REPORT BY THE FOUNDATION FOR WATER RESEARCH
WASTEWATER RESEARCH & INDUSTRY SUPPORT FORUM

ON

DESIGN CRITERIA & PERFORMANCE STANDARDS FOR URBAN DRAINAGE SYSTEMS IS HISTORIC PRACTICE STILL GOOD ENOUGH?

A WORKSHOP HELD
24TH SEPTEMBER 2003
AT
HILTON HOTEL, COVENTRY

SPONSORED BY FWR AND WAPUG

Foundation for Water Research, Allen House, The Listons, Liston Road, Marlow, Bucks. SL7 1FD, UK

FWR (Foundation for Water Research) is an independent charity dedicated to education and information exchange. Its subjects are the science, engineering and management of water resources, water supply, wastewater disposal and the water environment in general. FWR brings together and disseminates knowledge and makes this available widely.

WaPUG (Wastewater Planning Users Group) is a not-for-profit organisation established over fifteen years ago to promote best practice in the wastewater industry. Its terms of reference are to:

- Provide a forum for discussion between users
- Facilitate the exchange of information between relevant organisations
- Identify areas for improvement or modifications to and associated research and development of wastewater planning modules
- Identify education and training needs and encourage the necessary education and training.

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1 Executive summary

The workshop was entitled "Design Criteria & Performance Standards for Urban Drainage Systems Is Historic Practice Still Good Enough?". Basically the answer was "no", however that's not to say that things are bad at present but that in a changing climate (meteorologically and otherwise) it is time to question and move forward; we could and should do better.

Climate change is now accepted by most as being a reality and there is a strong probability that rainfall events are going to be more intense. There is continuous creep of impervious surface (roads, parking, roofs, conservatories, patios, etc.) so there is less infiltration and more instantaneous run-off. Inevitably these intense discharges of water will exceed the capacity of the underground drainage more often.

An example from Glasgow showed that engaging with the public so that they can appreciate the issues and the alternative costs and outcomes enables them to buy into the solutions. It is important that jargon does not hinder comprehension during public debate. Achieving public buy-in is probably more acceptable than 'decide and dictate' especially since 'predict and provide' is probably unaffordable without some attenuation of inputs if the goal were to be zero flooding.

We could increase the capacity of the underground drains at huge cost and disruption or we could keep the rainwater out of the foul drains by surface drainage, infiltration, delaying the flow and designing and designating flood routes. The latter would require cooperation and sharing of responsibilities across the existing organisational and legislative boundaries; making the necessary changes would be hard but ultimately more sustainable.

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2 Introduction

FWR and WaPUG decided that the best way to investigate the subject would be to convene a workshop of invited experts to assess for which elements we have the modelling tools and whether there are tools that need to be developed.

It was expected that the solution will be a combination of terrain modelling, fluid mechanics, hydrology, urban drainage, open channel hydraulics, computational fluid dynamics, data capture by remote sensing and meteorology. Accordingly lead experts were selected (Appendix 2) and invited who could contribute information on these aspects together with potential funders and "customers". FWR and WaPUG sponsored the meeting at the Renewal Conference Centre, Solihull so that it was free of charge to invitees, 23 of whom participated. Those who were unable to attend asked to be kept informed of proceedings. Attendees said that it was a very worthwhile day and questioned whether there might be successors in the future. The programme of the day is shown in Appendix 3.

3 Workshop

3.1 Chairman's Introduction

Nick Topham, Asset Delivery Manager (UID), Yorkshire Water Services

This is a very important subject and we need to view itr from the customers' perspectives. It is very easy for professionals to get drawn into the detail of modelling and engineering but it is the customers who pay the bills and therefore due recognition must be given to what customers are prepared to pay for.

Yorkshire Water's market research / opinion surveys have shown that customers would prefer not to pay much more than they are at present. However reduction of sewer and area flooding is one of the few areas that customers do consider worth paying more for.

3.2 Current Practices & the Necessity for Change - What is the problem, what can be done about it now and what is needed if we were able to do it?

Andy Eadon, Haswell Consulting Engineers; WaPUG R & D; FWR Ww Forum

For new systems there is the guidance document "Sewers for Adoption 5th Edition", which is described as

> "the definitive guide for those planning, designing and constructing sewers and pumping stations for subsequent adoption under Section 104 of the Water Industry Act. The 5th edition has been rewritten to reflect changes in technical practices, environmental and safety legislation and standards. Key changes can be seen in the sections covering (i) pumping stations for which a new specification has been developed providing the opportunity for a single, efficient and cost-effective design for use across the whole of England and Wales, and (ii) the legal agreement which has been written in plain English and simplified to recognise the Sewerage Undertaker as the adopting authority."

There is another version for Scotland. These valuable guides cover the layout, hydrology, hydraulics, structural and functional aspects of sewers. For economy designers want to connect the maximum number of properties with the minimum length of sewer. Design has been empirical and generally based on rainfall "return periods", i.e. to cope with a 1 in N years' rainfall event based on historic rainfall data[1]. Figure 1 shows the modifications (in an area of Derby) to an existing system to maintain or enhance performance. In this situation it is important to model the whole system and then run simulations using intuitive "cut and try" (a term coined by Dr David Wright). However there are many changing circumstances that will influence the design requirements:

- Climate change
- Growth including urban creep and creep of impermeable surfaces
- Maintenance, including changes in capacity due to siltation and cleaning
- Surface water from overland flow

[1] At the WaPUG Autumn 2003 conference Norman Fleming described the Greater Dublin Drainage Study. The project team includes the Hadley Centre for Climate Prediction and Research, which is part of the Met Office, so that increased rainfall intensities and rising sea levels are being allowed for when developing a road map for the next 30 and 50 years' drainage and treatment facilities. This degree of attention to the effects of climate change has not been allowed as common practice in the UK.

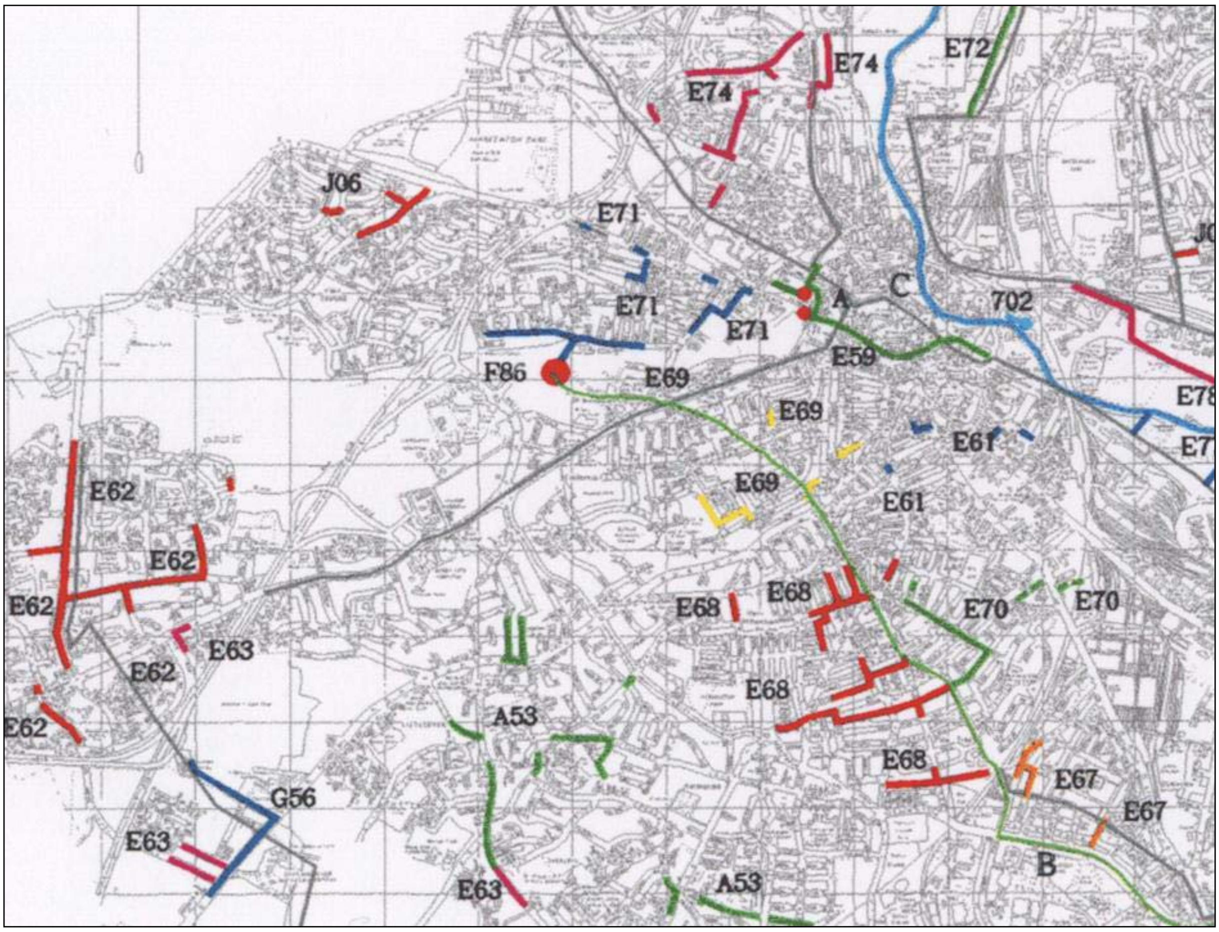

Figure 1 Illustration of modification to an existing sewer network

Improvements to existing sewerage systems uses a two or three stage simulation process (cut and try) which has never been formally acknowledged by the industry. It is felt that WaPUG could document this process and publish it as an industry standard. From this base it should be easier to use applied research for developing more appropriate design criteria to replace some of the empirical elements of the process. The stages use different models to account for the anticipated catchment changes bulleted, above and the prescribed design horizon.

In designing systems there is an expectation that the return period of the design storm equates to the flooding performance of the sewer system. This is largely an empirical approach with little evidence to support the assumption. There are a number of other variables which have a strong influence but tend to be averaged. To overcome the effects of some of these variables, a longer return period for the design storm has been used to provide a safer design. This, though having merit, increases the expected performance to the same level and further masks the uncertainty. There is therefore thought to be some advantages in adopting the 'factor of safety' principle to distinguish between uncertainty and expected performance.

3.3 Current Modelling Practice and Issues

Nick Martin, Thames Water

3.3.1 Introduction

This section gives an overview of current modelling practice, not in the way that we build models, but how we implement the strategies and triggers that our planners develop. Using the models we have to focus on the detail. We can model anything and it is deciding what we use in detail that is important.

Mostly we set design standards using design storms and return periods etc. How this is implemented is extremely important to us, but it not the only issue. Firstly there is it question of choosing whether to design with a 15 year 25 year or even 40 year design storm. There are enough variables in the modelling process that similar standards for protection against flooding can be achieved with alternative methods.

Most of the important points that we need to consider are included in the table that was attached to the original note of this meeting. This paper runs through the issues and variables that we have to consider when specifying a design.

3.3.2 Modelling overview

There is no dissension in the basic model building process. We all collect our data from the GIS, maps and if necessary survey and build network models. We collect rainfall and associated flow survey and other time based data. We verify our models by comparing measured flows with those generated from the measured rainfall, making changes as necessary to get good correlation (Figure 2). We then run simulations with demanding rainfall events and identify areas likely to flood.

From the water levels provided by the models we can understand where the system will flood. We can deduce why it happens at those places, and get an idea of what we need to do to the network to make service improvements. This is where the problems start because what we do to the network in the model will depend upon what we chose to select for our design criteria.

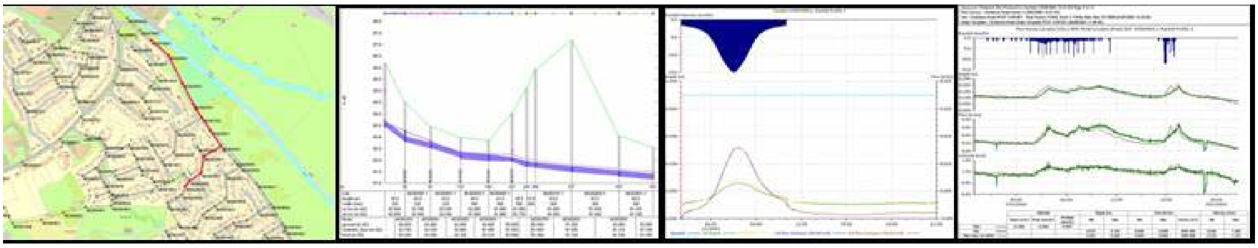

Figure 2 Typical network models (left to right) - Network Plan: Long section: Depth and flow graph: Verification graph

3.3.3 Design criteria

The fundamental criterion is return period of flooding. We usually get to that by assuming that we design for a return period for a rainfall event. We all have the same OFWAT reporting rules. A straw poll of water companies gave a range of return periods used from 1:15 years to 1:40 years. Why should this range of design standards be so large?

According to the OFWAT procedure, if a property been flooded in the last ten years it will be on the flood report. You might assume that designing for 1:15 years is likely to be OK but as Figure 3 shows, if you design with a 1:15 year event there is a 25 % probability of 2 failures in ten years. Designing for a 1:25 year event reduces the probability of 2 failures in 10 years to 11% and 1:40 to 5%. This leads to the question “what is an acceptable level of risk?” and in addition there is a range of other factors besides rainfall that are not directly related to the rainfall event.

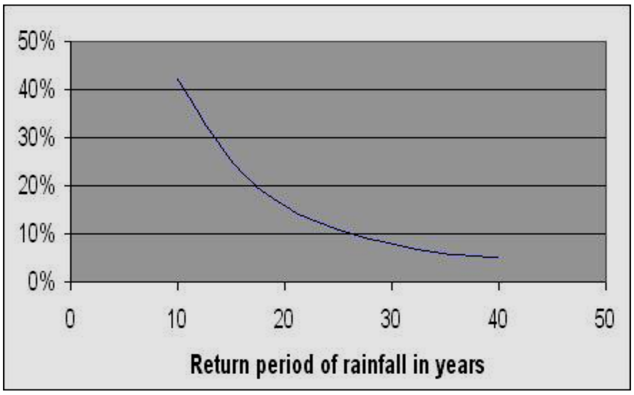

Figure 3 Probability of 2 events in 10 years

3.3.4 Simple risk considerations

Even with rainfall there is a range of risk. We design to a specified return period. The statistics come from daily rainfall records, they don not account for the actual duration of the event. We test the catchment to look for a critical duration of this rainfall, which could be ½ hour or 5 hours. It may be different for different solutions. The chance of the rain hitting this exact duration is small so we could have a small factor of safety here. But the records only take whole days, not rain events spanning two days, so the statistics may have lost some events. We assume that these two factors sort of cancel out.

Climate change – So far the UKWIR work is suggesting up to a 30% increase in design storm rainfall. We could increase our rainfall event return period to get a storm of that size. So far, for most companies this is in the “too new” class, but it is getting to be too important to ignore. Uplift in the order of 1:20 years to 1:40 years gives this increase in design events.

There are a number of other issues that the modelling process forces us to consider:

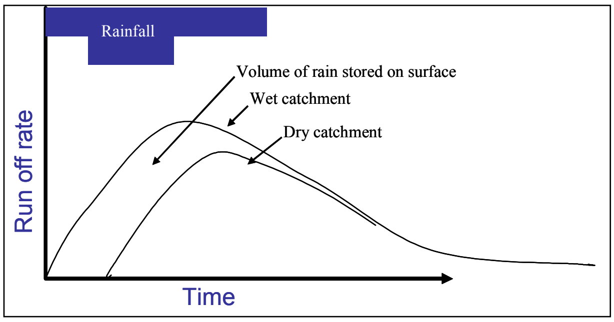

Figure 4 Effect of antecedent conditions

Antecedent conditions - The sewage flow generated in the catchments will depend upon the state of the catchment. A wet catchment will run off much more flow than a dry catchment (Figure 4). A summer storm is likely to fall on a dry catchment, a winter one in a wet catchment. But how wet? Can we say that catchment wetness and rainfall are independent of each other? In which case we could use an average condition or do we specify the worst case we have ever known? Most people probably design to allow for wet catchments. Statistically this gives us a factor of safety, experience says it is essential to do it this way.

Contributing surfaces – This is the collecting area for rainfall. The consensus is that we should allow for the expected growth in the catchment to the planning horizon of the solution. This should give a safe solution until the planning horizon, but since the expected life of sewers is longer than the planning horizon, we will inevitably have a problem in the longer term.

Base flows – Wastewater flows vary diurnally. Using average flows fits with the fact that rainfall can occur at any time of day. The alternatives, which give increasing safety (and cost) are design with peak runoff at peak diurnal and of using continuous peak value.

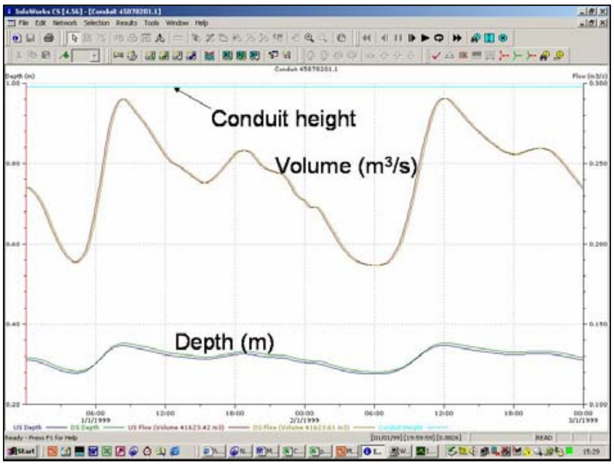

Figure 5 Two days' dry-weather-flow

Infiltration and ingress are a real problem because continuous monitoring is impracticable, and it varies with time of year, age of pipes and antecedent conditions. The consensus view seems to be to use the infiltration measured during the verification flow survey for design purposes. Unless reducing infiltration is part of the solution I prefer to use a value derived from historic flood events. This is often much higher than that during the verification survey and the implication from this is that infiltration and design storms are not independent.

Infiltration will also affect different types of solutions differently. Variations in infiltration may have an insignificant effect on an overflow scheme, but an enormous effect on a storage solution.

Details such as inlets, pipe roughness, siltation, manhole density, and pumping are all part of the network, and unless changes are part of the solution they are left as the verified values. A safer solution would be to allow for some deterioration in condition.

Boundary conditions – These can be details such as river levels at outfalls, Interfaces with other catchments, or unmodelled sewers. Do we assume worst case, which if the river is in flood could be serious? What is the chance of high river levels co-inciding with design events? Designing to worst case of all conditions is expensive, and the chance of all occurring together is probably low.

Acceptable flood depth. - The consensus is that this should be zero but most of us design with very little freeboard in our sewers – is it really valid to assume that our models are accurate enough to permit us to design to water level reaching ground level but no more?

Overland flow – How can we take account of overland flow? It is not ours to manage until it is in our sewers? If it comes out of the sewer it is flooding. But for those events that our sewers cannot accommodate perhaps we should consider alternative flow routes. Is it management of the failure mode or part of planned solutions?

3.3.5 Conclusion

From a modeller's point of view it is much easiest to take verified or average conditions for all the factors above and then improve the factor of safety in design by just increasing the rainfall return period. But from a purist's point of view this is not the way forward as there are several limitations; for example, no account is taken of experience that rainfall and base flows, particularly infiltration and ingress, are related.

Although the hydraulic elements of our models are pretty accurate and resilient, the hydrologic models are less good. The models are calibrated over pretty low rainfall events. How the catchment will perform in high rainfall events is not fully known. As we use bigger and bigger events we are less than certain that the event return period results are really representative of what will happen. I prefer to work with lower return periods but with realistic worst case scenarios selected for the events and solutions being tested. This will improve my probability against failure. For example assuming storms always have peak discharge coinciding with peak diurnal flow; summer storms don't get high infiltration but they do fall on wet catchments; winter events have maximum known infiltration and high river levels, but not rivers in flood! We have carried out some sample testing of doing designs based 1:15 with worst case conditions and compared the outputs with return period storms for average conditions. In general the 1:15 under these conditions is equivalent to the 1:25 year event.

3.4 What Performance is Expected from Sewers and Drains?

Paul Brettell, Severn Trent Water

The first question is whose expectations are we talking about? There are at least four stakeholders and their objectives differ (Table 1) and it is not possible to satisfy all of them in all circumstances, therefore risks have to be assessed and balanced.

Table 1 Stakeholder expecations of drainage

Customers	Companies	Regulator OFWAT	Regulator – EA
Reliable "unseen" service – talk of 20 or 40 year returns means nothing	Happy customers – not having to say "we aren't funded to do that"	Same as customers?	Little or no impact on receiving waters
Low bills	Low costs	Clarity about costs and outputs	No "incidents"
Low consequence if failure does occur – if there is going to be flooding it is better in the garden than the living room	Technical simplicity	Data	Improved habitats
Environmentally friendly	Confidence that solutions will work		
Any problems sorted quickly	A reasonable factor of safety		

risk = likelihood x consequence

- How can we assess the risks simply?
- What level of risk is society prepared to accept?
- What level of risk is society prepared to pay to avoid?
- What factors of safety should we use? During high rainfall is a CSO (consented storm overflow) into a watercourse in spate has a high likelihood but the consequence is low because of the large dilution a failure – should this be considered a failure?

There are further considerations such as "impermeability creep" (patios, conservatories, parking areas, roads, etc.) infiltration, etc. na doperation failure such as blockages, roots, collapses and plant failure e.g pumping stations.

All of these factors should be considered when assessing risk, but clearly different designers will make their own assumptions and therefore come up with different answers.

3.5 Discussion session

Q - How often do we [should we] do flow surverys after construction?

A - We don't do post-project appraisal (PPA) because there are no funds for this activity.

A – We have done PPA on upgraded CSOs but there are no results yet.

A – It is difficult to do PPA because of the long time period over which measurements have to be made to get anything really meaningful.

C – The EA is about to fund HR Wallingford to look at the interaction of rivers and sewers. The EPSRC-Defra-EA project on urban flood management will include modeling linking surface and sub-surface drainage.

Q – Flooding is suffered by <1% of the population [some of it self-inflicted by where they chose to buy their property] and yet 100% of the population is expected to pay to alleviate their problem, what is 100% prepared to pay. There is also the question of how [and where] people want to live and their perception.

C – The trigger for rehabilitation is generally failure has occurred and it is likely to recur.

Q- is "factor of safety" the same as accepted level of risk?

A – Structural Engineers have moved beyond FOS to Failure Mode, i.e. the premise that failure is inevitable and that therefore there needs to be a strategy for dealing with failure.

C - risk and uncertainty have been linked

A – OFWAT has done surveys to inform Ministers to answer the question "what is society prepared to pay?" prevention of sewer flooding will come out high

C – As part of a 15 year study of domestic flush behaviour slogans for altering behaviour were tested by behavioural scientists. They found that people did not respond so well to "bag it and bin it" as they did to "think before you flush" but the industry adopted the former, which has not been terribly successful. We need (as an industry) to recognise that there are specialists in communication, perception, behaviour management, etc. and to use their skills and knowledge.

3.6 Something I prepared earlier

5-10 minute - contributions from delegates

3.6.1 SUDS and Building Regulations

Mike Johnson - Office of the Deputy Prime Minister

The ODPM has been working with the Water Industry and Defra on a protocol for connections – this is that not more than 10 properties should be connected to a 100mm drain. SUDS is not a panacea but it is further up the preference scale than storm sewers; rainwater drainage is covered by Requirement H3; soakaways or infiltration are the preferred method of discharge; PPG 25 "Planning Policy Guidance Development And Flood Risk" (ODPM, 2003) gives joined up thinking on environmental and flooding policies. If we consider a typical 1930s semi-detached house, it was built with a garage as an optional extra, now it will have a paved drive, garage, conservatory, patio and porch, the net effect is that the run-off has doubled.

The Building Regulations require that new buildings have an adequate system of drainage – this is not the same as "effective". Section 59 of the Building Act 1984 requires that building continue to have an effective system of drainage – this is essential for foul drainage but advisable for storm drainage if nuisance and flooding is to be avoided.

SUDS give some problems within Building Regulations because they are perceived to be new technology; we therefore need to improve the knowledge base. Drain designers used to the comfort of mathematically based design processes e.g. flow section, flow depth, wetted perimeter and gradient. We have not got the experience to have been able to quantify the long term effects such as silting, loss of soakage capacity or compaction. We are running on at least 150 years of traditions with piped systems and we don't yet know for example whether a swale whose performance has deteriorated because of siltation can be renovated by spiking. What happens if a system fails long after the site is fully developed? How do you fit in a new surface water drainage system?

Q&A
C – CIRIA is developing design guidance on SUDS

Q – Is the solution to have both?

A – There must be adequate foul drainage as an absolute requirement for permitting a development. SUDS can be used for dealing with surface water and there should be the minimum possibility for cross connection. Appliance sellers should be supplying the EA's booklet "Making the right connection"
[It would be very helpful if this leaflet were available on the web – if it is it is pretty obscure.]

3.6.2 Network Performance and Customer Service - Is There a Connection?
David Balmforth - MWH

The traditional design approach, and embodied in SFA is a 2 year return period for pipe full, a 10-20 year protection against area flooding and 20-50 year protection against property flooding.

Regarding customer service, one of the main concerns is protecting property against flooding and there seems to be a trend to differentiate less between internal and external flooding. The flooded customer does not differentiate between causes, but WSP needs to understand cause and effect.

Figure 6 Road flooding

Flooding might not be sewer related. River and groundwater flooding are common. Flooding might also be the result of a highway drainage problem or it might have a hydraulic, structural or operational origin. The effect can be remote from the cause.

Hydraulic overloading is generally well understood and we have reliable modelling tools that relate overloading to flooding frequency and quantity but they cannot quantify the consequences of flooding. There has been a huge R&D investment in modelling and modelling tools are still improving.

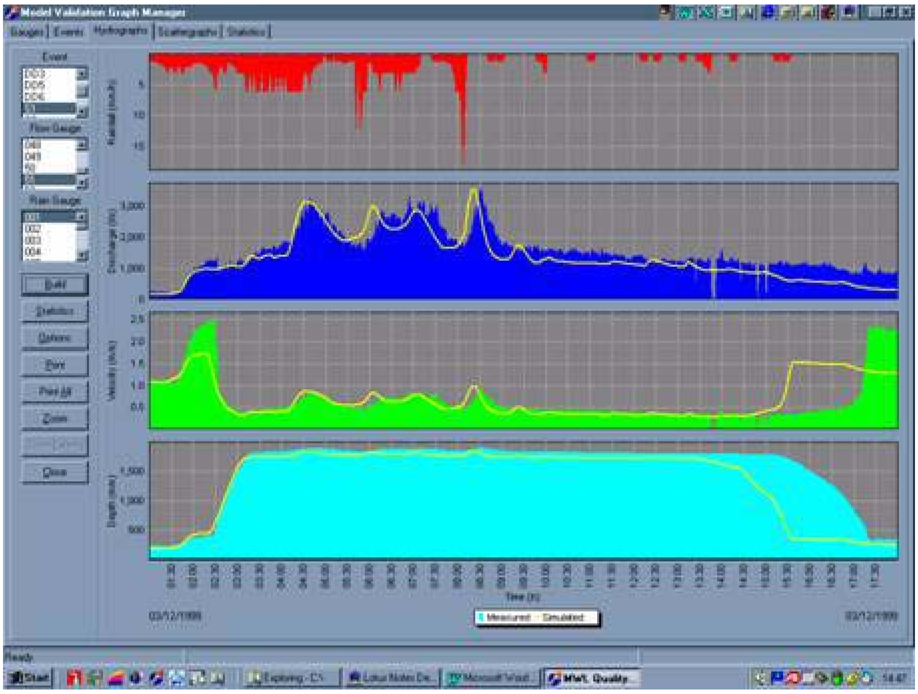

Figure 7 Hydrographs from model validation showing (bottom to top) depth, velocity, discharge and rainfall versus time.

Structural deterioration (Figure 9) not well understood and the necessary survey work expensive; a first pass assessment is required. Hydraulic modelling can replicate the impact of deterioration on flood frequency and volume but it fails to quantify the consequence of flooding.

In order to quantify consequences we need to model above ground pathways (Figure 8) and relate these to property levels, including basements and then combine the results with probability to arrive at a score for risk.

There is a connection between network performance and customer service but there is still a long way to go before we are able to model it quantitatively. One of the biggest gaps is in being able to quantify consequences of flooding.

Figure 9 Inspecting for deterioration

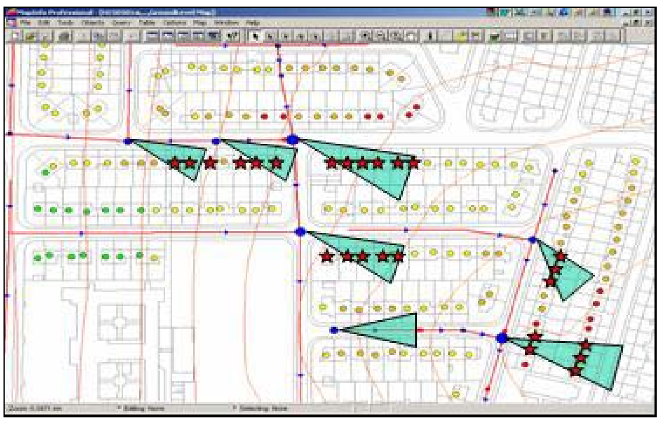

Figure 8 Predictions of overland flow for manholes and the properties affected

Q&A
C – We talk about flooding frequency when really we mean the return frequency of storms that will cause overflow at a manhole. This is not really the flooding frequency. It does not say when properties will flood; one of the research needs is to understand the data that are needed in order to be able to link rainfall with flooding. Even though we have tried to develop alternative parameters all we are really saying at present is the probability of a rainfall event [that is likely to surcharge the network at a particular point.

C – 65% of flooding events are caused by non-hydraulic events.

C – Changes to the infrastructure and development creep will move the points of risk.

C – A lot of the system is working nearly full and does not need much (e.g. silt or partial collapse) to tip it over to flooding.

C – As we have discussed it is not possible to build a sewer that cannot fail; therefore we need to recognise that failure is inevitable and to design this eventuality into the overall infrastructure so that when there is flooding it causes minimal damage. This will need cooperation between agencies that are not currently obliged to cooperate and it might need a change in regulations.

A – the point is well made though perhaps the word "failure" is inappropriate.

C – Colleagues dealing with fluvial (river) flooding are already doing this – Jim Hall at Bristol is working on this topic.

3.6.3 Linking Performance Standards to Service Delivery

Emma Langman – Faber Maunsell

The water company and its associated contractors and consultants are the service providers; they maintain and develop parts of the ASSET so that it can provide a SERVICE to the public, but what is really important to the public is the service; the asset is only the medium by which the service is provided. Only some of the work to maintain and develop the asset actually improves the service; some of the work has zero or even negative effect. The relationship between the asset and the service is often misunderstood. Without an asset there can be no service; any change in the asset today will have an impact on the future of the asset and the service. Providing a service to the public is the number one goal. Maintenance, renewal and operation of the asset must be geared to this service. Effective Performance Measurement is necessary to achieve this. The objective should be to maximise the size of the "good consequences" that we can achieve; this might seem obvious but the confounding factor in all of this is the uncertainties at every level. As has already been discussed there are uncertainties about the quantities of water, the condition of the asset and the effect of work on the system.

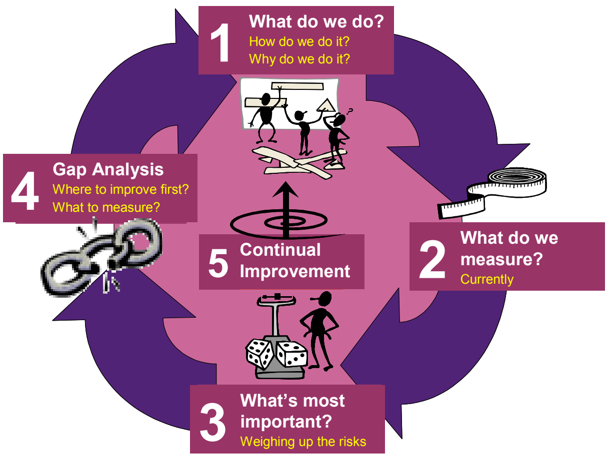

Figure 10 Performance Improvement Cycle (PIC)

Performance Indicators can be valuable provided they are logical; their use can avoid wasting resources, increase job satisfaction and drive improvement. No individual should have more than 4 or 5 PIs, they should cascade at each level.

Figure 11 shows a decision support tool that brings in the element of uncertainty in the data or outcome, etc. For example tossing a coin has a very high probability of coming down heads or tails, with a very small probability of it standing on edge, the bar would be equal red and green possibly with a very small band of white (depending how thick the coin is) for the uncertainty that it will be neither.

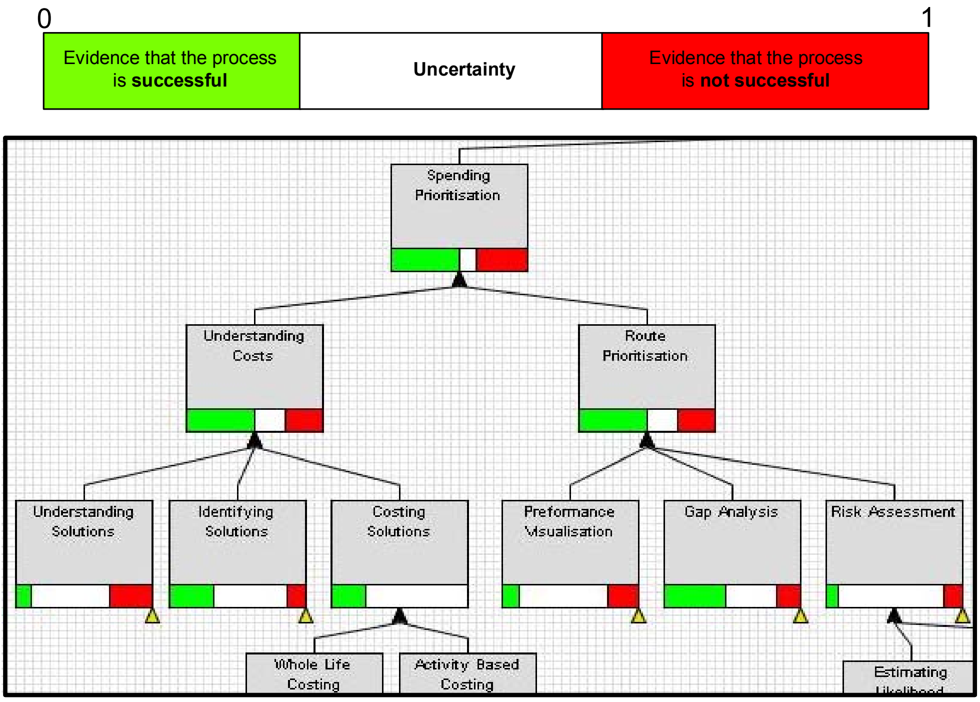

Figure 11 A model for weighting the importance of each element and of including uncertainty

This tool enables you to pinpoint problem areas, show up uncertainty, identify need for new PI's, demonstrate risk, facilitate communication with stakeholders, know how each process influences success, and/or prioritise action. It has been used successfully over a wide range of projects. It can be used to make and defend investment decisions, carry out scenario testing Demonstrate Best Value, and/or prioritise improvements and monitoring. It has been used on soft (employees, customer communication) and well as hard (physical networks) applications. The model could and has been applied to whole networks such as railways where it has allowed uncertainty in the data to be included. By moving the green, white and red bands it is possible to see where there will be maximum benefit from reducing the uncertainty of data and/or of making improvements. Figure 12 shows the summation of outcomes and uncertainties when each component at the lower level (children) have equal weighting, it is also possible to differentially weight the children.

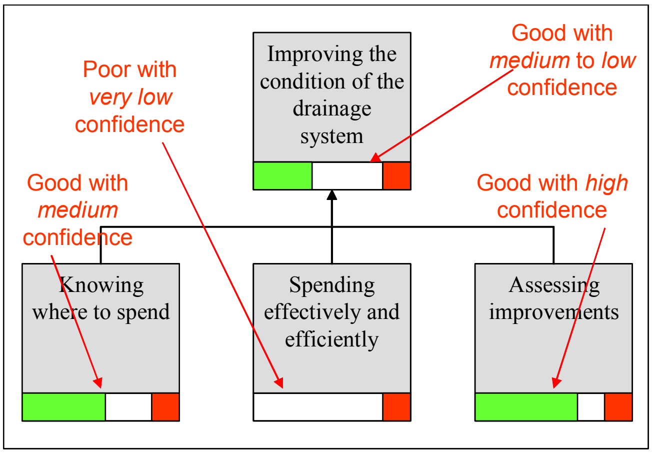

Figure 12 Summing the outcomes and uncertainties

3.6.4 Glasgow Strategic Drainage Plan

David Wilson - Senior Strategist, Scottish Water

Introduction

The Glasgow Strategic Drainage Plan (GSDP) (Figure 13) includes a Policy Review study to review

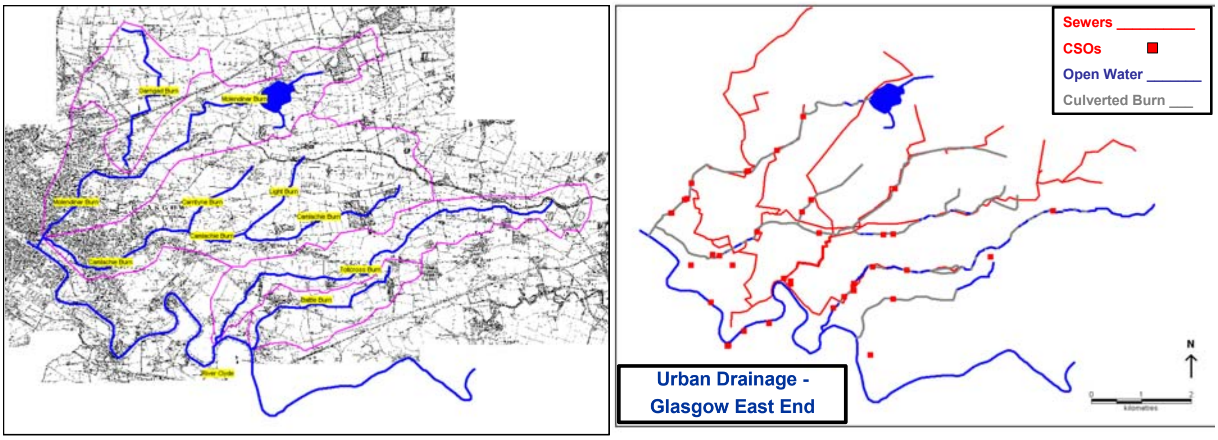

Figure 13 Glasgow Strategic Drainage Plan - The Need

existing drainage legislation, policy and practice and to make recommendations for improvements. It is clear that there were many interconnections between the sewers and the surface water system, some of which was open (and neglected) and some was culverted. Regeneration urgently needed but there are development constraints i.e. £1.5b. There was unacceptable risk of flooding: more than 265 homes were flooded in July 2002; the initial ABI estimate was that there was £100m damages for Glasgow area. There is poor water quality in the burns, which are generally Class C or D, with significant CSO discharges, poor aesthetic quality and low baseflows due to urbanisation. The problems are physically inter-related but responsibilities lie with different authorities and to solve the problems they need to work together.

Stormwater management

In dry weather, sewers convey waste water to the treatment works and rivers carry baseflows to the sea. Problems with existing systems in dry weather may include: operation of CSOs due to blockages or overloading, flooding due to blockages, infiltration of groundwater to sewers, cross connections of foul flows to storm sewers and low baseflows in rivers due to urbanisation. These problems are important because, unlike the temporary impacts caused by rainfall, they don't go away. However, the impacts of rainfall tend to be more dramatic and complex.

Figure 15 Glasgow July 2002

Figure 14 Flooding in Glasgow is not new - this is Paisley in 1994

The focus of this paper's discussion of design criteria is therefore on stormwater management.

Stormwater policy needs to control two aspects of rainfall impact: flooding and river water quality deterioration. Drainage systems need to be sized to meet an agreed set of design criteria. These criteria are subject to economic, social and environmental constraints and it has to be recognized that there will be occasions when extreme events will exceed the design criteria.

Existing drainage system

The existing drainage system serving Glasgow is a function of the age and extent of development and the various drainage policies and practices adopted over the years. Components include:

- Combined sewers (some of these were originally rivers);
- Partially separate sewers;
- Separate foul sewers;
- Separate stormwater sewers;
- SUDS elements;
- Land drains and ditches;
- Rivers.

Stormwater problems associated with this system include:

- Flooding (from sewers, rivers, overland flow);
- River water quality deterioration (CSO spills, storm sewers, urbanisation, farming).

Design principles

Objectives need to be agreed to allow design criteria to be established. We need to learn from past mistakes, understand the limitations of traditional procedures and make the best use of modern knowledge / recent research to set robust policy and appropriate design criteria. The two key principles are sustainability and cost-benefit.

Sustainability means systems should use resources efficiently and should not have a detrimental effect compared to the previous state. A new development added to a drainage network should not make conditions worse downstream.

Rigorous application of a cost-benefit approach would be expensive and time consuming so design criteria have evolved. Criteria do not have to be fixed - flexibility could allow significant cost savings for a small drop in standard or, alternatively, a much higher standard for only a small extra cost. For an initial macro assessment, application of fixed criteria is appropriate. Flexibility can then be considered later when more accurate tools have been built.

Figure 16 SW is investing in understanding its sewer inspections

Future drainage system

At this stage, it is worth considering the characteristics of a future drainage system. Amongst the complexity of issues surrounding urban drainage, a clear vision will help to guide decision making for both new developments and rehabilitation. The vision set down in the objectives for the GSDP is "sustainable urban drainage for Glasgow" but what does this mean in practice? If a new city were being designed from scratch, current drainage philosophy in the UK might suggest the following framework:

- Waste water to the WWTW;
- Storm water in SUDS to mimic the un-developed state as far as possible (i.e. quality and quantity of runoff, no flooding of properties);

- Rivers in green corridors, treated as assets with habitat and amenity value, natural flood plains preserved.

(NB: localised treatment of domestic waste water could be considered more sustainable than centralised treatment but is also less controllable (design, operation and maintenance) and not appropriate for established urban areas.)

Although we are not starting from scratch, this framework can and should be applied to new developments. The political and environmental value of re-using brownfield sites sometimes leads to more relaxed criteria being applied. However, where the existing downstream drainage system suffers from flooding and water quality problems, redevelopment should be seen as an opportunity to reduce the impacts caused by the previous policy. In the East End of Glasgow, the extent of regeneration is significant and this should be seen as an opportunity to gradually move towards the preferred state/vision. The framework described above should therefore apply to all new developments (greenfield and brownfield).

> Initial Strategic Plan Assumption: All new developments will be separately sewered. Only waste water will go to the WWTW, storm water will go in SUDS with no detriment to downstream storm drainage system / river.
>
> *With this assumption, the optioneering process does not need to take account of the detail of design criteria for new development, i.e. river water quality protection, river regime protection, flooding level of service for the site etc. These issues will be covered in the Policy Review report.*

Design criteria

Table 2 sets out proposed criteria for sewers and rivers. For strategic planning with simplified tools (macro models), long term objectives and fixed targets are appropriate. For detailed drainage area plans with more complex tools (detailed models), it may be necessary to also consider short and medium term target levels and consider flexible criteria.

Table 2 GSDP Design Criteria

	Indicator	Trigger level	Target Level	Design Method	Design Exceedance	Other Aspects	Initial Plan Optioneering Method	Comments
Sewers	Internal property flooding	1 in 10yr (10%) (Note 1)	1 in 30yr (3%) (Note 2)	Verified hydraulic model, FEH rainfall + climate change factor, take account of structural and operational conditions	Safe overland flood route to river, i.e. avoiding property and essential infrastructure. Use DTM in flood routing assessment.	If SUDS retrofit is part of solution, some controlled areas may be designed to flood more frequently than external target level.	Unverified macro model, FEH rainfall + climate change factor, precautionary approach when assessing whether flooding is internal / external	Internal flooding higher profile in Glasgow since event of 30 July 02. Should this justify stricter criteria than previous DAP standards? Insurance requirements for properties that have been flooded?
	External property flooding	1 in 5yr (20%) (Note 3)	1 in 20yr (5%)					
	Roads and other areas flooding	1 in 1yr (100%) (Note 4)	1 in 10yr (10%)					External flooding profile raised by Thames Water vs Peter Marcic case - repeated garden flooding judged to have infringed human rights
Rivers	Minor roads flooding	1 in 10yr (10%)	1 in 20yr (5%)	Verified detailed integrated catchment model, FEH rainfall + climate change factor, take account of structural and operational conditions	Risk assessment, SPP7 outer limit for area of concern defined by 0.1% probability (1 in 1000yr).	Target to include habitat and amenity enhancement, SEPA policy on de-culverting, added value of 'blue space'.	Unverified macro model, FEH rainfall + climate change factor, precautionary approach when assessing flooding type	Open channel rivers tend to have higher capacities than piped systems but consequences of flooding are usually greater - leads to more conservative design criteria. Critical duration events longer where there are rural areas in the catchment.
	Property and major roads flooding	1 in 50yr (2%)	1 in 100yr (1%) (Note 5)					SPP7 uses Risk Framework approach. Areas with 0.5% or greater (1 in 200yr) annual probability are classed as High Risk.
Intermittent discharges (CSOs etc)	Water quality or aesthetic quality problem in river	"Unsatisfactory" status (Note 6)	Determined by application of UPM procedure	Modelling tools as required by UPM procedure, FEH rainfall + climate change factor, take account of structural and operational conditions	Level of exceedance allowed by UPM standards.	Operational target to reduce number of CSOs. Detailed design issues, land availability, chamber design, screens etc	Unverified macro model, (a) minimum Formula A pass forward or equivalent, and where applicable (b) <=10spills/yr time series rainfall with climate change factor. (Note 7)	UPM Initial Planning Study needed to establish the Environmental Planning Framework and set targets. Simplified approach needed for initial macro assessment.

Notes:

1 OFWAT DG5 trigger is 2 in 10yrs reported and confirmed flooding. SW DAP Spec'ns also use 2 in 10 yrs trigger. New regional policy for Dublin is 1 in 20yrs trigger.
Sewers for Scotland 2001 also has surcharging criteria for new developments 1,2 or 5 yrs depending on ground slope/consequences of flooding.

2 Sewers for Scotland 2001 has 30yr design standard for new sewers (no flooding of any part of the site). BS EN 752-4 design is 20yrs for residential areas, 30yrs for city centres/industrial/commercial areas
Dublin Policy is 1 in 50yrs target for foul flooding, 30yrs for storm flooding. Other UK WSPs use 30yrs or 40yrs.

3 SW DAP Spec'ns have 1 in 2yr trigger for gardens. WoSW Spec includes parks, public open space in with gardens

4 Detailed assessments could distinguish between road types and specific locations, eg firestations, hospitals, schools etc

5 100yrs is minimum design standard for grant aided flood prevention schemes under 1961 Act. Also requires allowance for freeboard and climate change effects to 2050.

6 Existing definition of "unsatisfactory" given in SEPA's Technical Guidance Manual for Licensing Discharges to Water and taken from UWWTR Guidance note. Policy Report will review - Water Framework Directive will become driver.
Simplified trigger needed for macro assessment, suggest Formula A as minimum standard with additional trigger of 10 spills/yr where there is an impact on recreational waters
List agreed between SW and SEPA of uCSOs, SW have identified subset of vuCSOs (very unsatisfactory).

7 E.g. In the East End catchment, Tolcross Burn and Battle Burn discharge u/s of the Clyde tidal weir, recreational standard may be appropriate for the long term.

To meet the GSDP objectives, deficiencies in existing systems also need to be addressed. The following issues need to be considered:

- Indicators – parameters that can be easily measured for decision making and compliance testing;
- Trigger levels – the minimum level of service below which system performance is unacceptable and needs to be improved;
- Target levels – the desired level of service;
- Design method – including allowance for climate change;
- Aesthetic aspects;
- Environmental aspects;
- Risks of failure / design exceedance;
- Operation and maintenance needs.

Objectives and Vision of GSDP:

- Development constraint removal
- Flood risk reduction
- Water quality improvement
- Watercourse habitat improvement
- Integrated and optimized investment planning

The Vision for GSDP is: *Sustainable Urban Drainage for Glasgow*. Implementing the Plan will achieve further economic development and improved quality of life. As has been noted there are several responsible agencies and having identified the problems Scottish Water (SW) persuaded them to join it in a partnership to deliver the vision, the other partners are Glasgow City Council (GCC), Scottish Environmental Protection Agency (SEPA) and Scottish Enterprise Glasgow (SEG). It is jointly chaired by GCC & SW and there is a joint project management team comprising GCC & SW personnel, they are assisted by various consultant teams.

The Approach:
There are 3 strands of analysis: i.e. sewers, watercourses and SUDS. By analysing these the team will generate potential strategic options and then optimise the options to get the best value solution (macro model optioneering by December 03, detailed model optioneering from Oct 04).
Sewerage optioneering will be led by SW with SEPA and others, they will use macro models to assess basic deficiencies in the trunk sewer network and assess options to address shortfalls in capacity by the following hierarchy of measures reduce, attenuate, transfer, upsize.

Watercourse Optioneering will be led by GCC with SEPA, SW etc. and will use results of hydrological assessment and macro modelling to identify restrictions, consider practical locations for on-line attenuation options, e.g. ponds, examine off-line options where additional hydraulic relief is needed and assess options to address shortfalls in capacity again applying the hierarchy: reduce, attenuate, transfer, upsize.

SUDS Optioneering will be led by SW/SEPA with developers, GCC, etc. They will examine opportunities for use of SuDS in Glasgow East End (new development sites and retrofit) over 5, 10 and 15 year planning horizons and create a GIS database of potential SuDS sites and a case study for academic research (SuDS retrofit) at Shettleston.

Finally and importantly they have to identify sources of funding: Scottish Water; (Q&S2/3), GCC; (Scottish Executive, Europe, etc.). Special funding is needed because SW funding for sewers does not cover the level of strategic infrastructure investment needed in Glasgow East End, GCC can only procure improvements to watercourses through a Flood Prevention Order and developers cannot be expected to fund rectification of historical deficiencies. It is hope that funds will be found from amongst SW, GCC, SEG, Scottish Executive, Developers, Riparian Owners and the European Regional Development Fund.

Q&A
Q This has been a fascinating example and a good demonstration of the value of wider partnership. Who will be responsible for surface water management and ongoing maintenance? Will there be some sort of regional body, will it be undertaken by SW, SEPA, GCC or the LAs?

A It would be best undertaken by a partnership of SW and the LA. The partnership works best when it is led by the LA because the LA has the closest relationship with members of the public. It has taken time and experience for the partners to understand and appreciate each other's various roles, capabilities and responsibilities. Members of the public have become involved with the GSDP by virtue of GCC's partnership and by public meetings – they have buy-in to the solutions and an appreciation that a) everyone is part of the problem and b) that there have to be choices because the funds are limited.

3.6.5 Spatial rainfall for modelling: rain gauges, radar and return periods

Dale Murray - Hydrological Advisor, Met Office

The Met Office has increased the resolution of rainfall radar to 1km in some areas (Figure 17) to improve flood forecasting and severe weather warning in sensitive catchments; the data have 5 minute resolution. This coverage and the information it can provide is much better than is possible with rain gauges as the example of a severe rainfall event in Bracknell, Berkshire 0n 7th May 2000 shows.

A severe storm developed east of Bracknell and a slow-moving intense cell passed westwards over housing along the southern edge of the town; it deposited abouit 70mm rain in just over an hour. 300 properties were flooded and road surfaces were scoured by the surface water.

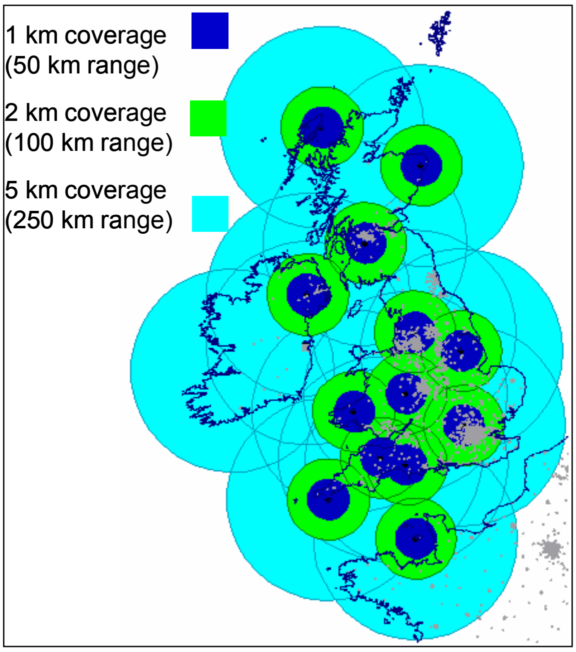

Figure 17 UK radar coverage

Photos courtesy the Bracknell News

Figure 18 Effects of the Bracknell storm - properties flooded (above) and road surfaces scoured (below)

The radar showed a very locallised the storm developing, hitting Bracknell about 1830, stretching out but with the most intense area lingering over the housing and moving off about 2015. By coincidence the area of greatest rainfall happened to be quite close to a rain-gauge "Beaufort Park" which corroborated the radar data. It measured 81.2mm rain and the 1km radar estimated the maximum accumulation was 88.2mm – though this was slightly removed from the location of the gauge.

Thus high resolution radar can give accurate locations of the peaks in rainfall accumulations, and improved estimation of rainfall rates and improved visualisation of the development and motion of the storm compared with rain-gauges (Figure 19). Many thunderstorm events completely elude even dense gauge networks; this case was exceptional because the storm centre passed very close to a gauge (at Beaufort Park).

Figure 20 summarises the event, the data collected and the consequence of that different resolutions would have on predictions, etc, that would be made from them.

The 1km resolution radar estimated there was 88mm rainfall over 2 hours; this would equate to a FEH (IH, 1999) return period of 262 years. The rain-gauge (which was not at the location of maximum rainfall) recorded 64.8mm; this would equate to a FEH return period of 87 years.

Data resolution (km)	*Max. Accumulation (mm)*	*Accumulation at Beaufort Park (mm)*
1	88.2	81.2
2	75.7	63.9
5	53.8	39.0

Figure 19 Storm accumulations from radar compared with gauge data at different resolutions

This case study has shown that 1km radar captures the intensity of rainfall well, and also indicates the extent of rainfall of certain intensities and the speed and direction of movement of the event. Using such data we could develop a suite of 'design' events from actual flood-producing radar-sampled storms that teach would us much more than modelling with rain-gauge data. This highlights the return period issue; it needs to be dealt with. The UKWIR- Met Office work on climate change predicts more lows and thus more frequent intense events.

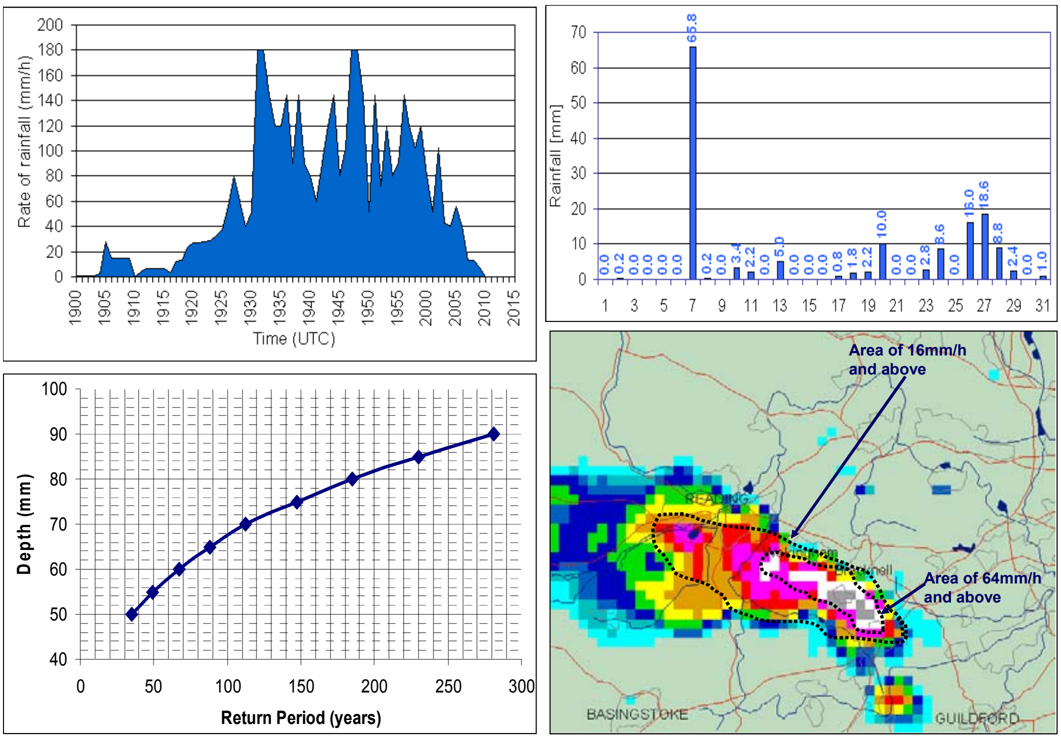

Figure 20 (top left clockwise) Minute-by-minute rainfall rate from the tipping bucket recorder at Beaufort Park 7th May 2000; daily observations for the TBR in May 2000, the spatial intensity extents from 1km radar; FEH return periods for 2-hour rainfall at Bracknell

3.6.6 Case study in Kent

Richard Allitt - Richard Allitt Associates Ltd

This case study illustrates some of the difficulties encountered in trying to ensure no flooding that poses a risk of internal flooding to properties. A small development of 6 houses was planned on a site in Sevenoaks, Kent. The site is prone to flooding (several times each year) from a surface water sewer. This sewer terminates at two large-diameter, deep soakaways (Figure 21) which have a very low soakage [infiltration] rate. The surface water sewer is in the bottom of a dry valley, it is fed by a 600ha catchment. For smaller storms the soakaway shafts provide sufficient storage but with larger or repeated storms their storage/soakage capacities are exceeded and flooding occurs. None of the adjoining properties are ever flooded internally because an overland escape route, which is at a lower level than the properties, comes

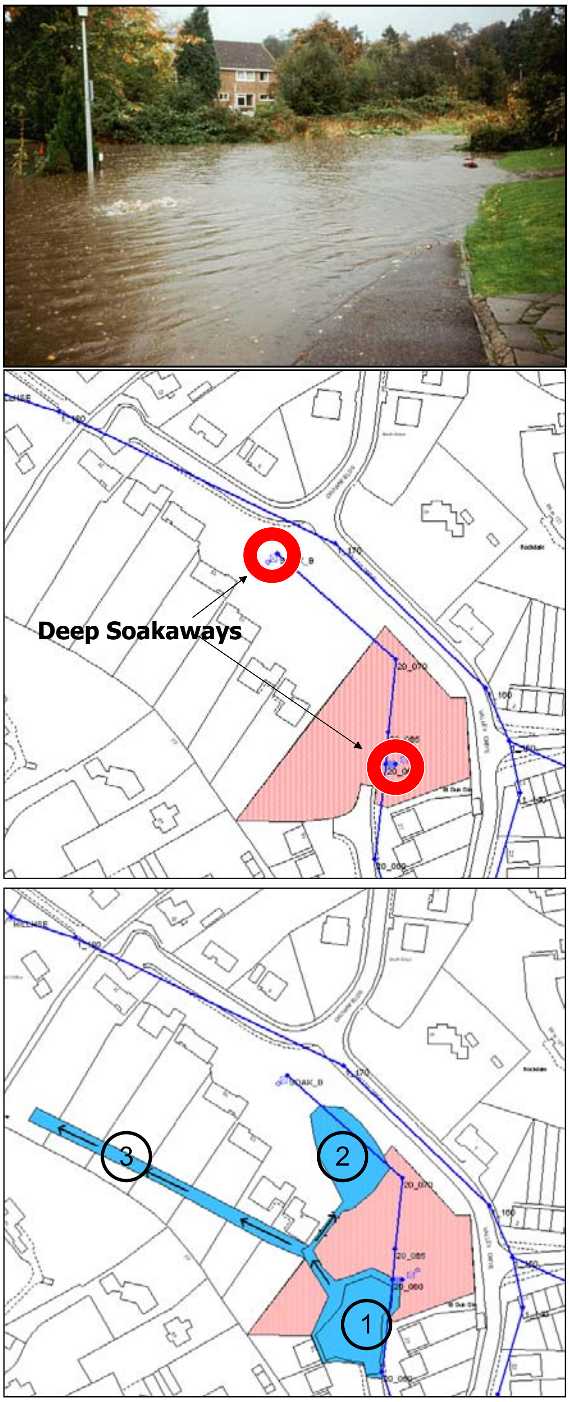

Figure 21 (top to bottom) the current flooding, plan of the site in dry conditions, the flood path and development 1→2→3

into operation. This can be seen in Figure 21, pond 1 forms first (also seen in the top photograph, it then spills to form pond 2 and when that reaches a critical depth the water flows across the back gardens (3).

The proposed development would have altered the drainage arrangements. The District Council has battled for over 7 years with a series of quite aggressive developers and considerable pressure. The Councillors on the Planning Committee were quite adamant that development could only proceed if the flood risk was reduced to a sufficiently low level. The Councillors (on advice) decided that criteria of no flooding from a 1:30 years event and no internal flooding from a 1:100 years event would suffice. This pre-dated the introduction of PPG25 though developers have argued that PPG25 does not apply because it is sewer flooding. Eventually planning permission was granted after the developer had proposed an acceptable solution comprising an additional soakaway, a large storage tank and a pumping system to empty the tank after the storm has passed to another surface water sewer that is at higher elevation. This meant that the developed had to give up one of the building plots. Southern Water has adopted the system.

The particularly interesting point is that the Councillors (and Officers) wanted to preserve the overland escape route and whilst they could (and did) imposes planning conditions on the Developer so that no ground levels were raised or boundary walls / fences built to block the drainage route there was no mechanism to maintain the escape route across third party land.

Another interesting point was that "Sewers for Adoption" appeared to restrict what the Water Company could do because they considered that they were only able to consider the proposals in relation to flows from the proposed 6 houses.

In the ideal world one would probably say that the site should not be developed but it was classed as a 'brownfield' site and there was very considerable pressure for it to be developed. Eventually a satisfactory outcome was achieved but it was certainly a battle and it was mainly the resolute stand of the Councillors which achieved the final outcome.

3.6.7 Design Criteria & Performance Standards for Urban Drainage Systems

Peter Coombs - Micro Drainage

Micro Drainage was founded in 1983 to bring within reach of civil engineers computer aided drainage design solutions running on P.C.'s. To date there have been 40 upgrades and there are >1000 existing customers. WinDes = 'industry standard' drainage design software. It is the policy of Micro Drainage to develop and supply software to the highest quality and reliability and it is accredited to BS EN ISO 9000 & TickIT.

Micro Drainage can design in accordance with SFA. It designs SUDS structures in accordance with CIRIA/BRE and Building Regulations, Requirement H3 and Framework for SUDS. Exceedance & Risk Checks are in accordance with SFA; it includes general design checks, hydraulic design checks, climate change, flood flow paths. Wizards allow multiple storm durations and/or return periods to be analysed in a single run and the sensitivity of networks to failure. Flood paths are predicted on the ground profile. The results are collated automatically and the critical storm duration shown for each pipe. SUDS can be incorporated into complete drainage system. The Design Audit tests a design against a set of pre-defined criteria and generates a report of the findings.

3.6.8 Design and performance standards for urban drainage systems

Prof. Richard Ashley - University of Bradford & Pennine Water Group

The Pennine Water Group has more than £5 million of research programmes:

- EPSRC/EA ‘AUDACIOUS’ (BKCC)
- EPSRC WLC of sewerage COST-S
- EPSRC & water industry WaND
- UK Govt OST/DTI Foresight
- EPSRC water industry Major Flooding FLOOD risk
- EPSRC DesRes Retrofit SUDS

In 2003 IWA published two relevant documents. The manual on Performance Indicators for Wastewater Services (Matos et al., 2003) and the Scientific and technical report on sewer solids (Ashley et al., 2003). The latter has 32 international authors and has been produced by the Sewer Systems and Processes Working Group of the IWA/IAHR Joint Committee on Urban Drainage. In the reports there are a number of elements that are relevant to aspects of the design and performance of urban drainage systems. The PIs manual is concerned with quantifying the performance in a global context and to agreed benchmark standards. A number of studies dealing with future economic and climatic changes have been associated with these reports. An OST/DTI Foresight project on Floods and Coastal defence aims to produce a long-term vision for the future of flood and coastal defence which takes account of the many uncertainties, but which is nevertheless robust, and which can be used as a basis to inform policy. So far it has considered the causes, future scenarios and likely impacts. The current phase of study is looking at the potential responses to manage the increased risks over the next 100 years.

Three of the latest ideas arising from these various projects are:

1. Self-cleansing sewer design

A recent PhD at the Free University of Brussels (Ma, 2003) has shown that if C_v (transport capacity) and w_s (settling velocity) are fixed by the upstream conditions, then a relationship between the slope S_{min} required to maintain a “clean” pipe and the hydraulic radius R_h can be developed in general terms:

$$S_{min} \propto 1 / R_h^{1/3}$$

Hence a circular sewer will be most effective in transporting sediment without deposition if it operates at y/D = 81 % (the relative depth at which the hydraulic radius is maximum for a given D). This result is particularly relevant for the sizing of smaller conduits, such as upstream sanitary sewers. This indicates that situations where there are low values of hydraulic radius (small flow cross-section compared with wetted boundary) are very demanding in terms of required slope (steep). For this reason, large-sized combined sewers should not be designed to have a circular cross-section. The relationship thus provides a rough theoretical basis to explore which cross-sectional shapes are most appropriate. It is obvious that narrow sections such as the egg-shape provide a comparatively better hydraulic radius for a given discharge. They are therefore, most appropriate for low y/D conditions, being more efficient in sediment transport than circular conduits. These ideas match the latest ATV 110 (2001) recommendations.

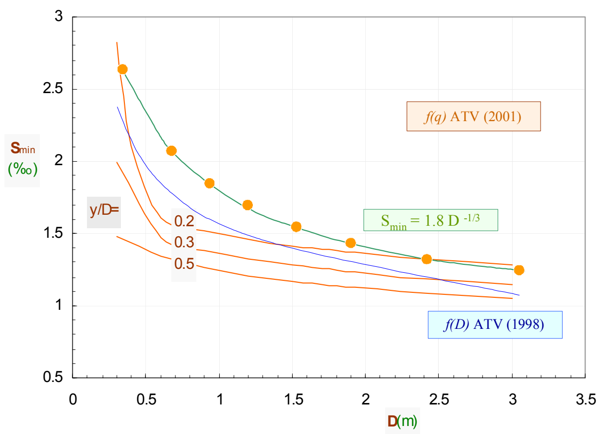

Figure 22 Ma's universal equation

2. Sewer flow quality modelling

Much of the new knowledge about the best way of managing sewer solids has been a rediscovery of approaches that have been in use for millennia, albeit with more advanced technological opportunities. Unfortunately, application of this new knowledge by sewer managers and operators remains relatively limited worldwide, due to a lack of awareness or a mistrust of new ideas. In addition, system designers, relying often on (sewer flow quality) computational model predictions, tend not to be questioning enough of the outputs that are visually impelling from GIS or GUI platforms, not realising that these outputs are often based on imperfect process knowledge. In terms of current practice, there are four types of problem with sewer flow quality models and their usage:

- Deficiencies in model performance due to lack of fundamental knowledge, which should be apparent from the Scientific and Technical Report
- Errors in model coding, limiting parameters and assumptions, usually arising from the need to deal with phenomena for which knowledge is lacking. This is due to the deterministic approach that requires a lot of data and effective process model description.
- Spurious model calibration and 'verification' using inadequate, misleading or inappropriate data; here, the verification of models using infrequent data and samples extracted from a single depth within the flow field can be understood to be of little value
- Unrealistic use of models by extrapolation outside the range of the coded relationships or outside the calibration achieved by data collection. Many of the relationships used in models have been developed in other situations, often for rivers.

The use of these tools without a proper appreciation of the complexity of the problems is of concern. In some countries, however, there is a wariness of attempting quality process modelling in sewer systems. A recent study has identified the limitations of the current generation of sewer flow quality models (Bouteligier et al., 2002) and highlighted the need to collect a lot of local data for these to be at all effective.

3. CSOs and spills

It has been shown conclusively that sewer solids are major contributors to the pollutants transported in suspension and thence being available to be spilled from CSOs during storm flows. Moreover, the major contributor is often the erosion of previously deposited in-sewer solids. This is exacerbated by the fact that CSOs and associated chambers, where installed, have negligible effect on separation of these solids into the flow passed to treatment. The uncertainties of future climate change make precise design of CSOs to today's conditions under AMP3 futile.

In summary, much of what we do is historical and much of it is effective. New ways of managing solids are often simply rediscoveries of old techniques. Nonetheless a lot more new knowledge is needed particularly regarding quality processes. It is a pity that research funding in this area has virtually ceased in the UK – perhaps due to the illusion that current sewer flow quality models actually work?

3.6.9 Northumbrian Water Limited – a Case Study

Richard Woodhouse - Investment Delivery, Northumbrian Water Limited
Garry Edwards - Associate Director, Entec UK Limited

The current situation is that there are

- 73 properties on the DG5 2 in 10 register
- 148 properties on the DG5 1 in 10 register
- Actual Flooding Properties - none added through risk.
- No properties over 10 years old. Don't remove with age.
- Extreme event is 1 in 40 year storm - assumption that extreme rainfall equates to extreme flows.
- New problems due to creep.
- Moving from FSR (NERC, 1975) to FEH (IH, 1999). Study to understand differences carried out

In order to prioritise the work each problem has a "Cause Report". This identifies the location of incapacity and outlines an option that may work. It gives a Flood Value to aid prioritization. The Sewer Flooding Group prioritises the problems. The Programme Manager takes the prioritised list and matches it to programme costs. Projects are launched and re-prioritised after feasibility assessment if this has increased costs.

The design philosophy is 1 in 40 year protection for property flooding, 1 in 20 year protection for curtilage flooding and 1 in 10 year protection for public open spaces and highways against flooding. Designs are checked for worst case storms. NWL has no problems associated with flooding investment other than those linked to errors in modelling. Capital solutions give protection even after extreme events.

NWL has a number of issues, which if resolved would improve the process:

- Rainfall data - radar coverage by the Met Office is poor.
- Post project appraisal – more would be valuable to answer questions such as, is storage utilised?
- Climate Change – we need clarification about how this should be dealt with
- Overland flows and the interaction of tides and rivers.
- Surface conditions - catchment wetness.
- Creep! - how do we predict increased hardstanding?
- Highway drainage connections.
- Costs benefit analysis. Cost versus decreased protection.
- High cost of projects. Low number of properties. Actual not at risk. High extreme events.
- Property purchase.
- Marcic case – how will this affect liability?
- And many many more.

3.6.10 Design vs Asset Life

Gordon Hindess - MWH

What is the? Accountants have said that the current renewal investment implies >500 years Asset Life this has been used by rehab contractors to try to boost the market. None of us will be around in 500 years to see if today's sewers last that long. The average age of the existing stock is >60 years and much of it is >100 years old. In Welsh Water's case the average age is 68 years and 33% is >100 years old. What really matters is condition - again Welsh Water, >70% in grades 1 and 2. The inference is that most assets can reasonably be expected to last a lot longer than 100 years. A more comprehensive analysis of age/condition data and deterioration rates is needed to get from political manoeuvring to technical reality.

What design life do we use? We could allow for future development and increase in water consumption, but: for how long? and how significant in relation to changes in storm element? We might select parameters that allow for a planning horizon which is often quite short. Development and increased water consumption may be significant in CSO design but insignificant in terms of peak flows.

The true design life probably unclear; it is likely that design life is much less than expected asset life, despite the high cost of providing underground capacity. Often designers do not assess how long it will be before the sewer becomes overloaded again, or where it will fail first and with what consequences. An increment on pipe size today may add 10% to cost but add at least 50% to capacity (for sewers up to 525mm diameter), however adding 10% to capacity in the future could easily cost >75% of the original sewer construction cost form this perspective it is false economy to construct to the minimum. This is a serious consideration if you are likely to have to increase capacity within 20-30 years.

Why have design horizons been short? There has been a pre-occupation with the number of properties on the DG5 register (especially 1 in 10). OFWAT is now looking at external flooding and longer return period internal flooding - but both may have been early indicators of tomorrow's DG5 anyway. All flooding is an indicator that the system is under stress and realistic assessment of future changes will show which ones need to be reacted to in today's investment. There has been a policy of "sweating assets" - providing capacity just in time might be economic if you are talking about modular tanks on the surface, but it rarely is if you are talking about creating voids under the ground in urban areas that are already congested. The UCSO programme retains more flow in system; if you keep more of total flow in the system you are almost certainly increasing the hydraulic "stress" somewhere. It is incredible that FRS storms are still used widely, whereas it is known that we have better data than the Flood Studies Report, for example FEH which generally gives greater precipitation.

It might be a harsh generalisation regarding climate change to say that there has been no quantified recognition of its effects - some present at this workshop probably have some understanding of likely effects and an approach to allowing for it in today's design - but I have not seen anybody doing it and anyway it's too late for yesterday's schemes! We have a limited understanding of intense "hot spots" within storms. The Bracknell Storm showed that there can be significant pockets of intense rainfall within bigger storms, but some of country (most of populated Wales) does not enjoy appropriate (1km) radar definition. In Wales, about half of current ARR properties are in the upper extremities of catchments where this high level of definition is crucial to understanding what is going on. There is a general failure to allow for creeping increase in impermeable area in existing areas. Home improvement is a major national hobby that alters internal drainage, it adds roofs, patios, drives, and gets rid of soakaways that don't work very well. Experience with adoptions has shown that these changes start to have an effect even before completion of large developments. Highway improvements, including plaza type pedestrianisation add to the extent of this impermeable creep.

Not all comparisons will look like Figure 23 - sometimes the relationship is reversed or the lines cross, but this is perhaps the most common version: also this is the case that matters because it implies under-design. As an example look at a 30 year storm - FEH rainfall is about 15% more than FSR: but the effective RP of the same amount of rain has dropped to <20 years. A very similar graph can be drawn for predicted climate change effects and, possibly, for creeping increases in connected impermeable area. It is easy to see that combining all these could under-estimate the rainfall entering the system well within the asset life by 40%, or more - so a 1 in 30 design may not even be achieving 1 in 10 years, within a relatively short time; and how accurate is our modeling anyway? Most other branches of engineering recognise their limitations and add on a factor of safety. Traditional sewerage design did this by using conservative principles, like pipe full flow conditions, incremental pipe sizes and not decreasing diameters downstream. Where is the factor of safety now?

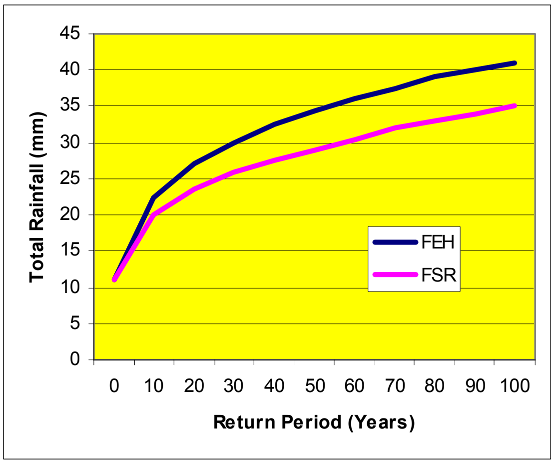

Figure 23 Rainfall return periods

To summarise the discussion of design life versus asset life, your design horizon has been shorter than you think. Design must allow for future storm flows recognising that small increases in flow can cause large reductions in return period. We should return to Victorian principles so that we don't have to go back and retrofit extra capacity in a few years' time. The greater the uncertainty about future flows, the stronger the reason for for building in a safety margin. Are we currently being realistic about this? The consequences of getting it wrong is that we invite costly incremental investment within 10-20 years.

Considering flooding and its impact and acceptability, recent design has often been focussed on DG5 (internal property), has lacked a clear objective for other flooding, has adopted a simplistic storm return period basis and has been of variable standard across country. External flooding may be just an early warning of the next addition to the At Risk Register. There has been a design attitude of – "no money for it, so ignore it", but there might be a very cost effective solution to it if it were done at the same time as an approved scheme; this could be a wise investment because it could pre-empt a problem that will need action tomorrow. The objective of getting property off the ARR has been interpreted as blanket use of 1 in 10 year design storm causing no flooding in the vicinity of property currently on the ARR, but this is dodging the issue of flooding RP in relation to storm RP. The OFWAT Report into investigating the costs of flooding schemes" (Crosbie et al., April 2002) used a limited data set, but identified three design return periods (10, 15 and 30 years). It also suggested that costs are not particularly sensitive to RP. A full study report must be about due and should be of more help, because it should be using an industry-wide larger data set.

Eliminating all flooding is not an affordable option and therefore we need to categorise areas by: potential impact, acceptable return period. We need to design not only to tackle specific flooding, but at the same time consider all flooding. The industry awaits the AMP4 settlements to confirm what is regarded as high enough priority and nationally affordable, but early indications are that relatively little external flooding will be tackled before 2010. Once the financial constraint is recognised, we need to categorise to prioritise and focus investment. The internal/external distinction is relatively easy, but there are grades of external flooding and much more testing to assign priority ranking is needed. If you don't consider all flooding problems, you may miss opportunities for inexpensive additional benefits or end up with haphazard phasing. If you can only do part of the job today, you still need to know how it fits into the longer term strategy.

Are these differentiations acceptable? Flooding in a city centre or prestigious development, 1 in 100 years, whereas excess flow in highway channel 1 in 1 year is acceptable and for low grade agricultural land several times a year might be tolerable [but from sanitary considerations not when the flooding is with foul sewage]. Perhaps the objective should be stated the other way round, starting with internal flooding of inhabited buildings and declaring that as a matter of policy this is unacceptable. This may be practically and technically unattainable, so what is a reasonable interpretation? Flooding shouldn't happen a second time to the same householder? We could argue that few people will be in same house 30 years after the first flooding event but, to achieve statistical confidence in achieving 1 in 30 (or is it 2 in 30) we might need to design for 1 in 50. The incremental difference between achieving 1 in 50 and 1 in 100 may be insignificant, so why not adopt higher standard, unless there is a significant cost penalty? If the cost of preventing internal flooding is greater than the value of the properties is it acceptable to buy the houses and let them flood as has been done in Holland? Any external flooding may result in overland flow to surface water drainage and this could lead to pollution. Current priorities seem to be perverse, they are driven by the "quality" programme; this might give this a higher design standard. Flooding that closes a major road is a much more serious problem than excess flow running down the channel. How would the farming community react to a policy that indicated that their problem was unlikely to be addressed in their lifetime?

An alternative design approach for the future would be to classify the whole catchment by acceptable return period, design the whole catchment for the shortest RP, tweak the design for next shortest and check the overall cost and effect. By a process of iteration it would be possible to derive the longest RP. One could imagine a catchment plan with a patchwork of colours, each indicative of acceptable RP (determining design standard). The whole catchment must achieve the minimum standard. Areas requiring higher standards become progressively fewer through iteration. With experience, I would expect some expedient rationalisation of the iteration process. This could lead to a situation, particularly where priorities dictate a phased approach, where design consciously (it is happening sub-consciously now!) introduces new or worsens existing flooding. Is this acceptable and would it invite justifiable compensation claims? If companies were forced into a "no detriment" condition for design, the cost consequences could be enormous (every scheme that maximises the use of existing capacity is reducing the level of protection somewhere).

3.7 Discussion

C – It is easiest to design with simple rules but these don't take account of real experience which shows that factors coincide, e.g. winter rain coincides with high infiltration or high river flows coinciding with high tides.

C – It would be better to use lower return periods and more realistic design boundaries.

Q – How do we represent what gets into the sewer and what flows across the surface?

A – There are so many agencies dealing with surface flow. We need to get them together cooperating so that we can understand this better.

C – The Danes have invested huge amounts trying to model failures without success because the probabilistic statistical techniques are still too limited. Customers cannot tell the difference between water coming from different sources (responsible agencies). Water re-use in the home could be part of alleviating the problem [see also Appendix 1].

C – The government is investigating the use of grey water both because it is a resource and as a means to would attenuate inputs.

C – Most water companies still use FSR approach to analysing rainfall; UKWIR has compared FSR with FEH.

C – Communication with customers (outreach) about flooding is valuable.

Q – Is intuitive “cut-and-try” accepted and is it a 2-stage process of trial and error?

C – Part H of the Building Regs shows preference for SuDS

C – One of the Water Companies designs all the way down through the system and then decides what it can afford.

C – You could call this iterative analysis

C – It would be better to design up the system.

C – If the form of urban areas is going to change then prediction from experience [extrapolation] are not going to be valid.

C – Society is complex and we shall be in trouble until we recognise this complexity and include people who are expert in this aspect instead of focussing on engineering skills exclusively.

C – Rainfall does not equal customer service and they do not equal network performance.

C – A scheme designed for a 40-year event coped with a 250-year event probably because much of the water didn’t get down into the sewers.

3.8 Workgroup session – the main points of the day

Delegates were divided into 4 groups to debate and agree (in 20 minutes) the key points of the day.

Group 1

- Modelling of sewer flow quality
- Definition of return period
- Understanding runoff – verification to design
- Control at source
- Catchment-wide integration
- Relationship with customers
  - Education about (waste)water management
  - Reassuring
  - Raising expectations
- Catchment specific approach
- Whole life costs
- Statistical jargon [obscures intended meaning] e.g. return period
  - Joint probability
- Regulations for accepted flood routes
- Exceedance of design criteria
  - A system designed for 40 year return rainfall coped with 250 year return rainfall because much of the surface water did not get down into the sewers
- Rainfall type
  - FEH / FSR / TSR
  - Climate change
- Continuous monitoring
  - National programme
  - Post-project appraisal

Group 2

- Need robust design tools
- Rainfall ≠ network performance ≠ customer service
- Service expectations of customer
- Extreme event management – above ground
- Better understanding of extreme events
    - A system designed for 40 year return rainfall coped with 250 year return rainfall because much of the surface water did not get down into the sewers
- Self-contained highway drainage
- Fragmentation of responsibility
- Valuation of each design parameter
- Managing expectations
- Post-project appraisal
    - We do not devote resources to learning from what we have done already, but we should

Group 3

- Clear customer objectives
    - Say as for Glasgow
    - Universal
- Measures for failures
    - e.g. 2 failures per year
    - Defined RQOs
- Agreed method of converting customer objectives to network operation objectives that are SMART
    - i.e., move from rainfall-return to event return frequency
- Co-ordination of approach with other related/associated bodies
    - i.e., land-drainage, highways, etc.

Group 4

- Improving the institutional and regulatory framework
    - Reshape the institutions
    - Getting buy-in from all parties
    - Planning systems are often the problem
- Tools methods and users
    - Recognition of minor [and relation to major] systems and legal protection
    - Designing for extreme events
    - Improve tools and their usage
    - Certification of users
    - Spatial rainfall
- Citizen issues
    - Willingness to pay needs to be better defined – acceptance of risk/responsibility
    - Education

There is a bit of a schism between those who want to be directed, which is understandable in a regulated industry and those who thought that customer buy-in would come thorough involvement and education.

Unintended obscurity through use of jargon was picked up by several and so was the fact that we miss the opportunity to learn via post-project appraisal. Perhaps “smart-pebbles” have a place here – devices which log and/or transmit data and that can be left in the sewers.

There was a similar conclusion to last year’s workshop that storm-water management needs to be coordinated between several agencies so that surface water is directed to locations/routes where it is tolerable rather than where it causes unacceptable damage.

All seemed agreed that rainfall per se is not a satisfactory basis for design.

3.9 Summary

Nick Orman - WRc

3.9.1 The Design Process

3.9.1.1 New Developments

The process of hydraulic design of sewer systems for new developments is outlined in Figure 24

The inputs are first calculated then a simple design process such as the modified rational method is used to produce an initial design. This initial design is then checked for flooding performance and refined in an iterative process until a satisfactory design is produced. This last stage can be described as an 'intuitive cut and try' approach.

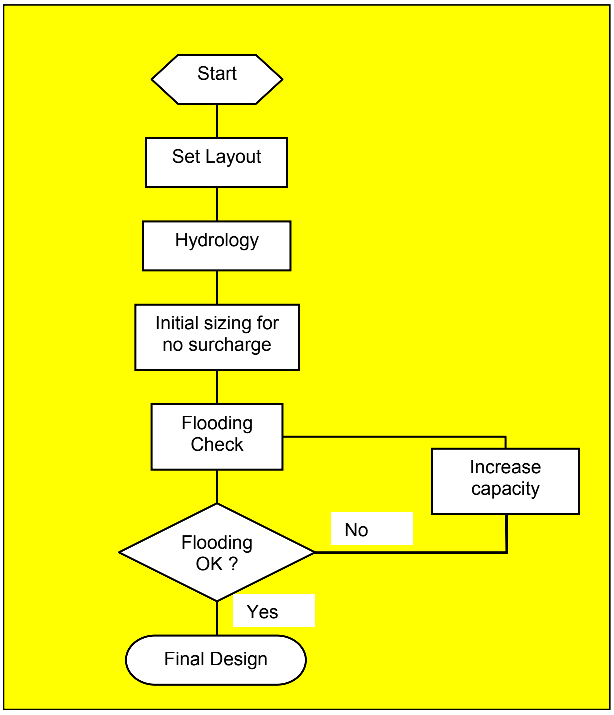

Figure 24 The Hydraulic Design process for new developments

3.9.1.2 Upgrading existing systems

When upgrading existing systems the process is slightly different (Figure 25). A further stage is added to identify the extent of the upgrading that is required.

In rehabilitation the extent of upgrading works (e.g. the number of pipes to be upgraded) often has a larger influence on cost than the scale of the works (e.g. the increase in the size of those pipes). The 'intuitive cat and try' approach must therefore apply to both stages.

The works carried out must be sufficient to solve current problems with allowances to ensure that the work does not need to be repeated in a short time. It is not necessary to solve problems in other parts of the system that do not meet the trigger criteria.

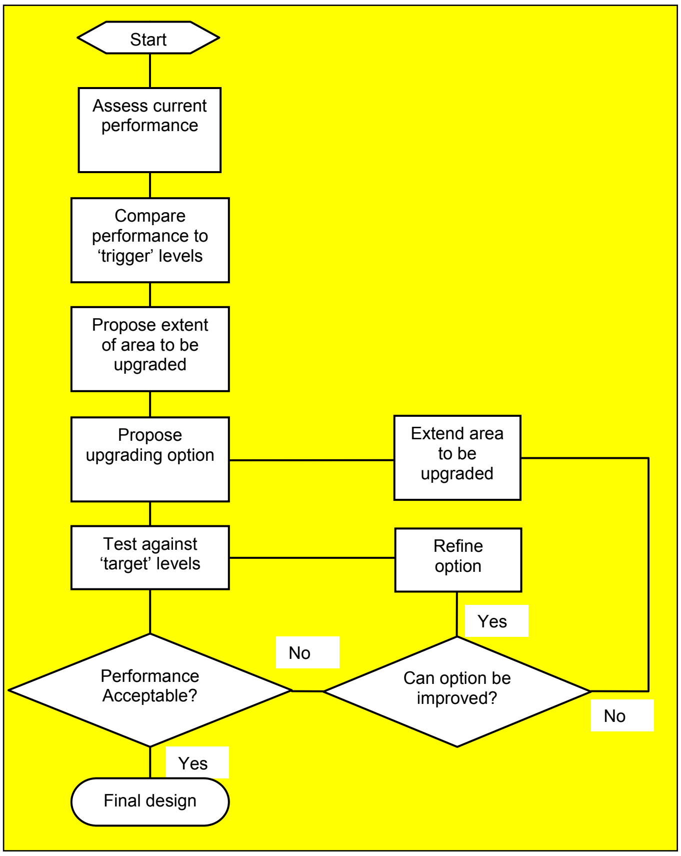

Figure 25 The design process for upgrading existing sewer systems

3.9.2 Design STANDARDS

3.9.2.1 Introduction

The design standards could have allowances for:

- Growth
- Urban creep
- Siltation
- Freeboard
- Overland flow
- Climate change.

One approach would be to simply increase the design rainfall return-period to allow for these but the rainfall frequency is only one of a number of variables.

3.9.3 Design Variables

3.9.3.1 Introduction

The design variables in sewer design include static factors such as the pipe network and the overland flow conditions as well as time-varying factors including:

- Rainfall
- Antecedent ground wetness.
- Base flows – including diurnal variation, and seasonal variation in infiltration.
- River levels.
- Tide levels.
- Growth and creep

The precise solution to the frequency of flooding will involve the study of the probability of coincidence of all these factors. One delegate questioned whether frequency modelling could ever be a precise study. Since this is very difficult in practice (usually conservative) assumptions are made which all contribute the factor of safety in the design.

3.9.3.2 The pipe network

The characteristics of the sewer network affects the ability of the system to cope with different types of storm. The use of SUDS is will also have an influence.

3.9.3.3 Above ground issues

The layout above ground will affect the consequences of flooding should it occur. The performance of the above ground environment (e.g. whether the runoff can actually get into the system) in very extreme events is particularly poorly understood.

3.9.3.4 Rainfall

As well as the classic intensity-duration-frequency relationship there is also the issue of frequency and duration of the inter-event dry periods, which influence both the pollutant load, and the sizing of tanks. On larger catchments the spatial variation and tracking of storms across the catchment can also have an effect. Synthetic storms can be calculated from Flood Studies data (the original Wallingford Design Storms) or the Flood Estimation Handbook method. These can give widely different answers. The effect of climate change is also a consideration. Potentially radar rainfall analysis could be developed sufficiently to allow at least patterns of historic rainfall events to be better known.

3.9.3.5 Antecedent ground wetness

The runoff is also affected by the antecedent wetness. Summer storms are generally assumed to fall on dry catchments and winter storms on wet catchments. The Wallingford procedure only provides values for summer storms.

3.9.3.6 Base flows

Base flows are made up of a number of components including foul sewage, trade effluent, which tend to vary on a diurnal cycle and infiltration which can also contain seasonal elements.

3.9.3.7 River and Tide levels

River and tide levels can restrict outfall from surface water systems, sea outfalls or CSOs. They can also induce infiltration into the system through leakage tide flaps or through the ground. Flows in rivers are often unrelated to the local rainfall that affects the sewer. River engineers tend to use more severe, lower frequency storms. Tides normally vary with twice daily as well as longer cycles. The question of how to combine these variables is currently being considered by a study funded by the Environment Agency.

3.9.3.8 Growth and creep

The amount of impermeable area will change over time as new developments takes place within the catchment and as changes are made to existing development.

3.9.4 The effectiveness of current design approaches

To establish the extent of any factors of safety in current design approaches we will probably need to undertake a significant amount of post project appraisal.

3.9.5 Methods of applying a factor of safety

In structural engineering a factor of safety is generally applied in the form:

[Design Standard] = [Performance criterion] x [Factor of safety]

In some cases different partial factors of safety are applied to different elements to reflect the levels of uncertainty associated with the measurement of that element. (e.g. a higher factor is applied to live loads than dead loads). In hydraulic design a risk approach is generally adopted to flooding. (i.e. risk = probability x consequence). A factor of safety approach could involve applying a factor to any one or more of the variables or assuming an extreme value for any of the time-varying variables.

4 Conclusions

The question posed to the workshop was "Is historic practice still a good enough basis for the design criteria & performance standards for urban drainage systems?". Broadly the answer was "No". There are several reasons for this; some are institutional and some are technical.

Most people accept that climate change is really happening and that the most likely consequence for the UK is an increase in the frequency of intense weather events; intense rainfall is expected to be more frequent in winter and drought and high temperatures in summer. The Met Office's Hadley Centre for Climate Change is generally recognised as a world centre of excellence and yet this UK resource is seldom included in drainage design teams in the UK [though it was engaged in Dublin]. The alternative possibility that melt-water from the Arctic could turn off the Atlantic Conveyer, resulting in severely colder conditions in the UK without the benefit of the Gulf Stream is considered much less likely.

The public's expectations that their premises should not be subject to flooding, irrespective of location are increasing and appear to be supported by the courts with a consequent change in the liabilities of those who manage drainage. Participants concluded that there needs to be more engagement with the public and their "gatekeepers" so that they understand the limitations of the agencies and engineering, the cost implications and the obligations on every member of the public to contribute to flood avoidance, or not exacerbating flood likelihood. Communications and behavioural experts should be engaged in this work.

Historically we have regarded rainfall return-periods as equivalent to (or surrogates for) flooding return-periods but this is a fallacy. Antecedent ground conditions have a major influence on the amount of run-off. The risk of sewer flooding depends on how much surface water gets into the sewers and also how much infiltration there is at the time. All of these are difficult to model and work is needed on these aspects.

Although the premise of the question is that current practice is based on experience, the workshop agreed that we have not been very good at learning from experience because there has not been sufficient allocation of resources to post-project-appraisal, nor to validating models over extended periods including through severe weather events. Partly this is a question of being allowed the funds to spend on this important aspect but partly it is a lack of development of robust, affordable monitoring hardware.

The planning and investment process has not recognised the life of underground assets and the high cost of retrofitting extensions compared with above ground assets. Many of the sewers in use today are over 100 years old, fortunately they were built oversize and to very high engineering standards and they are still serving well.

There are also some innovative strategic tools that do not involve drainage engineering such as rainwater capture at the individual properties to attenuate storm inputs or installing pumps to keep basements dry should also be part of the armoury. The former also has the potential to supplement water resources by providing greywater for toilet flushing and garden watering.

Participants were very struck by the example of partnering that is being applied successfully in Glasgow. The City Council, Scottish Water, SEPA and Scottish Enterprise Glasgow have come together to address historic surface water and sewer flooding problems. This has included engaging with the public to establish, after explaining the options, which they find most acceptable. Plain English and avoidance of jargon has been found essential in the public participation exercise.

5 Recommendations

The workshop concluded that today's custom and practice regarding design criteria and performance standards for urban drainage systems is not good enough especially in the light of climate change and changing public expectations.

1) The price review should allow (and require) service providers to account for climate change in their drainage schemes.
2) The price review should allow (and require) service providers to account for post project appraisal in their drainage schemes.
3) SuDS is not a panacea but it can make a contribution by reducing the load on the underground assets, however we have limited knowledge of their longer-term performance or methods of renovating them when performance deteriorates, work is needed in order that when they age flow does not by-pass them into the sewers.
4) Research and development is needed for robust and affordable monitoring equipment for sewer performance.
5) Design models need to be developed so that they can account for antecedent ground conditions when modelling run-off.
6) We should move from regarding rainfall return-periods as equivalent to flooding return-periods and to achieve this models need further development.
7) Highway design and management of surface water courses should be integrated with underground drainage design so that surface water is not diverted into underground drainage unnecessarily.
8) The potential benefits of emulating the community partnership for drainage that appears to have been so successful in Glasgow should be investigated and applied more widely.
9) There should be investigation into whether there is need for legal obligations and/or institutional change in order that the several agencies are able, and obliged, to cooperate.
10) Design should be allowed to take account of the long life of underground assets and the high cost of retrofitting extra capacity compared with above-ground assets.
11) The creep in impermeable surface should be recognised and wherever possible there should be measures that prevent or attenuate this extra run-off from discharging directly to the drains. Legislation might be required to oblige include attenuation and/or management of this extra water within the development.
12) Extension of the coverage of 1km resolution rainfall-radar is very desirable.
13) FEH rainfall is based on more recent data and should be used in preference to FSR.

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Appendix 1. Contribution from Auckland, New Zealand

Figure 26 Aerial view of North Shore City, Auckland, NZ

Joel Cayford gave a presentation to FWR's Wastewater Research And Industry Support Forum meeting on 28th November 2003 entitled "**Managing Urban Drainage in Auckland NZ**". Joel is a PhD atomic physicist turned Councillor for North Shore City Council, Auckland, and editor of www.watermagazine.com. North Shore City is one of 5 administrations in Auckland, it has 148 km of coastline· 13,000 hectares land area 9,400 hectares served by its stormwater system 3,300 hectares of impervious area (35 percent of the land area) http://www.northshorecity.govt.nz/. The predominant soil type is clay. The average annual rainfall is 1250 mm. The balance of development whilst maintaining water quality is sensitive. There has been a sharp change in conciousness and expectation in the last 5 years. Local councillors in NZ generally run as independents; the local newspaper had been raising awareness of the drainage/water-quality issue for several years; Joel was elected on a sewerage ticket! A high proportion of the population of North Shore City, Auckland has degrees. The rates are approximately equal thirds: sewerage (approx. $400/year), property charge related to value, and water usage (at $1/m^3).

The sewerage systems was modelled with full dynamic calibration following 12 months gauging of 34 sewer catchments in 1997 with 6 local rain gauges. The bacterial impacts of storms were measured. This showed that on an annual basis the loads were WwTP discharge 3%, sewer overflows 14% and stormwater 83% but that during some storm events the load from sewer overflows could constitute >50%. The quantification of the WwTP's contribution is regarded as politically important because it avoided diversion of resources to a discharge of low relevance. Microbial speciation showed the contribution from dog and other pet faeces is minor.

The "do nothing" option would have been to accept twice monthly beach closures because of excessive bacterial counts; this was not publicly acceptable. It was decided to invest $280 million which would reduce beach closures to two times per year. The options for reducing wet weather overflows were: repairing and replacing pipes to reduce inflow and infiltration, increasing the capacity of pipes and pumps to accommodate transport of excessive flows, adding storage facilities to contain excessive flows and increasing reliability to reduce dry weather overflows. A cost optimisation program was run to obtain the mix that would achieve a required performance (containment standard) at least costs. This was an iterative process using: SEWCOM, which uses capacity / costs relationships. The programme involved an extensive rehabilitation program in the leakiest catchments, overflow storage tanks were built underground at 4 locations and the trunk sewers in 1 village were replaced with 1.8 metre diameter pipes to increase capacity and provide flow attenuation.

The trend has been for continuous increase in impermeable areas, greater stream erosion, less open space (less stream recharge) and more cars. The city has decided it wants to reduce impermeable surfaces, minimise erosion, stabilise stream channels, minimise change to base flows in streams and reduce emissions from cars.

North Shore City plans innovation to attenuate flows. It wants to use the volume underneath paved surfaces for flow attenuation by incorporating 1m depth of porous aggregate (i.e. no fines) encased in geotextile, the paved surface and margins thus become swales. New houses will be required to install 5m^3 rainwater storage tanks (with diversion of the first flush of roof drainage); 3.3m^3 will be reserved for storm attenuation and 1.7m^3 will be for household use for toilet flushing, garden watering and washing machine use. Apparently this is also practised in Germany and it is quite satisfactory without any treatment. In some areas of existing development where there is flooding the council is paying to install these tanks to attenuate storm discharge as a less expensive alternative than increasing the sewer capacity.

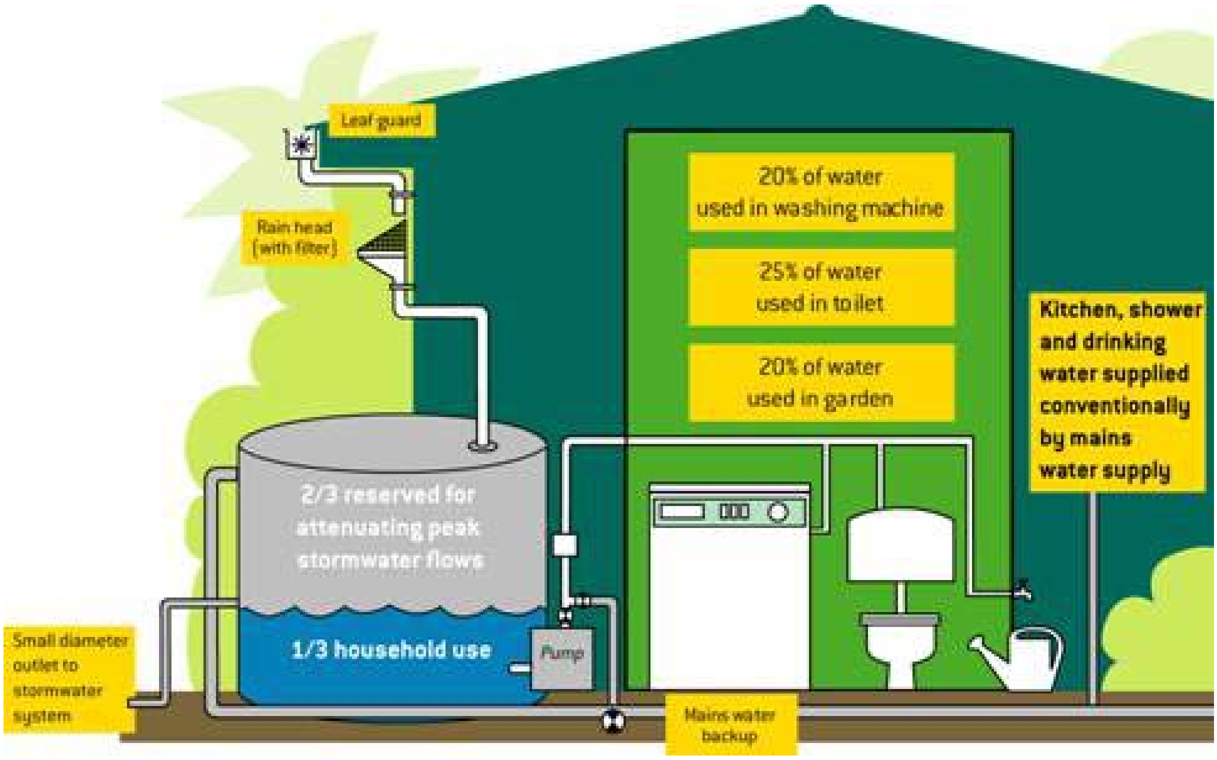

Figure 27 Rainwater capture for domestic use and to attenuate storm flows to the drainage system

Continuous communication to keep the electorate informed is regarded as having been very important.

Appendix 2. List of contacts involved with the workshop

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Appendix 3. Workshop programme

On 24th September 2003 the Foundation for Water Research's Wastewater Forum (www.fwr.org) has arranged a 1-day workshop sponsored by the Wastewater Planning Users Group (www.wapug.org.uk). The workshop will be free of charge to those who are able to contribute vital pieces of the jigsaw. It will be held at the Hilton Hotel, Coventry, West Midlands. The intention is that the workshop will be an interactive working session; it is not intended to be a spectator event.

Numbers will be limited, please send expressions of interest to tim@timevansenvironment.com.

Anyone who has been called on to explain the term 'return frequency' has probably had some difficulty in getting the message across. Recently water companies have been instructed to adopt higher design criteria to protect their customers from flooding; this implies that higher performance standards are expected but how are they going to be delivered?

Traditionally there have been empirical approaches based on 'custom and practice' which in turn has been based on the principle of 'affordability'. However, for the future there is an implied promise that the design criteria will achieve performance that matches demands, i.e. capacity matches storm frequency (or the design criteria are the same as the performance standards). In most areas this would be very unusual. We might rather expect to see something like:

Design Criteria = Factor of Safety x Performance Standard

It is easy to see that flooding frequency, though perhaps dominated by storm frequency, is influenced by a number of other semi-dependent or independent factors. Examples are; catchment wetness, inlet condition, pipe roughness, manhole losses, siltation, etc. There is also the question of allowing for change in future loading so as to give a reasonable design life for the investment, e.g. paved surface density and climate change over 50 years.

The 'design storm' (profile, duration and return frequency) may also need some examination in this context, since it still has strong links (and certainly its origin) in the very dated 'rational method'.

At present designers and clients are vulnerable to accusations of not having given due consideration to reasonably expected changing circumstances, and as a consequence leaving customers exposed to unacceptable risk. Government and regulators are also in line to share in these criticisms. The aim of this workshop is to proactively develop an alternative to custom and practice mediated by affordability.

A good start would be to list all the possible influences on performance, however slight, and then tabulate the assumptions that are made under the stage headings given in the table below.

It is believed that the concerns apply equally to new systems as well as to improvements to existing systems and in this respect it will be important to incorporate the guidelines currently in use for 'Sewers for Adoption' and for the introduction of sustainable urban drainage systems (SUDS).

Table - Design Assumptions vs Performance

Aspect/Topic	Model Build	Initial Verification	Final Verification	Design	Factor of Safety / Design Horizon
Rainfall Input	Design Profile	Design Profile	Actual Events	Design profile at critical duration	1:1 ?
Climate change	None	None	None	?	???
Antecedent Conditions	Average for design	Average for design	Actual	Average for design	???
Contributing surfaces	As surveyed	As surveyed	As surveyed	As surveyed ?	???
Base Flows	As given (default)	As given	As surveyed	As surveyed + growth ?	???
Infiltration	As given	As given	As surveyed	As surveyed ?	???
Inlets	Standard density	Standard density	Modified as surveyed	??	???
Pipe roughness	Given Std.	Given Std.	Modified as surveyed	Given Std	???
Siltation	No silt	No silt	As found	?	???
Manhole Efficiency	Given Std.	Given Std.	Given Std.	Given Std. ?	???
Pumping Plant	As given	As given	As surveyed	As designed ?	1:1 ?
Acceptable flood depth	Zero ?	Zero ?	Zero ?	Zero ?	???
Overland flow	None	None	None	None?	???
Boundary conditions	As given	As given	As surveyed	As given ?	???

The objective of the workshop is to agree how we can move on from custom and practice mediated by affordability to more objective design criteria that will protect all parties better and to identify gaps and decide a strategy for filling them and a timescale by which it will be possible to publish a guidance note or code of practice for designers.

Provisional Programme

0900 to 0930	**Coffee and Registration**
0930 to 0935	**Chairman's Introduction** *Nick Topham, Asset Delivery Manager (UID) Yorkshire Water Services*
0935 to 0945	**Welcome on behalf of FWR and WaPUG** *Tim Evans, Technical Secretary FWR Ww Forum* *Andy Eadon, Haswell Consulting Engineers; WaPUG R & D; FWR Ww Forum*
0945 to 1015	**Current Practices & the Necessity for Change** – what is the problem, what can be done about it now and what is needed if we were able to do it? *Andy Eadon, Haswell Consulting Engineers; WaPUG R & D; FWR Ww Forum*
1015 to 1045	**Current Modelling Practice** *Nick Martin, Thames Water*
1045 to 1100	**BREAK**
1100 to 1130	**What Performance is Expected?** *Paul Brettell, Severn Trent Water*
1130 to 1200	**Risks for Investment**
1200 to 1230	**Priorities for Change**
1230 to 1300	**Something I prepared earlier** *5-10 minute - contributions from delegates*
1300 to 1400	**LUNCH**
1400 to 1430	**Something I prepared earlier** *5-10 minute - contributions from delegates*
1430 to 1500	**What data are or could be available?** and **Which essential data are not available?** Discussion to identify showstoppers and defaults.
1500 to 1530	**Timescales for investigation**
1530 to 1545	**BREAK**
1545 to 1630	**Programme of implementing new guidelines/CoP** Discussion to draw together to contributions from the workshop and assess the timescales and practicability of producing a Code of Practice.
1630	**Close**