periods of recovery but with lower rainfall over the last two years no stream recovery has happened since Nov 2017. Problems may be exacerbated by pollution from outfalls over the upstream reach and these are being investigated further by the EA and TW.

Invertebrate communities in the upper part of the catchment are compromised. Only the more pollution tolerant RMI invertebrate groups, Gammarus and Olives, are present in any significant numbers throughout the river. Gammaridae are the only group to be found at all sites and stonefly (Plecoptera) are found at none. At the low scoring sites in the upper catchment the normal trigger level procedure built into the RMI system i.e. reporting breaches to the Environment Agency's National Incident Reporting system, is no longer being implemented. Volunteers have reluctantly accepted the chronic nature of the problems and that water quality and geomorphological improvements are dependent on the ongoing long-term works programmes, by TW and LB Harrow in particular.

Greater invertebrate diversity and abundance, including the only records of true mayfly (Ephemeridae), has been recorded in samples downstream of the upper DNR. A total of three individual flat bodied mayfly specimens have been recorded from three separate sites: Yeading Brook Meadows, Crane Park Island and Mill Road Weir. Other groups that are sensitive to degraded river environments, such as Caddisfly and Blue Winged Olives, are recorded at only a few sites above the upper DNR. These records are infrequent, with low numbers of individuals in the samples.

As the three sites downstream of Donkey Wood show higher RMI scores the trigger level breach reporting protocol continues to be followed. However, trigger level breaches were reported to the EA from all three of these sites in the winters of 2017, 18 and 19 (as shown in Figure 7). The trigger breaches have been accompanied by an extensive covering of "sewage fungus" on the river bed, which on all three occasions was traced back to the Heathrow outfall at Donkey Wood.

Heathrow Airport Ltd (HAL) has recognised that glycol supports the proliferation of sewage fungus in the river. In the winter of 2018 HAL started to operate the new £20 million glycol treatment facility on the Eastern balancing reservoir. In February 2019 Citizen Crane volunteers again recorded sewage fungus and trigger breaches at Crane Park Island and Mill Road.

In spring 2019 the Citizen Crane team met with HAL representatives to look at the system and discuss this issue. HAL noted that the system was only 50 per cent operational last winter and the operations team are still learning how best to optimise its use. There is a more detailed review of this issue in Section 6 below.

Further RMI Review by the EA

The Environment Agency team has reviewed these RMI data and compared them to other data sets in the region. Their main findings are as follows:

1. The Citizen Crane group shares data with the Environment Agency as part of the Riverfly Monitoring Initiative. As one of the most active citizen science monitoring groups within the

Hertfordshire and North London area, the level of data quality and consistency provided by the Citizen Crane group is highly valued.

2. While the riverfly methodology is perhaps less effective in the urban catchments, the results and observations provided by volunteers have enabled the Environment Agency to react to issues within the catchment which may otherwise have gone undetected, and also provide a robust picture of the changing river habitat quality through the Crane catchment. The data collected is contributing to the creation of a long-term dataset, which is hugely valuable moving forward.
3. The River Crane is one of the most heavily urbanised of the catchments in which riverfly monitors are active within the Hertfordshire and North London area. As a result, the Crane catchment is exposed to greater pressures and stressors
4. On the whole, the Crane catchment Riverfly scores are significantly lower than any other catchment within HNL – particularly those from the upper catchment, which rarely score above 3. However, similar scores are seen in stretches of other catchments which have a similar level of urbanisation – for example, the river Colne as it runs through Watford routinely scores between 2 to 5 at several RMI sites
5. The higher scores from the lower catchment – sites Crane Park Island and Mill Road Weir – are comparable to those achieved within the River Colne catchment at more natural and less impacted sites. This highlights the high ecological value of the lower Crane and demonstrates that, despite urban influences, the lower reaches of the river continue to be able to support a good quality invertebrate community, comparable to that seen in the neighbouring chalk streams
6. The Crane Catchment has a much higher incidence of trigger breaches recorded than other catchments within HNL, and the resilience of the invertebrate community to these appears to be very variable throughout the catchment. Though they have been impacted by pollution events through the last several winters, sites Crane Park Island and Mill Road Weir both appear to recover well and relatively quickly following trigger breaches and pollution incidents. This indicates a good level of resilience within the river channel – which is likely a product of the good quality habitat and flow through much of the lower reaches.
7. However, upstream where water quality, habitat, and flow are comparatively poor the river seems to show little resilience. Here, recurring incidences of pollution cause sites to regularly fall below their trigger level, and little recovery is seen following these events.
8. These findings highlight the importance of maintaining high quality habitat throughout the river corridor, and the significant impacts this can have on the resilience of the invertebrate community.
9. Sites at Donkey Wood down to Crane Park Island again highlighted potential issues around the Heathrow area during the winter and early spring months, prompting further EA investigation
10. Continuously low riverfly scores in the upper catchment have highlighted potential water quality issues – in particular, prompting an investigation into the Roxbourne Park to Ruislip Gardens stretch of the Yeading Brook West
11. There are a number of ongoing pressures which may be adversely impacting the Riverfly monitoring results within the Crane catchment and the wider London and Hertfordshire area. One of the most prominent issues currently impacting the wider area is prolonged dry weather and low flows. Though the river Crane is less impacted by this than other catchments, as it is not so heavily dependent on groundwater flow like the neighbouring chalk streams, it is likely that low flow conditions are having some impact on the river ecology. This may be particularly evident downstream of the confluence of the river Crane with the Upper Duke of Northumberland's river, where reduced input from the DNR may contribute to reduced water level and flow in the lower reaches of the Crane during periods of low flow
12. Environmental observations provided by the Citizen Crane riverfly volunteers are particularly important in generating an evidence base as we continue in a period of prolonged dry

weather. For instance, in June 2019 a large blanket of filamentous algae was reported at Crane Park Island. Prolific algal growth of this type is generally indicative of low flow and high nutrient conditions, and algal growth of this extent had not previously been observed here by volunteers. Evidence such as this is highly valuable in the monitoring of the impacts of low flow upon the ecology of our rivers.

Table 5 below shows the latest WFD data for the River Crane from the EA

Year		**2013**	**2014**	**2015**	**2016**
Ecological Status		Poor	Poor	Poor	Poor
Failing Elements	**Fish**	Poor	Poor	Poor	Moderate
	Invertebrates	Poor	Moderate	Moderate	Moderate
	Macrophytes	Moderate	Moderate	Moderate	Poor
	Diatoms	Moderate	Moderate	Moderate	Moderate
	Phosphate	Poor	Poor	Poor	Poor
	Hydrological Regime	Does Not Support Good	Does Not Support Good	Supports Good	Does Not Support Good

All biological quality elements assessed for WFD were failing to meet Good Ecological Status in 2016. More recent classifications are not yet available for external release. Note that the Citizen Crane project team has identified Good Ecological Status as the overall medium-term target for the river.

6. Wider Investigations and Observations

Overview

This section sets out the findings during Year 5 from other investigations and observations, either directly implemented by the Citizen Crane project team or linked to the project in some way. These include:

1. Outfall safari: first implemented on the Crane catchment in the summer of 2016 and reported in the Year Three report
2. Road Run-off: recognised as a chronic pollution source in urban catchments such as the Crane
3. SWOP: feedback from Thames Water on their misconnections programme
4. Long term outfall surveys: started by the Citizen Crane team during Year Two and continued for the last three years
5. Pollution reporting: listing pollution events identified and/or monitored during Year Five
6. Improvement works: overview of key ecosystem improvements implemented or proposed for the catchment
7. Mass balance for P and AN: first developed in the Year Three report
8. Overall conceptual model for the river system: first developed in the Year Two report and updated in Years Three and Four.

Updates on each of these are set out below.

Outfall Safari

In the summer of 2016 the Citizen Crane project carried out an "Outfall Safari" for the catchment. An App was developed to record the condition of surface water outfalls using the Thames Water reporting methodology as the starting point. This was then used by volunteer teams, who visited and reported on a total of 230 outfalls and around 35km of river corridor across the catchment over a six week period of relatively low flow. The River Crane Outfall Safari is believed to have been the first volunteer-led outfall monitoring project implemented in the UK.

The main findings of the initial Outfall Safari were reported in the Year 3 report. The main developments since then are as follows:

- All of the outfalls reported as being polluted have been investigated by Thames Water and/or the Environment Agency
- Several discrete pollution issues were identified through this process and have since been rectified
- The Thames Water SWOP was reviewed in the light of the findings of the Safari and those outfalls identified as polluted were either added to the SWOP or put onto a separate priority list for early investigation. These works have now been largely completed
- The Safari highlighted the grossly polluted upstream culverted channels above Newton Park and Headstone Manor. These findings encouraged TW to switch SWOP resources to focus on these areas, subsequently identifying major misconnection problems
- The Outfall Safari approach has been recognised by Thames Water and the wider water sector as being of high value in identifying problems as well as engaging local interested communities in monitoring and improving their river environment
- Thames Water is now working with ZSL and Thames 21 to deliver outfall safaris across their region under a seven year programme of work – which has been mainstreamed into the TW methodology for outfall management
- A second outfall safari will be carried out in the River Crane Outfall Safari in spring 2020. This will allow a comparison with the 2016 safari and provide a new baseline for the Smarter Water Catchments initiative.

In short this has been a very successful programme, reaping considerable benefits in terms of enhancing our understanding of the Crane catchment and enabling more targeted responses to specific pollution issues. The approach has subsequently been adopted across the TW region and is receiving interest from other parts of the UK.

Road Run-off

Road run-off is recognised as being a significant source of chronic pollution in urban areas, including the Crane catchment. Urban drainage catchments generally include run-off from the public highway as well as from properties. Road runoff is a particular problem following extended dry periods, as particulates and oils have built up on the road surface and are then flushed into the river system alongside the accumulated detritus held in the drainage system. The main pollution types from road run-off are sediment, road salt, hydrocarbons and metals. None of these are recorded by the organic pollution sampling undertaken by Citizen Crane. They can though be expected to have a significant and chronic negative impact on the ecology of the river.

The Citizen Crane project does not have a remit to investigate road run-off. However, there have been various initiatives linked to the project, starting in Year Four and continuing through Year 5. Progress over the last year is set out below:

- ZSL is working with Thames21 and various other parties through the Catchment Partners in London (CPiL) group to develop protocols for the identification and management of road run-off issues across London. The River Crane has been identified as one of several catchments that could trial this approach when protocols have been developed
- Road run-off from the M4 is believed to be a significant pollution source in the middle reaches – particularly as this is the busiest road crossing in the catchment. The project team has engaged with the EA, LB Hillingdon and Highways England with a view to developing an approach to mitigating the impact of this pollution source. Discussions are ongoing
- In September 2018 Frog Environmental appointed a 3-year funded PhD post at Swansea University to investigate road run-off issues. The scope will incorporate site investigation works – likely to include the Crane catchment.

The ways in which road run-off interacts with the wider river ecosystem will continue to be an area of interest and investigation for the Citizen Crane project. It is likely to be a key issue during Thames Water's AMP 7, linked to both Smarter Water Catchments initiative and the major SuDS programme for the next five years.

Surface Water Outfall Programme

The Surface Water Outfall Programme (SWOP) is managed by Thames Water's Environmental Protection Team (EPT) and has become a main practical means of identifying and rectifying chronic pollution problems identified through the Citizen Crane project. The EPT works to improve the status of the region's watercourses in partnership with the Environment Agency and other stakeholders. The EPT focus is on tracing and removing pollution from drainage misconnections to surface water sewers (which are designed to convey untreated rainwater directly into a watercourse).

The SWOP started in Asset Management Plan (AMP) Period 3 from 2000 to 2005 and since then has increased substantially in AMP 6 (to March 2020). TW's representative on the Citizen Crane steering group also helps to manage the SWOP and provides a very helpful interface with it.

The latest data on the progress of the SWOP in the Crane catchment is set out in Table 5 below

Table 6. Thames Water Summary of SWOP: AMP6 to date (September 2019)

	Outfalls	Misconnected Properties Identified	Misconnected Appliances	Misconnected Properties Rectified	Outstanding Misconnected Properties
AMP6 SWOP – Live projects	7	119	315	93	26
AMP6 SWOP – Signed off by the EA	38	462	1263	445	7
Waiting List	8	0	0	0	0
Total	**53**	**581**	**1578**	**538**	43

Note: Thames Water has also developed a new 'Network Resolution Team' to investigate outfalls identified through Outfall Safaris and other river walks. The aim of the team is to address polluted outfalls as soon as possible and determine whether a catchment is suffering from just a few misconnections and/or other pollution sources or whether the pollution is caused by widespread misconnections, which would require strategic long-term investigation through SWOP. This team is active in the Crane – though the project does not yet have any data on the misconnections work completed.

The following points are made in relation to these SWOP data:

- The SWOP is considered to be having a major beneficial impact upon the river system. Calculations presented in the Year 3 report indicated that the SWOP may remove in the order of 0.1 to 0.2 kg/day of P and AN from the river system for each significantly improved outfall.
- In total this would amount to something in the order of 6 kg/day of P and AN over the five-year AMP6 programme. This is the same order as the remaining loading within the river system
- The impact of the SWOP has increased in Year 5 (and in recent months to September 2019). This is due in part to the change in focus to the upper reaches of the catchment where major misconnections have been found, including housing blocks and school buildings, each equivalent to many individual properties
- One factor which is not yet well understood is the rate at which new misconnections are being added into the system. Without these data it is not possible to assess the net benefit of the SWOP – or whether the SWOP is even keeping pace with new misconnections. Through this project Citizen Crane has requested TW and/or others undertake further research into this issue
- Around 90 per cent of property owners appear to be rectifying their misconnection issues within a short period of receiving notice from TW. However, if property owners fail to rectify their misconnections, cases are being handed over to the Environmental Health departments of the relevant Local Authority for enforcement. TW identified two councils that had stopped responding to TW requests for support. These were approached by the project team and one has subsequently renewed active involvement whilst the other has stated it is not able to do so for financial reasons. This matter is still being assessed by TW and the project team remains available to engage with Environmental Health Officers and the wider council as appropriate.

TW's proposals for AMP 7 have recently been published. These set out an enhanced SWOP for the five years starting in April 2020, with 50 per cent more SWOP outfalls addressed over the region. It is anticipated this will include further measures on the River Crane.

In addition, the River Crane has been identified as being the UK's first urban 'Smarter Water Catchment', in a major project included in the AMP7 proposals. It is anticipated that this project will link closely with the Citizen Crane programme.

Long Term Outfall Surveys

The Citizen Crane project started to monitor the condition of selected outfalls in the lower reaches of the catchment in April 2016. The survey has continued every month since, with three SWOP outfalls being ever present and others added or removed as problems emerged and then were resolved.

Assessments are made of the condition of each outfall every month, including the flow, the amount of sewage fungus present on the apron and any evidence (visual or olefactory) of pollution. The main findings are noted below:

- In each case the SWOP has considerably improved the quality of the discharge
- In each case there is some evidence of residual pollution – in some cases consistent and in others occasional
- In one case (Hospital Bridge Road) the outfall's polluting discharge has proved very challenging to fully rectify. It has been signed off as a SWOP outfall but there is at least one active misconnection which has still to be resolved
- In two other cases (Hanworth Road and Lyndhurst Avenue) the outfalls have been largely clean (with little or no sewage fungus) for at least a year – only for problems to return over the last six months. This indicates the potential for new misconnections to happen on signed-off SWOP outfalls at any time
- The outfalls are also occasionally the source of other pollution problems. These include hydrocarbon pollution and white paint pollution reported over the last year. This illustrates the risks associated with the surface water drainage system due to either deliberate or accidental disposal pf pollutants. The project team continues to publicise these problems, as well as links to good practice information, through social media
- One further observation has been the potential for sewage fungus to occur on the outfall aprons during and following cold winter periods. It is suggested this is due to the effects of glycol de-icers used in road transport.

The data set is available to TW and the project team and may prove of value as a longer-term record of the performance of outfalls that have been through the SWOP.

These data indicate the problem of new misconnections being added to the network. There is no data available to assess the rate at which new misconnections are being generated. Informal observations though indicate that around 1 in 50 houses in any suburban West London street has scaffolding and/or a skip outside at any time, indicating extensive refurbishment taking place. Over a year this translates to around 1 in 15 houses being extensively refurbished, including some with new plumbing. Over a typical drainage catchment of 600 houses this equates to around 40 houses per annum.

The observations to date suggest that one or more of these refurbished properties is being misconnected, leading to new pollution issues, over the two-year monitoring period. Scaling this up to the Crane catchment as a whole (with say 150,000 properties) leads to a figure in the order of 200 new misconnections per annum. This rate compares with the total of 536 properties remediated to date during AMP 6.

This is only an initial first order calculation but may indicate why the SWOP is not seeing a major reduction in pollution issues in the catchment to date.

Pollution Events

Citizen Crane volunteers visit 16 sites along the river every month and are the eyes and ears of the project for these sites. Volunteers are encouraged to report any pollution problems identified during their site visits - to both the EA hotline 0800 80 70 60 and the TW incident hotline on 0800 316 9800. Broader issues around water quality and the condition of the river at the site are reported to the project steering group as well as contacts in the relevant local authority. This approach has resulted in a rapid response by the EA and/or TW to a number of pollution incidents as well as actions to clear up littering and fly tipping for example through the local authority.

A large number of pollution events have been identified and monitored over the Citizen Crane project and reported in previous annual reports. There have been fewer pollution problems identified in the last year. Given that the number of people out and about on the river has not reduced, this may reflect an actual reduction in pollution incidents during Year 5. There have been several minor incidents reported to Thames Water staff and these have all been investigated and resolved.

The major issue in Year 5 was due to glycol enriched discharges from Heathrow Airport, following a short period of cold weather in February and March. The RMI scores resulting from this incident are reported in section 5 above. Following this the Citizen Crane project team visited the new Heathrow treatment plant and met with their environmental management team. Key points noted were:

1. The 'fungus' is essentially a colony, largely consisting of bacteria but also containing fungi and diatoms etc. – hence the suggested alternative name of 'heterogeneous slime'
2. The bacteria – generally *Sphaerotilus natrans* – are always present in the river but will bloom if the conditions are right. The main controls are DO (30 to 80%); BOD (4 - 6 mg/l); TOC (7-8 mg/l) phosphorus (above 0.25mg/l) and ammonia (above 0.01 mg/l). Flow velocity needs to be above 0.05m/s and below 0.6 m/s – at which point it would break away from the substrate. This substrate needs to be gravel size or above and light is not a limiting factor
3. One area of disagreement was in the impact upon the downstream ecosystem – where the HAL report was indicating a marginal impact. The Citizen Crane project observations show that the downstream reaches (sites 9, 11 and 12) have been covered by this slime to some degree or another over the last three winters. The project RMI data showed a significant fall to below trigger levels at each site in response to this, as plotted in Fig 7 above. These data have now been shared with the HAL team
4. The HAL plant was only 50 per cent operational last winter and will be fully operational by the winter of 2019. The project team remains hopeful that a fully operational plant may result in little or no downstream impact on the river system. However, it may well be that further refinement is needed over the coming years to optimise its beneficial impact on the downstream ecosystem.

Improvement Measures

The Crane Valley Partnership and its partners have delivered a large number of river improvement measures over the last ten years and more are planned for the next five years. A summary of the key measures is provided below:

1. A large number of small and medium sized river improvement schemes have been implemented across the middle and lower reaches of the catchment in the period following the major pollution incident in the river in 2011. More than 5km of river and marginal habitat improvements have been undertaken in total and it is considered that these will have had a cumulative beneficial impact on the river ecosystem. These improvements are also likely to have enhanced the capacity of the river to deal with pollutant inputs and operate as a self-cleansing system. Narrowing the river channel and introducing more vegetation results in more oxygen in the system and more effective sediment scouring. Improvement and maintenance works have continued during Year 5

2. A major new scheme was completed in Newton Park West in the summer of 2018. This is being monitored by the Citizen Crane team as reported in section 4 above. Initial indications are that this is reducing the organic loading downstream of the site. It will be interesting to monitor this site over the years to come to see how this effectiveness varies over time. This and other such sites will help with the design of future SuDS schemes across the catchment

3. Further major river system improvements are scheduled at Headstone Manor over the next 12 months. Additional monitoring has already been put in place to help evaluate the effectiveness of this scheme. There is a further wetland scheme being installed at Elephant Park in LB Hillingdon and this may also be of value as part of an enhanced monitoring scheme

4. There remain large areas of the river system, particularly in the middle reaches, which are not functioning well - where the geomorphology is poor and the river is heavily shaded by vegetation. The RMI scores in the middle reaches are generally very low and this is considered to be largely due to the poor geomorphology of these reaches

5. The Thames Water Smarter Water Catchments initiative starts in April 2020 and is anticipated to include further river enhancements and SUDS schemes. The Citizen Crane teams expect to be included as an active part of this project, to provide real time monitoring and feedback to this programme, and help to optimise its effectiveness.

Review of the Conceptual Model of the River System

The Citizen Crane Year Two report contained an overview of the project's understanding of the River Crane as a system. The overview split the river into upper, middle and lower reaches as well as commenting on tributaries and sources of pollution.

In the Year Three report this conceptual model was reviewed and updated. The Year Three report also presented an initial mass balance for P and AN, considering sources, sinks and outflows. A conceptual drawing of the mass balance is presented in Figure 8 below.

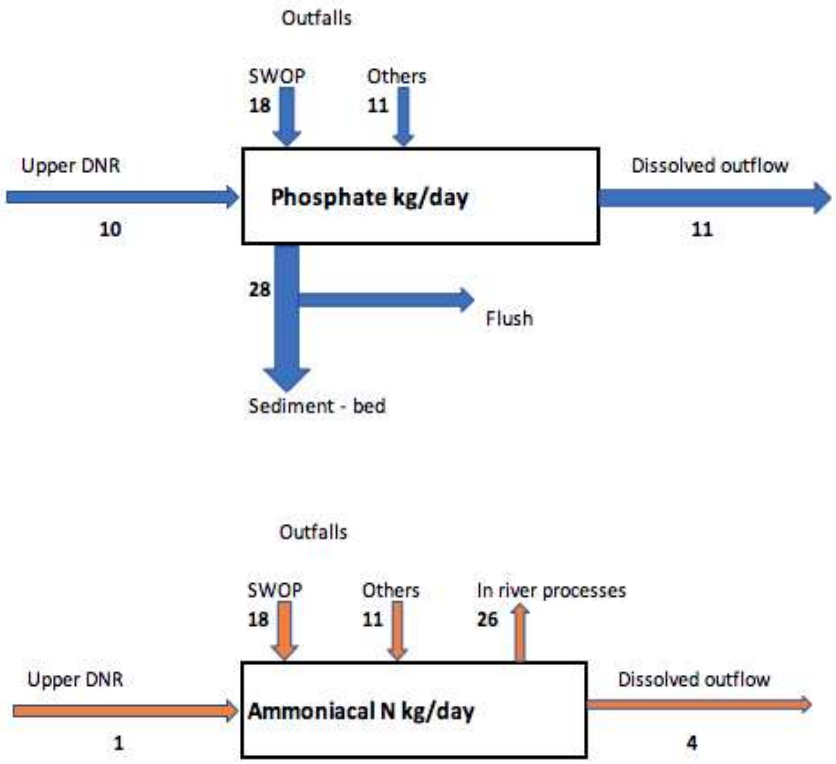

Fig. 9 Conceptual model for mass balance of P and AN on the River Crane

The conceptual model has remained largely unaltered over the last two years, with the following updates and amendments:

1. The SWOP has removed large numbers of misconnections from the system. However, this has not yet translated into large scale improvement in the water quality and ecology. This may be due to:

    - A lag in the system – such that improvements take time to manifest
    - New misconnections being added
    - Sewer network issues that are as yet unmapped
    - The effect of polluted sediment stored in the system – maybe as an aspect of the lag referenced above
    - Other counterbalancing factors such as the recent dry weather
    - Other pollution sources such as road run-off
    - Other factors such as poor geomorphology, over-shading etc

    Investigating and better understanding the processes involved here is a key objective of the team as part of the Smarter Water Catchments programme. An initial evaluation of the relative importance of these factors is set out in section 8 below.

2. The water quality plots are starting to show some improvement in conditions at the two source locations (Headstone and Newton Park). These improvements are also revealing further pollution sources in the middle reaches of the catchment which have not yet been properly investigated.

3. There appear to be two sections, in the upper reaches and the lower reaches, that have the capacity to be "self cleansing" – by removing the pollution load of ammonia (at both locations) and phosphate (in the lower reach). There is value in exploring this self cleansing capacity further and seeing if the conditions that create it can be replicated elsewhere.

7. Stakeholder Engagement

Volunteers

Citizen Science volunteers continue to be the mainstay of the project, undertaking the main data collection and monitoring tasks at 16 locations across the catchment. Volunteers are also playing a key role in the logistics of the project: water quality sample collection is managed by volunteers and they are also engaged with the wider reporting of surface water outfalls and their condition.

It remains essential to engage the volunteer teams as the project develops, particularly into the Smarter Water Catchments initiative from April 2020. Thames21 have become more engaged with the project during Year 5, particularly in the upper catchment. It is anticipated that their reach and volunteer base will prove valuable as the project develops.

Local Communities

The Citizen Crane teams continue to engage with local people during their monthly monitoring sessions and to hand out leaflets explaining the project and the wider issues of misconnections and river pollution. There are regular messages through social media about the project findings. Two walks and talks have been held over the last year, introducing local people to the project.

Thames Water

Thames Water is supporting the Citizen Crane project up to April 2020. Additionally, Thames Water is a key partner on the steering group and has acted positively with developments to the SWOP and other aspects of its programme in response to project findings.

TW has identified Citizen Crane as a key partner for the AMP 7 programme starting in April 2020. The River Crane will be the UK's first urban "Smarter Water catchment" in a pilot project scheduled for AMP7. This project is in part a response to the positive relationships developed over the Citizen Crane project. The Crane may also be a key part of the AMP7 SuDS programme, subject to the allocation of major funds for this programme. Further discussion of these future opportunities is provided in section 8.

Local Authorities

Generally, the relationships with local authorities and the project are positive and there has been particularly strong engagement with LB Harrow regarding their ambitious programme of improvements in the upper reaches of the catchment. During Years Four and Five the project contacted two local authority EH departments that had stopped engaging with TW on the misconnections programme. One of these has re-engaged with the programme but one LA has not, citing lack of resources. The TW programme for AMP 7 is exploring approaches to resolving this issue with EHOs at a wider regional level.

Academia

In Year Three the project helped to deliver a number of research projects and these were of value in developing the understanding of the catchment. There were no research projects delivered in Year Four or Five. However, the team remains willing to engage with academics around the use of the project data set and the catchment for related research purposes.

One major potential development is the start of a PhD looking at road run-off problems, based at Swansea University and likely to engage with the project as part of the research field work.

The project has also been engaging with the Project Camellia team. This is a major five year work programme, involving several university research teams, focussed on improving urban resilience to water related issues. One key focus of the programme is the Mogden surface water drainage catchment, incorporating the Crane and Brent catchments. It is hoped that this academic resource will be linked into the Smarter Water Catchments initiative over the next five years.

Wider World

The project continues to engage with the Catchment Partnerships in London (CPiL) group and has contributed to CPiL position papers on misconnections and road run-off in the last two years. There are a number of initiatives across London that are using the findings of the Citizen Crane project to inform their work programmes.

Citizen Crane and the Outfall Safari were presented as a key collaborative project at the National Water Summit in May 2018.

8. Overview of the Last Five Years

Purpose and approach

The Citizen Crane project has invested considerable time and effort evaluating the condition of the River Crane and working with partners to improve the river system over the last five years. The results set out in this report indicate that the base conditions of the system with respect to water quality and RMI have not changed significantly over this five-year period. There have been some encouraging signs regarding water quality in the upper catchment in the last six months, but it continues to be poor. The RMI data show if anything a small decline in overall river condition.

This overall outcome suggests that the root causes of the poor to moderate condition of the river system have not been greatly influenced over this five-year period – or possibly that improvements in some areas have been counterbalanced by problems in others.

This section of the report takes the opportunity to review the main and recognised controls on the existing and future river condition. These are listed as follows:

- Surface water outfalls, misconnections and the SWOP
- Network issues
- CSOs
- Road run-off
- Pollution events
- Heathrow
- Sediment
- Meteorology
- Upper Duke's River
- Geomorphology and river habitat
- SUDS and other interventions

The current understanding of each of these components is summarised below along with an evaluation of (a) how they may have changed over the last five years and (b) how they may be changed over the next five-year period.

Surface water outfalls, misconnections and the SWOP

Background: there are around 230 surface water outfalls in the catchment – as recorded by the first outfall safari in 2016. Misconnected properties effect around 3 to 5 per cent of the housing stock. The AMP 6 SWOP sought to remediate 45 surface outfalls in the Crane catchment. The Citizen Crane project and the outfall safari helped to identify the most polluting outfalls and the SWOP has been re-configured to deal with these.

Approach: misconnected properties have been considered to be a key organic pollution source in urban areas and these were therefore targeted in the AMP6 programme. The Crane catchment received a lot of attention, with 45 of the 200 SWOP projects across the Thames Region being carried out in this one west London catchment.

Changes over the last 5 years: the SWOP has investigated 45 of the 53 outfalls on the list. 538 polluting properties and 1539 polluting appliances have been remediated. The total amount of organic material removed by this process has not been formally calculated – though a first order calculation through this report indicates in the order of 5kg/day of P and AN removed from the surface water system. The river condition must therefore be better than it would have been without the efforts of the SWOP.

However, the organic pollution and ecological quality of the river have not significantly improved over the five-year period of the SWOP. This suggests that (a) misconnections are not as important a control on the river condition as first thought, (b) there is a delay in the recovery following their removal and/or (c) new misconnections are being added to the system at a comparable rate to their removal.

Proposals for the next 5 years:

1. The total number of outfalls to be investigated in the Thames Region AMP 7 SWOP is to be increased from 500 to 750. The numbers in the Crane catchment have not yet been decided.
2. A second outfall safari is scheduled for spring 2020. This will help to evaluate the changes in outfall condition since 2016 and target outfalls for the SWOP
3. The Citizen Crane monitoring will likely continue in some form to record any changes in the river condition
4. Some means is needed to properly evaluate the numbers of new misconnections being added to the surface water drainage network. This may also help to optimise an approach to publicising the issue and reducing the number
5. Efforts are enhanced to publicise the problems of misconnections, encouraging the public to remove them from the system and avoid creating new ones
6. Thames Water are proposing to work closely with council EHOs to improve the system for enforcing removal of misconnections.

Network Issues

Background: "network issues" is a catch-all term for failures of the sewerage system that lead to sewage effluent entering the surface water drainage system. There are various links and potential links between the two systems including: dual manholes with ineffective barriers in place; broken or defective rodding caps; leaking sewers that can be drained by a local surface water drain; sewer blockages that lead to overflows into the surface water system; etc.

There is considerable anecdotal evidence of cross-connections between the two systems causing pollution problems in urban rivers but the scale of the issue is not yet well understood. Middlesex County Council drainage engineers in the 1960s are understood to have resolved surface water pollution issues by connecting into the foul network. LB Harrow engineers report 209 dual manholes in the River Brent catchment in their borough with many missing or defective rodding caps.

Network issues are likely to cause sporadic pollution problems in response to high effluent levels or blockages for example. These are unlikely to be properly recognised by the existing Citizen Crane monthly monitoring network, although they may explain occasional very high pollutant concentration levels seen in the data.

A brief review of continuous ammonia data collated by the Environment Agency in the middle reaches of the river, and recorded in the Year 3 report, revealed peak ammonia levels at an order of magnitude higher than the background for a few hours to a day every month or so. This would be the type of record expected from a network issue.

Approach: there have been some investigations of network issues in the Brent catchment – where significant problems have been found. TW has reported that the problem is not as significant in the Crane catchment, but the project team is not aware of any investigations undertaken to support this view.

Changes over the last five years: the issue has not been investigated so the team is not aware of any changes over the project period. Professionals in the sector have indicated that this could be a significant issue in the catchment and needs to be investigated further. As the SWOP proceeded, without any appreciable improvement in the baseline river condition, this argument has become stronger.

Proposals for the next five years:

1. TW to engage fully with the network issue as part of the Smarter Water Catchments initiative
2. Continuous 15-minute monitoring sondes to be deployed at various locations across the catchment to measure the variations in ammonia and other key parameters and use the data to trace any network or other issues identified

Combined Sewer Overflows (CSOs)

Background: there are three CSOs in the Crane catchment. One of these (at the A4 crossing in the middle reaches of the river) was the source of the major pollution event in 2011 that killed virtually all of the river life downstream to the Thames. Notwithstanding this there has been little or no investigation of the impact of CSOs on the river ecosystem as part of the Citizen Crane project.

Approach: the issue has not been investigated

Changes over the last five years: TW has pledged to monitor the discharges from its CSO network across the region. The project team understands that this has not been implemented as yet in the Crane catchment.

Proposals for the next five years:

1. TW to engage with the CSO issue as part of the Smarter Water Catchments initiative
2. Monitoring data from the CSOs to be shared and reviewed
3. Sondes deployment (see above) to be mindful of the location and potential impact of CSOs

Road run-off

Background: many of the 230 surface water outfalls in the catchment are draining road run-off into the river system. Road run-off contains transport-related pollutants including hydrocarbons, heavy metals from brakes and tyres, as well as salt and de-icer following cold weather periods. The amount of pollution that enters the river system is a function of the amount and nature of the road traffic within the drained road sections and the maintenance regime for road and gully pot cleaning.

Road pollution often enters the system as an initial flush when heavy rain follows an extended dry spell. This can lead to oxygen sags in the river and consequent fish kills. These have been seen at regular intervals in the longer-term record on the River Crane and other London rivers.

Approach: this issue has not been a part of the brief for the Citizen Crane project. However, the team has engaged with parallel projects (a) looking at road run-off issues on a London-wide basis and (b) seeking to provide pollution control measures at the M4 crossing – believed to be the most polluting road source in the catchment.

Changes over the last five years: not known. There have been no fish kills related to road run-off in the Crane over the last five years that the team is aware of. Volunteers have reported flushes of dirty water following heavy rainfall events and build-ups of polluted sediment in some locations. Local major roads have also been reported with large amounts of grey sediment in the gutters and little evidence of gutter clearing.

Proposals for the next five years:

1. Continue to engage with parallel projects investigating and seeking to reduce pollution in road run-off
2. Link TW's Smarter Water Catchments initiative and SUDS programmes to road run-off management work so as to optimise outcomes for the river

3. Seek further information on the gutter and gully pot maintenance programme across the catchment – as a likely major control on the amount of pollution entering the river system

Pollution incidents

Background: pollution incidents are a feature of most river systems, where a pollutant escapes into the river and causes a pollution plume and the potential for ecosystem damage and fish kills. A long-term record of fishing in the Crane obtained by FORCE reveals that significant and major pollution incidents have been a feature of this river for at least thirty years.

Approach: the project volunteers have been going to the river every month for the last five years. Many of the volunteers visit a lot more regularly. Around 6000 leaflets have been given out to the general public about the project – and these include information on how to report pollution incidents. This approach has greatly increased the eyes and ears along the river, as well as encouraging the reporting of pollution incidents.

Changes over the last five years: there has been no systematic analysis of pollution incidents over the last five years. However, the project team is aware of at least a dozen significant to major incidents identified over this period, many by the project volunteers and several during the outfall safari. These have all been investigated and resolved by EA and/or TW staff. The use of the TW hotline in addition to the EA number has improved the response to pollution incidents in the view of volunteers and the project team – due to the additional resources of TW staff and their willingness to attend all incidents in a short time frame.

In the view of the project team this enhanced approach to identifying and rectifying pollution issues has greatly reduced the impact of pollution incidents on the river – at least in those parts of the river which are visible to the public.

Proposals for the next five years:

1. Review the data for pollution incidents held by the EA and TW
2. Enhance the public engagement about pollution incidents and reporting through the Smarter Water Catchments initiative

Heathrow

Background: around a third of the Heathrow site drains into the Crane catchment. This drainage passes through the eastern balancing reservoirs before entering the river. For the most part this is believed to be beneficial to the river system - and FORCE is in discussion with Heathrow about whether the amount of input could be increased, particularly during dry weather periods.

However, following extended cold periods, the inflow contains a major pollution source in the form of glycol de-icer from the aircraft and runway. This interacts with the river to form extensive blankets of fungus on the river bed which smother the invertebrate life in the river – as seen by the RMI data over several recent years.

The project team is not aware if this problem pre-dated 2014, when the Citizen Crane project started. No records have been seen to date. It is possible that the issue has been there for many years and had not been reported. Records seen by the project team do though indicate that the amount of glycol being used at Heathrow has increased significantly in recent years and this may have breached a tipping point for the river and the existing run-off management system.

Approach: the volunteer teams for sites 10, 11 and 12 downstream of the Heathrow outfall have been recording the impact of these discharges and liaising with Heathrow over the project period. Heathrow has recently invested around £20m in improvements to the balancing reservoirs and a new treatment

system for glycol. The current permit in place is 'descriptive'. The Project Team would like the EA to set numerical thresholds for the quality of effluent leaving the Eastern Balancing Reservoir.

Changes over the last five years: the river has been badly affected by fungus related to glycol from the airport in the winter and spring of at least three of the last five years. This resulted in reductions in the RMI score over several months and there is some concern about a possible cumulative effect as the RMI has tended to reduce at these sites over the entire monitoring period.

The investment by Heathrow in an enhanced management system and new treatment facility is warmly welcomed by the project team. The system was fifty per cent operational last winter and there were still fungal blooms in the river downstream. Heathrow acknowledge that it may need some fine tuning over the next few years to optimise its beneficial impact upon the river.

Proposals for the next five years:

1. Continue to monitor the river downstream of the Heathrow outfall
2. Continue to engage with Heathrow so as to optimise the benefits and minimise the negative impacts of the Heathrow outfall on the river system.

Sediment

Background: there are very large volumes of sediment in the river system. Initial investigations into the condition of this sediment (including by MSc students working with the project team) indicate that some or most of it is polluted. Samples contain high levels of hydrocarbons, heavy metals and phosphate for example.

Sediment can be bound into the river bed through time and the actions of marginal plants. It can also be flushed out of the system in response to heavy rainfall events. It may also be a source of dissolved pollutant through gradual release over time. Sediment will also build up in any SuDS and wetlands schemes developed in the catchment.

Approach: there is limited understanding at present as to the role of sediment on the water quality of the river or the value of the ecosystem. The poor quality of river sediment has though been a limitation on the remediation of parts of the river - due to the legislative controls regarding the disposal of hazardous sediment.

Changes over the last five years: there have been limited active changes to the sediment load in the river over the last five years. The build up of polluted sediment in the moat at Headstone Manor has necessitated occasional dredging at high cost over many years. The last dredging exercise was carried out in early 2019 and removed around 2000 cubic metre of organic sediment from the moat.

A mass balance for the catchment in the Year 3 report included a first estimate of 50 tonnes of phosphate in the sediment within the river system. This figure was determined by extrapolation from the analyses of sediment collected by an MSc student at various river bed sites.

The first major wetlands scheme developed in the catchment has been the Newton Park wetland, opened in 2018. This will inevitably build up a store of sediment over time. The project team is not aware at present if this is being monitored or of any plans for site maintenance and removal of the sediment.

Proposals for the next five years:

1. Further consideration of the importance and impact of sediment upon the river system – including a technical review of the findings to date

2. Use the findings of this review to guide Smarter Water Catchments initiative and SUDS programme actions.
3. Liaise with LB Harrow about the sediment accretion in the Newton Park wetlands scheme and the approach to mitigating this
4. Further investigate the amounts and nature of sediment across the catchment.

Meteorology

Background: the amount and temporal distribution of rainfall across the catchment is the fundamental control on the river condition. This control will vary over time. Extended dry periods will enhance the concentration of point source pollutants, whilst flood events will flush sediment and can lead both to network problems and road run-off issues. Both are forecast to become more common through climate change and there is some anecdotal evidence of this already occurring in the catchment. In addition, the lower catchment is vulnerable to pollution events linked to cold weather and glycol use at Heathrow (see above).

Approach: to date the project team has observed rainfall reports and used these to evaluate potential low flow and high flow risks. Monthly flow data are also a useful means of recognising low flow issues in the catchment

Changes over the last five years: there has been considerable variation in the climate over the last five years with extended periods of dry weather, cold weather and major rainfall events, all of which have affected the condition of the river. It is not possible to be definitive about the impacts. However, there was an extended period of relatively low rainfall in Year 5, and this may have partially masked any recovery in river condition over this period.

Proposals for the next five years:
1. Meteorology is clearly a given that has to be managed and accepted. However, it would be very useful to better understand the controls that the weather has on water quality and RMI data sets so that the data outputs can be better interpreted. This is another area where specialist technical support would be helpful.

Upper Duke's River

Background: the Upper Duke's River transfers water into the River Crane from the River Colne to the west. This is an artificial channel that has been operating since the sixteenth century and was constructed to supplement river flows and support water mills along the lower Crane and Lower Duke's Rivers.

Approach: Citizen Crane monitors the river flow and RMI, as well as taking water quality samples, at the base of the Upper Duke's River where it enters the River Crane. These data have indicated the importance of the inflow from the Upper Duke's, as the RMI scores have been highest in the catchment, both within the Upper Duke's at Site 10 and the downstream River Crane monitoring sites 11 and 12.

The Upper Duke's has a relatively high P loading compared to the Crane (thought to be sourced from upstream sewage treatment works on the River Colne) and a low AN loading. The positive changes in RMI scores indicates the relative importance of AN compared to P as an ecological control.

Changes over the last five years: the P concentration has remained relatively consistent over the last five years. The flow though has reduced significantly and, given the apparent importance of this inflow to the character of the river downstream, this is a major concern. The issue has been raised with Heathrow (and the EA), and Heathrow consultants are now also monitoring the flow rates as part of data gathering linked to the Third Runway scheme.

Proposals for the next five years:

1. Continued dialogue with Heathrow and the EA to ensure an appropriate flow continues to be transferred into the River Crane
2. Discussion with TW about P levels in the Colne.

Geomorphology and river habitat

Background: river geomorphology has a major control on the RMI score in the river. There are extensive parts of the river, particularly in the middle reaches, where it has been straightened, widened and deepened over the last hundred years. This has resulted in a slow and homogenous system, often with an extensive silt load, and an ecologically poor and uniform environment, which would generate low RMI scores almost regardless of the water quality.

The river is in this condition due to being heavily engineered as an urban managed channel for much of the 20th Century. River improvement works have been reversing this process along small and cumulatively significant stretches of the river, over the last 20 years.

River habitat is related to geomorphology, in that it is often poor where the river is heavily engineered. However, factors like over-shading and a lack of marginal habitat can in some cases be independent of geomorphology. Habitat can influence water quality as well as RMI – in that as the habitat improves more oxygen is introduced into the river, marginal plants intercept and sequester sediment, and plants can also remove P and break down AN.

Approach: the project team has become more aware of the importance of geomorphology and habitat on the RMI in particular and potentially also the water quality of the river. The water quality data have revealed reaches of the river (particularly in the lower river below the Upper Duke's confluence) which are self-cleansing, able to remove part of the P and AN load from the system. This self-cleansing ability is considered to be a largely a function of the high geomorphological and habitat value of these reaches of the river.

The project team has not directly engaged in habitat monitoring or improvement measures but has supported these activities.

Changes over the last five years: in 2016 CVP undertook a detailed geomorphological survey of the river using the "Urban River Survey" (URS) methodology. There have been a raft of river improvement works along the river over the last 5 to 10 years, many of them funded through the TW River Crane Improvement Fund. There has been no detailed work to directly assess the impact of these works on the river ecology – although there are clear habitat and aesthetic benefits derived, particularly where these works continue to be maintained and enhanced.

The project team has monitored the effect on the RMI and water quality of the major new wetland system installed at Newton Park in 2018. Initial data indicate a measurable improvement in water quality, and recent indications of an improvement in RMI, as a result of this installation.

Proposals for the next five years:

1. Continued support for schemes to enhance the geomorphology and habitat value of the river
2. Encouragement and support of projects that conduct before and after investigations, evaluating the benefits to the ecosystem of each river improvement scheme
3. Incorporate such before and after monitoring into the Smarter Water Catchments initative programme
4. Review of the URS data set and use this as a baseline for evaluation of further works over the next five to ten years

Sustainable Drainage Schemes (SUDS)

Background: SuDS reduce peak surface water flows and flood risk, remove pollutants, provide habitat for wildlife and can also have considerable amenity value. SuDS are however notably lacking in the Crane Catchment – though some recent developments have included SUDS proposals and the Newton Park wetlands could be described as a SUDS scheme. TW has proposed large scale SUDS as one of its key means of managing run-off. A programme of works for AMP 7 includes £55m of SUDS investment for 65 hectares of run-off benefit across the region. It is envisaged that some of these works will be delivered in the Crane catchment.

Approach: this issue is not part of the current brief for the Citizen Crane project. There have though been initial discussions on how SUDS may work on the Crane, how they could be implemented and the benefits properly measured and optimised. This work also links to the road run-off discussions referenced above.

Changes over the last five years: no major schemes implemented to date (with the possible exception of Newton Park – see description above).

Proposals for the next five years:

1. SUDS are proposed through AMP 7 and may also be a significant element of the Smarter Water Catchments Initative approach.
2. The locations and designs of SUDS are selected with reference to the baseline conditions in the river and with a view to best enhancing these conditions
3. SUDS schemes to incorporate appropriate baseline and post scheme monitoring

Summary

This report has set out the findings from monthly monitoring of key river variables (AN and P concentration; river flow; AN and P loadings; and RMI) at between 11 and 16 locations on the River Crane over the last five years. One of the over-riding findings is that the river condition has not improved significantly, despite the major efforts from TW's SWOP and other improvement programmes over this period.

This section of the report has gathered together the available information on eleven variables which either do or may influence the river condition. The project team's current knowledge about each variable is summarised in the table below, along with the efforts made over the last five years to assess and (where appropriate) beneficially influence the variable's impact, and our proposals for how this process can be developed over the next five years.

Table 7. Summary of key river variables, their importance and recorded change

Issue	Importance	Change in last 5 years	Priority for next 5 years
Misconnections	Thought to be high – but now in question	Major work in AMP 6 – but no appreciable change in condition resulting Initial estimates indicate the rate of new misconnections could be as high as the remediation rate	Continue SWOP; understand the rate of new misconnections; up the public engagement; increase engagement of the council EHO's

Issue	Importance	Change in last 5 years	Priority for next 5 years
Network Issues	Not known – believed to be very important on the Brent	Not addressed	Needs to be a focus – even if only to rule it out as a key issue
CSOs	Not known	Not addressed	See above
Road run-off	Not a control on organic pollution but could be significant for ecological value	Not addressed directly	Major opportunity for improvement linked to other work programmes
Pollution events	Significant – particularly major events (see 2011)	Good evidence for improvement in the early recognition and amelioration of events before they become major	Continue with this work + analyse the data from EA and TW records
Heathrow	A significant negative impact on the ecosystem for several months a year for several km downstream of the outfall (cold winters periods only). Potential for significant beneficial impact (particularly during low flows)	Pollution problems assessed and noted. Major investment by Heathrow coming on stream but not yet optimised	Optimise the treatment system. Explore opportunities for low flow enhancement
Sediment	Not known – though there is plenty of polluted sediment in the river system	Not addressed	Needs technical expertise to evaluate its potential importance
Meteorology	Fundamental	Evidence reduced rainfall in Year 5 impacted the river condition	Needs technical expertise to evaluate its importance
Upper Duke's	Recognised as key to benefitting the lower reaches	Reduced flows over the five years a cause for concern	Essential to ensure flows are protected in the future
Geomorphology and river habitat	Fundamental	Evidence of enhanced conditions (particularly in the lower reaches) due to improvements in the last five to ten years	Further river improvement works, particularly in the middle reaches, along with better methods of evaluating and optimising the benefits

Issue	Importance	Change in last 5 years	Priority for next 5 years
SUDS	Not yet known	Only the Newton Park system implemented with promising early results	Work needed to optimise design and maintenance regimes for environmental benefit

This table illustrates how our understanding of how the River Crane ecosystem operates has developed over the last five years. Whilst the works to date have not made a major beneficial difference to the ecosystem it can be stated confidently that works such as the SWOP and early pollution identification prevented further deterioration. In addition, the information gathered and the prospect of a major programme of works under the Smarter Water Catchments initiative, give considerable grounds for optimism that substantial progress can be made over the next five year period.

Developing a better understanding of the relative importance of these variables in controlling the ecosystem value will be of key importance to managing the next five years of the project. There is an opportunity, through the Project Camellia initiative, to bring specialist academic support to the project. This may be of value to many aspects of project development, including new modelling approaches for the Crane River ecosystem. This could provide a means to better understand the relative importance of these variables and model the impact of various interventions.

9. Future Project Strategy

Strategy to April 2020

The Citizen Crane project will continue until the end of the AMP 6 period in April 2020. Activities will include:

- Continuation of the existing Citizen Crane programme of work
- Reviewing the data collection sites and gauge boards by the end of Year 6
- Undertaking a second outfall safari in spring 2020
- Continuation of work with TW staff and CVP to develop the Smarter Water Catchments initiative programme
- Consideration of the TW SuDS programme and how this will link into the project
- Continuation of liaison with teams developing road run-off works so as to interface with these work streams as they move forwards
- Exploration of other opportunities – including Project Camellia for example and Cranford Park HLF project – and how these will link into the programme.

The following list was produced by TW during a review meeting in April 2019 and identifies the key tasks to be delivered for each Smarter Water Catchment in the lead up to the start of AMP 7 in April 2020:

- Engagement with partners
- Data gathering
- Catchment system plan
- Position paper
- Feedback
- Agree objectives
- Assess options
- Establish governance
- Feasibility study
- Detailed delivery plan.

The project team is working with TW and the CVP Development Manager to help to develop this programme. The team is also liaising with other Smarter Water Catchment initiative project teams in the River Chess and River Evenlode to ensure there is a consistent and optimised approach.

This approach is due to be discussed and developed at the Citizen Crane Forum in October. Note that recent discussions with TW indicate that substantial funding has not been available in the run up to AMP7 and therefore some of the planning tasks identified above will be delayed until the following year with the main implementation phase starting in April 2021.

Approach to Smarter Water Catchments and SuDS from April 2020 onwards

The Smarter Water Catchments initiative has been identified in the Thames Water AMP 7 proposals for April 2020 to March 2025. In discussion TW has indicated that these are medium to long term activities and the programme may well extend into AMP 8 (i.e to 2030). TW has also identified £55m of SuDS funding across the region for AMP7, aimed at removing 65 hectares of surface run-off from the sewerage system.

The over-arching aims of the Smarter Water Catchments initiative (and the SuDS programme) from a Citizen Crane perspective are set out below. This list has been shared with TW for discussion and development:

- The River Crane achieves Good Ecological Status
- The river is more resilient – i.e. stopping pollution at source or creating sustainable, downstream solutions that intercept and remove pollution from the catchment's surface water drainage system
- The river and its surrounding flood plain are developed as a linked network of habitats, recognised as being of high value for wildlife and local people
- River habitats are created and managed in a sustainable way with a high degree of involvement from the local communities and other interested parties
- Local communities, numbering around half a million people in total, have an enhanced understanding of the value of the River Crane environment and their roles in managing and enhancing it.

The Citizen Crane team has developed a list of activities for the AMP 7 period which would engage the team with the wider Smarter Water Catchments initiative objectives. This list has also been shared with TW and is set out below for discussion and development.

Table 8. Summary of potential Smarter Water Catchments initiative activities developed by Citizen Crane

	Activity	Delivery options	Timescale
1	Catchment* investigations and action		
1.1	Evaluate the scale of contribution of the following to AN and P loading in the upper (and possibly also the middle) catchment • misconnections • network defects • missing surface water caps in dual manholes • blockages • CSOs This is envisaged as a desktop study that involves collating all TW investigation records in the Harrow and Hillingdon drainage catchment. In addition to some in depth 'sub sampling' of a proportion of drainage catchment areas where systematic lifting of manholes and network investigations will give a representative snapshot of the condition and issues effecting the entire upper drainage catchment. *Note: the upper catchment has long been identified as a major source of organic pollution into the river. However, over the last few months, and as the SWOP has started to impact upon the pollution loadings in the upper catchment, further problems have started to emerge in the middle reaches of the catchment where less investigations have been done. Therefore the scope and scale of this area of work needs to be considered at an early stage, including consideration of all reaches in the first instance. It may be expected that SuDS schemes will be implemented in all parts of the catchment subject to opportunity and value.	Thames Water investigation	2020

1.2	Detailed water quality investigation in the upper (and possibly also middle) catchment to identify the surface water drainage channels that bring the highest concentrations of nutrients into the river. This would be done using SONDES to systematically monitor WQ in culverts, small tributaries, major outfalls and the main river. The findings of this study will help feed into the identification of pollution hotspots	Smarter catchments project officer SCPO*	2020
1.3	Make investment in the upper (and middle?) catchment drainage network based on the findings of 1.1 and 1.2	TW	To 2025
1.4	Map the surface water drainage network (particularly in Harrow and Hillingdon – but possibly looking at other boroughs subject to SuDS funding) and model urban diffuse pollution 'hotspots' – risk-based approach	Consultants/ TWsteered by citizen crane	2020
1.5	Scope options and asses the feasibility of constructing wetlands within the identified hotspots	SCPO working with key boroughs	2020/21
1.6	Build wetlands	SCPO working with key boroughs	2021-2025
1.7	Monitor and report on effectiveness of wetlands – by development of the CC monitoring system. Note: this is already being implemented on the Newton Park system installed by LB Harrow. This work shall include the accumulation of sediments and the long term maintenance requirements of the sites.	SCPO	2018 to 2025
1.8	Undertake broad spectrum analysis of chemicals in the river – at Spider Park and elsewhere subject to unexplained ecological failures revealed by RMI. Interpret results in relation to ecological impact and report	SCPO	2020
2	Misconnections		
2.1	Calculate the amount of AN and P removed by the SWOP in AMP 6	Thames Water	By end AMP 6
2.2	Develop and implement a method of data collection and analysis to enable a calculation of the rate of new misconnections in the catchment	Thames Water Possibly identify representative sub catchments to study for this	2020
2.3	Second catchment Outfall Safari. Review the findings from OS 1 and 2 and use these and other data to feed into the overall picture of catchment development	ZSL and SCPO	2020
2.4	SWOP works to remove sources of pollution	TW	On-going

2.5	Outfall Safari	ZSL	2024
2.6	Work with LA EHOs to develop an improved method of dealing with misconnections that are not initially rectified	TW and LAs	2020 and ongoing
3	Road Runoff Pollution		
3.1	Use the Road pollution Hotspots Map and action plans produced by ZSL, T21 and Middlesex Uni to scope and check feasibility of interventions at priority transport outfalls in the catchment	SCPO	2020
3.2	Engage with LAs and others to assess the scope of the gutter and gully pot maintenance regime	Third party project linked to SCPO	2021
3.3	Work with TFL and HE to install pollution intercepting interventions at these outfalls – if necessary, use Thames Water funding as match to encourage a collaborative approach	SCPO working with HE and TFL	2021-2025
4	Citizen Crane		
4.1	Review the data collection approach to date and the volunteer teams undertaking these works. Develop an approach for the next five years	CC Team	2019
4.2	Identify any wider roles and opportunities envisaged by TW and other project partners	CC Team working with SCPO	2020
4.3	Develop and implement training, recruitment and other support activities to allow these volunteer teams to meet their objectives	CC Team working with SCPO	2021-2025
4.4	Agree and implement the appropriate support structure for CC team for the next five years	CC Team working with SCPO	2020
5	Crane Valley Partnership		
5.1	Help co-ordinate activities with partners to meet SC and wider CVP objectives	CVP with SCPO and others	2020 to 2025
5.2	Engage with the wider community to enhance the value and appreciation of the Crane catchment by developing the role of the community in the SC and CVP programmes	CVP with SCPO and others	2020 to 2025
5.3	Co-ordinate an appropriate steering group structure to oversee the work programmes	CVP with CC, SCPO and others	2020 to 2025
6	Other Related Activities		
6.1	Engage with Project Camellia and other academic and third party initiatives as a means of engaging technical expertise in various aspects of the project	SCPO, CC, TW et al	2020 to 2025

6.2	Review the data for pollution incidents held by TW, EA and others and report	SCPO	2020
6.3	Continued engagement with Heathrow around the effectiveness of the treatment system and the potential for augmenting low flows in the river	SCPO and CC team	Ongoing
6.4	Technical review of the potential impact of sediment on water quality and ecological value of the river system	External, managed by SCPO	2020/21
6.5	Technical review of the impact of meteorological variability on the ecological value of the river system	External, managed by SCPO	2020/21
6.6	Review of the URS data set as a baseline for the geomorphological and habitat value of the river system (as recorded in 2016)	SCPO	2020/21
6.7	Support to geomorphological and habitat enhancement measures throughout the river system – including monitoring of the impact of the enhancements and ongoing maintenance measures	CVP and SCPO	Ongoing
6.8	Annual reporting on outcomes	CC and SCPO	Ongoing
6.9	Annual forum to review outcomes and programme for the following year	CC and SCPO	Ongoing

* The 'Smarter Water Catchments Project Officer' could be hosted by TW, CVP, T21 or ZSL for example. They would report to the CC steering group and/or a wider steering group formed through the Smarter Water Catchments initiative programme.

These activities have been identified as priorities to improve water quality in the Crane and Yeading Brooks by the Citizen Crane team. There are overlaps, such as the installation of wetlands, and positive feedback loops that can be achieved by hydro morphological and ecological enhancements and by improving community access. It is essential however to focus funding on removing sources of pollution into the river. Highest priority solutions are those that stop pollution at source and second are end-of-pipe solutions that capture pollution between the surface water drainage network and the river.

The SuDS programme will be a major driver for improvement in the catchment – subject to funding being allocated to CVP partners. At this stage the Citizen Crane team has developed a list of issues and objectives for any SuDS programme and this can be seen in Appendix A to the report.

Further work is clearly required to develop these programmes of work over the next six months and prior to the start of the AMP7 period. TW envisage that the first year of the programme will also be largely invested in project development with the main implementation period starting in April 2021.

10. Summary and conclusions

Five years of Citizen Crane monitoring by teams of volunteers has shown that, despite considerable efforts (by Thames Water, the Environment Agency and others) to reduce pollution from misconnections and other incidents, the water quality in the river has not significantly improved and remains heavily degraded in many places.

High concentrations of sewer-related pollutants are present, particularly in upper and middle reaches. Also, there are high levels of heavy metal and hydrocarbon contamination in the sediment throughout.

The ecology of the river is also constrained in many places by engineered river channels with a lack of flow variation, low flows and siltation.

Despite these problems the River Crane remains an important ecological asset for the five boroughs and half million local residents of west London. The river approaches 'Good Ecological Status' in the lower reaches, where it also shows the capacity for self-cleansing.

The main problems identified are as follows:

- Sewer network: poor design, structural failure, blockages and/or misconnected properties result in organic waste and nutrients discharging to the river
- Poor habitat diversity and diminished flood plain reduce the river's capacity to purify itself and support wildlife
- Over widened channels, exacerbated by low flows at times: leads to excessive siltation, smothering the riverbed habitats of animals and plants
- Urban run-off: carries pollutants such as heavy metals and hydrocarbons from roads and other hard surfaces into the river where they accumulate in the silt
- Urban river systems are complex and there is only a partial understanding of how the combinations of many variables control the condition of the river.

The main solutions identified are as follows:

- Investigate the extent of sewer failure in the upper catchment, repair faults and continue to tackle misconnected properties. Increase pro-active surveys for blockages and cross connections
- Renaturalise the riverbanks and add habitat features - creating a more diverse habitat along the entire river corridor
- Narrow the riverbanks in places and add habitat features to create low and high flow channels
- Install sustainable drainage systems (SUDS) and other means to intercept pollutants from roads, particularly in pollution hotspots
- Uncover the surface water drainage network and install wetland systems that reduce peak storm water flows plus capture and process pollutants
- Continue to support community citizen science that gathers data to inform interventions and evaluate their impact
- Engage with stakeholders and the wider community to showcase the value of the river corridor and how to protect and enhance it.

The project will continue to engage with key partners to deliver on these solutions, particularly through the Smarter Water Catchments initiative.

Appendix a: Delivery of SUDS in AMP 7

Note: these ideas and suggestions are based on internal review and discussion by the CC project group and are intended for discussion and development by any and all interested parties. This is version 1 and was produced in June 2019 and sent to Thames Water for consideration and feedback.

Overview

AMP 7 could see a significant amount of funding from water companies for new SUDS. These systems will serve to create more storage areas within urban catchments and to smooth out the hydrograph, reducing peak flows and potentially easing strain on key assets. The new SUDS can (and should) also serve to improve water quality and the ecological and chemical status of our rivers. These new assets will also have the potential to deliver ecological benefit and amenity value within the asset itself as well as downstream.

Several water companies, including Thames Water (and Anglian Water), have set aside funding in AMP 7 for new SUDS and stated that these projects will not be delivered via their framework contractors. Instead funds are likely to be diverted to Local Authorities, the Third Sector and other delivery partners, who will work in partnership with the water company to design, build, manage and maintain these assets throughout their design life and then potentially decommission/ rehabilitate these assets at the end of their design life.

There is great potential to deliver a significant benefit to urban catchments through funding these new assets but realising that opportunity over a >20-year time frame is a challenge, and risks being a missed opportunity without an appropriate strategy in place from the start, which allows for refinement and change with experience.

Challenges

- Optimising the opportunity for river catchments
- Availability and application of best practice guidance for designs to support water quality improvement and maintenance
- Availability of data to inform prioritisation of interventions (where the most benefit can be delivered)
- Availability and application of methodologies to support scoping/ identification of SUDS opportunities and associated constraints
- Achieving a consistent funding structure appropriate for long-term asset management i.e. separation of funding into CAPEX and OPEX, plus contingency
- Achieving engagement and support from all local stakeholders – including local communities

Points for Discussion

1. How can stakeholders support the development of a strategic approach (regionally or nationally) to realise the greatest long-term benefit from new SUDS assets in terms of ecology, water quality, water quantity and amenity value? At what scale could this be optimised?
2. How can stakeholders create a framework whereby recipients of funding are obliged to take a TOTEX view of any new asset they create?
3. If TOTEX for a new SUDS is e.g. 20-25 years, prior to requiring a major re-fit or decommissioning, how can funds be released from project sponsors over a 20-25 year time frame without any capital set aside for OPEX losing a significant amount of purchasing power over the life span of the asset?
4. How can these new assets be designed, built and maintained without major replication of work and wasted money?
5. What models of management, operation and maintenance best ensure a proper level of engagement with all interested parties including (or especially) local communities?

6. What is the optimum scale for a more joined up approach to deliver true efficiency and value? e.g. How could monitoring and maintenance contracts be managed in an efficient way?
7. Will there be a critical mass of new assets over AMP 7 to warrant consideration of some centralised functions to support value and realisation of long-term benefit?
8. Is there an opportunity to divert funds to existing SUDS that may be suffering from lack of maintenance or may not have maintenance plans in place? This may not get as much good press as a new system but in some cases will represent a better investment.
9. How could the creation of new assets nationally fit into the 25-year Environment Plan and could this open up projects to different funding sources over life span of the asset to support long term maintenance?

Potential Solutions

1. An initial literature and best practice review nationally and internationally for SUDS – considering not only design and operation – but management options, environmental and socio-economic valuations.

2. For utility companies and any other grant awarding body giving money for SUDS schemes to sign up to a code of conduct or way of working that ensures the recipients of funding take a TOTEX view of the new asset and;

    a) create a bidding framework that qualifies bidders in terms of competencies/ responsibility / understanding TOTEX
    b) Create a funding award structure that recognises TOTEX
    c) Ensures a maintenance contract (suggest 3 years, *or 5 years to fit with AMP period and tie in funder to maintenance?)* is tendered and awarded as part of the capital delivery of the project

3. Identify which parts of a new SUDS are site specific e.g. ground investigation and long-term access assessments, and which elements are common to all new SUDS. Separate these out and work with key stakeholders to develop a tool kit for all elements that are common to all systems to eliminate replication of work. Work out how to simplify decision making, reducing replication of resource intensive work. Figure out what we can standardise and at what scale.

4. Investigate the most appropriate scale at which to pool resources and consider the centralisation of certain functions in order to design, build and maintain new assets efficiently.

5. Investigate who is willing to take long term ownership / liability for new assets and gain a full understanding of their respective risk profiles.

6. Monitor. Create a standard ecological and water quality monitoring tool kit and SUDS adoption process (for monitoring) for Citizen Scientists. If we monitor, we can fine tune the OPEX budget and this will feed into efficient allocation of funds over the life of asset and start quantifying benefit of respective system designs.

7. Consider at the outset specifically how local communities can be engaged in the design, development and maintenance of these assets and build this into the process

8. Put a collection of systems in place to make sure poor designs that do not lend themselves to ease of long-term maintenance don't make it past the first hurdle.

Further Considerations

- Could value be delivered via some sort of centralised body acting regionally or nationally that could act as a neutral, value orientated design hub (or could positions be funded in an existing, appropriate body).

- Could a central body help develop and deliver tools to support identification of the SUDS opportunities, support selection of appropriate/ effective designs for each location and support development of tools for Citizen Science monitoring and fine-tuning of maintenance schedules during the operation of the asset.
- Could a centralised body support tendering process for contracts and perhaps even support contract management and commissioning services (probably via an approved list of contractors) - could this approach help deliver wider catchment objectives regionally or nationally?
- Could a central function hold (and invest?) OPEX budget and release funds strategically based on different inputs from monitoring data/ incidents and match funding opportunities?
- Could design risk and liability be managed in a different way?