Proceedings of the Institution of Civil Engineers
Municipal Engineer 000
xxx 2005 Issue ME01
Pages 1–8

Paper 14024
Received
Accepted

Keywords:
drainage & irrigation/waste water & disposal
Q2

Q1
Anthony Kirby
Costain Ltd

ice

SuDS—innovation or a tried and tested practice?

A. Kirby

There are many obstacles to the implementation of sustainable drainage systems (SuDS) in England and Wales as a viable alternative to conventional pipe systems. However, in Scotland these obstacles have been largely overcome and many SuDS schemes have been successfully implemented over the past decade. This paper will review SuDS in Scotland and compare the structure of the water companies north and south of the border, which is a major factor in implementing SuDS. Also, case study evidence will be used to show how a successful SuDS scheme was implemented in Aztec West, Bristol, over 20 years ago.

1. INTRODUCTION

The principle behind SuDS is to mimic the natural drainage processes of an area. Conventional development of sites often causes land to be covered with large areas of impermeable material that alters the natural drainage characteristics of the land. Conventional pipe systems are designed to convey the runoff from an impermeable area to an outfall as quickly as possible and in many instances can cause receiving watercourses to flood and become polluted. This, coupled with the fact that pipe systems also silt up during low flow means that, in the longer term, they are unsustainable.

SuDS are more sustainable than conventional drainage methods because they are designed to manage flow rates, protect or enhance water quality and are sympathetic to the environmental setting and the needs of the local community by dealing with runoff close to where the rain falls (source control) or attenuating flows and controlling discharges downstream.

This paper aims to review the current issues associated with SuDS in England and Wales and compare the situation with Scotland. SuDS are often seen as innovative solutions to land drainage problems. The paper will challenge this perception by drawing comparisons with 'water harvesting' in desert regions. Many early settlements in these areas of the world needed to harness the infrequent and low rainfall in order to survive. I argue that there are similarities between water harvesting in desert regions and some SuDS processes, even though there are very different reasons for storing the water. I also feel that there is much that we can learn to overcome present resistance to adoption.

Implementation of SuDS schemes in England and Wales is difficult because there is still a 'conventional pipe system' culture. Scotland, by comparison, has implemented many SuDS schemes and seems to have overcome the adoption issues. It is leading the way in the UK and detailed research of SuDS schemes at the University of Abertay[1] has contributed greatly to the successful implementation of many schemes.

Also, case study evidence is provided that shows it was possible to implement a SuDS-type scheme in Bristol over 20 years ago which may suggest we have not learnt much in this time period. Comparisons are drawn to water harvesting in the Negev desert, which are techniques that are 4000 years old. The paper aims to evaluate whether SuDS are really innovative solutions or are a tried and tested technique that has been forgotten.

2. SuDS—AN OVERVIEW

The Surface Water Management Train is a useful technique for developing drainage systems. The principles are given in Fig. 1.

This technique divides the area for draining into sub-catchments. Each sub-catchment may have different drainage characteristics and land uses, and hence merits its own drainage strategy. Dealing with water locally (source control) not only reduces the quantity to be managed at any one point but also reduces the need for conveying water off the site.

The management train starts with preventing both flooding and pollution. The train then progresses through local source controls to larger downstream site and regional controls. Runoff need not pass through all stages of the management train. It could, for example, flow straight to a site control or to a regional control. However, as a general principle, it is better to deal with runoff locally and return the water to the natural drainage system as near to its source as possible. If this cannot be achieved, then site and regional controls are considered in turn to attenuate and to treat flows before discharge to a receiving watercourse or groundwater.

There are two types of SuDS' lamelus 'soft' and 'hard' and these are described in the following subsections.

2.1. Soft SuDS

Soft SuDS comprise the many types of drainage devices that can be constructed in the soft landscape. These SuDS can be used to

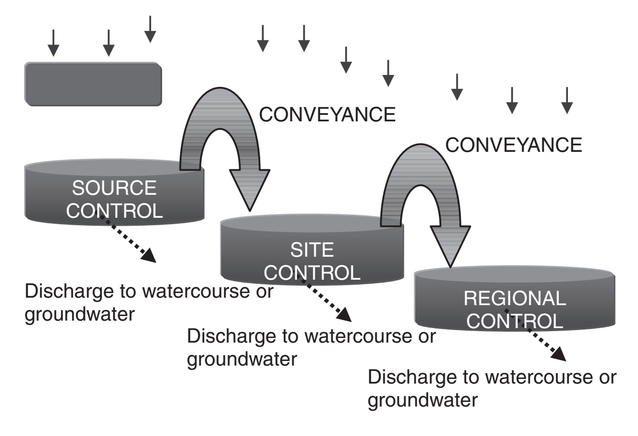

Fig. 1. Surface Water Management Train[2]

provide solutions to local, site and regional drainage problems. The most common types are described below.

2.1.1. Swales. Swales are vegetated surface features that mimic natural drainage patterns by allowing water to run in sheets through vegetation. This has the effect of slowing and filtering the flow, removing polluting solids. The trapped organic and mineral particles enter the underlying soil. Check dams can be incorporated at the outfall of a swale to attenuate flows in a storm but their capacity is limited in comparison with, say, a pond or basin.

In terms of amenity issues, swales are often used in land around developments, particularly road verges. Fig. 2 shows a swale adjacent to a housing estate in Scotland, where many of these devices have been implemented successfully. Local wild grass may also be introduced to the swale for visual interest and to provide a wildlife habitat.

2.1.2. Basins and ponds. Basins are areas for storing surface runoff but are free from water under dry weather conditions. They include the following devices

(*a*) flood plains
(*b*) detention basins
(*c*) extended detention basins.

Fig. 2. Swale within housing estatic (Photograph courtesy of Jeremy Jones[3])

Ponds are similar but hold water under dry weather conditions with the facility to store more water when it rains. These include

(*a*) balancing and attenuation ponds
(*b*) lagoons
(*c*) retention ponds
(*d*) wetlands.

Basins and ponds tend to be used towards the lower end of the surface water management train (site or regional level of control), and so are considered when source control cannot be fully implemented and are primarily designed for flow attenuation to prevent flooding at the discharge point to a watercourse or groundwater recharge. Outfalls from the devices are designed to control the outflow. Plants in the water can enhance calm conditions and promote settlement of solids.

In terms of amenity, basins and wetlands provide the landscape designer with many opportunities. Basins should not be built on but can be used for sports and recreation. Permanently wet ponds offer excellent opportunities for the provision of wildlife as well as being general recreation areas located in public open spaces.

2.1.3. Infiltration devices. Infiltration devices allow water to drain directly into the ground. They are primarily used as source control devices but runoff may be conveyed to them via a pipe system or a swale. Examples include soakaways, infiltration trenches and infiltration basins.

Infiltration devices can be integrated into and form part of landscaped areas. They are ideal for use as playing fields and recreational areas in public open spaces. They work by enhancing the natural capacity of the ground to drain and store water. When designing infiltration devices, the designer must give careful consideration to the groundwater regime of the area and whether aquifers may be polluted.

2.2. Hard SuDS

Hard SuDS are systems that are 'manufactured' and used above or below ground to control and treat surface water runoff. There are many devices; one system is described to illustrate the principles.

2.2.1. Permeable surfaces. Filter drains and permeable surfaces are devices that have a volume of permeable material below ground to store surface water. The runoff flows to this layer of material via permeable surfaces such as grass, gravelled areas, permeable paving blocks, continuous surfaces with an inherent system of voids.

Permeable paving blocks are used to drain car parking and pedestrian areas. This source control system allows rainfall to be intercepted through the concrete block paved surface into a unique sub-base before being released in a controlled manner to sewers or watercourses. Alternatively, if the underlying geology is suitable the water can infiltrate directly into the sub-grade.

Figure 3 shows a typical arrangement albeit this is for a tanked system where the flow is not allowed to infiltrate into the underlying geology. The water leaving the device is cleaned by filtration and microbial action and thus harvested for reuse for

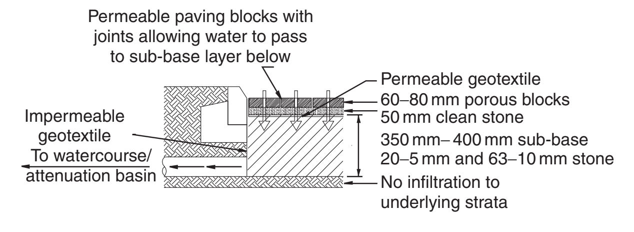

Fig. 3. Permeable paving-typical tanked system

secondary non-potable uses such as flushing toilets and watering soft landscapes.

This permeable paving system has recently been installed for the car parking area for the Fabian Way park-and-ride site in Swansea, West Glamorgan. The system has been designed to allow water to penetrate through the surface at a rate of approximately 9000 litres per square metre per hour. The water is stored under the blocks in the sub-base before infiltrating into the ground below. As the underlying ground has a history as an industrial site it is already contaminated. Therefore, any concerns of polluting the groundwater in the area were considered to be small in comparison to existing contamination levels.

Using permeable paving at this site had two main advantages.

(*a*) It avoided the need for the constructing new drainage outfalls.
(*b*) It offered an economic advantage over conventional gullies and piped systems.

The site is a large flat area and the paving has been laid level, so no false falls had to be created, as would have been the case for a conventional drainage system. The local authority (LA) has adopted the site and will undertake any maintenance works. The site will be monitored over the next 20 years to record how the system performs. The system successfully drained surface runoff from a storm of 50-year return period shortly after the scheme was finished.

3. SuDS—THE ISSUES

At present there are many issues associated with the design, implementation and adoption of SuDS, especially in England and Wales, not least because little is known about the performance of SuDS over long periods of time and whole-life costs. This makes adoption a problem. SuDS are very different to conventional drainage systems and there are grey areas about whose responsibility it is to adopt and maintain different types of schemes. Water companies have with experience of managing SuDS and are reluctant to adopt schemes because they perceive that there is a large element of risk.

In Scotland, many schemes been successfully implemented since 1993 and have subsequently been researched. This is providing data for the selection, performance and whole-life costs of schemes, leading to SuDS being promoted and the relevant authorities working together to ensure the schemes are managed effectively.

The following subsections below examine the selection, design and adoption issues in England and Wales before focusing on the success of schemes in Scotland.

3.1. Selection and suitability of SuDS. When selecting SuDS it is important to give equal consideration to quality, quantity and amenity design criteria. There will often not be a single answer, and a number of devices may need to be implemented in series to produce an overall drainage system.

Stuart Nemes[5] has carried out detailed research into the selection and suitability of SuDS. The research objectives of his work holistically were to promote further the implementation of SuDS in England and Wales by building on existing design guidance (catchment driven) and to produce a transferable methodology. His research was based around participatory 'action research'. This involved the use of 'insider knowledge' or stakeholders (e.g. developers, Environment Agency (EA), water companies) to identify opportunities and constraints as well as to identify and evaluate good practice. Feedback from SuDS sites was used to review the process.

His work culminated in the zoning methodology and a selection and suitability flow chart (*SuDS Guidelines—Zoning Methodology and Selection and Suitability Flowchart*). The principle of the flow chart is to provide the user with a holistic checklist for the implementation of SuDS in three key stages. Q3

(*a*) Determine catchment character.
(*b*) Consider proposed site in catchment context.
(*c*) Site-specific opportunities for and constraints to the implementation of SuDS.

The output of this research can be applied nationwide and given the right information can provide a rapid assessment of suitability of a proposed scheme. This is certainly a positive step in driving forward the implementation of SuDS schemes in England and Wales.

3.2. Design criteria and guidance

Design criteria need to be established at the outset of the planning process by the regulatory authorities, based on the concepts set out by the developer, the information on the site and the regulators' planning, management and environmental considerations. Fig. 4 illustrates the design process as a flowchart.

Selection tools are available to assist with the design of the SuDS. One such tool is that described in section 3.1 above. There is also a selection tool in the main guidance document for England and Wales, C522.[2] This tool is based on the surface water management train and leads designers through the selection process so that

(*a*) drainage techniques will be used in series to meet the design criteria
(*b*) source control techniques are generally preferred to controls further downstream (prevention being the first consideration)
(*c*) the chosen drainage system should be inspired by the original drainage pattern of the catchment.

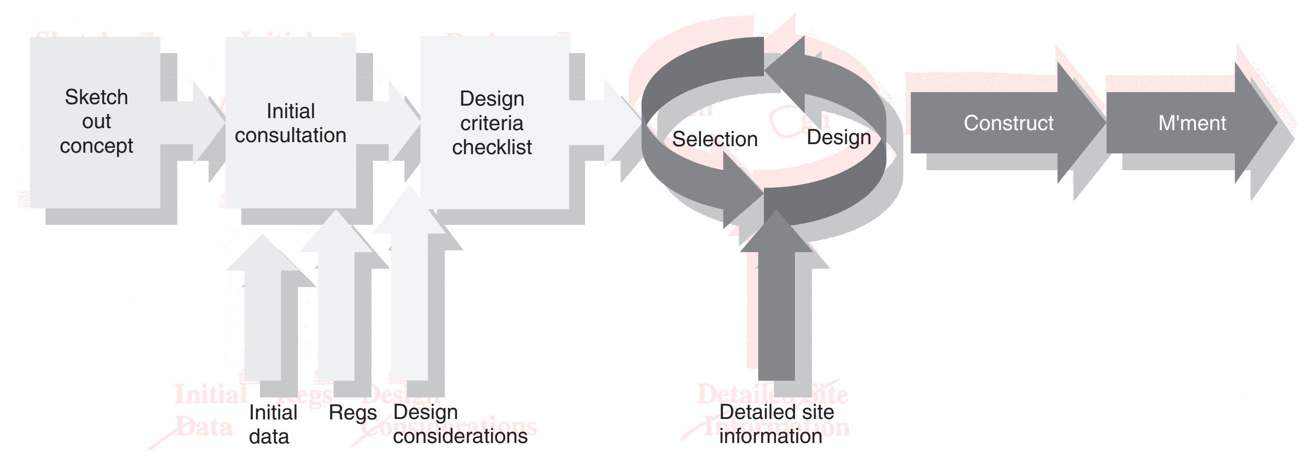

Fig. 4. Design process flowchart[2]

Selection and design of SuDs is an iterative process and factors have to be considered in increasing detail as a final solution is approached. In England and Wales, current guidance comprises two CIRIA manuals (C522[2] and C523[6]) and this limits the scope of some designs. The development of further guidance for England and Wales is ongoing and the National Working Group for SuDS will soon present the findings of detailed research and make recommendations. At present, water companies are working to actively promote SuDS and encourage their use where appropriate. There is an electronic database of schemes that have been constructed so that designers can be made aware of the selection criteria for different catchments. However, the mind set needs to move towards SuDS if implementation schemes are to be on the scale of Scotland.

3.3. Adoption. One of the main stumbling blocks to SuDS is that the current legislative framework in England and Wales is phrased around more traditional drainage systems and is not easily interpreted to include SuDS-type solutions. With conventional pipe systems, there are clear codes and guidelines to
Q3 adoption, (e.g. *Sewers for Adoption*) and water companies know how to maintain these systems, so the risks are minimal.

Adoption of SuDS is seen as a problematic because of the perceived long-term maintenance uncertainties, lack of information on whole life costs of schemes and a general lack of experience. A further reason is that the water companies in England and Wales are privatised and they do not want to be seen to take on liabilities that could affect profits.

Maintenance of SuDS devices may need to be carried out by contractors, developers/owners or even the EA. Developers are not interested in having the responsibility of maintaining devices, as they want to move on to their next development. The EA does not necessarily have the required knowledge or resources to maintain schemes and prefers to be a regulating and advisory body. This outlines the complexity of the issues of adopting SuDS schemes.

In England and Wales, the regulatory authorities are working together to set up a framework for SuDS adoption and maintenance. Dwr Cymru Welsh Water (DCWW)[7] for example has a SuDS policy that includes

(*a*) working with others to promote SuDS
(*b*) encouraging the use of SuDS where practicable
(*c*) promoting the habitat and amenity value of SuDS
(*d*) agreeing maintenance responsibilities
(*e*) encouraging a framework for adoption and maintenance.

DCWW has clear aims regarding adoption of SuDS and has working groups in place. However, there is much to be resolved before SuDS implementation is considered for every drainage scheme in Wales and Deww is currently working alongside the National Working Group in developing guidance. A defined standard is required along with clarity of responsibility so that risks to all regulatory bodies are significantly reduced. At present there is no 'SuDS for Adoption' document. What is needed is to define what types of devices are classified as SuDS and who would be responsibile for maintaining such Schemes.

Thus, the future of SuDS in England and Wales still looks uncertain. To drive SuDS forward the key elements are

(*a*) PPG or similar expression of government policy
(*b*) clarification of the legal position
(*c*) knowledge of SuDS performance
(*d*) the will to do something different.

A demonstration site could be set up for research purposes where there is no liability to any of the regulatory authorities. This would enable adoption and maintenance issues to be explored at first hand and would go a long way to drafting of a SuDS framework.

3.4. SuDS in Scotland

Around 1993, in response to Local Agenda 21 of the Rio Earth Summit, the River Purification Boards in Scotland put forward a strategy that would incorporate Best management practices (BMPs) in the drainage of new developments. The Scottish Environment Protection Agency (SEPA), in conjunction with the EA, further developed the strategy, and the acronym was changed to SuDS to promote the concept of sustainable urban drainage.

It was recognised that SuDS had the potential to prevent the deterioration of Scottish rivers by pollution from urban drainage; hence, since 1993 there has been a wide range of SuDS implemented across Scotland. The process has been aided in part because the statutory arrangements for the provision of sewerage in Scotland are different from those in England and Wales. This appears to have resulted in a more positive approach to the implementation of SuDS in Scotland by 1999 more than 200 schemes had been implemented using a variety of devices (Table 1), and by the end of 2001 the number had risen to 767.

In Scotland, the institutional arrangements underpinning urban drainage differ from those in England and Wales. Here the water authorities have remained in the public sector and this has allowed SEPA to have more influence than the EA in the installation of SuDS. In this context, the concept of 'partnership' has much more meaning. This is in great contrast to the standoff approach characterised by the EA in England and Wales, even though there is little difference between the primary legislation and statutory obligations in these countries.

3.4.1. SuDS implementation[9]. Ten years ago Scotland experienced the same difficulties that England and Wales are experiencing today. SuDS were not referred to in relevant legislation, and therefore responsibilities were not clear. Little was known about SuDS performance or whole-life costs, as there was no information available at the outset of initiating these schemes. This meant that the water companies, EA and LAs were unwilling to adopt SuDS, especially when drainage was shared.

This confusion led to the formation of the SuDS Scottish Working Party (SuDSWP) in October 1997. SuDSWP includes all the relevant parties who support SuDS including the Scottish Executive, SEPA, water companies, LAs and development interests. In working together, the achievements of the group to date are as follows.

(*a*) SuDS Design Manual for Scotland and Northern Ireland (2000).
(*b*) Framework Agreement: model agreement that outlines a responsibility of SuDS.
(*c*) SuDS requirement now an integral part of planning policy in the majority of areas.
(*d*) Research into SuDS well under way (including a SuDS Centre of Excellence).

As a result of the ambition of this group to overcome the problems in implementing SuDS, these drainage systems are now required for all new developments (where appropriate) and are now commonplace in Scotland.

Type	Total
Ponds	34
Detention basins	7
Infiltration systems	5
Infiltration trenches	34
Wetlands	10
Infiltration basins	4
Swales	36
Filter drains	47
Permeable surfaces	28
Total	**205**

Table 1 Types of SuDS planned or implemented in Scotland by mid-1999[8]

3.4.2. SuDS research and monitoring[10]. A team of researchers from universities in Scotland are currently undertaking a series of focused studies to assess the performance of SuDS. The primary aim of this work will be to generate performance indicators for monitoring SuDS and to develop a tool for the use of such indicators for assessing the performance of SuDS.

Research is being carried out regarding provision of a more holistic assessment of systems that have been constructed. Information on approximately 30 sites is being collected at regular intervals through site inspections. A strategy has been developed so that information is recorded with identified variations from a baseline condition (the condition on the first visit). The purpose is to assemble quantitative data on the routine changes and influences on the performance of systems (including seasonal variations). The conditions of systems are recorded on standard proforma sheets along with any other relevant information. The results of these inspections will then be verified with actual chemical and flow data, which have been gathered at certain sites.

Many practitioners do not feel comfortable in accepting SuDS as a routine solution and a greater understanding is required to achieve this comfort. There are still fears over the long-term performance of SuDS and their maintenance requirements because there are no widely accepted performance data on SuDS in the UK. There is a clear need for this information along with data on maintenance, reliability, economics and social acceptance. By demonstrating that SuDS are effective solutions, the uptake of this system will gain in popularity.

This work clearly demonstrates how seriously SuDS are being taken in Scotland. The mind set is clearly on SuDS for solutions to drainage problems and this research work will provide much needed additional guidance and other relevant information. Schemes in England and Wales should be able to benefit from precedents that have been (and are being) set in Scotland.

4. WATER HARVESTING IN DESERT REGIONS

The term 'water harvesting' includes methods for inducing, collecting, storing and conserving rainwater for various purposes. Although primarily meant for irrigation, stored runoff water can also be used for domestic and livestock purposes. Water harvesting has its main application in arid and semi-arid areas such as the Negev desert in Israel. Here, water harvesting differs from traditional water storage in dams by its small dimensions with regard to catchment area and low water volume.

4.1. Water harvesting in the Negev Desert[11,12]

Permanent rivers are totally absent in the Negev, and springs and locations for digging shallow wells are sparse. The casual visitor to the Negev finds it difficult to understand how the early settlements of 4000 years ago developed such a grand civilisation in the midst of such barrenness. However, a careful study of their techniques can reveal the answer.

In order to survive in an environment where the average annual rainfall varies between 25 mm (in the far south) and 200 mm (in the north-west), they had to devise ways of collecting and storing the surface runoff from sloping ground. The ability to collect and store potable water from runoff was the first imperative of desert settlement. Agriculture was also key to the civilisation of this area. In arid regions such as the Negev, crop plants' requirements for water are greatest just where the supplies of natural precipitation are the least.[13] This imbalance must be rectified by augmentation of the water supply and by strict water conservation at all times.

Collection and storing of the limited rainwater was achieved by the use of cisterns (Fig. 5 shows one of the existing cisterns in the Negev). These are artificially constructed reservoirs filled by direct flows during each infrequent rainfall. Early cisterns were crude and inefficient, but with the advent of watertight plaster, recognition of suitable rock formations and the proper construction of channels to collect overland flow, efficient cisterns were built.

Many hundreds of cisterns were built in strategic locations across the Negev—some located along the rim of a natural watercourse, and filled by flash floods. Most, however, were located to catch runoff directly from slopes through constructed channels.

For crop irrigation, runoff from winter rainfalls falling on adjacent slopes was gathered and directed to bottomland fields for periodic soakings. This allowed the soil to accumulate and store sufficient moisture to produce crops. This process is known as 'runoff farming', and the runoff farmers were able to develop intensive agriculture in the depressions of the bottomlands. These bottomlands totalled only around 5% of the total area of the Northern Negev Highlands. The agriculture was essential for sustaining life in the Negev and provided the catalyst for the grand civilisation of this region.

4.2. Comparison to SuDS techniques

The principles employed by the early settlements in the Negev to harness rainfall water are similar to some SuDS techniques.

Fig. 5. Typical negev cistern

Water harnessing in the Negev principally involved the conveyance of runoff to storage basins, replicating the natural drainage patterns of the land. In terms of SuDS, swales can be used to convey runoff and ponds and basins are used to attenuate and store the water if source control cannot be implemented. Here, the natural drainage pattern of the land should also be used as inspiration for the scheme. The reasons for storing water could not be more different between SuDS and water harvesting, but the basic principles are similar. Both require full control of the flow using natural drainage patterns.

SuDS build on the principles of water harvesting by considering quality and amenity issues in addition to the quantity requirement, which is paradoxically common in both types of processes. However, if SuDS are based on natural and ancient principles, then they cannot be described as innovative solutions to drainage problems. SuDS have also been present on land in its natural state; it is the development of the land over many thousands of years that has blinkered us from using natural drainage techniques in finding solutions.

5. AZTEC WEST: A CASE STUDY[14]

Aztec West near Bristol is a well-known office and light industrial development park. Parts of the site are still under construction but most of it has been complete for between 10 and 20 years. In the 1980s, its high-quality buildings and open landscaping set new standards for developments in the UK. The consulting engineers for Aztec West were Peter Brett Associates and they were responsible for the design of the site-wide drainage scheme.

5.1. Drainage design

The site drainage was designed before SuDS became a universal term, and the detention basin and retention pond design is one of the oldest examples of 'SuDS' for which the original design data are available. The landscaping and ponds are an integral part of the pleasant working environment created on the development.

The drainage scheme for the site was designed in 1978 when the 'urban drainage triangle' (quantity, quality and amenity) was not heard of. However, even in 1978 the design team covered these objectives.

5.1.1. Quantity. The discharge rate was set by the LA and was the only true design parameter that was used in the storage calculations. The site has four main storage ponds, three of which are cascaded in series and serve the majority of the development. Two of these ponds have permanent water (retention ponds) and the third is a detention basin that is dry most of the time. The storage quantity was designed for a storm event of 30-year return period using the best methods of the time.

5.1.2. Quality. The quality of the water in the ponds and the impact on aesthetics was of prime concern to the design team at Aztec West. Oil pollution was the main concern as the lakes were fed from car parks and roads, one of which was part of the M5 to the west of the site. Parallel and tilting plate oil interceptors were considered for the scheme but the cost of providing these was estimated at £60 000—a large sum of money in 1980. For this sum, it was recognised that a great deal of landscaping could have been purchased, so other alternatives that would add to the amenity appeal of the development were considered.

Ornamental fountains were chosen as the solution to the pollution problem. Hydrocarbons in oils are broken down under aerobic conditions and this was recognised by the design team. By providing fountains, not only was a method of providing and maintaining aerobic conditions identified, but also the amenity appeal of the site was enhanced. Provision was also made in the design to retrofit petrol interceptors if a problem ever materialised, but this has never been an issue in over 20 years.

5.1.3. Amenity. The brief was to produce a high-quality development with, what was at the time, a large landscaping budget. This meant that runoff flow storage had to be an integral part of the landscaping to provide amenity and added value to the development. Care was therefore taken to ensure that any civil engineering structures were as unobtrusive as possible. Walkways and furniture were provided around the ponds to encourage people to enjoy the amenity.

5.2. Comparison to best practice and specifications today

In over 20 years there have been no reported problems with the ponds at Aztec West. The ponds are stocked with carp and silver fish and the EA has health-checked the fish population and found everything to be in order. This is a good indicator to the performance of the ponds in terms of pollution control. So, if a scheme can be successfully implemented over 20 years ago, why is implementation of SuDS so difficult today? Detailed below are items that were or were not considered at the design stage of the scheme, and how these compare to best practice today.

5.2.1. Infiltration trenches and swales. At the design stage, neither of these SuDS devices was considered. Infiltration devices would probably not be considered today as the site is underlain with impermeable clay. Swales would also probably not be considered due to the public perception of them being ‘unpleasant’ and a ‘nuisance’. Swales have good hydrological properties but the public perception of SuDS and their aesthetic value are important.

5.2.2. Treatment volume calculation. There is currently a method for calculation of the treatment volume (permanent water) to be provided in retention ponds given in Appendix B of C522.[2] The recommended volume of permanent water is recommended to be $4xV_T$ (where V_T is the volume of water to be treated). Applying this method to the ponds at Aztec West, the treatment volume equates to approximately V_T. However, the provision of the fountains increases aeration of the ponds and the ponds were also designed with a hydraulically efficient shape.

5.2.3. Biodiversity. Today, biodiversity would be considered for a scheme like Aztec West. The ponds were constructed with depths ranging from 0.5 m to 1.2 m which falls within current recommendations. However, in addition to this, a vegetated margin with local aquatic plants would be recommended today to increase biodiversity and reduce pollutants through vegetative treatment.

5.2.4. climate change. Climate change was hardly talked about 20 years ago and so was not considered when the scheme was designed. Today, provision for climate change must be included in any design procedure. The ponds at Aztec would have to be sized for a storm event of 100-year return period rather than the 30-year period specified at the outset of the deign in 1978. Computer programs now allow the designer to go to this level of detail when designing storage devices.

5.2.5. Maintenance requirements. There are costs associated with maintaining the ponds at Aztec West, especially the fountains. However, the maintenance costs were not considered to be an influencing factor at the time of the design. The ponds, if anything, have reduced the maintenance costs of the area by decreasing the land area to be mowed and maintained regularly. Today, maintenance issues would be considered in much more detail, and performance indicators of the scheme would be assessed before implementation.

In conclusion, nowadays good design requires the consideration of many aspects. However, the success of the scheme at Aztec West in terms of all SuDS indicators promotes the view that appropriate SuDS should be encouraged wherever they can be accommodated. If properly designed and constructed, they can provide solutions to quantity, quality and amenity issues. It has been achieved before by schemes like Aztec West, so there is a precedent to work to.

6. CONCLUSIONS

The barriers to the implementation of SuDS in England and Wales are well documented and have been discussed here. However, the paper has shown that SuDS techniques are not new, and schemes have been implemented successfully in the past. The principles of SuDS are based around natural drainage patterns of the land and there is proof that these principles were used over 4000 years ago in the Negev desert to harvest water.

SuDS have also been implemented with great success in Scotland since 1993. In part this has been possible due to the structure of the Scottish water authorities, but credit must also be given to the determination shown by the relevant authorities to overcome the problems of adoption and maintenance. Also, the monitoring programmes in Scotland are providing the information required to successfully design and implement appropriate schemes.

The scheme at Aztec West is proof that SuDS are effective drainage solutions if designed and built correctly. Although this scheme was built over 20 years ago, it is still performing as intended and it fills much of the design criteria that are required today. However, its implementation in 1980 was relatively straightforward compared to the implementation process today.

It seems that the current barriers, especially in England and Wales, are a deterrent to SuDS even being conceived at design stage on many projects. However, the sustainability issue is slowly being recognised and research is being carried out into the long-term issues of SuDS. Many water authorities in England and Wales are prepared to encourage schemes if they are appropriate and successful SuDS have been implemented recently, a good example being that at Hopwood Services on the M42. However, schemes of this size are few and far between in England and Wales.

There is much to be done before SuDS are considered for all projects, not least a review of the current guidance. However, there is evidence that SuDS do perform better than conventional pipe systems, and provide sustainability if they are appropriately designed. It can be argued that SuDS are tried and tested practices but schemes need to be designed with careful consideration for them to be successful. At present we also cannot be sure of the long-term performance of SuDS but research and monitoring work should provide an insight into this.

References

1. Jefferies C. and McKissock G. *SuDS Reference Manual*. University of Abertay, Dundee. Q4
2. Construction Industry Research and Information Association. *Sustainable Urban Drainage Systems: A Design Manual for England and Wales*. CIRIA, 2000, Report C522. Q4
3. Jones J. *Finding a way though the maze*. SuDS Conference, Bradford, 2004. Q4
4. Thomas P. Fabian Way Park and Ride Scheme. *Proceedings of a SuDS Symposium*, Cardiff, February 2003.
5. Nemes S. Selection and suitability of SuDS: a holistic approach. *Proceedings of a SuDS Symposium*, Cardiff, February 2003.
6. Construction Industry Research and Information Association. *Sustainable Urban Drainage Systems: Best Practice Manual*. CIRIA, 2001, Report C523. Q4
7. Evans R. Sustainable drainage systems. *Proceedings of a SuDS Symposium*, Cardiff, February 2003.
8. Jefferies C. Implementation of SuDS in Scotland. *Proceedings of Coventry Conference*, September 1999. Q4
9. Guz F. SuDS implementation—the Scottish experience. *Proceedings at a SuDS Symposium*, Cardiff, February 2003.
10. McKissock G. Monitoring the performance of SuDS. *Proceedings of a SuDS Symposium*, Cardiff, February 2003.
11. Hillel D. *Out of the Earth: Civilisation and the Life of the Soil*. Aurum Press, 1992. Q4
12. Esser K. *Water Harvesting in Dryland Farming*. Obtained from http://www.nhl.no/noragric/research.htm. Accessed 4 March 2003.
13. Hillel D. *Negev: Land, Water, and Civilisation in a Desert Environment*. Obtained from http://www.unu.edu/unupress/unupbooks.htm. Accessed 4 March 2003.
14. Millerick A. A review of 20 years of SuDS specifications in the UK including a review of the operational experience of a 22-year-old SuDS system and how recent developments may alter the design approach. *Proceedings of a SuDS Symposium*, Cardiff, February 2003.