21st Century Sewer Design

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Abstract
Change in external factors, such as environmental legislation and climate change, will mean the future of sewerage systems is likely to be different from the past. Combined sewerage systems comprise the majority of existing sewers in countries, such as the UK. A study, funded by UK Water Industry Research Ltd has reviewed the current state of sewerage within the UK, the likely drivers for change and the consequent future impacts over a 25 and 75 year timescale. Potential responses to address the anticipated changes have also been considered. It is concluded that due to the wide extent and value of existing sewer systems, these will continue to be used for the foreseeable future. However, in order to meet the major challenges as a result of changing external factors, these need to be operated more effectively, new ideas need to be explored and moves to develop better and more integrated water management systems need to be started if sewer systems in the UK are to provide the anticipated required levels of service well into the 21st Century.

Keywords
Sewers; scenarios; socio-economic and climate change; driver-pressure-state-impact-response model; UK water industry.

INTRODUCTION

Large sewer networks are a feature of developed cities. Many of these convey combined storm and sanitary flows in the same pipe. In some cities, such as London and Paris, much of these systems are more than 150 years old, and replacement/renewal rates may be very low. Although the average rate for the UK is currently 0.4%, investment in sewer renewal is, in principle, not going to replace some of the current assets for more than 1000 years (Read, 2004). Although this is clearly unrealistic, whether or not this is a problem will depend on the serviceability and performance of these systems over time. There is anecdotal evidence that these types of sewer networks are unsustainable (e.g. Rouse, 2003), and there are a number of projects that are seeking to develop ‘more sustainable’ wastewater systems, that aim to reduce energy use, resource consumption and recover key nutrients such as nitrogen, phosphorus and potassium (e.g. Malmqvist & Malmqvist, 2005).

In consideration of the above, and looking to the future, UK Water Industry Research Ltd recently commissioned a project undertaken on their behalf by the Pennine Water Group. The project intended to examine the future by setting out a vision for sewerage in the UK up until 2080. The project, 21st Century Sewer Design, included both developments of an immediate nature (up to 2020) and those that are more futuristic (up to 2080). It reviewed both long and short-term changes which could impact on the design, installation, operation and maintenance of sewerage systems. The project considered longer term drivers for change and the impact on sewerage systems of:

- Socio, Political, Economic factors (including customer expectations)
- Environmental factors (Climate change, acceptable loads of pollution, odour and CSO spills)
- Cost efficiencies
- Other issues such as reduction of impacts of sewer related activities on highway users.

The project considered short – term changes, which may create more immediate drivers for change, such as Health & Safety, and waste disposal policies.. In addition, consideration has been given to areas where current practice may have to change as a result of these drivers such as:-

- Hydraulic design
- Physical design
- Biology (septicity, accretions, tree root penetration etc.)

Areas have been considered which would be affected by change brought about by external drivers, or which could be drivers for change in their own right, such as operability and technology. The advantages and disadvantages of various aspects of existing and developing sewerage have been considered, with suggestions for fundamental changes that may occur and which will make the current systems (especially gravity) impractical, or threaten viable performance (e.g. grey water and water conservation). Consideration has been given to the question of whether current practices in relation to sewerage systems actually need to be changed or if they can continue essentially as they are.

The study was also considered the services delivered by the Sewerage Undertakers in England and Wales, with each operating with varying forms of service delivery model. It is intended from the study to inform key stakeholders, particularly: Government; Regional Agencies, Water UK, the economic regulator (OFWAT) and the environmental regulator (Environment Agency) and to engender debate between these key stakeholders and amongst the Sewerage Undertakers who are responsible for sewers in England and Wales. A follow-on project (Stage 2) has already been commissioned by UKWIR to further investigate particular aspects of the findings. The approach, main findings and recommendations of the initial project are presented here.

APPROACH

What is a sewer?

A ‘drain’ and a ‘sewer’ are defined in the English Water Industry Act 1991. A ‘drain’ represents a pipeline and associated works (inspection chambers etc) which carry foul water from sanitary and other appliances in a single building, or group of buildings within a single curtilage, to a disposal point such as a septic tank, cesspool or a sewer. A ‘sewer’, is a system of pipework including manholes which serves buildings situated in more than one curtilage (DETR, 2000). Alternatively as: ‘A pipe or channel taking domestic foul and/or surface water from buildings and associated paths and hard-standings from two or more curtilages and having a proper outfall’ (National SUDS Working Group, 2003). Of major importance here is that <u>having a proper outfall</u> is a prerequisite in defining a sewer. This means that the Sewerage Undertakers currently cannot be responsible for stormwater source control systems as alternatives to conventional sewers as these have no proper outfalls.

Who manages and uses sewers?

The Institutional arrangements in England and Wales include a wide range of stakeholders who have an interest in sewer systems. The project has provided an in-depth review of the background and history of the development of sewer systems and itemised the respective duties, interests, expectations and roles of the key actors and stakeholders, as this was considered essential to define the context within and for which sewerage is managed (Ashley et al, 2005; Matos et al, 2003).

Logical Framework

It is essential to utilise a consistent approach in any study that aims to look into the future. Current sewerage system performance is altered in response to drivers and pressures in a semi-linear process (Figure 1), much of which is laid out in the sewerage rehabilitation manual (WRc, 1994):

1. Existing system operation and maintenance, which is monitored, then assessed against performance criteria.
2. Where service performance is deemed inadequate, a planning process is instituted that comprises assessment and design of new assets or modifications to existing assets to attain specified performance.
3. Once the design or modification is selected, it is implemented, perhaps requiring further detailed design and construction followed by commissioning.
4. The process is then repeated from (1) above.

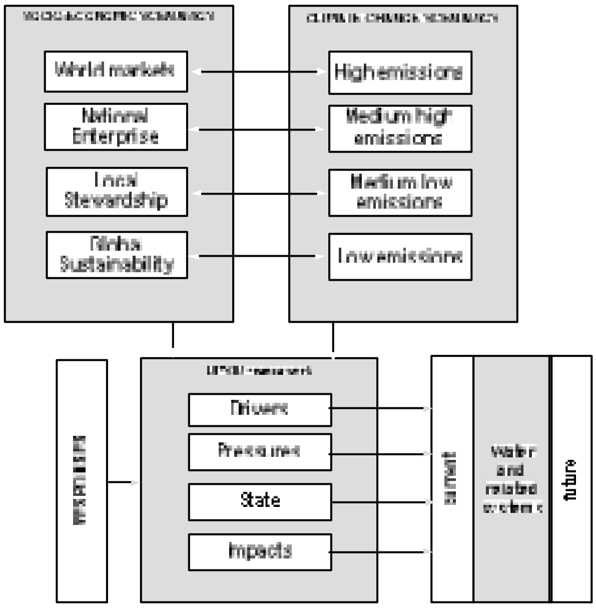

Figure 1 Logical Framework used in the study (in the last box the emphasis was on sewerage)

The change drivers operate in both the short (2020s) and long (2080) term, and in the former the main change drivers will be already functioning. The process listed above is expected to remain essentially the same in the short term (up to 2020s), depending upon the nature of the drivers. However, in the longer term, not only may the drivers change significantly, but the process itself may alter. Nonetheless some form of sewerage service provision is likely to be required even in the long term and the essential elements of monitoring, performance assessment, service enhancement, operation and maintenance would continue to be needed.

The logical framework used in the study, illustrated in Figure 1, comprises a drivers-pressures-state-impacts-responses (DPSIR) framework which may be used to ensure that all drivers are considered, together with their consequential effects, and that the responses to the drivers, i.e. used for coping or changing the state of the system, or intervening to influence the DPSI stages, are appropriately matched to the drivers. The overall logical framework also includes the external influences on the DPSIR system due to socio-economic changes (scenarios) and also due to climate change (related to emission scenarios).

The UK's Foresight Future Flooding project utilised both climate change predictions for the UK Climate Impacts Programme (UKCIP) (Hulme et al. 2002), and socio-economic scenarios (Evans et al, 2004). Socio-economic scenarios have been further developed by the Policy Studies Institute (PSI) and are based on two dimensions (Dahlström, 2005):

- Values: range from consumerism to community
- Governance: range from interdependence to autonomy

The four used in the study are outlined in Table 1.

Table 1 Socio-economic scenarios

Scenario	Characteristics	GDP (%)	Population (million)	Climate change (Hulme et al, 2002)
World Markets (WM)	People aspire to personal independence, material wealth and mobility to exclusion of wider social goals. Integrated global markets are seen as best way to deliver this. Internationally coordinated policy sets conditions for efficient functioning of markets. Provision of goods and services is privatised, under the principle of minimal government. Rights of individuals to personal freedoms are enshrined in law.	3.5	70 (35 million households)	High emissions (of greenhouse gases)
National Enterprise (NE)	People aspire to personal independence and material wealth, within a nationally-based cultural identity. Liberalised markets together with a commitment to build capabilities and resources to secure a high degree of national self-reliance and security are believed to best deliver these goals. Political and cultural institutions are strengthened to buttress national autonomy.	2.0	63 (29 million households)	Medium High emissions
Local Steward-ship (LS)	People aspire to sustainable levels of welfare in federal and networked communities. Markets are subject to social regulation to ensure more equally distributed opportunities and a high quality local environment. Active public policy aims to promote small-scale and regional economic activities, and acts to constrain large-scale markets and technologies. Local communities are strengthened to ensure highly participative and transparent governance.	2.0	61 (23 million households)	Medium-low emissions
Global Responsibility or Global Sustain-ability (GS)	People aspire to high levels of welfare in communities with shared values, more equally distributed opportunities and a sound environment. These objectives are thought best achieved through active public policy and international cooperation within EU and at global level. Social objectives met through public provision, increasingly at international level. Markets regulated to encourage competition amongst national players. Personal and social behaviour shaped by commonly-held beliefs and customs.	2.75	68 (29 million households)	Low Emissions

The study initially considered the 'state' in relation to sewerage systems. This related to the condition and performance of the system and also the performance of the service provider. The context defined the mission, the constraints, interactions, needs, outputs and the regulatory and financial framework within which the undertaking has to operate. State was then considered in terms of the main drivers for change, the resultant pressures and impacts. Hence this was considered as leading to changes in system state (of the assets and the service provider) that may require responses to manage. In some cases changes may not require a response as they may be welcome changes or opportunities that can improve the state and performance.

Defining the DPSIR components

Drivers and impacts

A series of workshops were held to brainstorm the main components of the DPSIR framework and to review how these may differ under the four scenarios. The most important of the workshops were those in London, mainly with key UK based players, and an international workshop in Copenhagen at the 10th International Conference on Urban Drainage. There were some 25 participants at the first and 61 at the second.

The main driver groups were identified (Table 2). Currently, the most important drivers relate to environmental regulations, with climate change expected to become gradually more important over time with varying impacts under different scenarios. Energy costs are starting to increase in the UK. The previous reductions in greenhouse gas emissions seen in the UK are now reversing; this is because the reductions occurred as a result of the closure of polluting industries and the better management of industrial impacts, rather than any fundamental changes to household impacts, and transport activities. Solutions adopted over the last decade to comply with the Urban Wastewater Treatment Directive have led to the greater use of energy intensive processes, such as additional sewage pumping. Hence current wastewater systems use considerably more energy than in the past. The UK water industry is a major energy user in the UK.

Energy costs are increasing markedly in the UK, in contrast with Government past predictions that costs would decrease. In general current wastewater systems use considerably more energy than in the past and their operation requires reliance on additional vehicle transport.

Table 2 Main Drivers and Impacts

Main Driver (also includes)	Impacts	Applicability across scenarios
Environmental legislation arising from environmental concerns (including stakeholder perceptions; aspects of public behaviour, responsibility and acceptability, link of willingness to pay to legislation.)	• Pressure mainly from external (to UK) sources • very large drive to comply with (external) legislation severely constrains ability of sewerage undertaker to innovate • UK customers do not connect their costs with the resource needs for compliance • New sustainability agenda in UK	Scenario dependent Less concerns about this under World markets as environment not considered important.
Climate change/rainfall/sea level rise/temperature. (stakeholder perceptions)	• Increasing uncertainty • Regional variations • Wetter winters, Drier summers /intense rainfall • More/less inputs: /odours/blockage • More risk of sewer flooding • Coastal pumping increasing • Heightened public awareness	Scenario dependent. Less concerns about this under World markets, although effects most extreme.
Energy and resource stress (Includes aspects of public behaviour, such as, amount of water used.)	• pressure to reduce energy usage and other resource usage • current technology and legislation has increased use of resources/energy, and/or increased emissions to atmosphere	Applies to all scenarios to some degree
Land use and urbanisation (including population and demographics, specific legislation, overland flows and flooding, interactions with urban watercourses, public behaviour, (lifestyles and age), infrastructure, buildings/contents, and fauna.)	• Surface urbanisation continuing • Strong development initiatives requiring sewer upgrading and expansion • More single person households – more overall flow (+40%) • Ageing population – different substances input • Ageing population better educated expectations of service quality higher	Magnitude of impacts scenario dependent – most urbanisation under WM and NE. May cease under LS.

Asset condition and performance, including serviceability (Includes specific legislation, public health, health and safety, sewer conveyance, social value of assets, maintenance, stakeholder perception.)	• Investment pressures and revenue suppression leads to under investment risks • Investment in monitoring of asset condition, deterioration and performance and relationship to risk-based costing may be inadequate	Scenario dependent, more wealth under WM and GS to invest. Parts of systems neglected under WM
Science, Engineering and Technology (Includes aspects of charging models, new technology).	• There is a socio-economic imperative to design and implement the outputs of R&D • May lead to good (and bad) innovation in relation to what may be more effective for sewer systems	Scenario dependent in terms of wealth (highest under WM) and lowest under LS)

Land use and lifestyles are important for sewerage systems, particularly when related to the scenarios outlined above in Table 1. 'Creeping' urbanisation due to lack of planning controls on domestic households is causing an increase in impermeable proportions of catchments, of the order of at least 10%, within some ten years of properties being built. This has major implications for the continuing effectiveness of downstream combined or stormwater sewerage and needs to be better controlled. Demographic trends show that even under current perspectives, there will be more single person households than multiple within the next 10 – 20 years, and that a rising proportion of the UK population will be 'elderly'. Single person households are estimated to use 40% more water (and hence generate wastewater) per capita than multiple occupancies. Elderly people use more pharmaceutical products and can be expected to introduce a lot of this type of "complex" waste into the sewer system. This will add increasingly more complex substances (xenobiotics and PCPPs) and also mildly radioactive inputs through excretions into the sewer network, leading to unknown reactions, odours, corrosion and other problems for sewer operation.

Table 3 Relative significance of drivers in 2020s and 2080s over the different socio-economic scenarios

Driver	World Markets		National Enterprise		Local Stewardship		Global Sustainability	
Timescale	2020s	2080s	2020s	2080s	2020s	2080s	2020s	2080s
Climate change/rainfall/sea level rise/temperature	H,l	H,m	M,m	M,h	L,h	M,h	L,h	M,h
Environmental legislation arising from environmental concerns (including stakeholder perceptions)	L,l	L,l	H,h	H,h	L,h	L,m	H,h	H,h
Land use and urbanisation (including population and demographics)	M,l	H,l	H,h	M,h	L,l	L,l	M,m	L,m
Energy and resource stress	M,m	H,m	M,h	H,h	M,h	M,h	H,h	M,h
Asset condition and performance, including serviceability	M,m	H,m	M,m	M,h	M,l	M.l	M,l	L,l
Science, Engineering and Technology	H,m	H,m	L,m	L,m	L,l	L,l	H,m	H,m

Key: H, M, L = high, medium, and low level of change from present conditions.
h,m,l = significance for UK sewers.

The project reviewed the drivers in relation to the scenarios in terms of the likely change within two timescales: 20 and 75 years and also in terms of the significance of the driver for sewers under each of the four scenarios as shown in Table 1. Note that the drivers may also be important under other scenarios, but the relative significance for sewer systems is not as important as for the combinations shown in Table 3.

Disasters

Potential major impacts affecting sewerage systems may arise from sudden changes. These may be considered as disasters, although there may be beneficial impacts, if for example, unlimited and impact free energy systems were to be introduced. Disasters fall into 3 groups: natural phenomena;

asset problems; man-made (although this overlaps with the asset problems). Examples of each include, respectively: meteorite striking planet; epidemic or pandemic traced to sewers; war. For each of these the possible impacts on sewerage could result in significant changes to their use or operation.

Responses

These are defined as measures taken to address the drivers, pressures and impacts and may be a mix of structural (technological developments e.g. from end-of-pipe to near-source systems) and non-structural measures (e.g. legislation or behavioural and expectation changes). Responses can be effected at any one of the stages of the DPSIR model (Figure 1). Effectiveness of a response is the ability to mitigate an identified impact, whereas the robustness is the variation in effectiveness of the response over the 4 socio-economic scenarios. Following the workshops, the main responses were grouped into four areas:

1. **Manipulation of sewer inputs** – wet weather and dry weather inputs, e.g. by disconnection, water re-use.
2. **Smarter management of existing infrastructure**, e.g. by real time control, better asset design, enhanced operational activity.
3. **New and Emerging Technologies to mitigate specific impacts**, such as local CSO treatment.
4. **Institutional Arrangements** and for example the influence of future legislation and land use.

Potential 'blue-sky' responses were also considered, such as:

- A closed water cycle loop as opposed to linear approach, with for example, household level treatment via engineered bacteria or nano-machines; converting waste and sending any solid residue to the sewerage undertaker in the mail; Closed Neighbourhoods (e.g. in USA, Netherlands).
- Improve the linear systems, with stormwater connections to sewers banned, leading to more overland flows, necessitating an acceptance of change to urban landscape and lifestyle (Netherlands). Also high technology control – offering timed "cut price" access to discharge sewage utilising spare local capacity off-peak and between storms. Or 'Designer' sewage. (as proposed by Henze, in Denmark).
- New uses for sewers, as e.g. solid waste 'packet' conveyors (already used for other utilities in France).

Where feasible, the responses were tested using a hydraulic simulation model of a combined sewer catchment with a population of 80,000. The main results are summarised in Table 4.

Table 4 effectiveness and robustness of technological responses

Response (driver group)	Effectiveness	robust	Timescale for implementation
Disconnection of Impervious Areas (Climate Change/ Land Use)	High	yes	2020-2080
Water Re-use (Climate Change/ Land Use)	Medium	limited	2005-2020
Sewer conveyance improvement – using advanced surfaces or cleaning (Climate Change)	Locally effective, but downstream problems	limited	2005-2020
Smarter Management - Real Time Control	High	Limited	2005-2020

(Environmental Concerns/Climate Change)			
Smarter Management – Energy Use (Energy and Resources)	High	yes	2005-2020
Smarter Management - Nutrient Recovery (Environmental Concerns/Climate Change)	Low, unless nutrient value increases	Limited	2020-2080
Smarter Management – Design, Sensors and Automation (Science and Technology)	High	limited	2005-2020
New and Emerging Technologies to Mitigate Impact (Environmental Concerns)	High	Limited	2005-2020

In addition to the technology responses considered in Table 4, Institutional and financial responses were also considered. These included: Institutional arrangements; industry; regulatory systems; voluntary agreements and transfer of functions between current agencies (a possibility under current reviews, Defra, 2005); change in business delivery models; cross subsidization of services; new services (not only sewerage) and local choice of level of service; direct government funding instead of locally raised revenues. In order to be able to consider this realistically, the review looked only at the short to medium term for these. In the medium to longer term, the role of planning processes for developments, strengthening of statutory consultation and controls on developments, the inclusion of 'Sustainability' in building regulations, compulsory on-site systems required for 'new build', the development of protocols, comprehensive and cumulative assessment mechanisms, together with the Influence on Legislation & Regulation, the cost-benefit-analysis demonstration of impact of new Directives & legislation and defensive research to pre-empt upcoming regulations and drivers. Many of these were considered to be effective and robust across scenarios, although under world markets regulations are likely to be much weaker than at present.

CONTINUING AS WE ARE NOW

A major feature of the study was to consider whether or not anything needs to change in the way in which sewer systems are designed, used, operated and maintained from the course we are on at present. For this, many of the drivers are already in place and responses are being made. Under current regimes, the implicit 'customer' for sewerage services is now no longer 'public health', rather environmental protection (the environmental regulator is the *customer*).

The main context for continuing as we are now is that existing sewerage systems are still a significant part of the urban landscape and are likely to continue to be used for the foreseeable future. There will generally be no abandonment of combined sewers, although under some scenarios there may be gradually, or a possible slow and continuous deterioration. There will be some 'separation' with new systems being separate, for which stormwater will be dealt with near-source. Due to new imperatives to collect data, the reality of the performance of existing sewers will become apparent, for both quantity and quality (CSO spills, diffuse pollution) as will the limitations in current modelling capabilities.

With the current institutional and regulatory systems continuing, there will be the need to achieve ever increasing efficiencies in performance. Climate change will necessitate more and more responses to deal with sewer flooding, even with current levels of service. There will be a need to consider wastewater systems more explicitly in terms of impacts on and from urban planning, due to the creeping urbanisation. Customer satisfaction is likely to decline as charges increase, particularly for the continuing need for new and better environmental management. There will be little opportunity for the sewerage undertaker to influence the constantly increasingly stringent legislation. There will be further imperatives to increase energy use, to deliver improvements in short time scales, although under some scenarios this may be tackled. Asset deterioration will need to be better understood and linked to the more rational selection of service delivery levels, with assets constructed in the past 25 years now nearing the end of their effective lives and needing replacement.

The main responses already coming into use are the growing use of separation and source control for new systems, the changing role of CSOs in terms of the need to provide pre-spill treatment, a growing appreciation of the need for energy management; the awareness of the need for better management of existing assets instead of replacement or large scale asset construction. Under new legislation and financial perspectives there is a growing attempt to improve customer/public engagement in understanding how services are delivered, with the new CCWater established in 2005. Currently there are very limited incentive schemes for disconnecting stormwater from combined systems, and these provide derisory rebates to customers and have virtually no effect. These will have to be improved more in-line with schemes such as those in Germany, the Netherlands or the USA, where storm water charges depend directly on stormwater or impervious area connection.

An example of the current approach that will have far-reaching implications for at least another century and which aims to deliver new assets using and complying to institutional and economic imperatives, is the proposed Tideway Tunnel (Thames Water, 2005). Problems can be envisaged due to both the high energy usage and the possibility of tunnel loss of capacity due to sedimentation, also due to technology and asset 'lock-in' for many years. (Jacobs Babtie, 2005). This contrasts with the approach being taken in many other countries, where real time system operation is being installed for Vienna (Fuchs et al, 2005) and in Boston, where the original large scale sewage storage tunnel has been reduced in size due to a large scale stormwater disconnection programme (MWRA, 2006).

Table 5 provides a timed perspective on what may happen if we continue as we are.

Table 5 Characteristics and anticipated consequences of maintaining the "status quo" under current perspectives

Decade	Characteristics and consequences
2010	• Asset deterioration more apparent due to limited investment - with operational problems increasing. • Energy costs rising despite attempts at greater efficiency. • More flooding from sewers due to climate change and land use effects. More encouragement to use source controls. S106 modified and right to connect amended. SUDS or equivalent now first approach to stormwater management in new developments. • S101A modified and need to retrofit communities to sewers arguable only in terms of detailed sustainability assessments. • Customer satisfaction falling; political climate affecting regulators and government willingness to increase charges. • Priority substances and nutrient removal costs beginning to come onstream for compliance with WFD daughter and other directives.
2020	• Further tightening of environmental regulations (now also including sustainability) and control/constraints imposes new constraints on CSO and WWTW discharges. Sensitive waters being expanded: e.g. Humber estuary, possibly whole North Sea, necessitating huge investment. CSO spills to be phased out. • Water demand increasing due to more households, with only limited success at demand management, hence DWFs increasing. • Energy costs substantial in water industry and only partially passed on to customers. Creates incentives and new approaches to generating more power from wastewater systems (e.g. sewer turbines). • Evident climate change with growing uncertainty – more sewer flooding as above. • Income dropping as balancing what allowed to charge with costs becomes even more difficult. Inset arrangements and increasing competition and markets opening up mean that it is increasingly difficult to plan business.

	• Under LS and GS scenarios there may begin to be some divergence around this time from the NE and WM 'tracks' with abandonment of sewers in the former and retrofit source controls (disconnections), changes in spatial planning making water more prominent, becoming the norm. • With no new and effective approaches to better customer engagement, the sewerage undertakers would be perceived to be inefficient and expensive; hence revenue raising will be problematic. Problems blamed on Companies, even where these are not within the sewerage undertakers' means of control.
2050	• Obvious and evident climate change, which has beneficial effects in terms of customer and media awareness and understanding of need to pay. Negative impact is the increasing uncertainty in asset management planning due to climate variability and predictions. • Nonetheless environmental priorities would still be high, other than under WM, with new, even more prescriptive 'unreasonable' regulations effectively prohibiting any wastewater discharges other than where watercourses need the inflow. • Asset performance deteriorating even further unless under WM there is more wealth to invest selectively in assets. Under LS asset deterioration may be unimportant due to progressive abandonment. • Energy problems would have to be resolved even under NE, otherwise by 2050 wastewater system operation as currently practised would not be sustainable. • Customer and stakeholder perceptions as above unless significant efforts are made to change relationships.
2080	• Possible uncontrollable climate change. Obvious, but only under WM would there be sufficient wealth to address the problems and only for certain parts of the sewer asset system serving wealthy or important areas. Lesser climate change impacts under LS and GS, but limited resources anyway to respond. Under these scenarios there may already be progressive abandonment of sewers. WSPs will lose some of their functions under these scenarios and may become reabsorbed into 'public' bodies. • Generally more tight environmental regulation other than for WM. • NE is possibly the worst possible scenario as climate change will be medium to high, wealth will be limited, income constrained, assets will not have been adequately maintained and external regulation remains very strong (although UK may secede from the EU). Hence by this time WSPs will not in themselves be sustainable as companies, particularly as most of the apparent problems will have been blamed on their incompetence by media and regulators.

WHAT NEEDS TO CHANGE

In the short term up to 2025

It is possible to get smarter with the way in which existing sewerage assets are operated and managed. Currently there is not full coverage of data about asset condition or performance. This will become even more important when the sewerage undertakers adopt more 'private sewers' serving groups of properties in the next few years. With new and cheaper sensors this can readily be addressed. In addition new advanced robotics will help maintain systems. From this it will be possible to utilise dynamic operation of systems, via RTC, gaining more capacity from the existing assets. It is essential that there is better acknowledgement and account taken of risk and uncertainty. The use of, for example existing sewer flow quality models that do not have the capability to predict reliably the quality of sewage spills has to be acknowledged by formal uncertainty analysis. This should then be linked to much more detailed risk assessments for the performance of assets than is currently being done. With much more performance monitoring to check compliance with environmental regulation this will become a necessity not an option in the future. The continuing use of high-energy systems will become untenable. Although most sewers in the UK are gravity, an increasing reliance on pumping has developed, often to convey sewage to a remote end-of-pipe treatment plant, or to address small localised hydraulic capacity problems. In response to European Directives; the continuing reliance on this approach is illustrated by the plans for the new Thames sewer tunnel in London, where future energy needs may be unsustainable.

Worldwide there is a move towards some form of joining together the whole water cycle in 'Integrated water management' (IWM), without distinction between water supply, disposal and flood management. In England and Wales, the diversity of the Institutional arrangements makes such an approach problematic. Nonetheless, under a new look, Defra, is beginning the process of integration at least for drainage systems in the urban area (Defra, 2005). With the new duty to include sustainability considerations in the Water Bill for the economic regulator, it is essential that the water industry begins to take IWM seriously.

Medium to Longer term to 2080

Currently new sewers are separate, although many of these connect ultimately into the older combined sewers that already exist in towns and cities. Stormwater may be discharged to local watercourses. There needs to be a more comprehensive look taken at how stormwater is managed within an IWM perspective. The barriers to utilisation of source control systems need to be addressed, possibly through primary legislation. These barriers include: adoption, maintenance and responsibility, and also the unquantifiable risks associated with these responsibilities, which limit their attractiveness to sewerage undertakers in England and Wales. Statutorily, the undertakers are responsible only for sewers which have an 'identifiable outfall'; a facet that most source control systems do not have. Nonetheless, on development sites these systems are slowly being used. Options to address problems of overloading of existing combined sewers, for flood or CSO control include stormwater disconnection. This may be retrospectively. This approach is being used in Boston (USA) and in the Netherlands a massive programme of disconnection is planned. In England and Wales, disconnection is seen as being practicably impossible and also too high risk. In the Thames study, this option is discounted due to the disruption that would be caused to the streets of London and also because any disconnected inputs could, under current legislation, still have the right to reconnect to the sewer network in the future. Investment is required in studies to properly define when and where disconnection is likely to be effective and feasible. However, any implementation and benefits are likely to be in the medium to longer term.

Currently the water industry is regulated in quinquennial cycles. This makes longer term planning difficult. There are some areas where this is recognised, such as water resources, where the planning horizon is 25 years. If sustainability is to be included in wastewater planning, then it will be essential that longer term views are taken. This is an issue mainly for the way in which the industry is regulated.

Although there are immediate problems from the way in which energy is used, longer term there will be even greater pressures under the current approaches. In addition, there will be a greater need to conserve resources and reduce waste, another pillar of sustainability. Although, most sewer systems operate under gravity, their 'sustainability' is potentially in doubt due to the large amount of embodied energy and resources used in construction and to a lesser extent, in operation. Although there is a lot of anecdotal evidence that sewers are not a sustainable solution to sanitation, this seems to not have been properly investigated in developed countries. The water industry (worldwide not only UK) is in a good position to develop new ways of closing cycles for energy, water and resources. Much more could be achieved in extracting energy from sewage, and this should become easier in the future, with a more stable sewage stream arising mainly from sanitary flows, with much of the stormwater removed. New technologies could readily be developed in this area, and future cost increases in energy will make the required investment more attractive.

Much of the above relates to how sewerage related services can be delivered more sustainably. In the medium to longer term, scope needs to enlarge to encompass whole systems: IWM; closed resources cycles and inter-relationships between services. Decisions will need to be made as to whether it is better or not to keep improving 'environmental quality' as encouraged by the ever increasing expectations and demands embodied in legislation, or if it is not better to invest elsewhere in better education, new energy sources etc. If these decisions are to be made properly, then the other main area where current practices need to be improved is in stakeholder and customer engagement with the way in which services are provided. Although laid down in the Aarhus Convention, public engagement also requires effective education and capacity building in order to understand issues and make informed choices. If those who are expected pay for water services are not engaged in these processes, then the ability to raise the funds to cover any new contingencies will be severely constrained. Currently, customers in England and Wales are perhaps the most remote in Europe in terms of their ability to engage with the water industry. For long term survival, this has to change.

CONCLUSIONS and RECOMMENDATIONS

The large value of the existing sewer asset base in England and Wales means that sewers as we know them will be with us for a long time into the future. Whether or not these sewers are 'sustainable' is open to question and needs much more investigation. Nonetheless there are significant pressures that will require at least a better approach to operation of this existing asset base. The design and installation of new systems is likely to progress down a variety of routes, depending on future socio-economic and climatic scenario. In some visions, there will be many more on-site and local systems, in others we will continue to build new sewers that will connect into the existing network. Present operators and decision makers are faced with complex choices and some of these have to be taken very soon, unfortunately existing governance, regulatory and institutional arrangements may constrain the ability of the sewerage undertakers to make the best and most sustainable choices.

There are a number of areas where changes need to be made in the way sewerage systems are planned and utilised. Many of these changes require better engagement across the key stakeholder groups to surmount the barriers currently constraining more effective and efficient sewerage related services.

Institutional systems and Regulator behaviour and expectations are at the root of the way in which the water industry can respond to all of the identified drivers. The water industry needs to ensure that it influences these so that there are no impediments to delivering responses and services in the most effective and efficient, and ultimately the most sustainable way. Specifically, engaging with Ofwat and its successor, to ensure that there is more of a longer term and strategic approach to investment and the research and innovation that accompanies this. Also working with Ofwat, Government and the Environment Agency to develop a shared understanding about the real nature of 'sustainability' and how this might be achieved in the delivery of all water services. As part of this partnership working, investigate possible changes in the responsibilities of the key actors involved in delivering sewerage and other services.

Environmental Protection

There is a need for **more reliable and accurate models** of pollutant transport and transformations in stormwater and sewage (Ashley et al, 2004). This is required so that engineering options to modify systems to comply with existing and new more stringent environmental regulations can be accomplished in effective ways. More reliable design, accounting properly for uncertainties in model results and using a risk-based approach, is required to better understand the related phenomena and build confidence with the economic and environmental regulators, and ultimately the public, so that funds are made available in a timely manner to address the needs of new and emerging environmental based legislation. With better scientific assessment of the risks and uncertainties associated with model use and results, risks can then be more effectively included in decisions related to the selection of responses.

Better monitoring and communications are required to comply with new regulations; hence research is needed to ensure that low cost reliable sensors and communication technology are further developed. This can be obtained from other industrial sectors, but needs to be developed so that it is low cost and reliable. Data processing capabilities need to be built so that the new, higher levels of data availability can be used to better understand systems and improve system performance in a cost effective manner. As new knowledge is gained of system performance, this will need to be fed back into design methods. This should involve a reappraisal of asset investments from previous AMP periods in order to improve future design capabilities rather than to criticise previous work.

Research and development is needed in several areas in order to enhance the operational performance of systems:

- Promote the **rapid implementation of RTC systems**, mainly to utilise spare system capacity in order to reduce discharges to the environment.
- **Further develop sensor and communication technologies** to allow planned and dynamic operational activities; better system knowledge can be used to justify and optimise expenditure on operational activities.
- **Develop better techniques to identify blockages**, constrictions and flooding risk and to plan sediment removal and sewer cleaning, this will reduce sewer flooding incidents and may impact favourably on the quality of CSO releases.
- **Develop technologies to eliminate man-entry** where practical, such as robotics and remote sensing techniques.

Development is needed of **techniques that can provide high rate treatment** and removal of designated pollutants either at the entry, within or exit to sewer systems. Given the new stringent environmental regulations, new treatment processes offer the potential to operate systems in a different way by including treatment as well as collection and transport within the functions of a sewer system. They may offer the potential for significant cost savings on meeting new environmental regulations.

Stormwater disconnection effectiveness at reducing pollutant loads by spill reduction and also by promoting better treatment at WWTW (and also aiding with flood risk control) should be investigated and application protocols drawn up. This response is also relevant to a number of the other driver/impact groups below.

Customer and other stakeholder perceptions, awareness, behaviour and understanding are important aspects of the main drivers in this group. New approaches to influence these are required in order to better align expectations and behaviour with willingness to pay for services delivered. Work is needed in partnership with CCW and Ofwat, and if necessary, an independent 'water awareness body' established if CCW are not able to fulfill the required functions.

True environmental protection has to be balanced with human needs. It is essential to show how these can be balanced in as open a way as possible by using **sustainability assessment tools**. These need to be applied more widely within the water industry and the techniques and criteria for application better developed. Such tools can be used to resist demands from regulators likely to lead to unsustainable solutions and also to influence environmental regulations where these are also likely to lead to unsustainable solutions.

Climate Change

This driver group and the recommended responses are aimed at ensuring customer protection from the impacts of climate change, which are mainly related to flooding, and possible increased CSO spills, resulting in increased likelihood of contact with raw sewage and damage to property and above ground infrastructure. The following is recommended:

Improved modelling of sewer flooding, overland flows and impacts on customers is required (currently underway as part of the FRMRC programme: http://www.floodrisk.org.uk/).

Research into the impact of source control technologies on catchment runoff, consequent sewer system performance and the long term costs and environmental impact.

Continuing studies will be required to **examine the latest outputs from the UKCIP models** and the implications for sewer systems. Continual studies are required; as future climate models should provide rainfall and regional climate scenarios with reduced uncertainty. Further studies are also required to examine the impact on river flows and catchment runoff processes as climate change occurs, in conjunction with the EA. This is a developing area of science; studies will probably be funded by other sectors, however, Water Industry funding will be required to synthesize these outputs to assess the consequential impacts on sewer networks.

Research on customer expectations and their perception of linking climate to system performance is required. The outputs from this work will be needed to justify any additional expenditure required to address the impacts of climate change. This study has demonstrated that under each of the socio-economic scenarios there will be significant customer resistance to additional expenditure on sewer systems.

Asset Performance

The **large amounts of data and knowledge** gained from enhanced sensor networks should be used to better link performance with asset condition. This information, available for the first time in large quantities, will allow more logical and transparent allocation of expenditure on system operation and any improvements. This may radically change the activities undertakers carry out. Research is required to develop accepted methods to link asset condition and performance based on this new data stream and to link it to planning tools such as the Common Framework.

Research into **improving the hydraulic conveyance of existing sewer pipes** should be carried out, the modelling study here indicated that improvement in conveyance would reduce the impact of sewer flooding but would have a limited impact on sewage volumes released from CSOs. Studies should also investigate the effectiveness of operational (cleaning) and capital (relining surfaces) activities on sewer performance.

Resource Utilisation

It is important to carry out **studies into energy utilisation** in sewer networks; the results of this work should allow sewerage undertakers to take operational measures to reduce energy utilisation.

Energy/resource use should be a key consideration in any future capital works, it is therefore very important that current design codes are amended to include energy use explicitly in the same way as flow capacity and acceptable flood return periods. Design codes should also include a requirement to reduce operational activities, such as sediment removal, adjustment of hydraulic controls etc.

This should be part of the standardised protocol approach recommended using sustainability assessment methods, in particular the life cycle analysis tools.

On a longer term, research should be conducted into **technologies that may offer either energy recovery opportunities or ways to operate systems with a lower energy need**.

Institutional Structures and Regulation

It will be essential to **quantify the costs of new and existing environmental legislation**. This information is needed to convince legislators and customers as to the level of resources required to achieve stated levels of environmental protection and the consequential burdens to the land and atmospheric environments.

Research is required into the **impact on sewer undertakers of the current proposals to introduce a more integrated approach** to the management of flooding and ultimately the whole urban water cycle. This research could be defensive in nature and carried out so that Water Companies have the information required to make informed comments in any future consultation process as new regulations and structures are formulated. As part of this, it will be essential to seek ways in which service providers can better 'join-up' the water cycle in integrated water management, accounting for all quantity and quality balances within the cycle.

Research should be carried out to **quantify the impact of current and proposed planning and building regulation changes**, and voluntary codes such as for sustainable buildings, particularly with regard to the opportunities to utilise source control measures to limit flooding and separation to limit environmental impacts. It is unlikely that any reductions in water use within buildings will have a significant effect on sewer system performance, other than a small additional blockage risk and a possible increase in odours.

The **application of the concept of "sustainability"** to the activities of sewer undertakers has the potential to have a significant impact on operations and thus profitability. Currently Ofwat are consulting on their sustainability duty (Ofwat, 2006). Defensive research should be carried out so that practical sustainability measures can be developed so that companies can demonstrate the relative sustainability of their operations in contrast with other industrial sectors.

It would be advisable to carry out **studies into the long term sustainability of current water companies** once the levels of impact of the perceived future change drivers has become apparent.

Research into the **effect of the current institutional and regulatory structures on the level of innovation** in the UK Water Industry is needed, particularly if the industry needs to innovate over reasonably short timescales to meet future challenges. These studies should identify constraints on innovative behaviour and involve comparison with other UK infrastructure based industries and water industries in other developed countries.

ACKNOWLEDGEMENTS
The study reported here has been promoted and funded by UK Water Industry Research Ltd (project WM/07). The authors are grateful to the other contributors to the project from the Pennine Water group and the UKWIR project steering group. Advice has also been provided by Wolfgang Schilling, Jean-Luc Bertrand-Krajewski and Bob Andoh. Thanks are also due to the many people who took part in the workshops.

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