Thames Tideway Tunnel

Interim measures to reduce infraction fines.

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Report

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Executive summary

Any long term solution to the Thames Tideway CSO problems would take many years to implement, so I propose interim measures to much improve the Tideway within two to three years.

The European Commission has taken out infraction proceedings against the UK for slow implementation of the UWWTD. The European Court of Justice has found against the UK on the Thames Tideway. Thus it is likely that infraction fines will be imposed. My information is that these could be substantial, based on the current tunnel completion date of 2023 as high as Euros 2.0 bn. I am advised that they would be based partly on the *"Environmental impact of non-compliance* ". A reduction of one point out of five points on the "*environmental impact of non-compliance*" or "*member state conduct*"might save as much as Euro 200 million, about £160m.

Standards for ecology, aesthetics, and health impact have been set for the Tideway. The current STW improvements, and the Lee Tunnel would reduce the spill volume from 39Mm3/year to about 18Mm3/years, a long way to achieving the dissolved oxygen standards. However the Thames Tideway Tunnel will not be operational until about 2023. Thus interim measures could be implemented to reduce "*the environmental impact of non-compliance"* until the tunnel is operational. The object of these interim measures would not be to meet the standards set for the Tideway but to **mitigate the environmental impact** to the extent that the substantial fines would be reduced. These measures would also provide an environmental improvement during this period.

CSO spills could be reduced by **reducing water use** further , by implementing SuDs, by **connecting** some sewers **to other STWs**, adjusting the CSO weir levels, **removing restrictions in the sewer system**, and by implementing **real time controls**. Sewage litter can be reduced by constructing a **vortex system** at the CSOs to pass forward a concentrated flow and spill much less of the floatable matter. **Booms** around the CSO outlets could retain sewage debris and **skimmers** could collect escaped debris.

Fish are considered the most sensitive ecological species and dissolved oxygen standards have been set to minimise fish kill. A **diffuser system** using compressed air or oxygen would be able to raise the dissolved oxygen levels in the river to mitigate dissolved oxygen sags. Near real time monitoring and mobile oxygen bubbler vessels would supplement.

The Tideway is not a designated bathing water and is not subject to the Bathing Water Directive. For navigation reasons, the PLA has recently banned bathing in the Tideway except with a special licence. Health impact of those in the **London Docks** can be mitigated by putting in **water treatment** of the relatively small quantities of top up water. The rowers in the Hammersmith area are already ten times less susceptible to gastric infections than the general public. Improvements to Mogden STW, due for completion in March 2013, will much improve water quality in the Mogden/Hammersmith stretch of the Tideway where there are many rowers. A **traffic light system** could be provided to warn rowers should adverse conditions occur.

These works should be implementable within two to three years, ie likely to be within the time scale required by the European Commission. The cost is estimated to be about £30 million, much less than one point reduction in the environmental impact of non-compliance. In addition it would also demonstrate to Londoners early improvements in river water quality. Also the tunnel, when operating, would not eliminate spills entirely and such an interim scheme, if continued to operate, would also improve the environment when the tunnel spilled several times each year.

I recommend that such interim measures be studied, and if found to be appropriate, implemented.

Contents

1.Introduction

This note is prepared on the basis that the Thames Tideway Tunnel is a committed project but the tunnel cannot be operational until 2023. Even were it decided that Integrated water management/Green Infrastructure/ Sustainable Urban Drainage Systems were to be implemented then it would still take many years for the Tideway to be satisfactory.

However the European Commission has taken out infraction proceedings against the UK for slow implementation. The Advocate General has found against the UK on the Thames Tideway. Thus it is likely that infraction fines will be imposed. I am advised that they would be based partly on the *"Environmental impact of non-compliance "* and partly on the length of time between the date for completion assumed by the Commission and the environmental impact being deemed satisfactory. Presumably this would be when the Thames Tideway tunnel becomes operational or any other system reaches a satisfactory situation. My information is that these fines could be substantial, based on the tunnel becoming operational in 2023 possibly as high as Euros 1.5bn.

Standards for ecology, aesthetics, and health impact have been set for the Tideway. The Thames Tideway Tunnel would achieve these standards.

The defra River Basin Planning Guidance Vol 2 August 2008 states "*The WFD requirement is to make judgements about the most cost-effective combination of measures."* Since completion of the tunnel is about 11 years away, and it could not provide benefit until complete and operational, should not the WFD consideration also include the interim period?

This report looks at ways that the "*environmental impact of non-compliance*" could be reduced during the interim period until the tunnel is operational. These would have to be relatively cheap and quick to implement. After completion about 2023 the tunnel would still spill several times a year and these measures could also provide some long term benefit but that is not a priority.

In any case the proposed interim measures would provide significant benefit in greatly reducing the impact of CSO spills on the Tideway at very limited cost and within about two to three years..

I have discussed this report in early draft form with the Environment Agency and twice with Thames Water and have adapted it accordingly.

2. Potential infraction fines

Infraction proceedings

The European Commission has taken out infraction proceedings against the UK. The Judgement of the Court, case C-301/10 dated 18th October 2012, states in para 95 "*Consequently, it must be held that, by failing to ensure: appropriate collection of the urban waste water of the agglomerations of London(Beckton and Crossness collecting systems)..the United Kingdom has failed to fulfil its obligations under that directive.*

Thus it is likely that infraction fines will be imposed, based partly on the period of non-compliance.

Period of non-compliance

The period of non compliance is from the deemed start of non compliance to deemed end. I examine both dates below.

Start of infraction period

The date for compliance specified in the Urban Waste Water Treatment Directive is 31st December 2000.

The Court in its judgement appear to consider that the appropriate date is "*the situation prevailing in that Member State at the end of the period laid down in the additional reasoned opinion.*" Para 91. The additional reasoned opinion was sent on 1st December 2008. "*The additional reasoned opinion dated 1 December 2008 prescribed a period of two months from receipt thereof for the United Kingdom to comply with its obligations resulting from directive 91/271.*" Para 75. This date would be 1st February 2009 or very shortly thereafter. It is noteworthy that this date is already some 8 years after the date for compliance in the Directive.

I understand that defra consider that the date will be some significant period in the future, as an instance 2017.

Date of completion

The question then is whether compliance will be deemed to be when the tunnel " begins" dealing with the problem or when the problem is fully addressed.

I understand that DEFRA takes the view that there will be no penalty proceedings brought against the UK because the Commission will treat compliance as the point at which the tunnel construction begins or is approved, rather than completed.

I understand that the Commission's view is that compliance is when the system is functioning in accordance with the UWWTD, which would be when the tunnel is completed and operating.

The Commission's view does seem the logical conclusion.

The Thames Water Stage 2 consultation states in the document Timing "*Subject to approval, our provisional start date for the construction period is 2016....(duration is expected to be six to seven years*." That would mean completion in about 2023.

This date compares with the completion date in the Thames Water report of December 2006 Vol 1 Tunnels and shafts page 14 of 2019. Thus the project has already slipped about four years.

The tunnel will be some 20km long. It could not become fully operational until the whole length had been completed. Thus any delays would compromise the scheme becoming fully operational.

Tunnelling is always at risk of unknown geological features. For instance the London Water Ring main tunnel constructed under London in the early 1990s, hit a water bearing fault which required ground freezing to be able to tunnel through it. This delayed the tunnel by several months. As the Tideway tunnel is mostly under the river access from the surface to any problems would be difficult and require special equipment.

Thus it is possible that the date for the tunnel becoming operational, about 2023, could slip further. This could increase the period of non-compliance and hence the infraction fines accordingly.

Thus the period of infraction could well be from the date in the reasoned opinion, 2009 to the date of completion 2023, a period of 14 years. The analysis below is based on the period from 2017 to 2023, a period of some 6 years.

Amount of the fines.

Only the court can hand down a fine on the Commission's application. The text below assumes that the period of non-compliance would start in 2017. However this could well be 1st February 2009, more than doubling the fines.

I have not been in touch with the Commission and do not have the relevant documents. However I have received an email from a lawyer who has. He states:

"My team and I have come up with the following estimate of the fine the UK can expect to be liable for in the event that it loses its case before the ECJ. It is EURO 891,845,800.

This breaks down as-

Lump sum: Euro 2500000 (aimed at punishment)

Daily penalty: Euro 395820 (or Euro 144m per year) (aimed at pressuring the UK into compliance)

The daily penalty is based on the following calculus which the Commission and the Court use:

600 (flat rate) x 10 (seriousness of infraction) x 3 (duration of infraction) x 21.99 (UK 'n' factor).

Say the ECJ hands down its decision in Summer 2012. By Summer 2015 the Commission will have brought enforcement proceedings asking the court to recognise that the 2012 judgment has not been complied with and to lay down a fine. By Summer 2017 the Court will have ruled on this application, awarding a lump sum and period penalty. The clock begins to tick on the daily penalty from 2017

If it is not until the Summer 2023 that the tunnel is opened, " six years*" the total liability will be Euro 866,845,800."*

"The seriousness coefficient contains a value of between 1 and 20. I have estimated 10.

Using the Commission's own published guidance and the case law...I have calculated this figure on the basis of the following analysis:

Member state conduct – 4 out of 5

Environmental impact of non-compliance – 2 out of 5

Impact on competition – 2 out of 5

Miscellaneous (e.g. size of population affected, importance of compliance with this specific law to the functioning of the EU) – 2 out of 5.

The estimates in all these headings are on the conservative side. For example, the Commission could easily press for the maximum on member state conduct... Regarding environmental impact, the Commission will probably view this as above rather than (as I have estimated) below average seriousness. Likewise the impact on competition, and in terms of population, London is one of Europe's most populous cities so, once again, there is real scope for uplift."

Based on the analysis above, it would be quite possible for the seriousness of infraction to be 15 rather than the 10 used in the analysis, increasing the infraction fine by about 50%. If so the fines could amount to about Euro 1.5bn.

However, were the Commission to assume that the date in the reasoned opinion were to be the date for completion, then the period of noncompliance would be 14 years. Thus the fines would amount to about E2bn. I have been informed that "*EU Water Commissioner's office spokesperson has said that they are seeking 2Bn Euro infraction fines to be applied to the UK*."

Doubtless the British Government will argue about most of the factors and is hoping that the UK would not be subject to such large fines.

However the one criterion I will concentrate on in this report is the "*environmental impact of non-compliance*". This can vary between 1 and 5. Based on the calculation above, reducing the impact number by one point would reduce the fine by about 10%, ie by some Euro 200m, about £160m. The Commission might well take a more serious view of this and if so there would be greater scope for improving the environment and reducing the fine further. By showing early improvement in the environmental impact, the interim measures might also help on reducing the size of "*member state conduct.*"

If so, then interim measures could reduce the extent of the environmental impact of non-compliance and also potentially reducing the size of the infraction fines.

An interim solution would not need to meet all the standards laid down but would need to reduce the environmental impact of non-compliance in a cheap way to a level where the fine would be lower and the net cost beneficial. They would also need to be implementable within two to three years. Such interim measures could also be beneficial in providing an environmental improvement when the tunnel is operating.

The rest of this report looks at how this could be done, and to what extent it would reduce the environmental effect of non-compliance.

3. Protection of Ecology and other standards.

Whilst the aim of the interim standards is to alleviate environmental impact rather than to meet the standards that have been set for the Tideway it is helpful to know what those standards are so one can identify measures to alleviate them.

The objective of the Urban Waste Water Treatment Directive is "*to protect the environment from the adverse effects of ...waste water discharges.*"

It is to be noted that the UWWTD makes no reference to any actual level of protection or any standards.

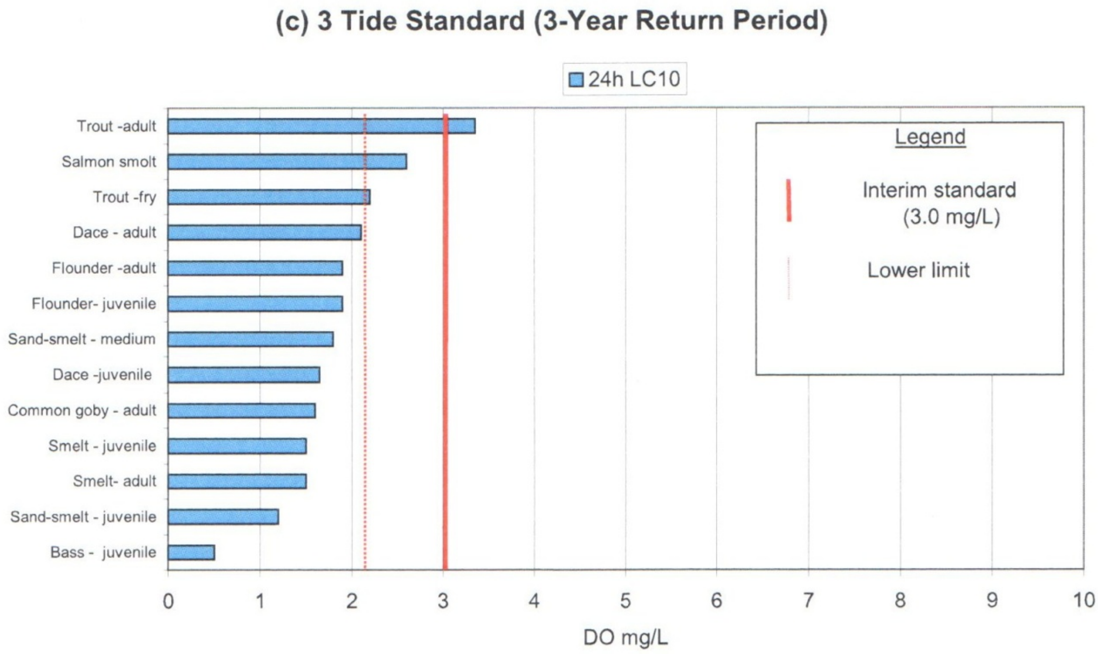
This was interpreted by the Thames Tideway Strategy Steering group as "*To reduce the frequency of those discharges that cause significant aesthetic pollution, or to limit the pollution caused, to the point where they cease to have a significant adverse impact.*"

The Thames Tideway Tunnel and Treatment (TTTT) report, 2006 Vol 1 Objectives states "*since it is generally recognised that fish are the most sensitive indicator of ecological quality, the decision was taken to derive standards that are protective of relevant fish species.*" These are set out below

Table 3 DO Standards for the Tideway

Dissolved Oxygen (mg/l)	Return Period (years)	Duration (tides)
4	1	29
3	3	3
2	5	1
1.5	10	1

These were arrived at following trials of the dissolved oxygen sensitivity of the various fish species in the fish suite, the most sensitive of which were salmon. The trail results are shown below.



There are effectively no salmon in the Tideway and the EA now say they are not sustainable in the short to medium term. Post 2023 adverse temperature conditions would affect any returning salmon. According to Turnpenny and Liney,2006 the lethall temperature for salmonids is 27.8C but the Freshwater Fish Directive says for salmonids the temperature should not exceed 21,5C. Solomon has shown that salmon did not enter the Avon River when the temperature was above 21C. In the Thames "*Migration is under-represented at temperatures above about 22.5 C in July, 22 C in August, and 19 C in September."*Solomon 2011. Turnpenny et al 6-14 says "*Summer temperatures in the ...Thames can reach 23-24 C. "* With climate change these are likely to rise 2 to 3C.Modelling has shown that because of climate change salmon from southern England could not survive in the long term, primarily because of changes in the marine conditions in the post-smolt area of the Atlantic. The standards could still be appropriate if other fish species took the place of salmon. However Sea trout are similar to salmon. Lamprey and eel can tolerate low dissolved oxygen conditions. Sturgeon are being introduced to the Gironde in south west France but it is likely to be about a century before conditions for them are suitable. Twaite shad are rare visitors, and are reported to be more tolerant of low dissolved oxygen content than salmon. Thus it may be that the standards set are higher than necessary.

However, the object of the interim measures is to alleviate adverse environmental conditions, not to meet the standards themselves.

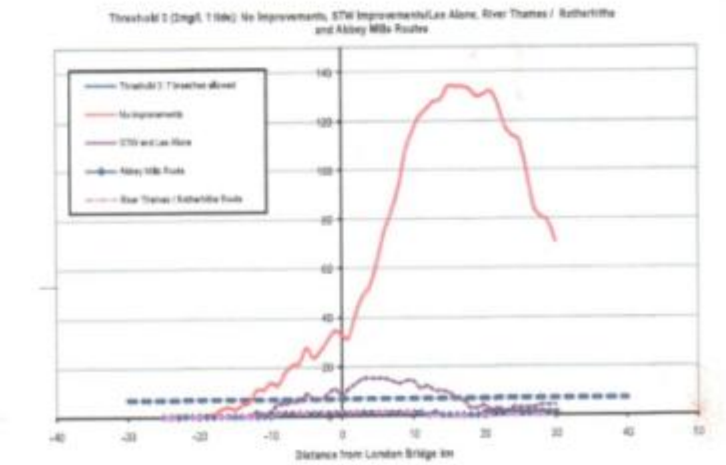
Thames Water TTTT Solutions 2006 vol 1 page 19 states*"It is unlikely that small-scale meausres (use of bubblers and litter collection vessels) can fully mitigate the effects of not intercepting the CSOs in the middle section of the Tidal Thames."* Since then the Lee tunnel has been authorised. It is not intended that the proposed measures are an alternative to the main measures but as an interim measure. Thus there seems good reason to study the interim meassures to see what can be acheived and whether they are worthwhile implementing.

4. Benefit provided by works already under construction

The works already under construction include upgrading of the Mogden, Beckton, and Crossness STWs. As a response to the 2011 fish kill in the Chiswick area, Thames Water have said " *I do need to assure you that once the extension is completed in March 2013 the works will be able to handle a similar situation without even using its storm tanks, let alone discharging to the river."*

Once all the upgrades and the Lee Tunnel are completed, about April 2015, the volumes of stormwater discharged to the river will fall from about 39 Mm3/year on average to about 18 Mm3, less than half, see Table provided by Thames Water.

Modelling of the river system has been done by Thames Water and shown in the Needs report



2010. Plots have been prepared of the number of breaches in the 34 years of modelling on the y axis and the distance upstream and downstream of London Bridge on the x axis. The plot above shows the situation with the 2mg/l standard. The red line shows the number of breaches with the current CSO and STW system. The standard to be obtained is shown by the dark blue horizontal line. The mauve line shows the situation after the Lee tunnel and STW improvements have been completed. This shows that the current works go a long way towards meeting the required dissolved oxygen standards. The situation with the other three standards is set out in Appendix A.

The most upstream breach of the standard is at chainage -7 km and the most downstream point where the dissolved oxygen content starts to improve is +14km. These are half tide plots. I am informed that the tidal excursion is about 14 kms. Thus the most upstream point of any failure is about -14kms, about the Barn Elms wetland centre and somewhat downstream of the Hammersmith pumping station outfall. and the most downstream +21kms, about the Beckton STW.

Thus the most upstream position is about the Barnes wetland centre. The most downstream is about Beckton STW. However the most downstream condition is the threshold 1, 4mg/l which is not a standard for fish kill but for potential hypoxia effect. Without this threshold the most downstream point would be 4km plus the 7 km tidal excursion, 11km, about the mouth of the river Lee. In reality, if the system proposed is adopted, the water moving downstream from the mid tide point would already have been aerated so it would probably not need to inject air further downstream than the half tide point +14kms as the aerated water, would be carried naturally downstream during the ebb. Thus, for the downstream position, I have taken +14kms, approximately the mouth of the River Lee.

5. Reduction of spills and debris collection

Objectives

The TTSS adopted as an objective *"To reduce the frequency of operation and limit pollution from those discharges which cause significant aesthetic pollution, to the point where they cease to have a significant adverse effect."* This was re-endorsed in the TTTT Objectives report of December 2006.

Environment Agency Assessment

It is very difficult to identify which CSOs are providing debris that results in a significant adverse effect. The Environment Agency developed a protocol. This identified areas of the river which are sensitive to aesthetics impact. In broad terms these were the river from Kew down to Westminster, around Greenwich, and around the Thames Barrier.

The EA then assumed that "*the volume of discharge is a key factor in determining the extent of the adverse aesthetic impact created by a particular outfall. Thames Water sewer models were used to estimate the mean volume discharged from each for 21 historic rainfall events. CSOs that discharged an average of greater than 50,000 m3 were assumed to make a significant contribution to the aesthetic impact, whilst those that discharged less than 1,000m3 were assumed to cause no significant impact. CSOs that discharged between 1,000 m3 and 50,000 m3 were assessed for the nature of the area into which the discharged, by reference to figure 1... 35 CSOs were deemed to be unsatisfactory because of the contribution they make to the aesthetic impact of storm sewage discharges."*

I have not been able to find any specfic analysis to support the choice of 50,000 m3/year as the level at which a CSO must have an adverse impact. Thus this analysis is a subjective assessment.

Impact of sewage litter

It is generally accepted that sewage derived litter makes up 10% of the total litter. The figure is from the Tidy Britain Group**.** There is limited evidence to support this figure but it is a generally used figure. Thus 90% of the litter/debris is not sewage derived.

"*Shortly after discharge floating matter disseminates relatively quickly so the plug of sewage effluent moves unnoticed with the ebb and flood of the tide."* HPA recreational users report page 52.

Jacobs Babtie Review for ofwat.

As part of their review Jacobs Babtie team did a trip on the Thames on 31st August 2005 and reported "*...several days after the most recent rainstorms, floating debris was seen in several locations. The slicks that the TTSS describes in its reports were observed, and, on close inspection, it was clear that some of the debris contained in them was sewage-derived. However, our opinion is that it would not be immediately apparent to a casual observer that the debris was any more than windblown litter and vegetation- a fact reflected in public responses obtained during the TTSS*." Independent review for ofwat Feb 2006 page 8.

Jacobs Babtie continue on page 9 "*In addition to the slicks, litter was seen to have accumulated on the banks of the Tideway. However much of this is coarse debris which is likely to have originated from sources other than the CSO discharges. Much of the bankside of the Tideway is overlooked from adjoining residential and commercial buildings or is accessible to the public, albeit access to the actual waterside is made only infrequently. Numerous leisure vessels provide visitors to London with river tours. Thus bankside litter deposits may be considered a very visible aesthetically feature from the public standpoint."*

In which case the collection of all litter by skimmers would be a significant aesthetic improvement.

The DETR 1997 guidance on the UWWTD states to identify an unsatisfactory CSO it would need to have "*a history of justified public complaint*." The Environment Agency have stated " *the number of formal complaints regarding sewage debris is relatively few."*Bain email. Thus there do appear to be only a few complaints from the public.

On page 11 Jacob Babties quote from the eftec report The Market Benefits of Options for the Thames Tideway appended to the TTSS Cost Benefit Working Group Report which they say states

> *"...although reducing CSO events would be associated with reduced amounts of sewage litter, this is currently only a small (10 per cent) proportion of the total litter and debris in the Tideway at any one time, and what there is appears to be invisible much of the time, at least as far as individual perceptions are concerned.*
>
> *This is one of the findings of the SP (TTSS's stated preference survey) as well as being the view expressed by consultees from the London property market. We might expect certain river users to notice a difference, in particular those who come into close contact with the water, such as rowers, houseboat owners and those who frequently walk by the river. However, in general the public are unlikely to detect much visible difference, and this includes owners of riverside property who, as we have just argued, tend to partake in river-based activities from a greater distance... The Thames is a tidal river downstream from Teddington, and levels of suspended silt and mud in the water are naturally high and always will be. Reducing CSO events will not have any impact in this regard.*
>
> ***Therefore, little aesthetic change in the water is to be expected due to Tideway Strategy options, and this, together with the low correlation between riverside residence and involvement in river-based water sports, suggests that any impact of the Tideway options on property prices is likely to be minor."***

These statements were made about the baseline in 2006. Since then the baseline now includes the Lee tunnel, in itself removing more than half the spill volume, as well as improvements to the water quality and storm overflows from the 5 London sewage treatment works. Thus the effect from sewage litter would be even smaller for the new baseline.

On the Tideway Tunnel, Jacobs Babtie concluded: *"in general the public are unlikely to detect much visible difference."*

Thus, although the Environment Agency have identified 35 CSOs as contributing to the aesthetics impact, that impact does appear to be relatively low. This should be taken into account when assessing the environmental impact of non-compliance.

6. Reducing flows into the sewers

One method to reduce CSO spills is to reduce the flow going into the combined sewers. This can be done by reducing water use, the use of Sustainable Urban Drainage Systems(SuDS) , and by diverting the sewer flows to other catchments.

Reduce flow into the sewers by reducing water use.

Thames Water have said that population will increase, true, and therefore, assuming constant per capita water use, CSO flows will go up, thus leading to increased CSO spills. I examine this below to see if it is possible to reduce sewer flows during the interim period and hence reduce CSO spills.

The area sewered to the Tideway interceptors is similar to, but somewhat smaller to that supplied by Thames Water with water, so, judging by eye, a factor of about 85% of the water deliverd ending up in the sewers would seem to be a reasonable assumption.

The analysis of water projected to be supplied by Thames Water is given in the Thames Water WRMP 09 , table WRP4-FP. This shows water delivered in 2007/8 as 1633 Ml/d and in 2022/3 1533 Ml/d, a 100Ml/d reduction. Therefore the water delivered, and hence reaching the sewers,is projected to go down during this interim period.

The figure projected for leakage in london 2007/8 was 590 Ml/d and in 2022/3 397 Ml/d, a reduction of about 200Ml/d. Some of this leakage will end up in the sewers, and a reasonable assumption might be that 50% of the leakage reaches the sewers. On this assumption the sewer flows by 2022/3 would reduce by about 100 Ml/d.

Thus already there would appear to be a reduction of about 200 Ml/d in sewer flow by 2022/3.

A further way to reduce sewer flows would be greater demand management. In its Strategy discussion document TW says it will meter all homes by 2030, an increase in the number set in the previous WRMP of 80%.

There are several lines of interceptor sewers. I have no way of knowing how the flow reductions would split. However, since the lower flows in the higher interceptors should mean even less of a spill into the lower interceptors, a reasonable assumption might be that the sewer flow in the lowest interceptors, ie te ones that spill into the Tideway, would be reduced by about half. If so then the flow in the lower interceptors would reduce by about 100Ml/d by 2022/3.

My proposal is that such action to reduce sewer overflow during the interim period should be studied, and, if viable, implemented.

Sustainable Urban Drainage Sytems

One way to reduce storm runoff into the sewers is Sustainable Urban Drainage Systems. These use swales, soakaways, porous pavements and other detention systems to reduce/delay storm runoff.

Thames Water in its Strategy Discussion Document spage 17 tates "*We will take steps to reduce the amount of rainwater that enters our sewers.*" As a strategy in the short term (2015-2020) page 19 *"A major part of this long-term goal will involve working with the Environment Agency and local authorities to promote and install sustainable drainage systems."*

This was studied in Appendix E to the 2010 Needs report, for three pilot areas and appreciable reductions in storm runoff were found. The report is difficult to understand but on page 42 quotes a reduction in overflow of greater than 50%.

However it must be recognised that this effect would take time to build up to full amount so only a proportion redcution of storm runoff could be expected in the earlier years.

Reduce flow into the interceptor sewer system.

Another way to reduce the spill volume is to reduce the catchment flowing to the interceptors and the Tideway CSOs. I have identified two options.

Divert to the Hogsmill STW catchment.

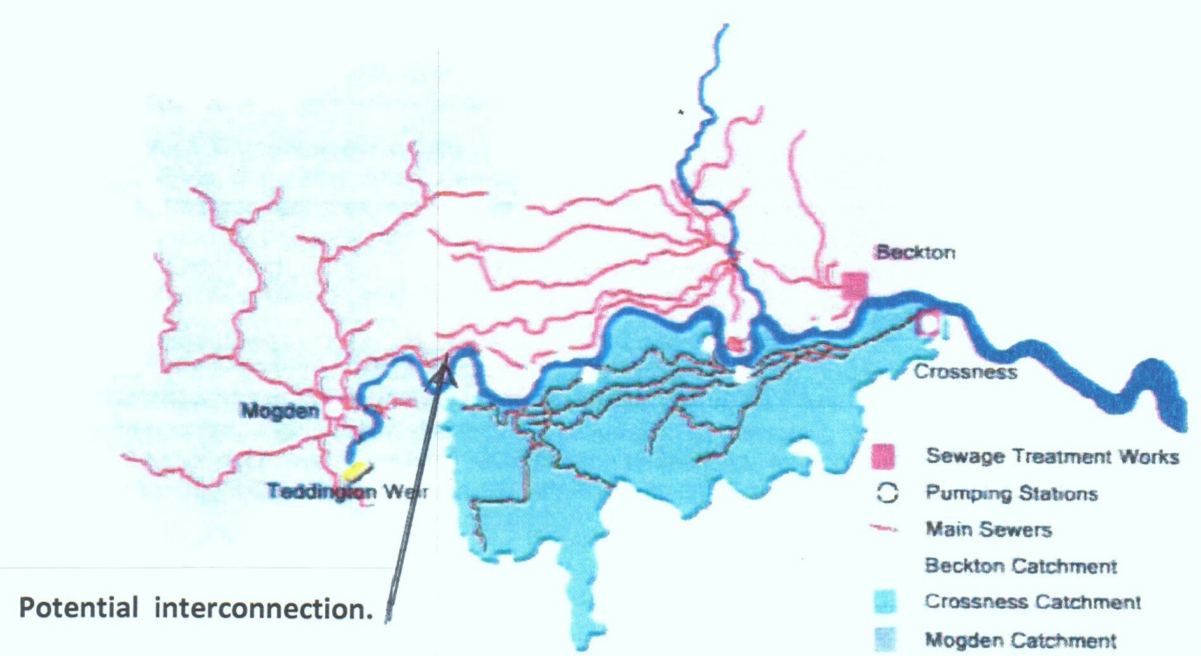
One way for augmenting water resources considered in the rdWRMP09 is to divert some of the flow going to Crossness STW to the Hogsmill STW works upstream of central London. Such a scheme was identified in the dWRMP 09. It was called Hogsmill B with a 20Ml/d (1/4 cumec) diversion.

This would both increase the flow over Teddington Weir, and thus could be used to augment the water resources for London, as well as reducing the dry weather flow in the southern interceptors by about ¼ m3/sec and reducing the CSO spill volumes from them. This dual benefit should be looked at.

Divert to the Mogden STW catchment

The plan of the sewerage network shows a Mogden main sewer coming almost as far as Hammersmith.

Figure 4.1 Catchment areas draining to Mogden, Beckton and Crossness STWs



My understanding is that there is a disused sewer about 3ft by 2.5ft running westwards along the Chiswick Mall (or thereabouts). About 30m of new sewer would be needed to connect this to the

Beckton low level system. The reused sewer would connect to the Mogden sewerage system and hence Mogden STW. This might well be able to carry about ¼ cumec to ½ cumec of sewage that would normally flow to Beckton STW, hence decreasing the flow in the northern low level sewer and hence decreasing the CSO spill volume. Since, according to the TW spill volume schedule, Hammersmith pumping station operates for some 690 hours a year, then this option should reduce the CSO spill volume in the Hammersmith area by about 500,000 m3/year, a significant reduction. Further, this CSO is right at the head of the section of Tideway so its benefit would apply to the whole length downstream. If the works involved were to be only another 30m of sewer then the cost of this option would be very low and it could be implemented quickly.

This option has yet to be looked at but should be.

Connect to the Thames / Lee tunnel.

There is a tunnel under the Beckton and Crossness sewer catchment that connects the Hampton intake upstream of Teddington Weir to the Lee Valley reservoirs. It is normally for conveying raw water abstracted from the river Thames. A presentation image for the WRMP14 studies show that this has a capacity of at least 300 Ml/d, about 3.5 m3/sec. Were it possible to divert storm water from the Beckton catchment into this tunnel then it would reduce the flow to the sewer interceptors. It could also provide a small increase in water resource. A separate storm water system would need to be identified and a drop shaft constructed. I believe such a system has not yet been considered but should be.

7. Suggested meaures in the sewer system

Remove restrictions in the sewer network.

Restrictions in the sewer network can result in more flow being discharged to the local river than necessary.

Appendix B to the Needs report 2010 describes the situation in a number of other cities , mostly European. On page 37 it describes that "*80 flow restrictions were eliminated*" in Hamburg.

The London sewer network is almost entirely concrete and brick with fixed sizes. This was developed over a a long period so what was considered optimum many years ago may well not be optimum now. The TW sewer model is now much better and more accurate than at the time of the TTSS study in 2004.

As an example I understand that there are a few known restrictions in the London sewer system. For instance I understand that the connection between the Fleet sewer and the lowest interceptor sewer is only about 3 foot across and that this restricts flow in the Fleet sewer from flowing into the low level interceptor, irrespective of whether there is spare capacity in the intrceptor. This results in larger spill from the Fleet CSO. Whilst enlarging the connection may not be easy, because it lies directly below the Blackfriars Bridge road interchange, this illustrates one action that could be taken in the intermediate time to reduce spill volumes.

Whilst the restrictions along the lowest interceptor sewer may have been studied as part of the Tideway Tunnel project, there may well be restricitons in higher parts of the sewer network that could be changed beneficially, thus reducing CSO spils or moving them further downstrem so they have less impact. Thus, as part of the Interim measures, it is proposed that the sewer network be studied to identify the restrictions and whether they could be altered to provide benefit to the system and reduce CSO overflows.

Real time control and detention tanks.

There are many interconnections between the sewers and the interceptors. At present these operate with a fixed weir. However the levels of the weirs were constructed many years ago and may no longer be optimum. Of importance, many of the most polluting storms are in summer when the river flow are lowest. These storms tend to be summer thunderstorms and to be localised. Thus conditions will vary appreciably from one storm to another. Thus ther may be spare capacity in an interceptor because the rain has not fallen in part of the catchment draining to it.

It is reported in Needs case Appendix B that in Barcelona storm events are managed using real time control (RTC) and detention tanks. A RTC system is being developed in Paris. Page 6 also lists RTC as also being implemeted in Lisbon, Marseilles, Vienna. Many cities have also built detention tanks to assist RTC and minimise CSO spill.

The Thames Water Strategy discussion document states on page 19 "*Our strategy also includes the increased use of innovative, real-time control and monitoring systems. We have alreday begun installing this technology, whch will help us to manage our network more actively and take swifter action to avoid operational problems."*

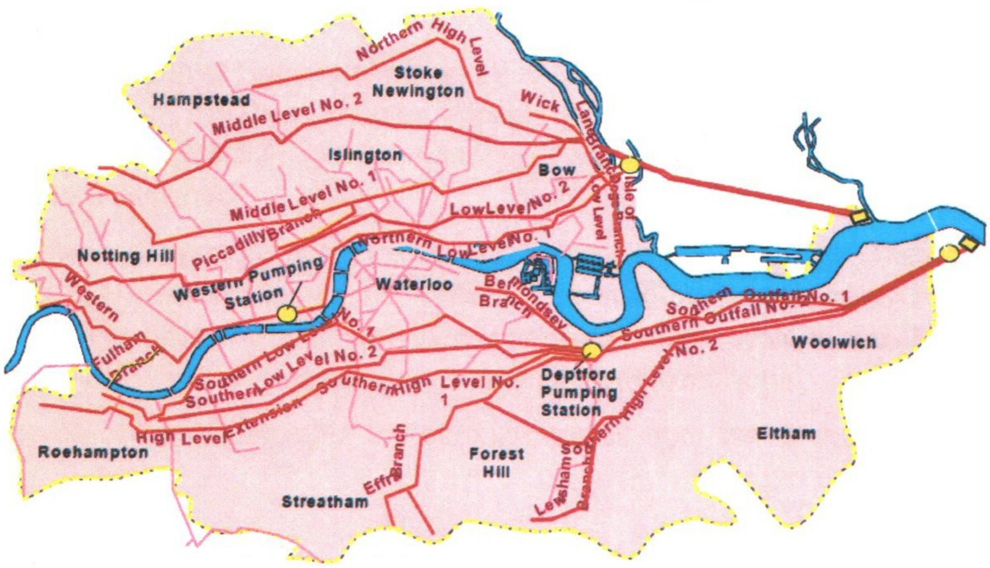


Figure 1.4: The Beckton Sewer Catchment

In particular in London there is a system of trunk sewers going down the historic "valleys" and interceptors going largely horizontally to carry away flow to the east. The levels of the interconnector structures are fixed. Thus they are not able to adaprt to the different conditions of summer thunderstorms. Thus there is likely to be appreciable scope for passing more flow down the interceptors and less CSO spill into the river. For instance if more sewer storm flow in the Notting Hill or Hampstead area could be retained in the upper interceptors, then there would be less flow in the Low level sewer and hence less CSO storm spill. These measures would require moveable weirs with actuating motors.

Detention tanks were looked at by TTSS but rejected as a single solution as there was not sufficient spare and such a system could not be sufficient. However, in conjunction with RTC, detention tanks in the less developed areas, particularly south of the Thames, could be looked at as part of RTC.

However, detention tanks are long lived assets and it is possible that the short term benefits would not be sufficient to warrant their construction. This would need to be assessed.

Whilst TW has looked at RTC in regards to the lowest interceptor that spills into the Tideway Tunnel , my understanding is that little study has been done of the higher level interceptors.

The sewer model should be run to see what benefit could be obtained from RTC, with or without detention tanks. Were any such measures found to be sufficiently beneficial in reducing CSO spill they should be implementable within about two years, the time scale being considered for interim measures.

Vortex separation of sewage debris

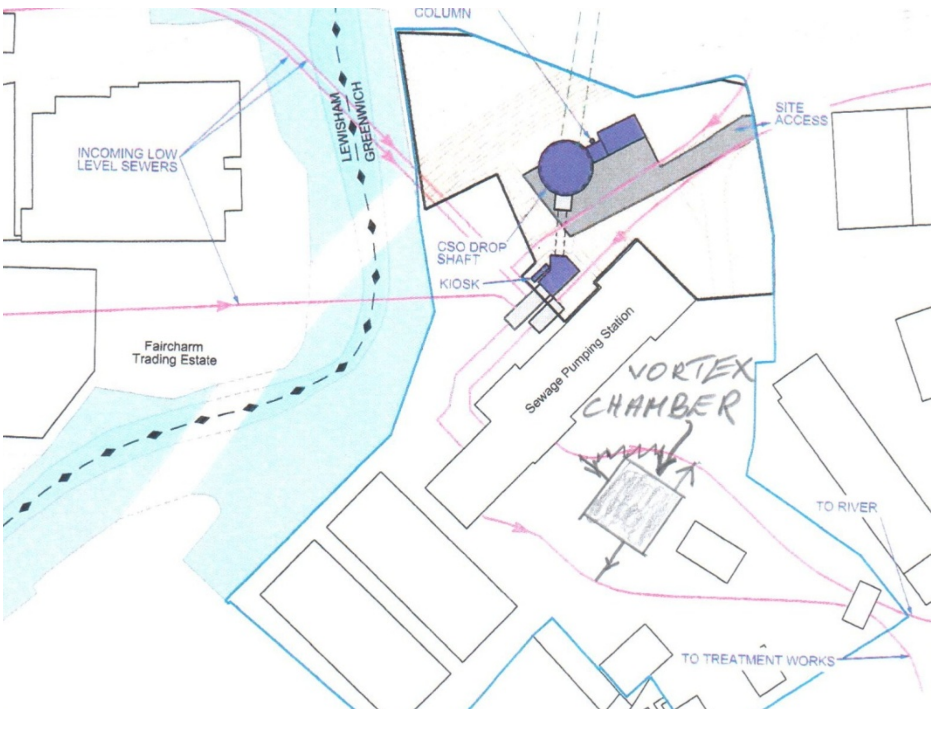
It is the floatables that give rise to most of the aesthetic impact. A vortex can help to separate out the floatables from the remainder of the storm water flow.

Such a system was looked at by Thames Tideway Strategy Steering group in 2003. However, at the time, experience of such a system was limited, most systems needed a significant driving head which was not always available, and such a system would not reduce the frequency of spill events. Thus it could not provide a total system.

However a vortex separation system could provide part of a suite of interim measures. Since then I have identified a vortex system Hydrospin, provided by Steindardt of Germany. Further information on such a system is given in the technical paper in Appendix E.

This system has been tested and found to result in concentrations of floatables of 85% to 99%, see page 9 of Appendix D. The Steindart web site states on page 4 the "*1,000 installations already operate successfully.*" Thus the system does appear to have good potential and operating experience such that it warrants considering.

For instance such a system could be considered for Greenwich Pumping Stations where there is both pumping head and a good pass forward flow, see plan below. This pumping station would discharge about 4 Mm3 a year, see Table of Performance in Appendix A. This is one quarter of the post Lee tunnel annual baseline overflow of about 18Mm3/year. Thus such a system, if feasible, could have a significant benefit to the visual impact in the Greenwich and Thames Barrier locations where there are many tourists and the discharge is into a particularly visually sensitive area.



A possible location of the vortex chamber is shown in the plan above.Thames Water have provided me with the designflows from a 15-year 120-minute event of Heathwall 12 m3/sec and Greenwich 36m3/sec. These are very large flows and would need very large vortex structures. Anyway the return period is outside the period for an interim measure to operate primarily for an 8 year period, thereafter flows to the tunnel considerably reducing the flows to the interim measure.

Both options may well be outside the cost range for interim measures on their own. The TW Table of performance shows the post tunnel situation as an annual spill four times a year of 571,000m3 lasting 35 hours. Thus there would still be an appreciable quantity spilling into a prime tourist area. Thus, in this case, there would continue to be a significant impact on the tourism area. This would need to be taken account of in the assessment as to whether the expenditure would be worthwhile or whether it would form part of the permanenet works.

Were a vortex system not be feasible or economical, then an alternative would be to install screens here as set out in my Project Justification Report. It might be possible to reuse one of the screens that are currently at Abbey Mills and will be redundant on commissioning of the Lee tunnel.

Consideration should also be given to installing such vortex systems at other CSOs where there is both sufficient pumping head to drive the vortex and space to build the vortex. It is possible that some pumps might need to be replaced with ones providing a higher head. Some of the space taken for the tunnel construction might be useable for such a vortex. The other sites with potential might include Lots Road pumping station, Western pumping station (although under some conditions there is no pass foward flow here), and Heathwall Pumping Station. The problem with the Lots' Road and Western pumping stations is that they are close together and Ihave been informed that, under some high storm conditions, all there is no pass forward flow at Western PS, all athe flow being pumped into the river. If that is so then, under those conditions, the benefit of a vortex at Lots Road would be small as all the concentrated debris would be pumped out at Western only a limited distance, about 2km, downstream. Looking at the plan of Heathwall there is pass forward flow but the indication is that there would not be sufficient space on the site between the pumping station and the outfall.

Thus it looks quite likely that vortex chambers for the sort of flow in the London sewers would be expensive or there not to be sufficient space. There would then be the question as to whether there would be long run benefit sufficient that it would be worthwhile iplementing anyway and , if done sufficiently early, could form part of the interim measures.

Optimise CSO spill levels.

One measure which Thames Water have examined as part of their planning for the tunnel is the level of the overflow weirs of the CSOs. These are, anyway, to be altered to minimise spill at some CSOs so that the fewest drop shafts are needed.

As an interim measure the sewer model could be run and the CSO weir levels adjusted to provide optimum interim conditions.

Cost of in-sewer systems.

Until further information is available it is not possible to provide any estimate of the cost of such in-sewer measures to reduce discharge to the Tideway of polluting matter. As a budget for removal of restrictions, reductions in contributing flow, Real Time Control, and raising some CSO weir levels, I have allowed a budget of £7m. Some of these works would also benefit the long term.

If the estimated remaining cost of some of the works such as the vortices, exceeded a certain sum, assumed by me to be about £3m but subject to review, then those proposed works are unlikely to meet the cost benefit for interim measures. However they could still be implemented as an early part of the long term measures.

8. In river control of sewage debris

General system

In various places a floatingboom has been used to concentrate the floating litter/debris which is then collected and disposed of. One such installation is at Cardiff Harbour, see the last page of Apendix C. It may be possible to provide similar booms at the Thames CSOs, thus concentrating the floating sewage litter so it can be retained when a spill occurs and not escape into the river.

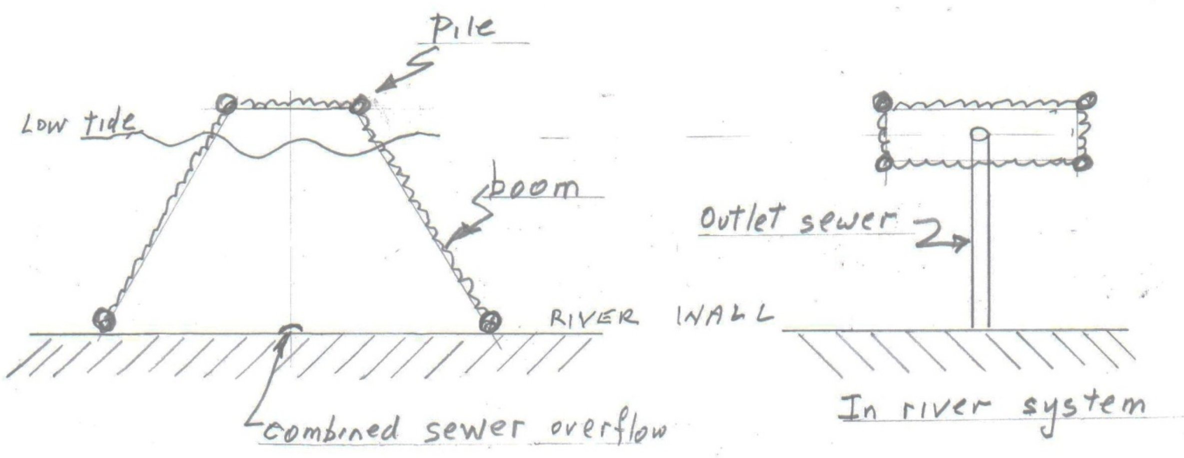
I have been in touch with Bolina Booms who supply such booms. The booms would need to both float at high tide and to retain the collected debris when part of them are sitting on the foreshore during low tide. The proposed arrangement consists of vertical piles in the form of a trapezium with the long side the shore and the short side in the river and parallel with the river flow. The booms would be flush faced Bolina environmental booms fitted with alternate kite floats to keep the boom stable and upright when dried out at low water. The boom would be kept in position by four piles at each point of the trapezium with floating collara around them to move with the tide.

Picture of a typical boom installation

The debris within the booms would need to be collected. It is proposed that this be done by a floating craft. This could be by having a trash trap at the outlet of the boom which is then lifter up, a mechanical grab with fine mesh. For the finer debris a fish pump could be used to suck up the surface water in a similar way to that used for moving fish from one tank to another.

Picture of a variable water level boom.

Below is a sketch of the iitial boom arrangment when the CSO is in the river wall and also when the CSO is out in the river.



Category 1 CSOs that operate frequently and have an adverse environmental impact	Category 2 CSOs that do not operate frequently but which have an adverse environmental impact	Category 3 CSOs which have no significant environmental impact	Category 4 CSOs that operate frequently but have been assessed as having no adverse environmental impact
Acton	Stamford Brook	LL1 Brook Green	London Br
W Putney	N W Relief	Falcon Br Relief	Isle of Dogs P/S
Hammersmith P/S[1]	Wick Lane	Horseferry	Canning Town P/S
Putney Bridge	Church St	Wood St	
Frogmore	Queen St	Goswell St	
Jews Row	Smith St	Pauls Pier	
Falcon Br P/S	KSP	Battle Br	
Lots Rd P/S	Grosvenor	Beer Lane	
Ranelagh	Savoy St	Iron Gate	
Western P/S	Norfolk St	Nightingale	
S W Relief	Essex St	Union Wharf	
Heathwall P/S		Wapping Dock	
Clapham		Cole Stairs	
Brixton		Bell Wharf	
Regent St		Ratcliffe	
Northumberland St		Blackwall Sewer	
Fleet		Henley Rd	
N E Relief		Store Rd	
Deptford			
Greenwich P/S			
Abbey Mills P/S			
Charlton			
Holloway			
Shad Thames P/S			
Earl P/S			
TOTAL 25	TOTAL 11	TOTAL 18	TOTAL 3

Location of boomed CSOs

As can be seen above in 2004 the Environment Agency considered 36 CSOs as unsatisfactory.However there have been a number of changessince then. Because of changes since then a number of CSOs now have zero discharge in the Table of performanace. These are Abbey Mills, Wick Lane, Church St, Queen St, and Norfolk St.

Constructing a boom system costs money and anyway a CSO with a low spill volume would not be worthwhile booming. Arbitarily I have taken a limit of 3,000m3/year as a cut off point. This removes Stamford Brook, Smith St, KSP, Grosvenor ditch, Essex St,and Charlton from the list of those to be boomed. The only two schemes left in category 2 are NW Relief 4,100m3/year and Savoy St, 8,500m3/year. From the Admiralaty chart the outlet from the NW Relief looks to be in the river. This would probably preclude it being boomed. Savoy St is small and in a area which is sensitive to view by the public. Thus I would propose to exclude that CSO.

Holloway is a small CSO spilling about 8,000m3/year into the Tideway well downsream of Tower Bridge so the river is large. The two Jews Road CSOs have a combined discharge of 10,000m3/year with a spill duration of 7 hours. Thus, for an interim measure scheme, it is unlikely to warrant booming them.

An outlet on the bed of the river makes booming more problematical with the high tidal currrents in the Thames. From the Admiralty Chart it would appear that Hammersmith, Heathwall, SW Relief, Lots Rd, Clapham, and Brixton have outlets on the bed of the river at or near low water and any boom might obstruct navigation to/from adjacent wharves or bridges. For the time being I have assumed that these could not be boomed.

From the Admiralty chart it would also appear that Acton, Falcon bridge, and Greenwich also have outlet near low water. However it would appear that a boom here is unlikely to obstruct navigation. The question then is how quickly will the floatables rise to the surface. I have no information on this. I have had, therfore, to make a broad assumption. I have allowed for a rectangle 5m by 25m with the long side parrellel with the tidal flow.

Frogmore CSO discharge is into the River Wandle. I have allowed for an angled boom across the Wandle with a length of 50m.

Tideway indicative boom layout

Site name	CSO	Vol/year	Spill time	Against wall	Distance to chart	Min width m	In river
	no	k m3	hrs/year		datum m	bridges/river	dimensions
Acton	1	300	163				5m x 25m
W.Putney	5	35	119	Y	30m		
Putney bridge	6	70	111	Y	30m	40	
Frogmore	7	100	130	River Wandle		50	
Falcon Br P/S	9	780	291				5m x 25m
Lots rd	10	1,200	410	Pier			Not posible
Ranalegh	14	300	153	Y	60m		
Western P/S	15	2,300	228	Y	30m		
Regent St	22	25	19	Y	zero		
Northmbrlnd	23	80	47	Y	zero		
Fleet (B bridge	27	570	83	Y	10m		50m
NE Relief	29	800	300	Y	40m		
Deptford	32	1,900	343	Y	40m		
Greenwich	33	4,000	240				5m x 25m
Shad P/S	28	100	69		50m		
Earl P/S	31	600	207		40m		
Hammersmith	4	2,300	690				
Heathwall	16	700	240				
Brixton	20	270	137				
Clapham	19	14	15				

That would result in 15 CSO discharges into the Thames and Frogmore into the Wandle being boomed. The result is that, based on the TW Table of Performance, about 80% of the overflow that is classified by the EA as having an adverse environmental impact would be boomed, thus much restricting the amount of sewage debris that would enter the free flowing Thames.

Approval

Approval from the PLA and the Environment Agency would be needed for the technical aspects of these measures.

Cost

Bolina booms have quoted a budget price of £1,246,000 for the supply, assemble and instlling the above instalation including piles and piling and including Lot's Road which has subsequently appeared to be a restriction on navigation.

They have made this subject to good acccess to set up pontoons into the Thames near the site and that each site is accessible by river from one to another. They have also excluded the cost of licences to work in the river or the provision of Health & Safety files. They have also made the quote subject to site survey for possible extras including wall seals, engineering design, ground investigation, UXO surveys, permits and permissions, planning aplications and licences plus possible delays due to inopportune weather or tidal conditions. Making a broad brush allowance of £3/4m for these elements and some contingencies would bring the boom cost to £2m.

Retained sewage litter collection.

There are various methods of taking the sewage debris from within the boom. One method is a Trash Trap. This collects the trash in a metal mesh container which can be lifted out by a barge and boom arm and emptied into the hole of the collector vessel.

General Description

The 'Trash Trap' is constructed in galvanized steel with a metal mesh basket. The basket incorporates small holes to allow the movement of water to continue whilst collecting the floating debris. Typically 1t capacity but can be made to different sizes depending on application

The Trash Trap is a useful complimentary tool to OPEC's boom range.

In general booms can only be used as a temporary measure to act as a containment barrier against floating debris.

Another method if the retained sewage debris is small is to use a fish handling vacuum pump as supplied by Afak techniek BV of Holland. This is normally used to move fish from one tank to another but should be suitable for collecting floating debris and water into a nearby barge.

Such systems would be operated from a powered work boat with a lifting arm and a cargo bay and a screened water discharge system, probably during the upper part of the tidal cycle to provide floating access to the boom structures.

I have no knowledge about the cost of such a powered work boat but assume that about £1m would be a reasonable budget.

In river litter collection

The main in river collection system would be skimmers which would collect floating litter, including that not sewage derived, thus reducing sewage litter and also improving the general appearance of the river.

Thames Water have two such vessels Clearwater 1 and Clearwater 2 which cost £4m and were commissioned in Septemeber 2007. They were designed to operate as far upstream as Kew and to navigate London's bridges. In operation, the screens sit 450mm deep below the river surface. Debris is direced on to the screens by the inner hulls of the vessel, where the debris is picked up by mechanical screening equipment and conveyed to the rear of the vessel where it is drained ready for disposal into a refuse barge. In March 2008, after 6 months service Thames Water stated " *The vessels which have collected over 40 cubic metres of litter from the River Thames since September 2007 have greatly contributed to improving its environmental and aesthetic quality, ensuring it is fit for river users, and for this years Oxford and Cambridge boat race crews. To date, the skimmer vessels have been a real success story, enabling uss to collect large volumes of litter, which overflows from the sewers during periods of heavy rain."*

Thus the overall aesthetic effect has been beneficial. Thus, with the Lee tunnel and the STW upgrades removing more than half the spill volume, and the potential addition of vortices, screens, and booms controlling some 80% of the remaining overflow, it is likely that no extra litter skimmers would be needed. Thus the craft would continue to operate but now concentrating in the areas where booms were not installed, primarily Hammersmith, Lots Rd, and Heathwall.

There may be remaining problem of oils and debris that is too fine for the current skimmers to collect. I understand that there are skimmers developed to collect oil and similar, so they could be considered.

Fig 3.1 – Typical Oil Skimmer

Approvals

Such a scheme would need the approval of the Environment Agency and the PLA.

Implementation period

It should be implementable within about two to three years, ie within the period likely to be required by the European Commission.

Cost

The current litter collectors cost £2m each so assume that the oil and fine matrial collector cost a similar amount, say £2m.

9. Dissolved oxygen improvement.

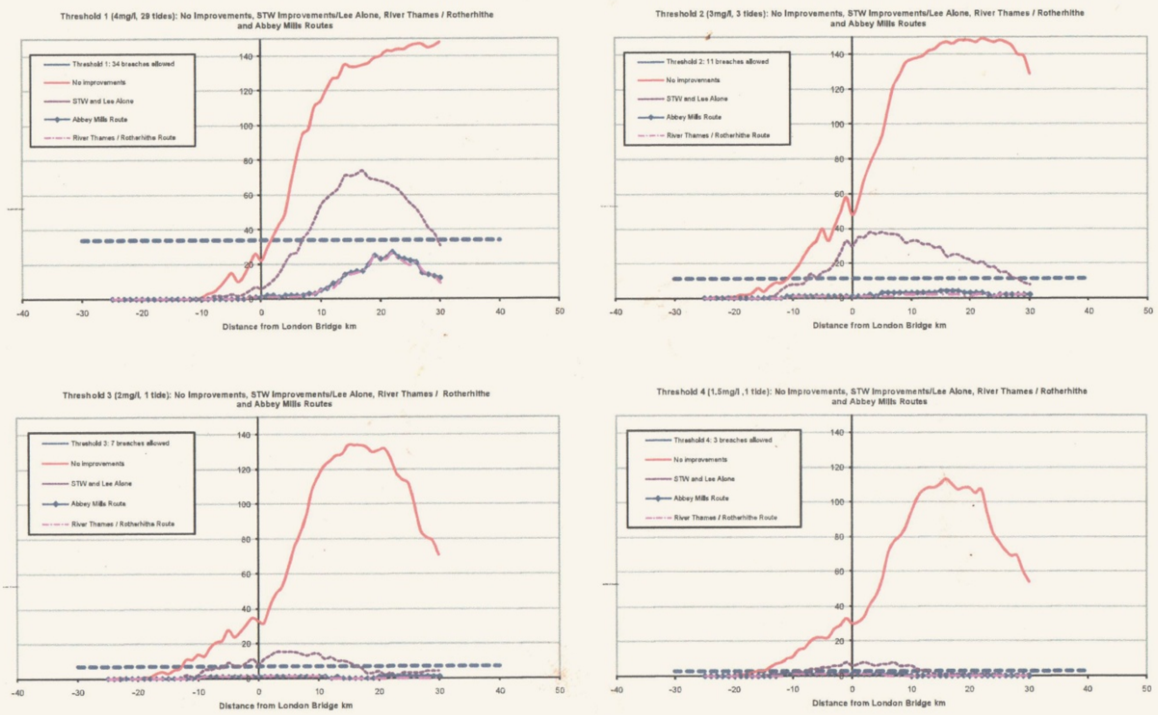
Background

One of the main issues is the impact that the CSO spills have on the dissolved oxygen content of the Tideway. The objective set in the Thames Water report Objectives and Compliance Working Group Report 2006 is "*To limit ecological damage by complying with the DO standards specified in the table above.*" The Table above is,

Dissolved Oxygen (mg/l)	Return period (years)	Duration (tides)
4	1	29
3	3	3
2	5	1
1.5	10	1
Note: The objectives apply to any continuous length of river >=3km. Duration means that the DO must not fall below the limit for more than the stated number of tides. A tide is a single ebb or flood. Compliance will be assessed using the network of Automatic Quality Monitoring stations (AQMS)		

Post the Sewage treatment works upgrades and the Lee tunnel the dissolved oxygen failures are much reduced but still exist, as shown in the plot below.

Figure 5.2 Comparison of Dissolved Oxygen Standards Compliance – (a) No improvements, (b) STW improvements and Lee Tunnel, (c) River Thames/ Rotherhithe routes and (d) Abbey Mills route (negative figures refer to distances upstream of London Bridge)



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The objective of the interim measures is, within a limited budget and in a short time, to minimise the number of failures of the dissolved oxygen standards.

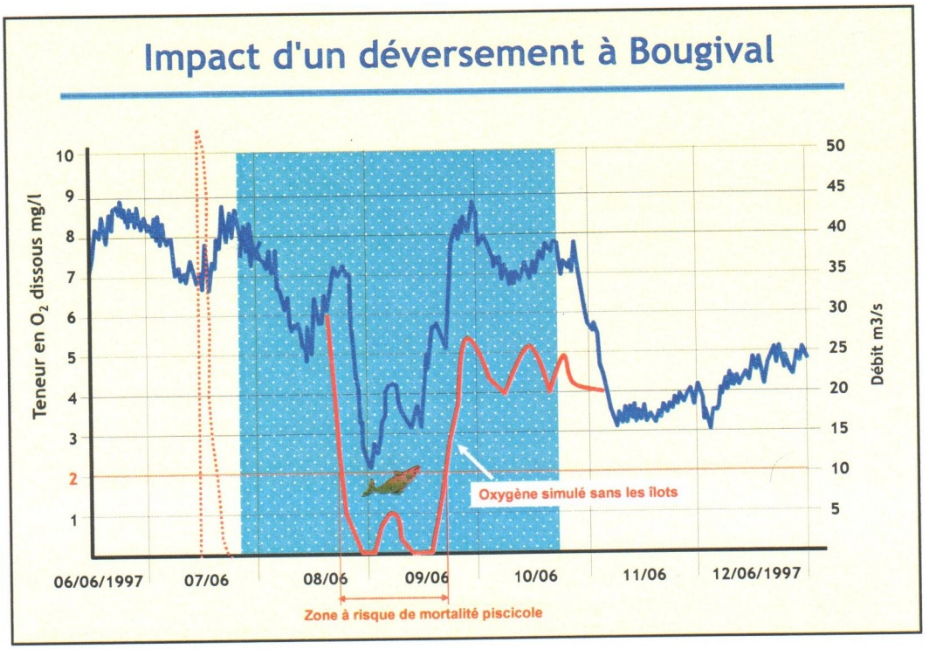
One way of reducing the number of breaches is to raise the dissolved oxygen content of the river. This can be done by injecting air into the river through fine grained diffusers.

Evidence from elsewhere

The Cardiff Harbour coarse diffuser system, see Appendix C is designed to turn the water over rather than to inject air into the water body. This is done by having on land air compressors pumping air through pipes laid on the bed of the harbour connected to coarse diffusers. Thus this demonstrates that an air injection system using on land air compressors linked to pipes and diffusers can be can be put in place and can operate satisfactorily, but not that it can raise the oxygen content of the water.

In the upper Tideway, a land based oxygen injection system has been used to raise the dissolved oxygen content in the Chiswick/Barnes stretch of the upper Tideway to reduce dissolved oxygen sags emanating from Mogden STW. I have been unable to obtain any information about this system.

In Paris the French have used a system of pipes and diffusers to inject oxygen to raise the dissolved oxygen content of the River Seine, see Appendix B for details. This has been used to raise the dissolved oxygen content of the Seine by about 2 mg/l, see image below showing the modelled dissolved oxygen content of the river following a storm in red and the actual conditions achieved in blue.



This shows the substantial benefit that occurred.

Dryden air/oxygen injection system.

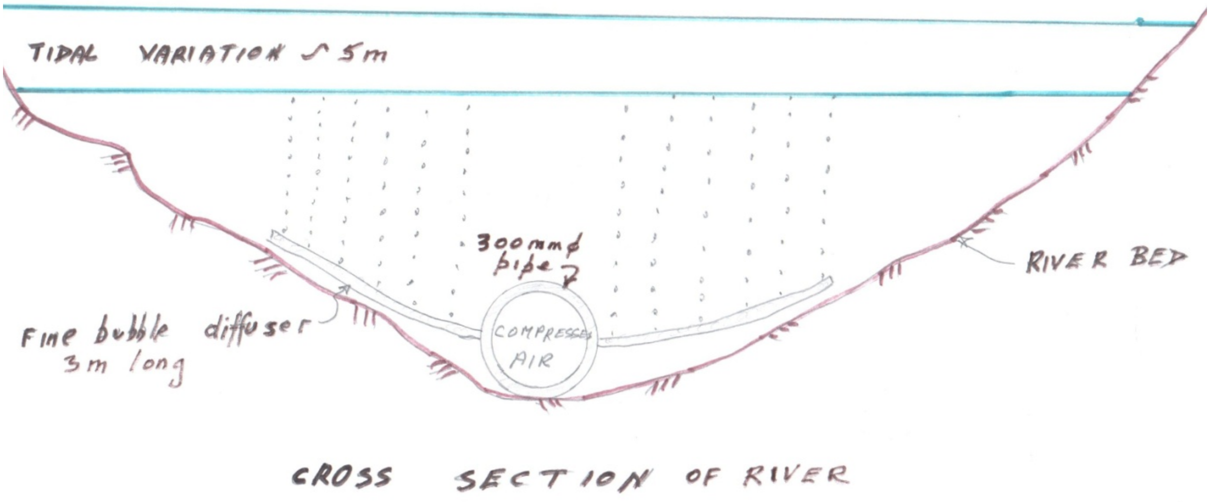
Dryden Aqua make fine bubble diffusers. Their web site page headed lake & pond aeration, states *"Dryden Aqua manufacture a very fine bubble diffuser that has its own internal ballast. The diffusers are semi flexible tube type diffusers that have the best of ceramic diffusers and membrane diffusers but without the disadvantages...Air is passed through the diffusers and the fine diffusion cloud of air passes through the water... The aeration system will dissolve oxygen into the water, one diffuser code 6.2.10 diffusing 10cum/hr of air will add at least 25 kg oxygen to the water per day..."*

System

The diffusers proposed would not be the coarse discs used in Cardiff harbour and elsewhere to turn bodies of water over, but fine bubble air diffusers designed to increase the oxygen content of the water body. The large surface area of the fine bubbles aids oxygen transfer through the bubble water interface, but also because more water is moved there is also an increased transfer between the surface of the water and the air. Each diffuser is designed to input 1kg of oxygen from the air to the water each hour.

The diffusers are tubes, about 32mm diameter, made in lengths generally about 3m long and just negatively buoyant so they rest on the bottom of the terrain.

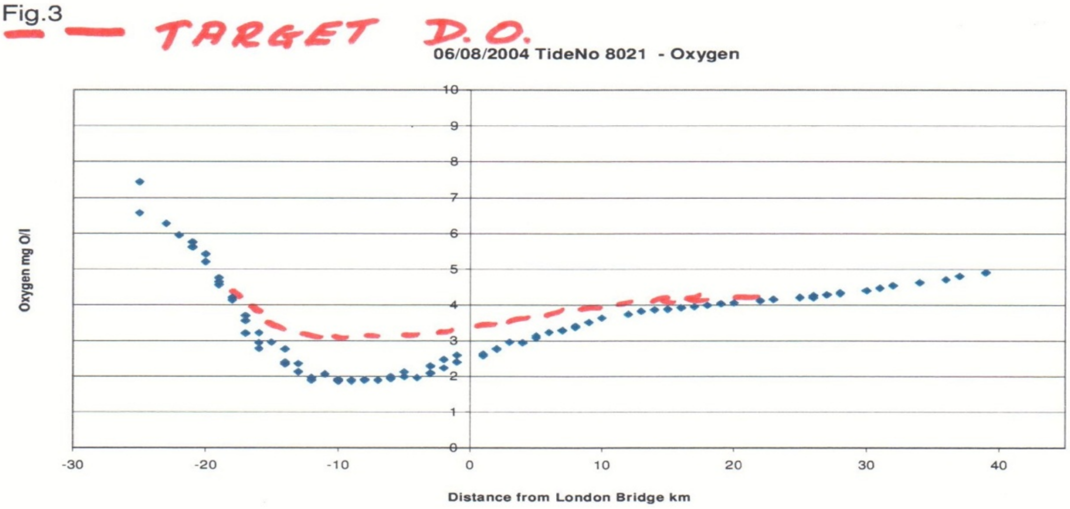
They would be attached to an air pipe. This would normally be HDPE and about 200mm diameter laid on the bed of the river.



Considering the width of the river, it is suggested to have two air pipes, one on each side of the deep water section of the river. This would provide a greater width of aeration, and enable the pipe and diffusers on one side to be maintained or the channel dredged whilst the other system remained in operation.

The EA has provided the longitudinal profile of the modelled dissolved oxygen content of the river during the storm of 6th August 2004. This storm is quoted as having a rainfall return period of 1 in 14 years and 1 in 40 years so its return period is almost certainly beyond that set in the standards. I have marked on this what I understand to be the target dissolved oxygen content to meet the

Fig.3



standards.

For the Hammersmith section take the lowest dissolved oxygen level and the highest water flow assumed to be 200,000m3/hour then the aeration system of 1km with two pipes and a diffuser every 10m on either side of each pipe equating to 400 diffusers, would input 400 kg of oxygen /hour into the water. In theory this would raise the dissolved oxygen content by 2mg/l. The actual transfer conditions would depend on the storm water CSO overflow volumes and BOD. To assess this the system need to be modelled in the water quality model.

If a greater transfer rate were required, then oxygen could be pumped through such a system, increasing the transfer rate by a factor of 3.

It is important to note that this is an interim system until the tunnel is operating sufficiently. Thus the object is to alleviate the dissolved oxygen sag. However it would be most helpful to know what the air system can achieve.

Location of installations.

A similar arrangment of diffusers has been installed in Cardiff harbour. This meets a need to turn over the static water in the harbour. This is a different aim than that proposed on the Tideway. However it does demonstrate the ability to install and operate such a system. Further information on the Cardiff arrangment is shown in Appendix C

The Environment Agency report Assessments of Thames Tideway Combined Sewer Overflows, Annex A shows that, downstream of Heathwall, only Deptford and Greenwich have an adverse effect on dissolved oxygen. Thus it would probably be appropriate to space the diffusers upstream and downstream of the identified CSOs, thus minimising cost. There would need to be a number of air compressor stations along the river bank.

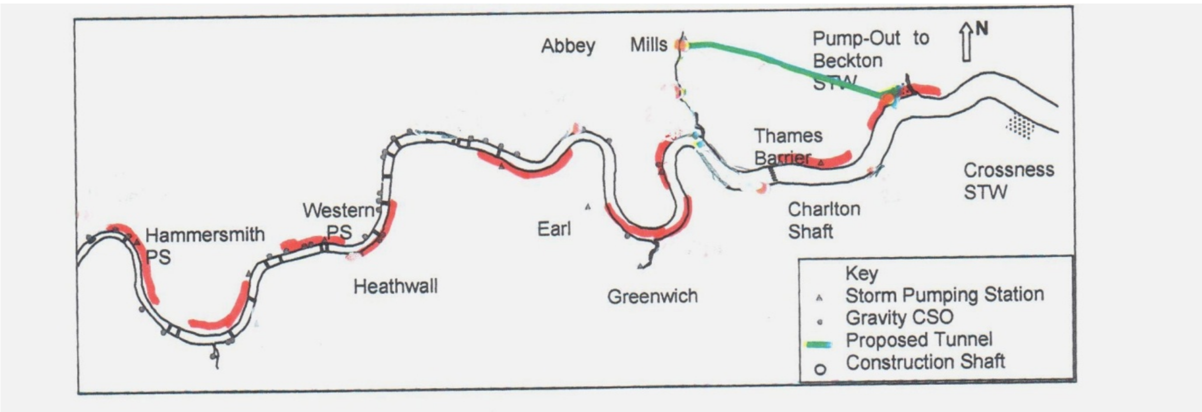
The lengths of diffusers would be in stretches, generally both upstream and downstream from an air /oxygen plant. In general the stretches would be up to 2 km in length.

Places where Thames Water own, or have access to, land such as at existing pumping stations, or land obtained for the tunnel construction sites, could be appropriate for on shore air blower or oxygen generation systems. Possible locations were identified as at the pumping stations at Hammersmith PS, Carnwath Road tunnel site, Falconbrook PS, Western PS, Heathwall PS, Shad PS, Chambers wharf, Earl PS , Greenwich PS, Isle of Dogs PS, Woolwich PS , and Becton STW. See plan below for the provisional sitting of the diffuser installations and the lengths covered.

Regarding the space needed I am informed by Dryden Aqua that "The two main air blowers, would measure about 2m x 2m as a foot print in their acoustic enclosures, then one would need at least 1m clearance. The oxygen generator will take up more room. There needs to be spece for the buffer tank and columns. However we can use the air blower to drive the VSA." On 10th December 2012 Dryden Aqua stated, "The sisze of the system (375 kg/hr) will have a footprint of 12.8 m x 7.3m x6.1m.

I have site plans for almost all of these sites. Shad and Earl look congested so I have assumed that it may well be necessary to replace Shad with Chambers Wharf and have the Greenwich system going more upstream. I have asked for, but have yet to receive plans of the Woolwich site. Lots Road site itself appears too congested, although the adjacent site for the water screens of the defunct power station might be a possible site but it is not on land owned by TW. Falconbridge also looks too congested so this is replaced by Carnwath Road tunnel site. Thus it seems reasonable to assume at this stage that nine diffuser installations could be put in.

It was intended that Appendix D would show the actual proposed site areas for each installation but TW have put a confidentiality restriction on the plans of some of the sites. Whatever, I have now reappraised the information available to me and made the best judgement that I can on the available information.



Several of these installations are set back from the river wall. However there are CSO conduits of appreciable size connecting these installations to the river and it should be possible to install the air pipes, about 200mm dia, in these conduits without measureable loss of overflow capacity. In general the length from the on-land installation is generally reasonable but the Greenwich installation is nearly 1km from the river.

The longest distance between these installations would appear to be 6.5km, from Heathwall PS to Shad PS. Here there would be a gap of some 4km. However, with a tidal excursion of some 14km, this should still be satisfactory. Thus there would be about 10 stretches of diffusers.

If necessary it would also be technically possible to mount the air compressors on a floating barge, connected to the shore by a flexible electric cable, and to the diffuser system by a flexible air pipe.

Depth of water

From the Admiralty charts, upstream of London Bridge the general charted depth in which the diffusers would be laid would be about 2m. Downstream of London Bridge the general charted depth would be about 5m.

At Tower Pier and Silverton, the predicted tidal heights from the PLA website for July to September, the most critical quarter, are a spring tide high water of about 7.4m. With the charted depth of about 5m then the water depth would be some 12.4m. With the pressure drop along the air pipe, then it is likely that a compressor pressure of at least 1.5 bar would be required.

With a predicted spring water low tide of about 0.2m, then the minimum water depth over the diffusers would be about the 5m chartered depth.

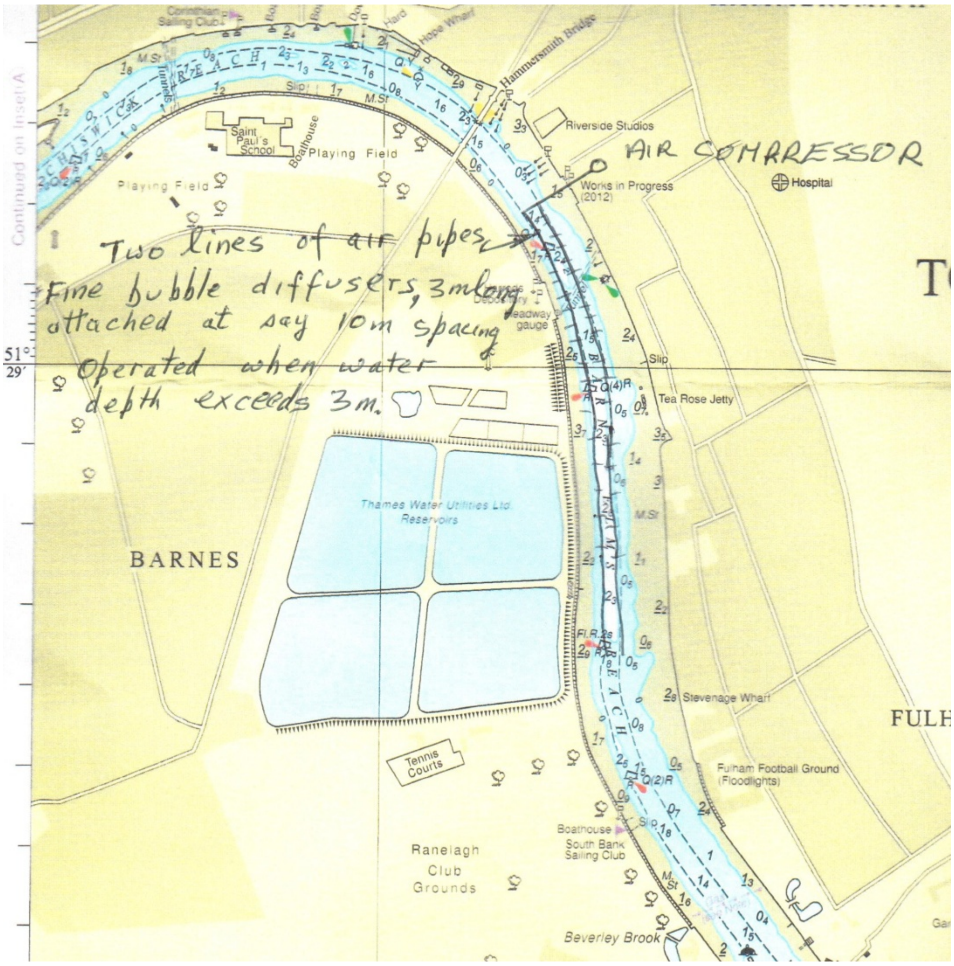
The average water depth over the diffusers here would be the charted depth of say 5m plus the mean tidal height of about 3.7m, a total of about 8.7m. It is proposed to have a screw compressors rated at 2.5bar which would cope with this sort of pressure variation.

In the Chelsea reach area, the predicted maximum tidal height is a spring tide of about 6.7m above chart datum giving a total water depth of about 8.7m.

With a low water of about chart datum the minimum water depth would be about 2m. A minimum depth of 2m is satisfactory when the tide is flowing as the rising bubbles are swept along with the tide. However around low tide when the water flow is slack, the bubbler system might have limited affect.

The average tidal height appears to be about 3m, giving an average depth of water of about 5m over the tidal cycle. This would be more than sufficient.

The plan below sets out a provisional layout of the most upstream diffuser length, that from Hammersmith pumping station. Being the most upstream this has the shallowest depth and the smallest tidal cubature.



Temperatures

The amount of oxygen in the water varies with the water temperature. There is data in the HPA report of the river water temperature in 2005 and 2006. This shows summer temperature of about 20C, with some readings of 22C and one of about 24C. There is also projected to be a temperature rise in the summer of about 1.4C by 2050 due to climate change.

Salinity conditions

The Environment Agency has shown a low flow profile of salinity with about 2,000mg/l at London Bridge, effectively fresh water, and up to about 6,000 mg/l at Becton STW, the most downstream installation.

Design conditions.

There is very little information on which to base the design of the system. However a few general considerations can be made. As can be seen from the FARL report, the cold conditions in winter do not give rise to a significant number of potential failures. As temperature rises then the saturation level of water reduces, meaning it can carry less oxygen. However the reduction in oxygen solubility with increasing temperature is not the main issue. When water temperature increases the biochemical activity of bacteria increase exponentially. The bacteria can then exert their BOD and reduce the oxygen content of the water.

Air diffusers have a greater effect the lower the oxygen content of the water. For instance at 2mg/l, the transfer is about 2kg of O2/diffuser/hour whereas at 4mg/l of O2, a diffuser will do some 0.5 to 1.0 kg of O2/hour/diffuser. Thus above 5mg/l of O2, the diffuser system would have reduced benefit.

Thus the air/oxygen diffuser system would be appropriate at below about 5 mg/l.

Assuming that the diffusers would be sized to raise the oxygen level by 1mg/l in one 12 hour tide, then this would require about 100,000 kgs of oxygen /day. The Dryden Aqua web site states that each diffuser diffusing 10 cu.m/hr of air will add " *at least 25kg/of oxygen*". Thus some 4,000 diffusers would be required.

Dryden have reviewed the limited amount of information available and believe that a diffuser system with two lengths of pipe averaging 1km each and a diffuser each side at 10m spacing would provide 400 diffusers and 10 such lengths would provide about 4,000 diffusers. With occasional use of oxygen, should be able to maintain a dissolved oxygen content in the river above 4mg/l., thus meeting the environmental target of 4mg/l.

What is needed to firm up the design is information about the BOD and COD of the river water and the CSO spills.

Potential negative issues

Frequency of operation

It had been suggested on the basis of the post Lee tunnel number of failures at standard 3, 20 failures of the dissolved oxygen (DO) standard in 40 years, that the diffuser system would not be worthwhile. Use once every two years might well be too small a benefit. However the reality is that the most frequent failure of the DO standards is standard 1. The plot in the TW Needs report, Appendix A of this report, shows for standard 1, about 75 failures in what appears to be 34 years. That is already 2 ½ times a year. In addition there would be a number of "near misses" and the operators would need to operate the diffuser system to try an ensure that a failure did not occur. Because failure would be difficult to predict, there could well be another 3 to 6 times a year. Thus the diffuser scheme would be required to operate a sufficient number of times a year to warrant its installation.

Grounding.

In a note by Thames Water they state that "*any structure on the bed of the river would be very vulnerable, especially at low water when it is not uncommon for craft to ground*." First there is no evidence provided of how frequently craft ground. Below London Bridge the depth would be about 5m at spring low tide and significantly more at other times. There are very few ships of this size still using the river. Above London Bridge the minimum water depth for the diffusers is about 2m. Few private river craft draw this much. The tourist craft and the waste craft are under professional masters who seldom, if ever, run aground. In any case should a vessel run aground on top of the plastic pipes or diffusers, then they would be pushed into the underlying soft river sediments.

Silt.

"*The Thames is a very silty river and the system would require considerable maintenance*."The river is indeed a very silty river. However the air would be going out through the diffusers so would effectively clear off any silt lodged in the outer part of the diffusers. As shown below it would be quick and easy to raise the sections of the system for inspection and maintenance.

Dredging.

It is possible that the PLA would wish to dredge part of the channel. For this to happen, then the pipe and diffuser system would be made to float and recovered in sections, see the section on maintenance.

Buoyancy of small craft

Adding air to water reduces its buoyancy, which can theoretically be a problem with swimmers and small craft. However, given the depth of the water and the volume of air passed through the diffusers, the change in water density is so small as not to result in a problem. Such systems have been used previously in natural swimming areas.

Anchoring of other craft

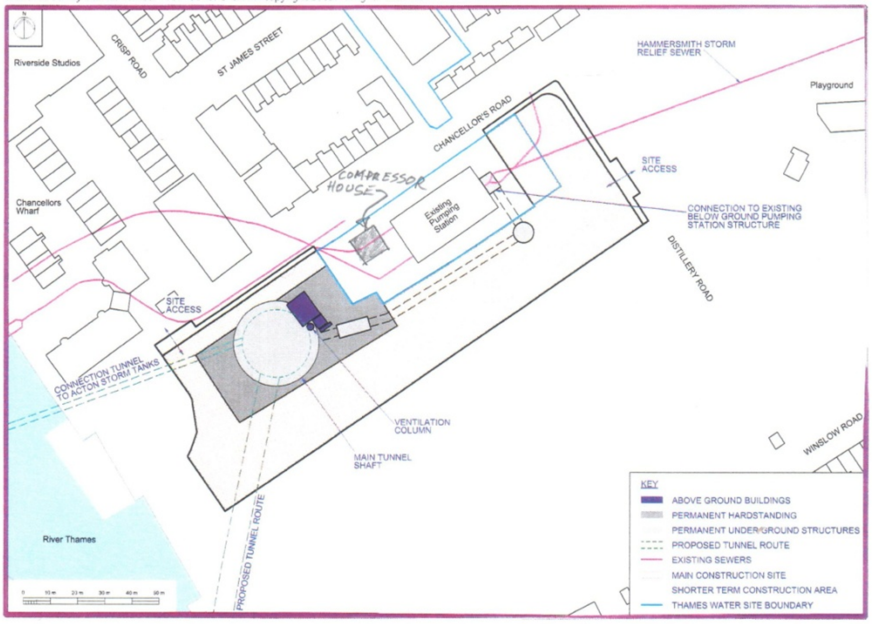
There would need to be a prohibition on anchoring in the vicinity of the system. This should not be a problem as few craft anchor in the Tideway, they either pick up a large buoy or go alongside. In any case the system would not cover the full length , there being gaps between the stretches where anchoring could take place. In any case the system would be requird to obtain the approval of the PLA.

Onshore installation

The onshore installation would consist of one or two air compressors within a sound proof structure. There would also need to be a power supply. Presumably, since most of the sites are current pumping stations, there would be sufficient spare capacity in the incoming power supply. However the appropriate switchgear would also need to be provided.

During peak times, it might be necessary to pump oxygen and air through the diffusers. What would be required to do that is a couple of Vacuum Pressure Swing Absorbers, effectively a couple of vertical tanks. These can be mounted above the air compressors.

From the plans of the installations found on the Thames Water Tunnel web site, it would appear that there may well be space for such an installation at the proposed sites.



Preferred site at Hammersmith Pumping Station – showing use during construction

Operation

The air system becomes much less effective when the dissolved oxygen content of the river exceeds about 5mg/l. This is because the oxygen transfer coefficient drops appreciably. Thus close monitoring would need to be provided using monitoring buoys and near real time readings. Thus, were there to be a plume of low dissolved oxygen water then, as it was carried back and forth by the tide, then the relevant diffuser stretches could be switched on and off automatically as necessary to oxygenate the water. This limited operational period would save in operational costs.

Maintenance

Dryden Aqua have developed a way of bringing the pipe and diffusers to the surface by attaching the air pipe to another pipe. Normally this second pipe sits on the bed of the river with water in it. When it is required to bring the diffusers to the surface for inspection or repair, the second pipe is filled with air and both pipes float to the surface, bringing the diffusers with it. To sink the system again, the second pipe is filled with water and the system sinks.

Benefits for fish

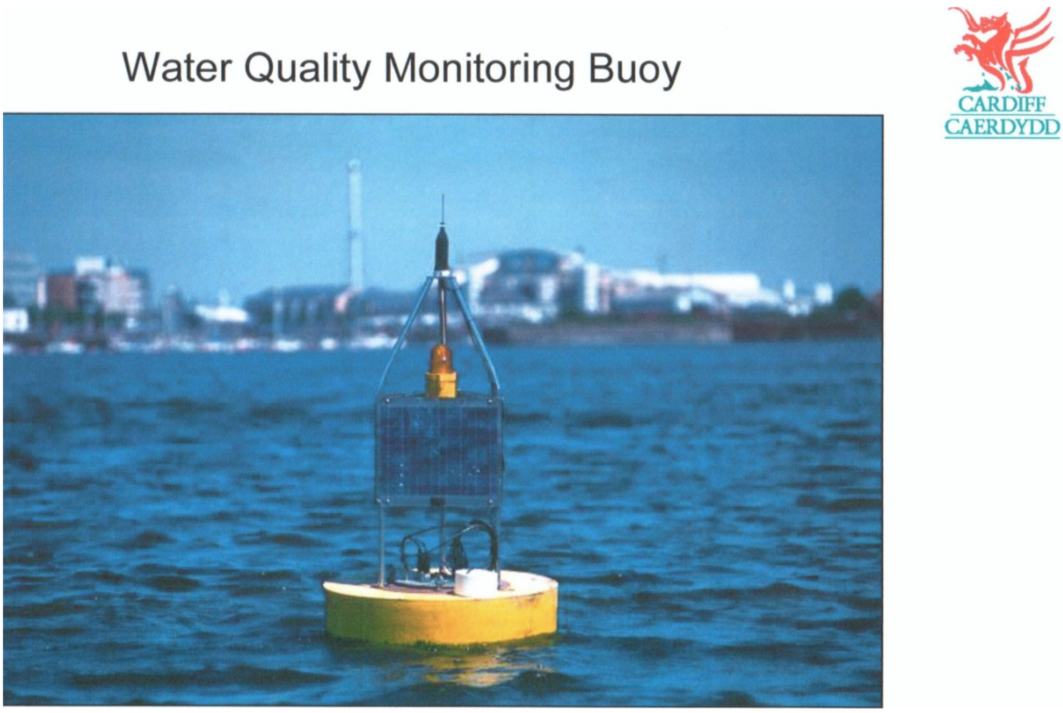
Dryden Aqua comment by email" *We went through a similar exercise for the Manchester ship canal, which is on the same scale... The diffusers will create a path for the migratory fish will follow. Also if the aeration system does not maintain a complete path, each air diffuser can act as a life support island of oxygen to support the fish. One diffuser can support around 1 tonne of fish, and will provide a safe zone during period of heavy pollution or during the DO drop that will occur at night."*

Appropriate modelling

In my view the only way of analysing the future conditions, and trying to see what the benefit of a normal rise of DO due to the proposed air diffuser system, say, to a 1mg/l rise, would be to put the various potential alleviation schemes into the TW water quality model, try various alternatives, and see what the benefit and outcome would be. That is the approach that I have proposed.

Monitoring

A near real time monitoring system would be provided, similar to that at Cardiff Harbour, to measure the dissolved oxygen content in the river every 15 minutes and to give prompt warning of any issues and unusual dissolved oxygen conditions. There are already several monitoring points in the river but it may be necessary to provide a few more.



Floating bubblers

Should a dissolved oxygen sag become an issue then the monitoring system would enable the two existing mobile bubblers to be despatched promptly. (See the front cover for a picture of one of the bubblers.) However this would only be a standby measure and not part of the routine measures to raise dissolved oxygen levels in the river.

Thames Water , in their Stage 2 consultation in the note on options page 3 state "*We currently use "mobile" boats to reduce the impact of untreated sewage overflowing to the River Thames...so our bubbler boats inject oxygen into the river helping fish survive sewage discharges...There are severe limitataions as to where these boats can go due to tides and bridge heights."* That may be true at present when the most damaging condition is an overflow of final tank effluent from Mogden STW which can then be taken upstream by the tide.

However the Needs case modelling figure 5.2 , see Appendix A of this document, shows that, with the Mogden STW improvements and the Lee tunnel, the base case, there would be no half tide failure further upstream than 8kms above London Bridge. With a half tide flow of another 7km, there would be no failure of the standard further upstream than 15kms. This is downstream of Hammersmith Bridge. Thus Hammersmith Bridge would generally be the upstream limit of operation during the interim period.

Admiralty chart 3319 gives the tidal depths upstram of Hammersmith Bridge can drop as low as 0.7m on a spring tide and there is seldom 2m charted depth. Downstream of Hammersmith Bridge the water depth is appreciably greater, charted depth generally being about 2m. The chart also gives bridge clearances at Highest Astronomical Tide (HAT), the highest spring tide expected in any one year and lasting only an hour or so. The chart gives a minimum clearance at HAT of 4.5m (Albert Bridge). However Hammersmith Bridge (south) is only 3.1m clearance at HAT. Studying the pictures of the bubblers, see front cover of this report, it would appear that the bubblers are unlikely to be significantly constained when operating downstream of Hammersmith Bridge, as they would during the interim period.

Cost

The cost of the diffuser system is estimated by Dryden Aqua at some £10m. In addition I consider it appropriate to allow for a contingency element, and the enhanced monitoring system. Thus I consider an appropriate budget cost for this system to be about £12m.

Conclusion

I cannot see a reason why such a system based on injecting air through diffusers to raise the background dissolved oxygen content could not be developed and work satisfactorily to raise the dissolved oxygen sag and alleviate the environmental impact.

I don't know how such a scheme would turn out, but, considering the potential benefit in reducing the environmental impact of non-compliance, and the amount of the potential infraction fine, then it does seem to me worth modelling to identify how much benefit such an scheme might bring. At the moment the EA is refusing to do this, despite a requirement in the River Basin Management Plans guidelines to assess the benefit of any combination of measures.

10. Health improvement.

Bathing.

On 1st July 2012 the Port of London Authority enacted *"a new byelaw to control swimming in the busiest part of the Thames between Putney Bridge and Crossness by making it necessary to get the prior consent from the harbour master." "Here you encounter a fast running tide, bridges and eddies which can drag a person underwater in a trice. And there are also passenger vessels which* carry *over six million people a year and 1,000 tonne barges carrying freight."*

This is almost all the length of the Tideway affected by CSOs.

There is a quote about a swimmer having to have "*the event carefully planned and managed with safety boats in attendance at all times."* Presumably the event would be managed to be several days after a significant CSO spill so water quality conditions would be improved.

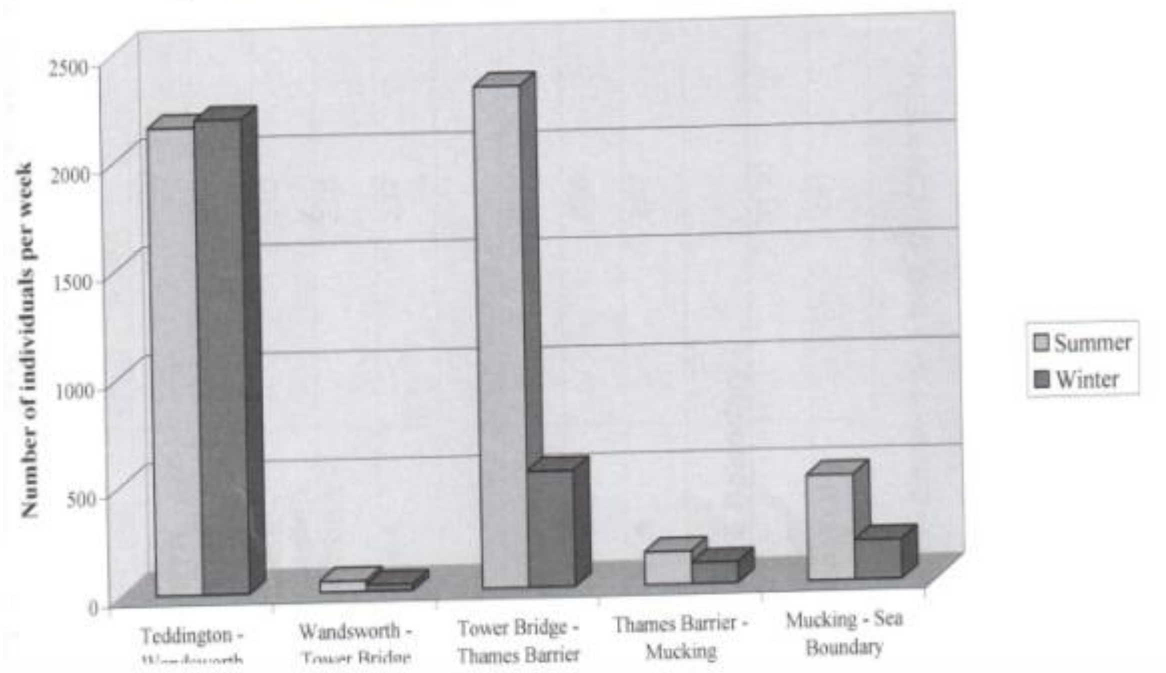
In any case none of the Tideway is designated as a bathing water under the Bathing Water Directive and so there is no statutory designation to be met.

Identification of other recreation

The number of recreationalists was surveyed and the numbers reported in the document "Recreational Use of the Thames estuary."

The numbers found in each reach is shown on the histogram below.

Figure 1 Watersports Activity on the Thames Tideway



This shows that the two most important recreational areas are the Hammersmith area, mostly rowers, and those in the general area of the London Docks.

Rowers in the Hammersmith area.

The Health Protection Agency (HPA) report The Thames Recreational Users Study 2007, states on page 1 "*there is little evidence to link the presence of high levels of bacterial indicators of faecal pollution to the level of risk to human health."*

page 48 "*The 95 percentile of indicator organisms in the upper tideway permanently remain above the WHO microbiological standards for recreational water and this represents a potential health risk to recreational users*." Thus there is a background health risk in the Tideway irrespective of the CSOs.

However the "*WHO guidance is only aimed at bathers*" total immersion and risk of ingestion " *and as such is not necessarily indictors of risk to other recreational use such as rowers, sailing etc..."* HPA page 8.

"*There is evidence to suggest that the influence of secondary treated effluent from Mogden sewage treatment works is as great as that of the less frequent but common CSO discharges."* HPA 2007 page 54.

Since then improvements are being made to Mogden STW including much increasing the flow to full treatment, improving the normal discharge quality, and greatly reducing the storm overflows. Following the storm of 2011 which killed many fish in the Chiswick area, Thames said " *I do need to assure you that once the extension is completed in March 2013 the works will be able to handle a similar situation without even using its storm tanks, let alone discharging to the river."*

The key information from a major study of health risks to recreational users in the upper part of the Thames (upstream from Putney Bridge) is summarised in the TW 2010 Needs report:

"*An assessment of health impacts upon recreational users of the River Thames was conducted and reported by the Health Protection Agency in 2007. This report, which quoted an EA estimate of between 3,000 and 5,000 recreational users of the tidal Thames... While there was evidence of an elevated health risk (gastric infection) to recreational users in the upper Tideway two to four days after a CSO spill event, the rate of gastric infection among recreational users was very low (12.8/1000/year) compared to the general population (190/1000/year). This may be due to the relative good health and fitness of recreational users, a greater awareness of hygiene and health and safety issues, and a developed immune response to infection from repeated exposure, which results in asymptomatic infection*."

The fact that gastric infection rates among recreational users in the upper Tideway are less than one tenth of the incidence level in the population as a whole, is a fair indication that the Thames health baseline, and the possible impact of the intervention, are not significant on a national scale in terms of the potential health impact.

In any case the improvements at the Mogden STW will significantly improve the water quality in the Chiswick/ Hammersmith/Putney area, one of the main areas for rowers.

The HPA study and the PLA announcement was done after the EA assessment. Thus the Environment Agency assessment should be reconsidered, taking on board the evidence from the HPA study and the PLA restriction. It is likely that this would then much reduce the assessed health impact from the upper Tideway CSOs.

The HPA study does state on page 58 that "*Predictive models of microbiological parameters... indicate that levels of these indicators can be predicted with reasonable accuracy given timely information about discharge events.*" I understand that since then Thames water has implemented a monitoring system at each overflow so it is likely that such information could be provided. *"The simplest and possibly most cost effective manner of making this information available to the recreational public would be through existing internet facilities." " A simple "traffic light" system could be used."* Thus the interim measures could include the provision of such information.

Thus a further interim measure, in addition to the upgrading of Mogden STW, could be the development of the microbiological model and the running of it to provide the traffic light system. A budget cost estimate for this could be about £100,000, within the accuracy of the overall cost estimates.

Recreation in the London Docks

From the histogram above one can see that the other major area of recreational use is in the Tower Bridge to Thames Barrier reach. Looking at the details in the Recreational Use of the Thames Estuary report these are very largely dinghy sailors and water skiers in the London Docks. These are discrete non-tidal bodies of water where the only contact with the River Thames water is the abstraction of a small amount of waterto top up the docks following loss from evaporation or leakage.

Assuming that the evaporation per year is about 600mm and that this occurs over a period of 200 days then the evaporation rate would be about 3mm/day. Allow a similar amount for seepage making a total of 6mm/day. Taking the areas of the Royal Docks as about 84ha, then the top up rate would be about 5Ml/d. A similar calculation for the West India Docks gives about 2Ml/d.

As part of the interim scheme it is suggested that water treatment be provided to the top up water. These would have to cope with significant turbidity at times. One method that could be considered would be some form of moving bed sand filter to remove solids and disinfection using hypochlorite. Such a scheme might well also provide some long term benefit and could continue as an element of the permanent scheme.

Cost estimate.

A broad brush estimate of cost for the traffic light scheme and the two small water treatment plants is, I am advised, about £2million for the Royal Docks and about £1m for the West India Docks, a total of about £3 million. Such a system should be implementable within two years.

11. Conclusions.

The British government has been taken to court by the European Commission for failing to meet the UWWTD on the Thames tideway and the Advocate General has found against it on the Thames Tideway sewer system. Thus the imposition of fines seems likely.

On the basis of the information given to me, the fines depend on the length of time of infraction and the environmental impact of non-compliance. These could be as high as Euro 1.5bn. A reduction of one point out of five points on the environmental impact of non-compliance might save as much as Euro 87million, about £70m. Two points better out of five would double the benefit.

The current works of upgrades to the Tideway sewage treatment works and the Lee tunnel, will reduce the volume of spill from the current 39mm3/year to about 18Mm3/year and much reduce the number of dissolved oxygen failures.

CSO spills could be reduced by connecting part of the system to another Mogden or Hogsmill STW, adjusting the CSO weir levels, removing restrictions in the sewer system, and by implementing real time controls. Studies would need to be carried out to assess the scope and cost of such measures.

Discharge of sewage debris to the river can be reduced by constructing a vortex system or screens where appropriate, and by installing booms around the CSO outlets. The retained debris can be collected and skimmers used in the river to collect that which escapes.

Fish are considered the most sensitive ecological species and dissolved oxygen standards have been set. The current works of the improvements to the sewage treatment works, particularly Mogden STW and the Lee tunnel, go a long way towards reaching the DO standards. A diffuser system using compressed air and, on occasion, oxygen would be able to raise the dissolved oxygen levels to reduce fish kills further and greatly mitigate the dissolved oxygen sags.

The Tideway is not a designated bathing water and is not subject to the Bathing Water Directive. For navigation reasons, the PLA has recently banned bathing in the Tideway except with a special licence. Health impact of those in the London Docks can be mitigated by putting in water treatment of the relatively small quantities of top up water. The rowers in the Hammersmith area are already ten times less susceptible to gastric infections than the general public. Improvements to Mogden STW will much improve water quality in the Chiswick/Mogden stretch of the Tideway where there are many rowers. A traffic light system could be provided to warn rowers when adverse conditions occur.

These interim works should be implementable within two to three years, ie likely within the time scale provided by the European Commission for completion of the tunnel.

Interim measures, such as those proposed, would do much to reduce the "*environmental impact of non-compliance.*"

The cost is estimated/budgeted to be

Flow diversion, in-sewer measures, RTC, etc	£ 7m
Vortices (or as early part of long term measure)	£ 3m
Booms around CSOs	£ 2m
Workboat to collect boom debris	£ 1m
Oil and fine litter skimmer	£2m
Fixed diffuser system and monitoring	£ 12m
Docks water treatment and warning system	£ 3m

Total about £ 30 million,

This is about half the cost of a one point reduction in the scale of five on the "environmental impact of non-compliance" of £70m.

I recommend that such interim measures be studied, and, if found to be appropriate, implemented.

Professor Chris Binnie

MA, DIC, Hon D Eng, FREng, FICE, FCIWEM.

5th February 2013.

Appendix A modelling of the river conditions and Table of performance.

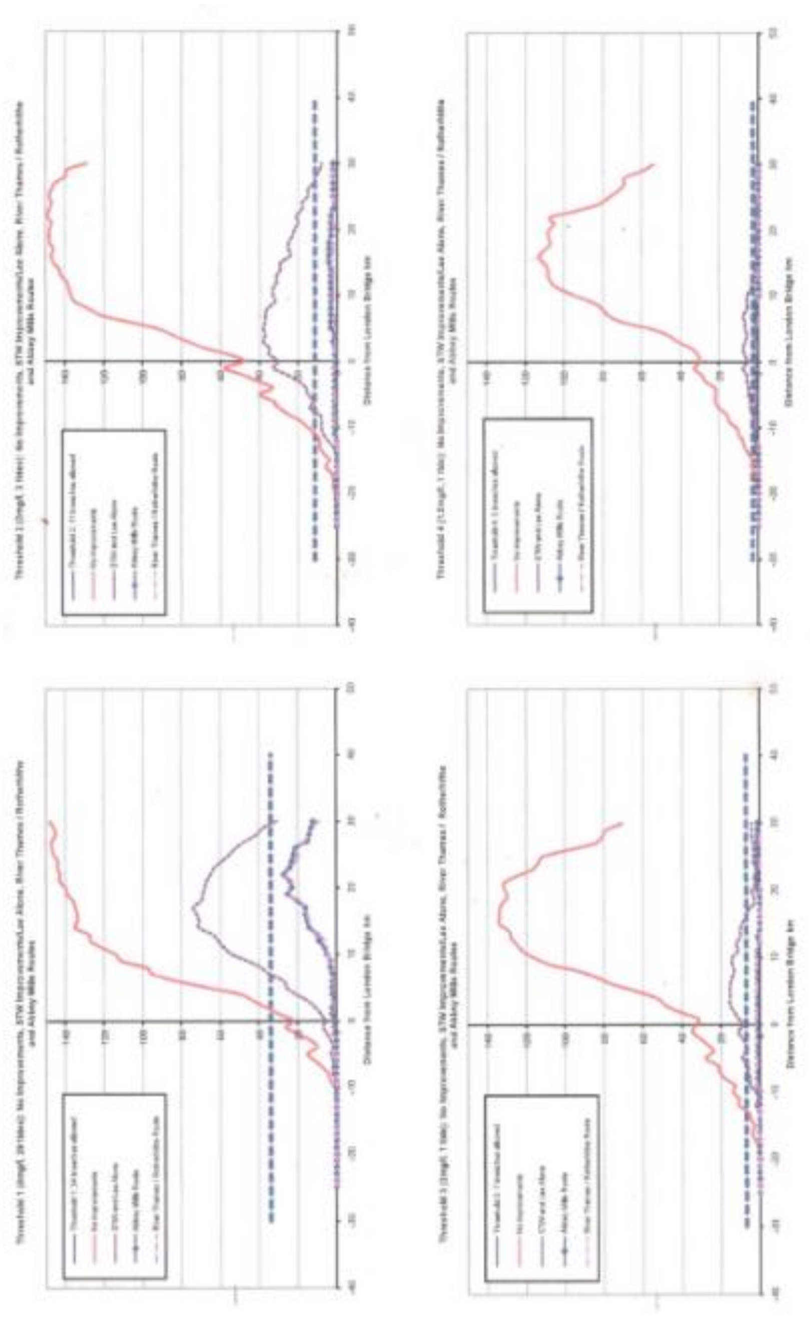


Figure 5.2 Comparison of Dissolved Oxygen Standards Compliance – (a) No improvements, (b) STW improvements and Lee Tunnel, (c) River Thames/ Rotherhithe routes and (d) Abbey Mills route (negative figures refer to distances upstream of London Bridge)

Table of performance

LTT ID	EA Cat	CSO Name	Existing System & Existing STW 2006 (June 2011) Total Volume (m^3) [a.]	No. of Spills [a.]	Spill Duration (hrs) [a.]	STW Improvements and Lee Tunnel 2021 (June 2011) Total Volume (m^3) [a.]	No. of Spills [a.]	Spill Duration (hrs) [a.]	Recommended Phase 2 Consultation Scheme 2021 (June 2011) Total Volume (m^3) [a.]	No. of Spills [a.]	Spill Duration (hrs) [a.]
CS01X	Cat 1	Acton Storm Relief	312,000	29	152	325,800	30	163	0	0	0
CS02X	Cat 2	Stamford Brook Storm Relief	500	2	2	500	2	2	400	2	2
CS05X	Cat 1	West Putney Storm Relief	34,300	26	113	36,400	28	119	1,500	1	4
CS37X	Cat 3	LL1 Brook Green	0	0	0	0	0	0	0	0	0
CS03X	Cat 2	North West Storm Relief	2,800	1	1	4,100	1	1	700	1	1
CS04X	Cat 1	Hammersmith Pumping Stn	2,208,000	50	648	2,362,100	51	690	103,600	1-3	16
CS06X	Cat 1	Putney Bridge	68,100	33	107	70,800	33	111	1,600	1	3
		Upstream Putney Bridge Total / Maximum [b.]	**2,626,000**	**50**	**1,023**	**2,800,000**	**51**	**1,086**	**108,000**	**3**	**26**
CS07A	Cat 1	Frogmore SR - Bell Lane	17,300	26	124	18,100	27	130	500	1	4
CS07B	Cat 1	Frogmore SR - Buckhold Road	85,600	19	68	88,600	21	72	1,500	1	3
CS08A	Cat 1	Jews Row - Wandle Valley SR	300	1	2	2,900	1	5	0	0	0
CS08B	Cat 3	Jews Row - Falcon Brook SR	7,400	2	7	7,500	2	7	7,500	2	7
CS09X	Cat 1	Falcon Brook Pumping Stn	708,900	40	263	779,300	42	291	56,200	4	26
CS10X	Cat 1	Lots Rd Pumping Stn	1,135,000	38	346	1,263,000	42	410	91,600	4	31
CS11X	Cat 2	Church Street	0	0	0	0	0	0	0	0	0
CS12X	Cat 2	Queen Street	0	0	0	0	0	0	0	0	0
CS13A	Cat 2	Smith Street Main Line	1,400	4	8	1,500	4	8	1,500	4	8
CS13B	Cat 2	Smith Street Relief	0	0	0	0	0	0	0	0	0
CS14X	Cat 1	Ranelagh	283,000	26	142	305,700	27	153	18,500	2	10
CS15X	Cat 1	Western Pumping Stn	2,046,200	37	200	2,323,900	41	228	244,500	4	24
CS17X	Cat 1	South West Storm Relief	227,900	12	38	238,400	13	40	3,900	1	3
CS16X	Cat 1	Heathwall Pumping Stn	654,900	34	200	748,300	38	246	62,500	4	26
CS18X	Cat 2	Kings Scholars Pond Storm Relief	1,400	2	4	1,800	3	5	500	1	2
CS19X	Cat 1	Clapham Storm Relief	12,700	5	12	14,400	6	15	7,900	1	5
CS20X	Cat 1	Brixton Storm Relief	264,600	28	131	278,600	29	137	5,700	1	4
CS21X	Cat 2	Grosvenor Ditch	2,600	3	7	3,000	4	9	500	1	3
CS39X	Cat 3	Horseferry	3,400	3	7	3,800	3	7	300	1	2
CS40X	Cat 3	Wood Street	0	0	0	0	0	0	0	0	0
CS22X	Cat 1	Regent Street	22,200	4	12	25,700	8	19	0	0	0
CS23X	Cat 1	Northumberland Street	71,500	13	34	88,400	14	43	300	1	2
CS24X	Cat 2	Savoy Street	8,400	18	47	8,500	18	4	1,400	4	7
CS25X	Cat 2	Norfolk Street	0	0	0	0	0	0	0	0	0
CS26X	Cat 2	Essex Street	2,100	3	6	2,300	3	6	0	0	0
CS27X	Cat 1	Fleet Main	521,100	20	73	571,200	23	8	36,80	4	14
CS42X	Cat 3	Pauls Pier	0	0	0	0	0	0	0	0	0
CS55X	Cat 4	London Bridge	8,300	7	14	8,900	7	1	4,300	5	10
		Downstream Putney Bridge to London Bridge Total / Maximum [b.]	**6,086,000**	**40**	**1,74**	**6,784,000**	**42**	**1,975**	**546,000**	**5**	**191**
CS28X	Cat 1	Shad Thames Pumping Stn	91,900	15	70	100,400	15	69	71,300	4	14
CS43X	Cat 3	Battle Bridge	0	0	0	0	0	0	0	0	0
CS44X	Cat 3	Beer Lane	0	0	0	0	0	0	0	0	0
CS45X	Cat 3	Iron Gate	200	1	2	200	1	2	300	1	2
CS46X	Cat 3	Nightingale Lane	0	0	0	0	0	0	0	0	0
CS49X	Cat 3	Cole Stairs	0	0	0	0	0	0	0	0	0
CS50X	Cat 3	Bell Wharf	0	0	0	0	0	0	0	0	0
CS29X	Cat 1	North East Storm Relief	782,400	31	286	847,400	31	303	84,300	4	32
CS51X	Cat 3	Ratcliffe	0	0	0	0	0	0	0	0	0
CS31X	Cat 1	Earl Pumping Stn	539,000	26	184	593,900	30	207	50,500	4	26
CS30X	Cat 1	Holloway Storm Relief	7,800	8	18	8,400	9	23	7,000	2	9
CS52X	Cat 3	Blackwall Sewer	0	0	0	0	0	0	0	0	0
CS36X	Cat 2	Wick Lane	0	0	0	0	0	0	0	0	0
CS32X	Cat 1	Deptford Storm Relief	1,471,500	36	252	1,976,000	39	343	161,300	4	29
CS33X	Cat 1	Greenwich Pumping Stn	8,322,500	51	672	3,940,100	28	240	571,500	4	35
		Downstream London Bridge to Greenwich Total / Maximum [b.]	**11,215,000**	**51**	**1,484**	**7,466,000**	**39**	**1,187**	**946,000**	**4**	**147**
CS56X	Cat 4	Isle of dogs Pumping Stn (Foul only)	12,900	6	9	13,100	6	10	13,100	6	10
CS35X	Cat 1	Abbey Mills Pumping Station from STATION F	15,319,000	56	873	0	0	0	0	0	0
CS35X	Cat 1	Abbey Mills Pumping Station from STATION A	4,099,800	45	403	0	0	0	0	0	0
CS57X	Cat 4	Canning Town Pumping Stn	0	0	0	0	0	0	0	0	0
CS34X	Cat 1	Charlton Storm Relief	600	2	3	900	2	3	900	2	3
CS53X	Cat 3	Henley Road	0	0	0	0	0	0	0	0	0
		Downstream Greenwich to Henley Road Total / Maximum [b.]	**19,432,000**	**56**	**1,288**	**14,000**	**6**	**13**	**14,000**	**6**	**13**
		Crossness STW Storm Tanks	308,300	5	27	50,200	3	8	50,600	3	9
		Tideway CSO				609,100	3	19	698,300	3	22
		Total / Maximum [b] to the River (CSO + Tunnel Overflow)	**39,667,000**	**56**	**5,567**	**17,723,000**	**51**	**4,288**	**2,363,000**	**6**	**408**
Sewarage Treatment Works [c.]		Beckton Catchment	444,610,000		8784	508,290,000		8784	508,240,000		8784
		Tunnel Pump Out	n/a		n/a	6,201,000		791	22,128,000		1551
		Beckton STW (Catchment + Tunnel Pump Out)	444,610,000		8784	514,490,000		8784	530,370,000		8784
		Crossness STW	200,560,000		8784	230,940,000		8784	230,280,000		8784

Notes

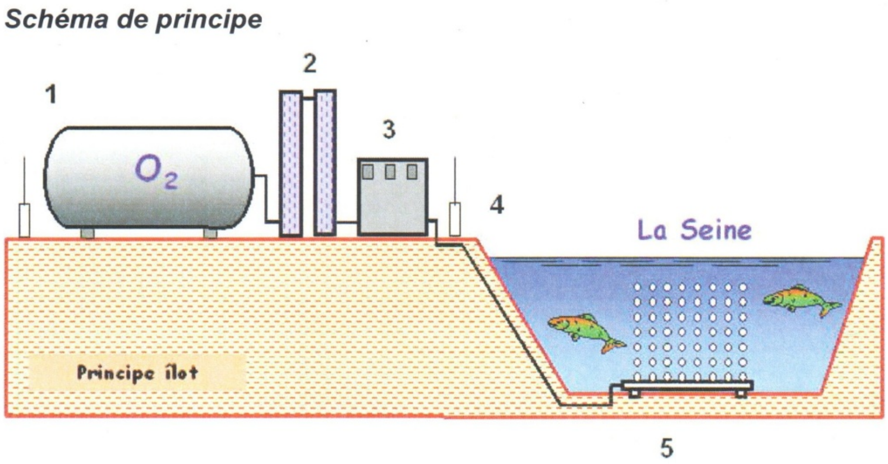
a. All CSO spills less than 100m3 have been removed. Volume, number and duration of spills have been adjusted accordingly.

b. For Volume and Duration, the sum of all CSO spills in the reach is reported. For Number of Spills, the maximum number of spills in the reach is reported.

c. Typical Year Model simulation is only for 270 days. The table includes infilling the remaining days with average daily DWF for Beckton and Crossness STW.

Appendix B Information about the Seine system

The Seine at Paris is a large river and Paris is a smaller city than London. The Seine at Paris also well upstream of the tdal limit, thus te river continues to flow seawards. As I understand it, there are five oxygen injection stations in the Sene immediatly downsteam of Paris. These are able to inject liquid oxygen into the Seine.

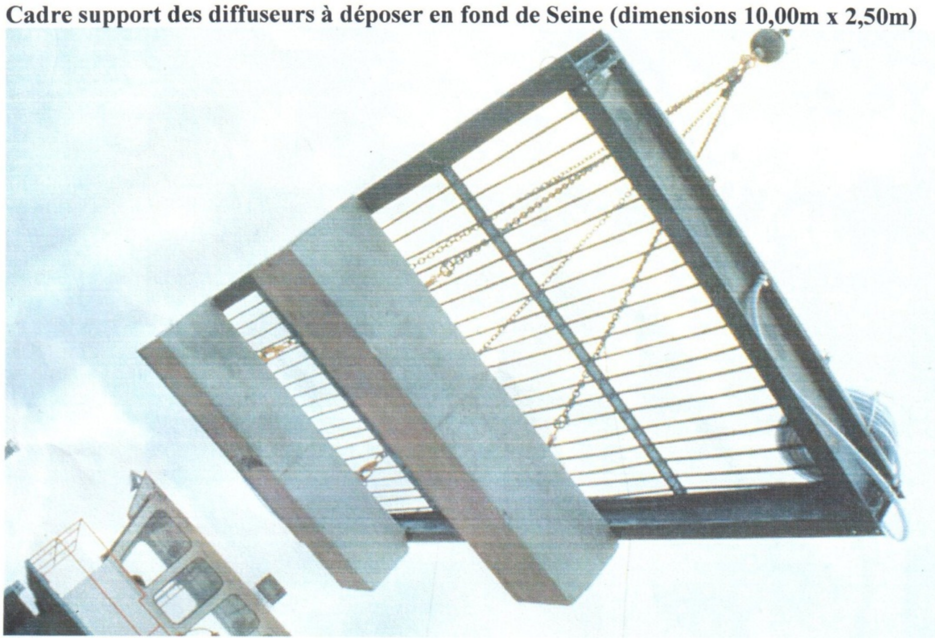


1 - Stockage d'oxygène liquide
2 - Vaporiseurs de remise en pression
3 - Armoire de régulation
4 - Tubes d'alimentation en oxygène gazeux
5 - dispositif d'insufflation d'oxygène

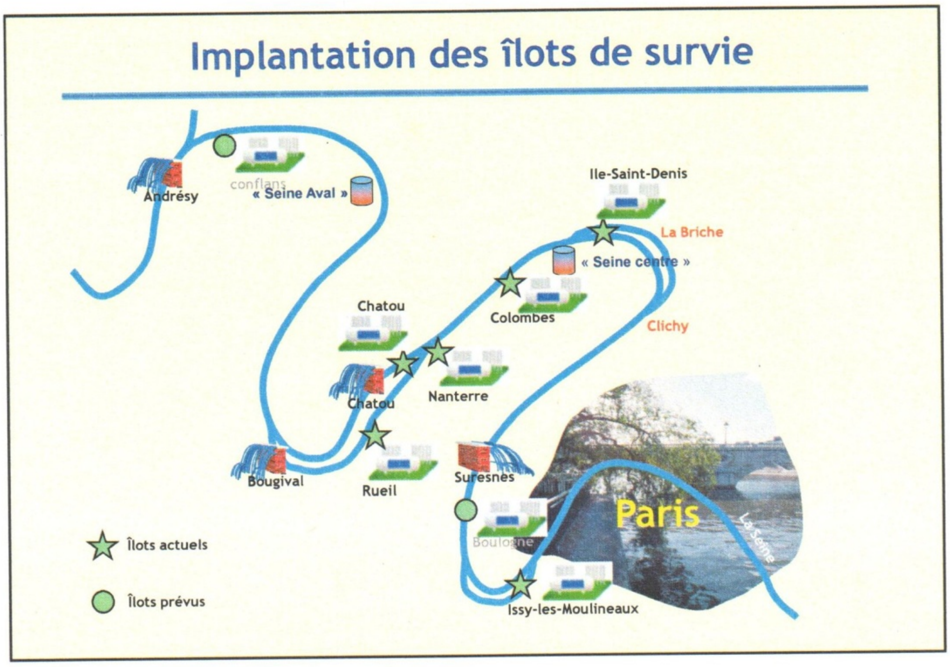
A picture of the diffusers is shown below.

Diffuseurs utilisés

Cadre support des diffuseurs à déposer en fond de Seine (dimensions 10,00m x 2,50m)

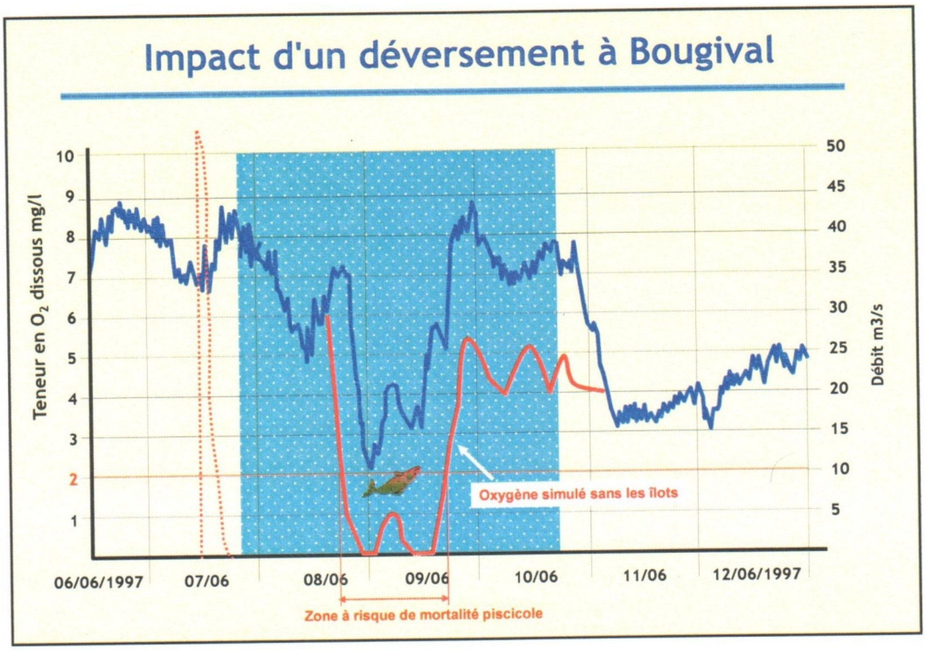


There are six such installations just downstream of Paris.



The picture below shows the size of the Seine and the diffusers in operation.

There is one plot of the benefit they have brought, as shown in the plot below for Bougival. This shows the dissolved oxygen content of the river following a storm on 7th june. The blue shaded area is when the diffusers were operating. The red line is what the water quality model of the river prdicted would have happened. As can be seen for a day the dissolved oxygen content would have been between zero dissolved oxygen and 1mg/l. This would have resuslted in severe fish mortality.The blue line is what the diffusers wer actually able to acheive. At no time did the dissolved oxygen drop below 2mg/l and the drop below 3mg/l was only about 4 hours. Based on the Tideway fish trials suite of fish only salmon would have been significantly affected. This shows the substantial benefit that such dosing can bring.



Elsewher in the presentation it implies that the river flow at the time was some 200m3/sec.

This demonstrates the gret benefit that can be obtained by installing diffusers and injecting air/oxygen into the river water.

.Appendix C Description of the Cardiff Harbour scheme.

Introduction

In the 1970s Cardiff Harbour was a rundown area with a poor environment. "*A neglected wasteland of derelict docks and mudflats...incapable of supporting most aquatic life.*" WEM Nov 2011 page 27. In the 1990s it was decided to impound the harbour and a barrage was installed across its mouth. The harbour area had a number of sewage and CSO discharges into it. The scheme is described in the Special issue of Water and Maritime Engineering June 2002 and illustrations have been kindly provided by the Cardiff harbour Authority.

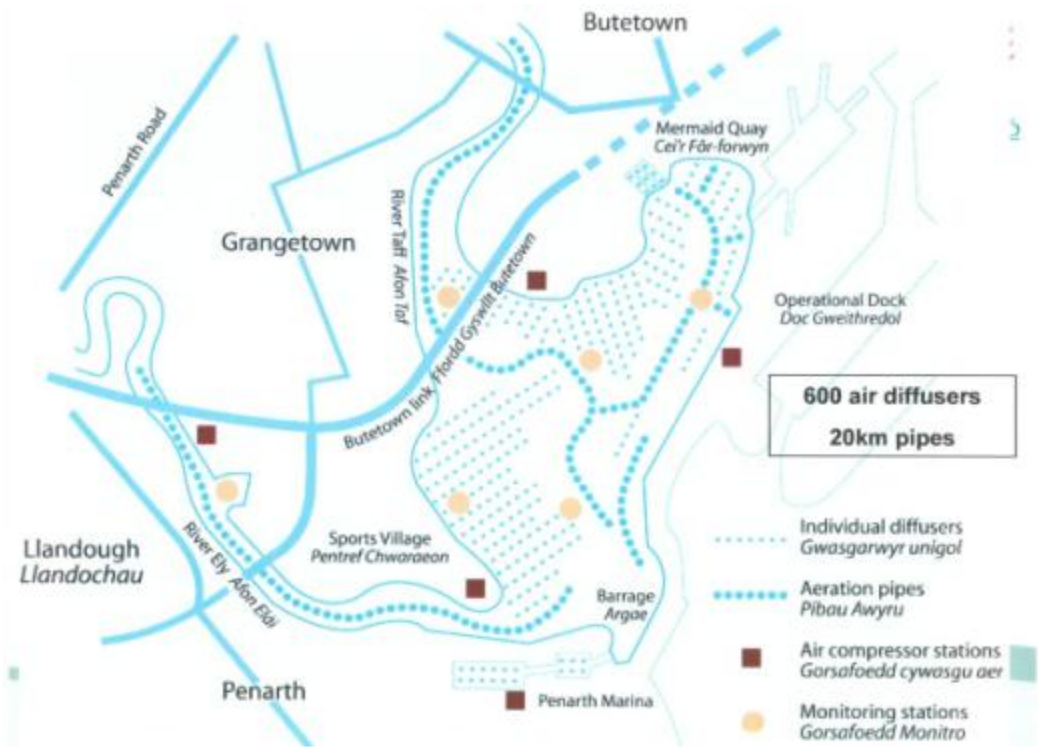
Scheme description

Page 84 "*Sixteen major sewers have been diverted from the bay prior to impoundment.*"

Page 131 "*Althugh major sewage and other outfalls have been diverted from discharging into the impounded water, there are still some inputs of sewage, industrial effluent, and diffuse inputs from the river catchments and discharges from combined sewer overflows (CSOs) during high rainfall events....Combined sewer overflows contribute high waste loads...the discarges were located in the rivers Taff and Ely*" I am informed that there are still frequent CSO discharges.

Fixed and mobile bubbler system for dissolved oxygen content

Page 84 "*The original concept for dealing with low oxygen levels was the provision of direct injection by Vitox units at a number of points around the perimeter of the bay...In practice a system of aerators has been installed in the bay with the agreement of the Environment Agency. The aerators inject air into the water body rather than oxygen, and are designed to operate continuously during the period from March until September each year.*"



The 600 coarse bubble diffusers are connected to air delivery pipes from the compressor stations on the shore. Thus this installation show that it is feasible to lay pipes on the bed of a water body and bubble air through them. The object is not to increase the dissolved oxygen content of the water but to turn over the water such that the surface water and the low oxygen bottom water are turned over, thereby eliminating stratification and raising the dissolved oxygen content of the water body.

A mobile bubbler is used should such action be required.

Monitoring system

The monitoring system consists of sensors hanging from the 9 buoys providing water quality data every 15 minutes.

Water Quality Monitoring Buoy

The data is relayed and displayed both in the Cardiff Harbour Authority (CHA) and EA offices and live on the web so anyone can view it in near real time. In addition the historical data can also be interogated on the web. Below is a sample I downloaded from the web showing the readings every 15 minutes, in near real time mode for one of the sampling points.

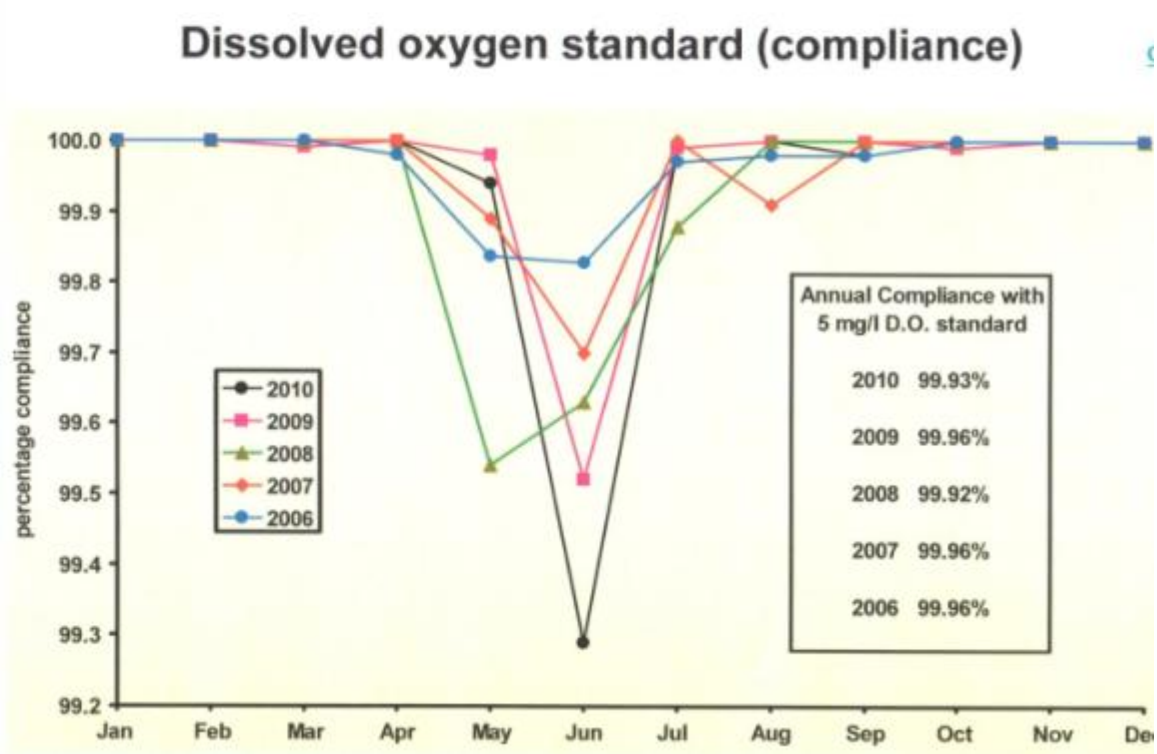
Site 5 Top & Bottom (all

	Min: 11.19 Max: 11.41 Mean: 11.29 Median: 11.29 St.dev: 0.04	Min: 93.0 Max: 96.4 Mean: 94.8 Median: 94.7 St.dev: 0.7	Min: Max: Mean: Median: St.dev:	Min: Max: Mean: Median: St.dev:	Min: 7.25 Max: 8.17 Mean: 7.74 Median: 7.73 St.dev: 0.22	Min: 305.0 Max: 338.0 Mean: 319.0 Median: 318.0 St.dev: 5.8	Min: 0.15 Max: 0.16 Mean: 0.15 Median: 0.15 St.dev: 0.00	Min: 1.001 Max: 1.190 Mean: 1.089 Median: 1.091 St.dev: 0.062	Min Ma Me Me St.c
Date/Time	**Site 2 S5 Bay 00010441 ODO Conc [mg/L]**	**Site 2 S5 Bay 00010441 ODO% [%]**	**Site 2 S5 Bay 00010441 DO Conc [mg/L]**	**Site 2 S5 Bay 00010441 DO% [%]**	**Site 2 S5 Bay 00010441 Temp [C]**	**Site 2 S5 Bay 00010441 SpCond [uS/cm]**	**Site 2 S5 Bay 00010441 Salinity [ppt]**	**Site 2 S5 Bay 00010441 Depth [m]**	**Site S5 000 OD [mg**
26/01/2012 00:00	11.33	96.1			8.17	311.0	0.15	1.010	
26/01/2012 00:15	11.33	96.1			8.15	319.0	0.15	1.014	
26/01/2012 00:30	11.33	96.0			8.13	321.0	0.15	1.013	
26/01/2012 00:45	11.35	96.3			8.16	315.0	0.15	1.012	
26/01/2012 01:00	11.36	96.4			8.16	314.0	0.15	1.007	
26/01/2012 01:15	11.34	96.3			8.16	317.0	0.15	1.010	
26/01/2012 01:30	11.34	96.2			8.16	317.0	0.15	1.008	
26/01/2012 01:45	11.32	96.0			8.14	316.0	0.15	1.005	
26/01/2012 02:00	11.30	95.8			8.13	316.0	0.15	1.011	
26/01/2012 02:15	11.35	96.2			8.12	314.0	0.15	1.009	
26/01/2012 02:30	11.34	96.1			8.12	318.0	0.15	1.007	
26/01/2012 02:45	11.35	96.1			8.10	315.0	0.15	1.008	
26/01/2012 03:00	11.30	95.7			8.09	316.0	0.15	1.008	
26/01/2012 03:15	11.30	95.7			8.07	330.0	0.16	1.006	
26/01/2012 03:30	11.26	95.2			8.05	317.0	0.15	1.007	
26/01/2012 03:45	11.23	95.0			8.03	319.0	0.15	1.008	

.

This network of sensors and near real time display enables any oxygen sag to be rapidly identified as it starts and rapid action to be taken at the relevant point in the harbour.

The aeration system has been operating since about 2001. During the early years there were problems with receiving near real time data from the monitoring buoys. However since 2005 the new arrangement now gives reliable near real time (15 minutes interval) readings for anyone connected to the web. This has enabled the scheme to meet its 5mg/l DO target reliably.



Thus such a scheme can be a very effective and reliable long term solution.

Booms and skimmers for litter collection

For litter collection the Cardiff scheme uses booms, and a litter collection and skimmer arrangement.

Cardiff harbour ,page 91, "*CHA has procured a purpose-built vessel and booms in order to deal with the considerable amount of debris that builds up in the bay following floods.*"

Conclusion

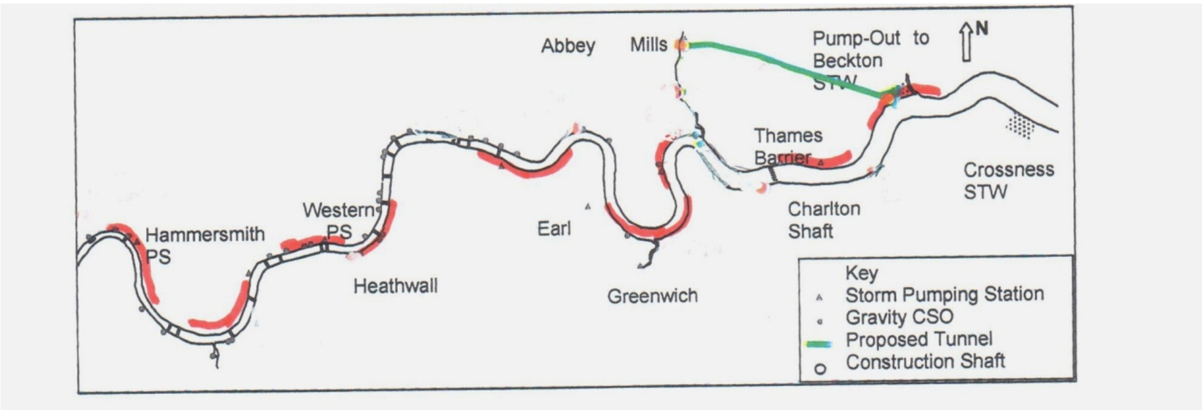
Thus the Cardiff harbour arrangment of fixed coarse grained diffusers and mobile bubblers, a near real time monitoirng system, and booms and mobile skimmers, has enabled the Cardiff Harbour to meet its dissolved oxygen and litter targets, and hence the UWWTD.

Appendix D Location of onland diffuser systems.

It had been intended to include plans showing the loaction of the air diffusers/oxygen generators on each site. However, for security reasons, TW have required that the plans be considered confidential.

Locations proposed.

Hammersmith PS
Carnwarth Road tunnel site
Western PS
Heathwall PS
Chambers Wharf tunnel site
Greenwich PS
Isle of Dogs PS
Woolwich PS plan awaited
Beckton PS big site, presumed space somewhere



Appendix E Information about the Hydrospin vortex separation system

Study of Water Surface Control as a Debris Reduction Measure for the Improvement of the Combined Sewer System

Le contrôle de la surface de l'eau comme méthode pour réduire les déchets dans le but d'améliorer le réseau d'assainissement

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RÉSUMÉ

Les villes qui très tôt se sont engagées dans la construction et la gestion de systèmes d'assainissement utilisent généralement des systèmes unitaires. Toutefois, lors d'évènements pluvieux intenses, le débit d'eau qui s'écoule dans les réseaux de ces villes augmente et des flux non traités – eaux usées et eaux pluviales – sont rejetés dans les milieux récepteurs publics, induisant contamination et odeurs. Dans les villes qui utilisent des systèmes unitaires, il est donc urgent de mettre en œuvre des mesures d'amélioration à des fins de santé publique. Les objectifs d'amélioration sont : 1) la réduction de la charge polluante, 2) la santé et la sécurité publique, 3) la réduction des débris.

Cette étude traite de l'un des objectifs d'amélioration immédiate, à savoir le contrôle de la surface de l'eau, développé à l'aide d'un dispositif de réduction des débris, composé d'une plaque de contrôle et d'un déflecteur. Le CSE (contrôle de la surface de l'eau) a été installé dans des chambres de partage existantes afin de réduire la quantité de débris contenus dans les eaux d'assainissement non traitées et rejetées dans le milieu aquatique public. L'effet de la réduction de la quantité de débris et la durabilité des équipements ont été évalués, et l'efficacité du CSE a été démontrée.

MOTS CLÉS

Système d'assainissement unitaire, amélioration du système unitaire, mesures de réduction des débris, surverse de réseau d'assainissement unitaire, eaux usées non traitées

ABSTRACT

In cities where the combined sewer system is employed, there is a need for urgent and intensive performance of measures for improvement. For the combined sewer system, immediate improvement goals are: 1) reducing the contamination load, 2) ensuring public health and safety, and 3) reducing debris

This study deals with one of these immediate improvement goals, that is, with Water Surface Control, which was developed as a debris reduction measure and consists of a control plate and baffle. Water Surface Control (WSC) is a mechanism designed to guide debris towards an interceptor by means of the baffle, and to draw the debris into the interceptor sewer with a vortex produced by the control plate. WSC was installed in existing diversion chambers in order to reduce the outflow of debris contained in untreated sewage discharged from the diversion chamber into the body of public water. The debris outflow reduction effect and equipment durability were evaluated, and the effectiveness of WSC was demonstrated.

KEYWORDS

Combined sewer system, combined sewer improvement, debris reduction measures, combined sewer overflow, untreated sewage

1 INTRODUCTION

In Japan, the combined sewer system in which both foul water and storm water are treated using the same sewer is employed in cities which have, from early on, been engaged in the creation and management of sewage works. However, when there is heavy rainfall in such cities, the water flowing into the combined sewer pipes increases and untreated combined sewage, i.e. a mixture of foul water and storm water, flows out as a combined sewer overflow and is discharged into the body of public water. As a result, water contamination or foul odors occur in the public water body, so that combined sewer system improvements are required from the viewpoint of public health.

In cities where the combined sewer system is employed, there is a need for urgent and intensive performance of combined sewer improvements. As immediate improvement goals for the combined sewer system, it is necessary to: 1) reduce the contamination load, 2) ensure public health and safety, and 3) reduce debris. As an improvement measure for debris reduction, it is stipulated in technical standards that a mechanical screen be installed or other measures taken to minimize the outflow from the diversion chamber of debris contained in the combined sewer overflow occurring during rainfall. Against this background, Water Surface Control (WSC), a device that has low initial costs because it has a simple structure, operates without electricity, and is easy to maintain, has been under development since 2000.

This study deals with WSC which consists of a control plate and baffle. For WSC employed as a debris reduction measure, we examined its debris outflow suppression effect for the debris contained in combined sewer overflow discharged from the diversion chamber, and its durability in order to investigate the effectiveness of installing it in a diversion chamber.

2 OUTLINE OF WATER SURFACE CONTROL

2.1 Outline of Water Surface Control

WSC is installed in the diversion chamber of a combined sewer system for the purpose of suppressing the amount of debris contained in the untreated sewage discharged as an overflow during rainfall which flows out into the public water body.

WSC is a debris outflow suppression mechanism consisting of a device called a baffle, which guides debris towards and above the interceptor sewer, and a device called a control plate, which produces a vortex to draw the debris into the interceptor sewer and flush it downstream (treatment plant) together with intercepted untreated sewage.

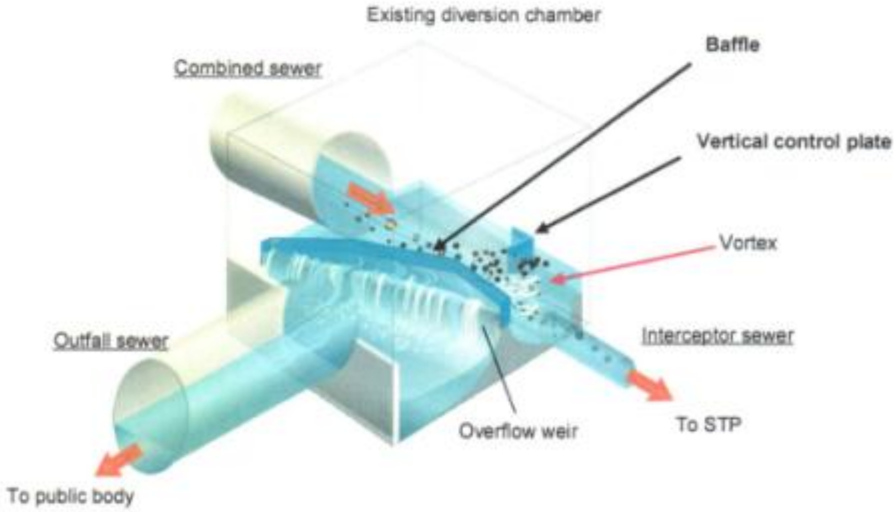

Fig.1 Outline of Water Surface Control (WSC)
(Baffle and vertical control plate type)

2.2 Principle and structure

WSC is a device that uses the flow energy of water to make it easier for the debris floating in the existing diversion chamber to flow into the interceptor sewer.

2.2.1 Description of devices making up WSC

(1) Baffle

The purpose of the baffle is to prevent floating debris from flowing out together with untreated sewage overflowing from the overflow weir and to guide the debris toward near the mouth of the interceptor sewer.

The baffle is installed in the existing diversion chamber with a clearance of 150 mm or more upstream of the overflow weir which releases combined sewer overflow during heavy rain. Its height is set so as to be higher than the overflow weir at the top and lower than the overflow weir at the bottom.

A baffle is made by forming stainless steel into a shape as shown in Fig. 1, and this is then installed in the existing diversion chamber with anchor bolts.

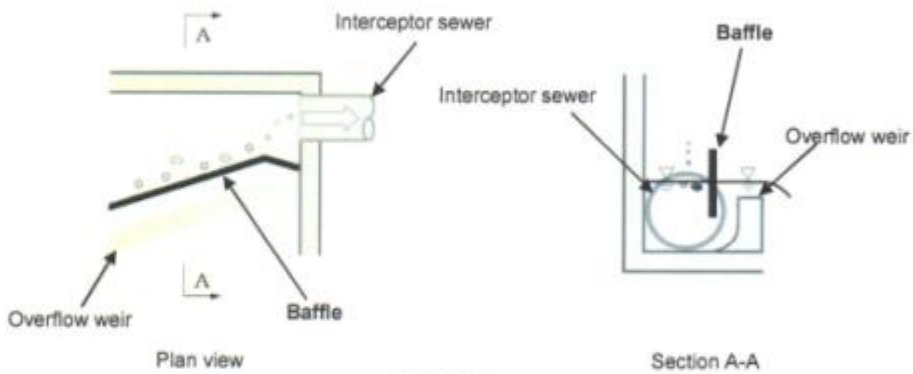

Fig.2 Baffle

(2) Control plate

1) Vertical control plate

The vertical control plate produces a vortex near the mouth of the interceptor sewer in the existing diversion chamber in order to draw the floating debris in the existing diversion chamber into the interceptor sewer.

The vertical control plate is installed upstream of the interceptor sewer in the existing diversion chamber and its height is set so as to be higher than the overflow weir at the top and lower than the overflow weir at the bottom.

A vertical control plate is made by forming stainless steel into a shape as shown in Fig. 3, and this is then installed in the existing diversion chamber with anchor bolts.

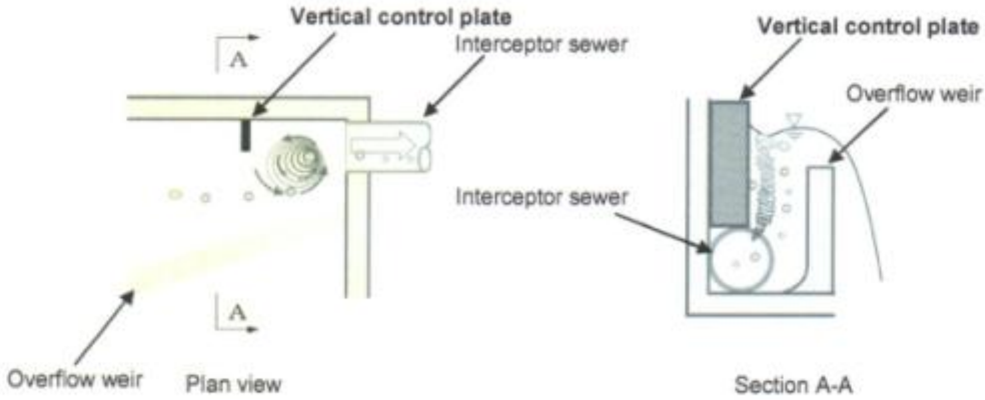

Fig.3 Vertical control plate

2) Horizontal control plate

The horizontal control plate controls the water surface or flow velocity distribution in the existing diversion chamber in order to form an open channel flow near the mouth of the interceptor sewer, thereby drawing the floating debris near the water surface into the interceptor sewer.

The horizontal control plate is installed upstream of the interceptor sewer in the existing diversion chamber and its height is set so as to be lower than the overflow weir at the top.

A horizontal control plate is made by forming stainless steel into a shape as shown in Fig. 4, and this is then installed in the existing diversion chamber with anchor bolts.

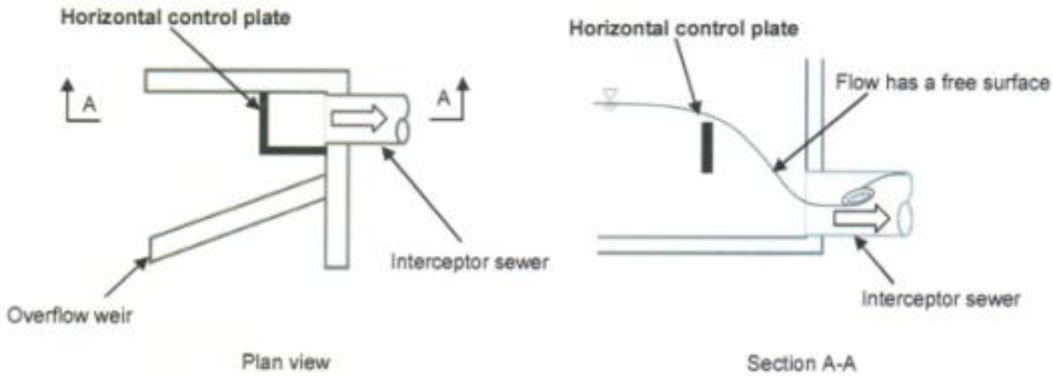

Fig.4 Horizontal control plate

2.2.2 Device configurations

There are five different device configurations of WSC depending on the combination of baffle and control plate. Before installing WSC, a preliminary survey of the existing diversion chamber is conducted to observe the flow conditions and water level. Then, a configuration appropriate for the existing diversion chamber in question is selected based on the observation results and the design specifications set by the relevant local authority, paying attention to the design water level, the heights of the overflow weir and interceptor sewer and the amount of available space near the interceptor sewer.

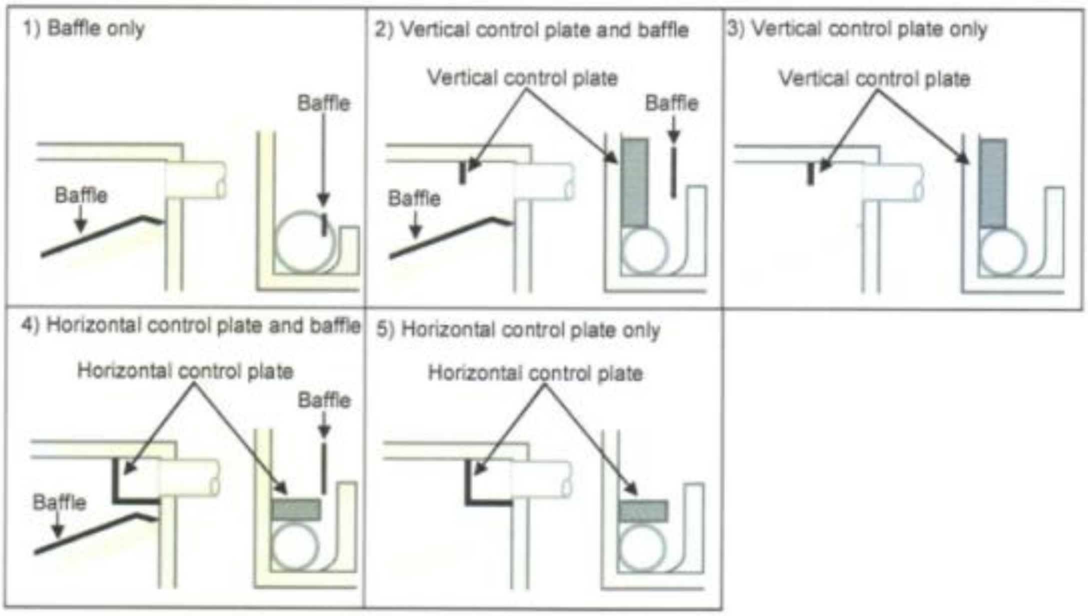

Fig.5. Five configurations of device

2.2.3 Scope of Application for WSC

WSC can be applied to diversion chambers that meet conditions 1) to 4) described below. However, WSC can also be applied to diversion chambers that do not meet these conditions if structural changes are made or a detailed study is conducted.

1) The distance between the baffle and the overflow weir is at least 150 mm.

2) The interceptor sewer is connected to a sidewall of the diversion chamber.

3) The interceptor sewer and the combined sewer are not connected or in close proximity to one another.

4) The bottom of the combined sewer is lower than the top of the overflow weir.

2.2.4 Preparation for the installation of WSC

To install WSC, it is necessary to determine the basic conditions, conduct a preliminary survey, design and plan the layout, produce and install the devices, and then conduct a follow-up survey. A preliminary survey and follow-up survey, characteristic of the provision of WSC, are outlined below.

(1) Preliminary survey

WSC is a device used to help guide debris to the interceptor sewer by means of the water flow energy in the diversion chamber. It is difficult to accurately ascertain the water flow conditions if only a theoretical study is conducted. A preliminary survey is intended to ascertain the water flow conditions in the diversion chamber while it is raining by using a water gauge and a CCD camera. A plan for the optimal layout for the baffle and control plate in the diversion chamber is developed based on the information obtained then.

(2) Follow-up survey

It is necessary to confirm that the vortex produced after the devices for WSC have been installed draws debris into the interceptor sewer. The follow-up survey is conducted to confirm that debris is drawn into the interceptor sewer after the baffle and control plate have been installed in the diversion chamber. If the planned effects cannot be attained, a plan to make improvements to the devices should be developed.

3 PERFORMANCE EVALUATION METHOD

For performance evaluation, we examined the ability of the device to suppress the debris contained in combined sewer overflow discharged from the existing diversion chamber from flowing out into the public body of water, and examined the device's durability.

3.1 Debris outflow suppression ability

3.1.1 Evaluation method

Debris outflow suppression ability was evaluated using the screening retention value (SRV), which serves as an index indicating the improvement rate for debris outflow suppression through installation of WSC.

In the calculation formula, $TSRE_{with}$ denotes the rate of debris intercepted in the existing diversion chamber and flushed into the interceptor sewer in the case where WSC is installed. $TSRE_{without}$ in the calculation formula denotes the debris interception rate by the overflow weir alone in the case where WSC is not installed.

$$SRV(\%) = \frac{TSRE_{with} - TSRE_{without}}{1 - TSRE_{without}} \times 100$$

$$TSRE_{with} = \frac{\text{Amount of debris in interceptor sewage}_{with} + \text{Amount of captured debris when WSC is installed}}{\text{Amount of debris in interceptor sewage}_{with} + \text{Amount of debris in overflow}_{with} + \text{Amount of captured debris when WSC is installed}}$$

$$TSRE_{without} = \frac{\text{Amount of debris in intercepted sewage}_{without}}{\text{Amount of debris in intercepted sewage}_{without} + \text{Amount of debris in overflow}_{without}}$$

Amount of debris in interceptor $sewage_{with}$: Dry weight of debris intercepted when WSC is installed

Amount of captured debris when WSC is installed : Dry weight of debris captured when WSC is installed (increase in amount of intercepted debris)

Amount of debris in $overflow_{with}$: Dry weight of debris flowing out to discharge side when WSC is installed

Amount of debris in intercepted $sewage_{without}$: Dry weight of debris intercepted when WSC is not installed

Amount of debris in $overflow_{without}$: Dry weight of debris flowing out to discharge side when WSC is not installed

SRV does not denote the debris interception rate, but the rate of improvement. Thus, even if the rate of TSREwith remains the same, SRV varies when the rate of $TSRE_{without}$ changes.

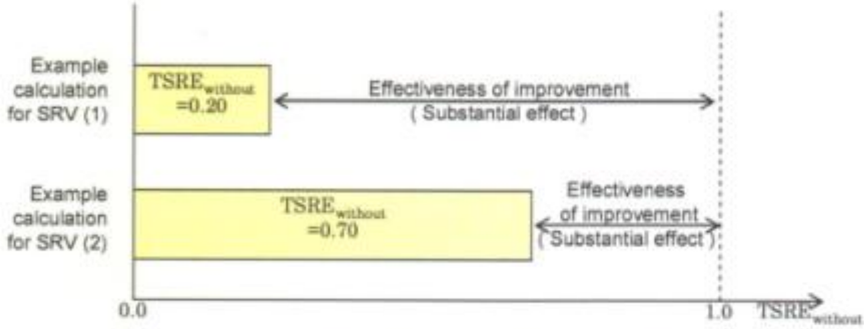

Fig.6 Relationship between $TSRE_{without}$ and the effectiveness of the improvement

3.1.2 Investigation method

(1) Outline of investigation method

The investigation was conducted in the 36 existing diversion chambers of combined sewers that were in service. The investigation was performed using two patterns, that is, by the artificial sewage method in which water trucks are used on a clear day to simulate the swelling of water quantity on a rainy day and in which artificial debris is dropped into the system, and by the natural rainfall method in which natural rainfall and real debris are used. The dry weight of the debris flowing through the interceptor sewer and the outfall sewer in each existing diversion chamber was measured before and after the installation of WSC in order to calculate $TSRE_{with}$, $TSRE_{without}$ and SRV.

(2) Debris investigated

Debris is generally referred to as solid matter contained in sewage and forming a deposit in the sewer.

In the artificial sewage method, a preliminary examination was performed to monitor the debris contained in the combined sewer overflow in the diversion chamber under investigation and, based on these examination results, artificial debris made of deficient components, i.e. about 50 percent dead leaves, 40 percent paper and 10 percent polystyrene foam was dropped from an upstream manhole to reproduce the debris during natural rainfall.

In the natural rainfall method, we performed investigations using real debris.

Photo 1. Added artificial debris

(3) Debris collection method

In the artificial sewage method, nets were installed to collect debris on the interceptor sewer side and outfall sewer side. The nets were set up at the beginning of overflow and removed on its completion. In this method, debris was collected in order to examine the amount of outflow of debris contained in the combined sewer overflow and the amount of intercepted debris flowing into the interceptor sewer.

In the natural rainfall method, water was collected in the diversion chamber at positions as close as possible to the combined sewer and just before the outfall sewer to in order to examine the amount of inflow of debris into the diversion chamber and the amount of outflow of debris contained in the combined sewer outflow.

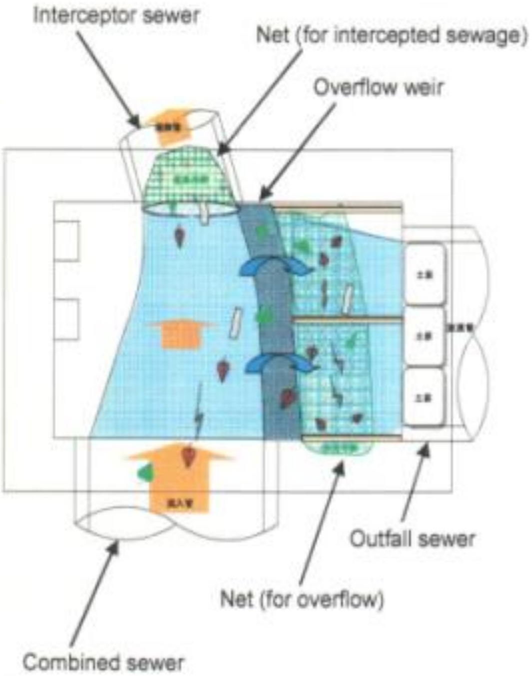

Fig.7 Schematic of debris collection method (Collection method using artificial sewage)

(4) Measurement of amount of debris

The debris collected in the net was classified into 1) paper, 2) feces, 3) kitchen waste, 4) grass and wood, 5) hair, 6) plastics, 7) metals, 8) oil balls, and 9) other, and the dry weight of each was measured.

(5) Number of times survey was performed

Survey data collection was performed three times for each diversion chamber.

3.2 Durability

To examine durability, a follow-up survey was performed for 2 months after installing WSC in 36 diversion chambers. The survey items performed include checking: 1) the anchors, nuts and bolts for looseness, 2) the baffle and control plate for deformation, 3) entwining of waste around the device, and 4) device components for corrosion.

4 SURVEY RESULTS

4.1 Debris outflow suppression capability

The survey results from the 36 diversion chambers are shown in Table 1.

Table 1 Survey results of debris outflow suppression capability

Chamber Number	$TSRE_{without}$	$TSRE_{with}$	SRV (%)	Combination of system: Baffle	Vertical control plate	Horizontal control plate	Chamber Number	$TSRE_{without}$	$TSRE_{with}$	SRV (%)	Combination of system: Baffle	Vertical control plate	Horizontal control plate
1	0.665	0.776	33.1	✓	✓		19	0.766	0.966	85.5	✓	✓	
2	0.445	0.669	40.4	✓	✓		20	0.000	0.880	88.0	✓		
3	0.316	0.634	46.5	✓	✓		21	0.000	0.893	89.3	✓		
4	0.089	0.683	65.2	✓	✓		22	0.000	0.920	92.0	✓		
5	0.000	0.668	66.8	✓			23	0.000	0.932	93.2	✓	✓	
6	0.225	0.756	68.5	✓	✓		24	0.000	0.937	93.7	✓		✓
7	0.627	0.892	71.0	✓			25	0.000	0.938	93.8	✓		
8	0.685	0.911	71.7	✓	✓		26	0.423	0.971	95.0	✓		
9	0.460	0.850	72.2	✓			27	0.351	0.977	96.5	✓		
10	0.000	0.738	73.8	✓	✓		28	0.122	0.972	96.8		✓	
11	0.616	0.911	76.8	✓			29	0.295	0.978	96.9	✓	✓	
12	0.119	0.812	78.7	✓			30	0.000	0.974	97.4	✓		✓
13	0.000	0.794	79.4	✓	✓		31	0.582	0.990	97.6	✓	✓	
14	0.109	0.830	80.9	✓	✓		32	0.340	0.992	98.8	✓	✓	
15	0.452	0.908	83.2	✓	✓		33	0.000	0.988	98.8	✓	✓	
16	0.000	0.836	83.6	✓	✓		34	0.000	0.990	99.0	✓	✓	
17	0.316	0.893	84.4	✓	✓		35	0.000	0.991	99.1	✓		
18	0.336	0.897	84.5	✓	✓		36	0.302	0.995	99.3	✓		

An example of some survey data (Chamber Numbers 26 and 36) is shown in Table 2.

Table 2 Survey data

Chamber Number	Test number	WSC not installed: *1 (mg)	*2 (mg)	$TSRE_{without}$	WSC installed: *3 (mg)	*4 (mg)	$TSRE_{with}$	$TSRE_{without}$ (Average)	$TSRE_{with}$ (Average)	SRV (%)
26	1)	3,825	3,311	0.536	36,736	61	0.998	0.423	0.971	95.0
	2)	6,621	6,024	0.524	10,410	725	0.935			
	3)	8,162	30,618	0.210	45,918	884	0.981			
36	1)	11,650	41,637	0.219	42,146	27	0.999	0.302	0.995	99.3
	2)	18,886	51,417	0.269	2,611	23	0.991			
	3)	46,247	64,567	0.417	24,456	125	0.995			

*1 : Amount of debris in intercepted $sewage_{without}$

*2 : Amount of debris in $overflow_{without}$

*3 : Amount of debris in intercepted $sewage_{with}$ + Amount of captured debris when WSC is installed

*4 : Amount of debris in $overflow_{with}$

SRV is used for evaluation in this study, which is the evaluation index chosen at the SPIRIT21 Committee to evaluate debris removal technology with respect to improvement of the combined sewer system. The SPIRIT21 Committee set the development target (required performance) at an SRV of 30 percent or more.

SPIRIT21 is a new technology development project utilizing strong industrial-academic-government collaboration. It addresses various subjects relating to sewage works especially in the areas where promotion of technological development needs to be a priority. Its purpose is to guide and promote private-sector-driven technology development as well as the rapid and varied practical application of developed technology.

According to the results of the current survey, SRV was between 33.1 and 99.3 percent after installing WSC in the existing diversion chamber. Thus, the effectiveness of installing WSC was demonstrated. The interception rate when WSC was installed was between 63.4 and 99.5 percent, and this also demonstrated that it is a good device for debris outflow suppression.

Table 3 shows the WSC configurations and their mean capabilities. High values resulted in the case of all configurations, that is, the mean SRV was 78 percent or more and the mean interception rate was 85 percent or more. Capability showed little dependency on the combination of baffle and control plate.

Table 3 Capability by configuration

Combination	Locations applied	Average		
		$TSRE_{without}$	$TSRE_{with}$	SRV
Vertical control plate only	1	0.122	0.972	96.8%
Vertical control plate + Baffle	20	0.281	0.858	78.3%
Horizontal control plate + Baffle	2	0.000	0.956	95.6%
Horizontal control plate only	0	—	—	—
Baffle only	13	0.223	0.900	86.0%

4.2 Durability

In the follow-up survey of durability, each of the survey items was checked and the results were that no problem was found in the 36 existing diversion chambers. Some entwining with debris was seen, however, its extent was too small to impair WSC functioning, and at present there is no effect on durability. The WSC has no moving parts and the device itself has no failure-prone elements, so the risk of failure is judged to be very low.

Making a comprehensive judgment from the follow-up survey results and WSC structure, the durability of WSC can be evaluated as excellent.

5 CONCLUSIONS

WSC can be evaluated as having excellent performance with regard to 1) and 2) below. As a debris reduction measure for use in improving the combined sewer system, installation of WSC in the existing diversion chamber was found to be effective.

1) Investigation of WSC with regard to SRV found that it has performance higher than the development goal set up at the SPIRIT21 Committee.

2) Investigation of the durability of WSC found this to be excellent.

LIST OF REFERENCES

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