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.

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Aztec West

Aztec West near Bristol is a well-known development for offices and light industrial units. Its high quality building and open landscaping set new standards in the 1980's for development in the United Kingdom. Aztec West's main infrastructure was designed and built between 1978 and 1982. The consulting engineers were Peter Brett Associates and the author was the design engineer responsible for the drainage of the site.

Figure 1: Plan of Aztec West development with retention ponds and detention basins. Drawing supplied courtesy of Peter Brett Associates.

It was designed before SuDS became a universal term and it is one of the oldest examples of detention basin and retention pond design for which the original design data are available. Most examples detailed in the Ciria 523[1] manual of best practice will take several years to yield long term data and experience. On older catchments reference is seldom made to the original design objectives and specifications as these can be difficult to research.

Parts of the Aztec West site are still under development but most of it has been completed for between 10 and 20 years. It is regarded as one of the most prestigious office developments in the country and the landscaping and ponds are an integral part of the pleasant working environment created on the development. The current operators are Arlington Business Services Ltd.

SuDS are now judged under the objectives of the **"urban drainage triangle"** of **Quantity, Quality** and **Amenity**. We had not heard of this triangle in 1978 but the design team objectives covered these points. The quantity was dictated by the local authority in the form of limited discharge while the quality and amenity objectives were in the interests of the client and both were endorsed and encouraged by them.

Quantity

The site has 4 main storage ponds. 3 storage ponds are arranged in series (cascaded) and serve most of the development. Two of these ponds have permanent water and would be referred to now as retention ponds [(2)] while the third is a detention basin that is dry most of the time.

The allowable discharge was agreed by the local authority. It was decided to provide storage based on a 30 year return period Bilham[(3)] event. The recommendation of Road Note 35[(4)] at the time required the engineer to seek Met Office guidance on rainfall. The Filton Met Office station provided rainfall records so the Bilham formula could be calibrated locally. Later the Wallingford Procedure was published in 1981[(5)] using FSR[(6)] rainfall and the latest FEH[(7)] data became available in 1999. This data improves on the Bilham approach but as local data was used to calibrate the model the later methods do not offer any major advantage in this case.

The TRRL approach[(4)], current at the time, assumed 100% runoff from paved areas. In 1981 the approach was to assume 75% runoff from paved areas (summer season) while in later years this has been increased for winter rainfall to a typical value of 84% [(8)].
The functioning of the cascading ponds was too complex for any "short cut" manual method of calculation so the author wrote a computer program tailored for the site. It ran for a considerable time on a Commodore Pet computer with 36k memory. Dozens of runs were required and when in 1982 a significant storm was recorded some validation was possible – the water level was 100mm lower than predicted which suggested the TRRL assumption was a little conservative and confirming the later percentage runoff equation from the Institute of Hydrology.

Quality

I was not concerned with the quality of the discharge so much as with the quality of the water in the ponds and the impact on the aesthetics. However these two objectives are interrelated. Oil pollution was my main concern as the lakes were fed from car parks and roads that included part of the M5 motorway to the west.

I visited Milton Keynes (circa 1979) to obtain their experience of oil pollution. They had constructed large amenity ponds fed from road and car park drainage. Measurements carried out by the Technical Services Department of the Borough of Milton Keynes[(9)] where Parallel Plate Oil interceptors were used, showed that up to 360 litres/hectare of oil was washed off car parks every year and was skimmed off the oil interceptors. These car park areas were still relatively new and as some absorption was assumed the quantity considered for deign purposes was 450 l/hectare per annum [(10)].

This implied that at Aztec West the average concentration of oil in the runoff from car parks would be 28ppm. This would be diluted by runoff from roofs but much higher concentrations could be expected from "first flush" runoff at low intensities. Data supplied by Anglian Water Authority showed that they had experienced concentrations as high as 110ppm prior to treatment but most results were less than 10ppm[(10)].

The parallel plate or tilting plate oil interceptors were claimed to reduce oil concentrations to less than 5ppm for 95% of the time and measurements at Milton Keynes supported this claim. Oil could be visible as iridescence at concentrations greater than 20ppm and visible oil was unacceptable. Therefore the traditional 3 chamber oil interceptors were not considered for any other purpose than intercepting oil spills on individual car parks. Their performance would not guarantee a 5ppm standard for 95% of the time.

Two manufactures A.W.S Delta Limited and C.J.B. Developments estimated £250,000 for the construction of the interceptors in 1980. This was based on a droplet size of 0.06mm. A standard based on the American Petroleum Institute's recommended particle size of 0.15mm reduced the cost to £60,000 and it was believed it could achieve a standard of less than 20ppm.

These were large sums in 1980 and a great deal of landscaping could be purchased for these amounts. Furthermore I believed that car design had improved and would improve further to reduce the levels of oil pollution (an assumption that was not supported by a study in 1999[11]). I could not be certain that these expensive devices were necessary and there were other alternatives that would add to the amenity and aesthetic appeal of the ponds.

Hydrocarbons break down in aerobic conditions. Large ornamental fountains in the lakes are an aesthetically pleasing method of maintaining aerobic conditions. The fountains also disturb the surface disrupting the formation of any film and the appearance of iridescence. The ponds own ability to treat the oil pollution could be harnessed and it was evident from the above data that they only needed to reduce concentrations by a few p.p.m. to maintain an aesthetically acceptable effect at all times.

My research indicated that it was unlikely there would be a problem. However provision was made to retrofit the TP oil interceptors if a problem materialised. In 20 years no problem has been reported.

Amenity

Our brief was to produce a high quality development with, what was then, a large landscaping budget. The land was valued at the time at £500,000 an acre, which was a very high valuation for office/industrial development. It meant that any storage provided had to be an integral part of the landscaping to provide amenity and added value to the development. These principles did not have to be dictated by a statutory authority as they were the natural design objectives supporting the interests of the client.

We also took care to keep the necessary civil engineering structures as unobtrusive as possible and care was also taken with the quality of concrete finish where it was visible.

Paths were provided around the lakes and the upper lake links with a central walkway that provides a pedestrian access through the site. Furniture was provided to encourage people to enjoy the amenity.

Figure 2: Upper retention pond showing fountains. Willow trees retained and vegetation on the far embankment.

The experience over 20 years.

The author has visited the site several times since it was built. The author interviewed the Management Company before Christmas 2002 to obtain their experience and views of the ponds.

The fountains are maintained quarterly. The divers who inspect the fountains have reported some silt near the base of the fountains but none is evident near the edges of the ponds. Silt has never had to be removed from the ponds as part of their maintenance.

The ponds are **stocked with carp and silver fish**. The EA has recently visited the ponds and **health checked** the fish population. Fish have had to be removed due to overpopulation and some fish have grown too large. These fish have been transferred to stock angling clubs. This is an encouraging indicator of the health of the small ecosystem of the ponds. There are usually a large number of fowl in the vicinity of the lakes and these also appear healthy. The EA may not be able to provide this service in the future and it is planned that the fish husbandry will be taken over by the same company that services the fountains. The ponds have not exhibited any odour problems nor has any oil or iridescence been observed in their normal operation.

A large number of people picnic on the sites during the summer and the author observed a hardy couple eating sandwiches and feeding the ducks in the middle of December. On one of the smaller ponds to the north there are some colourful fish that may have been released by local residents – not strictly recommended but not unusual in ponds near residential areas.

Overall the ponds are seen as a major asset by the management of Aztec West and they require minimal maintenance. The effect has been so successful that additional smaller ponds have been constructed elsewhere on the site.

How would the Latest Specifications and Best Practice manuals differ in approach?

Have we learnt anything in 20 years? Yes we hope so. We did not **consider infiltration trenches** or stone filled drains. The ponds on Aztec West are not lined because the clays are impermeable. However stone filled drains are known to be very effective in the treatment of hydrocarbons and may have been considered as an alternative means of assisting the lakes in improving water quality. They can also be combined with filter strips. A proposed Ciria report due for publication next year will offer further guidance on the treatment potential of various SuDS structures.

We did not consider **swales** either and I still would be careful about their adoption on a site like Aztec West. The experience of swales near roads and residential developments has not been entirely successful where residents have perceived them to be "unpleasant" or "an eyesore and a nuisance" [(13)]. It is important to avoid the eyesore of verges that remain saturated for long periods and struggle to support grass. Swales have very good hydrological properties but the public perception of SuDS and their aesthetic value are important. If Aztec West was built on permeable soils the siting and design of swales would be less problematic. The combination of an infiltration trench built under a swale, known in the Netherlands as a wadi, may help to solve the potential problems of waterlogging and unsightly appearance.

Backdrop manholes were placed at the head of the lakes to cater for the retrofitting of the TP oil interceptors. If these did not need to be constructed then **rockery inlets** similar to the new water features on the site could have provided greater aeration and they are more attractive than a headwall.

A method for the calculation of **treatment volume** (permanent water) to be provided in the lakes is available in Appendix B of Ciria 522 and implemented as part of the Micro Drainage suite. The treatment volume in the lakes equates to Vt calculated by this method. However retention ponds are now recommended to have up to 4 times this volume of permanent water. It would not have been difficult to increase their size a little but I doubt whether as much as 4Vt were necessary in the light of their successful performance. It must also be remembered that fountains aerate the lakes and this was intended to improve and accelerate treatment and they also have a hydraulically efficient shape – see below.

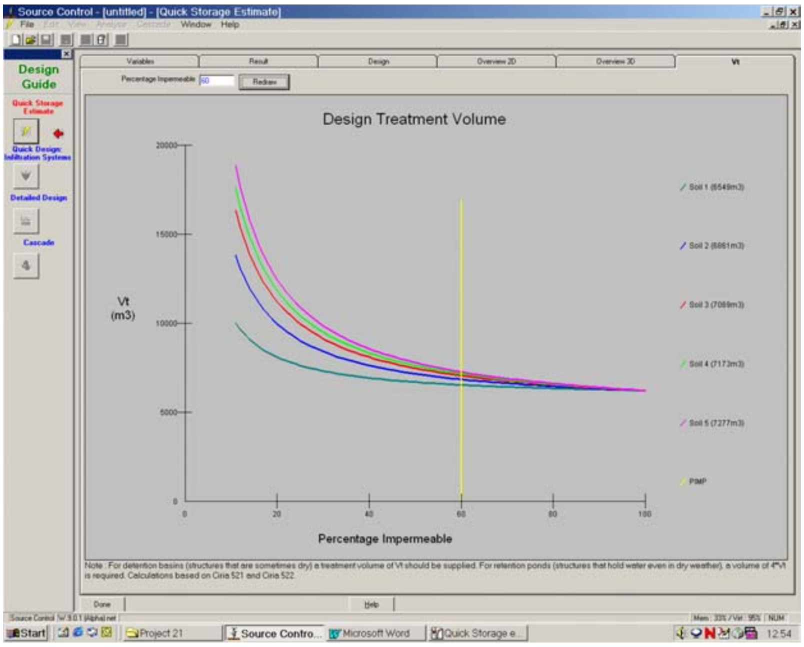

Figure 3 Treatment Volume Vt – calculated by Micro Drainage

It is curious that an extended detention basin only needs to accommodate Vt. This would encourage some designers who are short of space to avoid a permanent water feature which would be a regrettable, and I am sure unintended, implication of the current recommendations.

However the total Vt could have been increased by providing an extended retention basin at the site of the "dry" storage area at the bottom of the development.

The **pond shape** also affects the quality performance of the pond. Short-circuiting (a short flow path between inlet and outlet) is a hindrance and can be avoided by providing a length to width ratio of 3:1 as recommended by Ciria 522. However islands near the inlet and subsurface berms may also improve the distribution of flow[24] . The layout of the Aztec West ponds avoids the possibility of short-circuiting by placing the inlets and outlets as far apart as possible and adopting a tear drop shape.

Biodiversity must also be considered. The depth of the ponds vary from 0.5m to about 1.2 m which is within the current recommendations. However a vegetated margin with local aquatic plants is now recommended to increase biodiversity and reduce pollutants through vegetative treatment.
The landscaping of Aztec West is fairly formal. I cannot comment on whether the architect or client would have accepted the idea of a natural and informal margin. We did preserve and encourage (pollarded them etc) the existing willow trees along one embankment on each pond. This area could have accommodated more shallows and vegetation that included native species. There is, however, evidence of some self seeding of vegetation in the margins and weed is present in the lower pond. Some recommendations [12] state that "good design of SuDS can leave a hummocky finish to create micro-habitat niches". Yes if a hummocky finish is appropriate to the landscaping objectives. Aztec West demonstrates that a healthy ecosystem can be created within a formal garden framework although some more vegetation could have been accommodated.

Recent studies[11,13,] on detention basins and retention ponds serving roads in Scotland and England have shown high **levels of lead** and other metals in the sediments. The paper on two drainage systems serving the M25 reported that the lead concentrations had decreased significantly between 1991 and 1999 with the introduction and increased use of non-leaded fuel. The lead levels reduced from 95-7860 to 71-1580 ug/l. Unfortunately the levels of oil pollution in the stormwater ranged from 20 to 120ppm which is not markedly different from the Milton Keynes experience in 1979 although this may vary from catchment to catchment. Dr Ward stated that the concentrations of lead in the silt were as high as

1%. This experience may not be general but it suggests that if silt is to be removed from ponds it should be tested and advice sought on its safe disposal. The fish in the Aztec West ponds do not show signs of distress and are known to be healthy and breeding.

Rainfall specifications have changed in the last 25 years but the differences would have had very little impact on this site. However climate change was not considered then and it must be included in any design procedure nowadays. A comparison of the Bilham formula, FSR method, FEH method, and local data from the Filton Met office is given in table 1.

Bilham	19mm/hr
Filton	18.5mm/hr
FSR	18.3mm/hr
FEH	19.4mm/hr

Table 1: 30 year return period and 120 minute storm duration.

In some locations in Britain there is a very marked difference between the FSR and the latest FEH results (>40% on a 1 hour duration, 100 year return period).

The **methods for estimating storage** have changed over the last 25 years as computer programs have enabled first principle analysis to be used in every case. Specifications for allowable discharges and return periods have varied a great deal throughout the country and throughout the decades.

Table 2 illustrates the different results that would have been obtained by some specifications and how they might perform after **climate change**. The return period of the protection offered in the year 2080 is shown in the last column. The more recent results also show the volumes produced by 100 year RP specifications as these are now becoming commonplace.

Specification Date	**Volume m3**		**RP in 2080 years**
1975*	21000		72
1979**	14425		22.5
1985^{+}	9327		6.5
2002^{++}	12309 (30yr)	18237 (100 yr)	14 / 46
2080 $^{??}$	15847 (30yr)	23220 (100 yr)	30 / 100

Table 2. The effect of different specifications on a 60 ha catchment in Bristol with 360l/s allowable discharge similar to Aztec West.

Assumptions:

* Mid 1970's	Courage Brewery, Reading: 10 year return period Manual Calculation (14) (overestimate by 2 to 3 fold to allow for approximations inherent in the calculation and an overestimation of runoff)
** Late 1970's	Aztec West 30 year RP with TRRL runoff (computer analysis on a Commodore PET)
+ Mid 1980's	Wallingford procedure assumption mid 1980's FSR Rainfall with summer runoff and 30 year RP (Computer analysis Micro Drainage).
++ 2002	FEH rainfall with winter runoff 30 year on-site and up to 100 year off-site protection (Computer Analysis by Micro Drainage).
?? 2080	Climate change (Assume +20% UKCIP, computer analysis Micro Drainage)

Even if climate change does occur the hydraulic protection afforded by the Aztec West ponds will be significant.

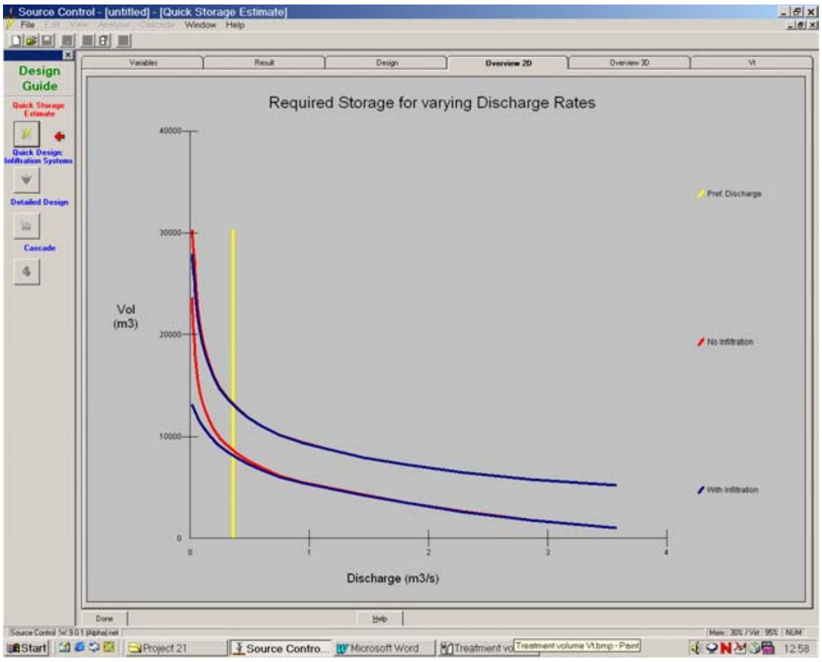

Figure 4: Variation in storage volume with outflow and infiltration. Calculation by Micro Drainage.

Note that if the predicted increases in climate change do materialise then the level of protection afforded by these structures will reduce. Designers in 2003 should at least track **flood flow paths** that may occur as a result of climate change and if necessary divert overland flow away from buildings [15, 16]. We have not conducted a study of the impact of climate change on Aztec West and it was not part of anyone's brief in 1978. However the main storage structures are connected by overland routes via the road network but the road detailing, particularly at junctions, can be important in this regard.

A comparison of Infiltration specifications

Although infiltration systems were not used on Aztec West it may be helpful to discuss how the design approach to these has altered in the last 25 years. The early specifications for **soakaways** required a simple ½ inch (13mm) of storage. BRE Digest 151[17] improved on this rule of thumb and included an in-situ infiltration test but used a generalised standard for rainfall throughout the country. However the infiltration test only required 5.5 litres of water in a 150mm diameter augured hole. The test as described in the current references of Ciria 156 [18] and BRE Digest 365[19] requires a much larger hole to be dug to the full depth of the soakaway to provide a more reliable assessment.

Also the methods of calculation have improved, particularly those published in Ciria 156. The method is transparent and the engineer has control over safety factors. This method is widely recommended and referenced in the latest building regulations[20]. It has also been fully implemented in the Micro Drainage suite of computer programs [8].

Soakaways have had a bad press in the UK. It has been demonstrated (Pratt [21]) that the latest specifications BRE 365 and Ciria 156 give similar results. Watkins[22] further demonstrated that these later British specifications are also compatible with European practice. However some older specifications (BS8301[25] and BRE digest 151) appear to under-design by up to 10 fold. Professor Pratt concluded that "It is possible that the past poor performance of some soakaways has been mainly due to undersizing through the use of previous design guidelines". Or the performance and maintenance of soakaways designed to the latest specifications should not be judged on the designs of the past without consideration of the vastly improved design methods.

Design Method	Volume excavated (m3)	Factor of Safety
BS 8301	5.0	1
Danish	13.8	4 on storage
PSA 125	11.0	3 on infiltration
BRE 365	12.6	Various assumptions
BRE 151	1.4	1
Swedish	12.3	2.5 on infiltration

Table 3: Summary of design soakaway sizes to receive stormwater from 400m2 impermeable surface (after Watkins[1])

Conclusion

Aztec West is an example of a privately managed SuDS design. I initially wished to include an adopted detention basin in Thatcham, Berkshire as an alternative example of SuDS on a residential site also designed in the late 1970's but the paper would have been too long. Suffice it to say that there are examples of good operating detention basins on residential sites where the major maintenance expenditure is mowing the grass.

Arlington Business Services Ltd. do charge their clients for maintaining the common areas of the site. They were unable to give me a cost for the maintenance of the SuDS elements separately as they viewed the maintenance of the flower beds, lawns and lakes throughout the site as normal practice and the cost of this type of work can be obtained from landscape contractors. The fountains are maintained separately but they are not an essential part of a SuDS design but are seen as an attractive addition that many private clients favour. In the case of Aztec West we recommended their use for aeration in addition to their aesthetic appeal.

The possibility of oil pollution, heavy metals and fertilisers etc. should be considered in every design. These considerations encourage both the use of SuDS systems and their correct design. The designer now has recommendations on maintenance, treatment volumes and planting regimes to cope with these factors and improve the amenity of the site and the quality of the discharge.

We did not understand 25 years ago the degree to which stormwater was such a potential pollutant. Urban run-off is responsible for over 11% of total polluted Scottish rivers and 31% of seriously polluted Scottish rivers [23].

We will learn more about these aspects in coming years but we had the ability 25 years ago to design good SuDS systems and with a growing body of experience and case studies there is no reason to fear them.

Examples of bad design can also be found. The only specification that we used to receive from an approving authority was the allowable discharge. However good design requires the consideration of many aspects. There are also many approaches to SuDS. A purist may say that it is all or nothing - "a system that contains one pipe is not a proper SuDS system". This misapprehension should not be allowed to discourage the use of appropriate SuDS wherever possible. If the only possible SuDS structure that can be accommodated on a site were a soakaway for roof drainage then we would encourage the designer to consider it. The author would also encourage the designer to design it properly and to ensure that the building contractor constructs it properly.

Drainage design has become more challenging in the last few years and engineers should welcome it.

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