Case study

Upton – Northampton

We would like to acknowledge the contribution and kind permission of English Partnerships and Pell Frischmann in the publication of this case study that features in CIRIA C635 Designing for exceedance in urban drainage – *good practice*.

Please note that the positioning of some of the buildings and ground levels were adjusted for illustrative purposes, the inclusion of a freeboard and the nature of the local topography means that some of the swales will actually provide protection up to the 1 in 200 year return period.

1. INTRODUCTION

The Upton development lies to the South West of Northampton. It is a greenfield sustainable urban extension developed in a partnership between English Partnerships and Northampton Borough Council. Once completed, the development will include approximately 6000 dwellings. It is being constructed in phases, with phase 1 covering 37ha and comprising of some 1400 homes and associated infrastructure such as schools, work units, retail and community development. It is located immediately north of the River Nene floodplain, which provides the outfall for surface water runoff. The first advanced infrastructure contract started in 2003 and house building commenced in 2004.

This case study is concerned with a sub area of phase 1, known as catchment D. This consists of 16ha of development of which 8ha is impermeable. It is illustrated in Figure 16.1.

Upton's key development principles relate to promoting sustainable growth and an enduring, distinctive environment. Sustainability was embedded in both the Upton Design Code and Urban Framework Plan. From the drainage perspective this was expressed by the following requirements.

- stakeholders are to be involved at an early stage
- surface drainage shall be by means of Sustainable Drainage Systems (SUDS)
- the drainage of the site from extreme events and impact on downstream systems should be explicitly allowed for.

It is important to note that these requirements are entirely consistent with the recommendations of Sewers for Adoption, Edition 5 (Water UK and WRc 2001). For the purposes of this case study, it was necessary to amend part of the design to create an exceedance problem and demonstrate how it should be considered.

2. STAKEHOLDER INVOLVEMENT

The key stakeholders in the development are:

- English Partnerships (developer).
- Northampton Borough Council (land drainage and planning).
- Northamptonshire County Council (highway authority and planning).
- Anglian Water (sewerage undertaker).
- Local residents (potential occupiers).

An 'Enquiry by Design' took place for Phase 1 in 2001, which allowed the residents, local stakeholders and key decision makers in the area to become involved with the development of the design.

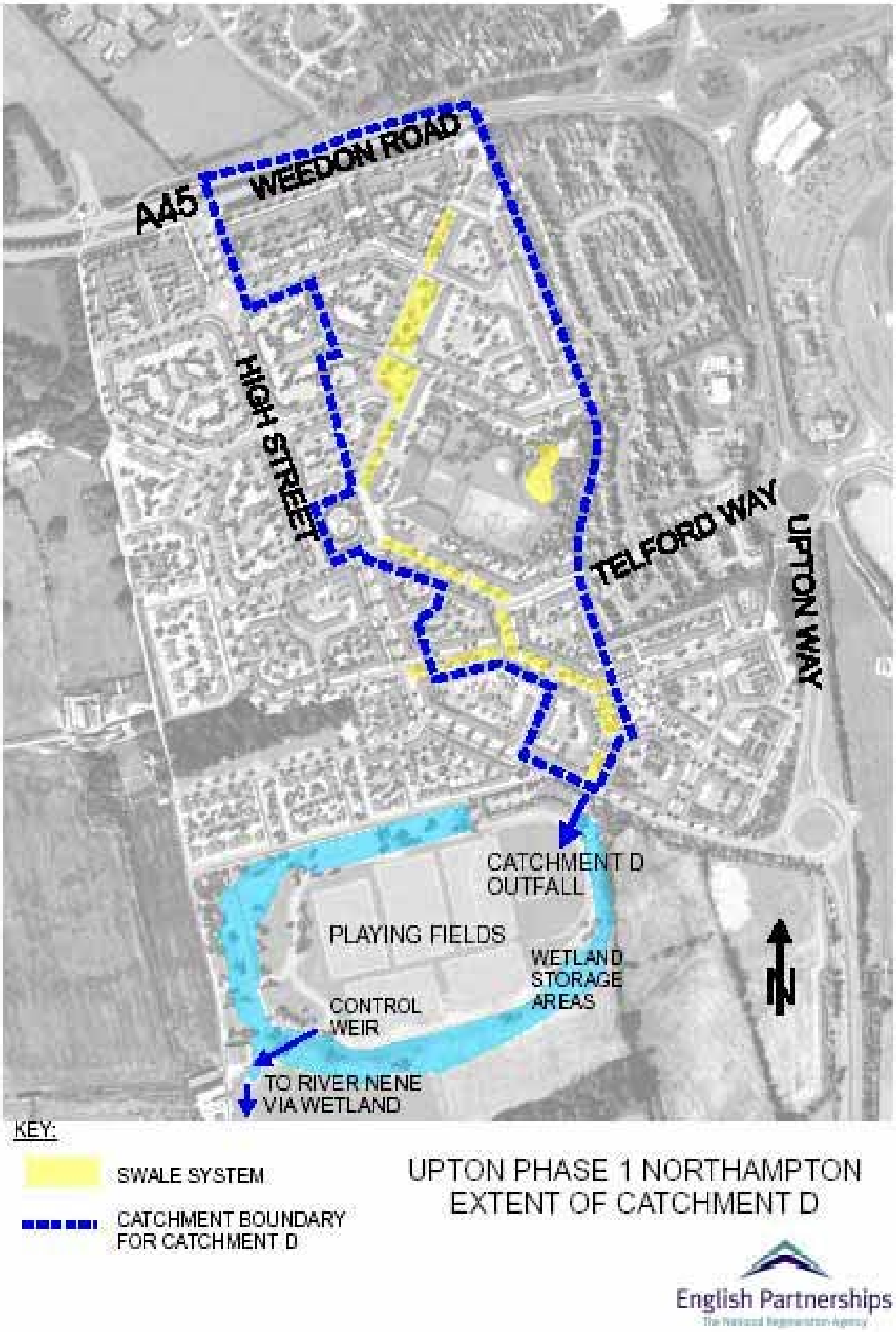

Figure 16.1 Overview of catchment D including details of the outfall from the surface water drainage system (courtesy English Partnerships)

The scheme had support from the Environment Agency who approved a Flood Risk Assessment for Upton Phase 1 in 2003. Northamptonshire County Council, Northampton Borough Council and Anglian Water were also supportive of the sustainability approach and the principles involved, but difficulties emerged in early consultations regarding the adoption of swales and the linking pipework and flow controls. Legal and statutory challenges outweighed a shared appreciation of the potential benefits and hampered progress of the scheme.

Surface water drainage was to be delivered primarily through a SUDS scheme. The SUDS scheme consisted of a system of linked swales that convey runoff to wetland storage areas around playing fields adjacent to the River Nene as well as having a storage and infiltration function. Permeable paving, rainwater harvesting and water butts were to be provided by developers of individual sites. This led to difficulties over adoption of the surface SUDS elements.

Permeable paving to courtyards is a significant SUDS element. In addition, Anglian Water applied the condition that infiltration devices could not be connected to the adoptable piped system. This meant that permeable paving connected to the piped system had to be tanked. Furthermore AW required that hydraulic design for the adoptable sewers had to demonstrate self cleansing with the permeable paving operating as designed (ie discharge attenuated) whilst having capacity to receive additional runoff, should the permeable paving fail (ie discharge unattenuated).

None of the stakeholders would agree to adopt the surface SUDS components. To resolve this, it was agreed that the Upton Management Company, which has English Partnerships and Northampton Borough Council backing, would undertake the necessary maintenance.

3. DRAINAGE OF DEVELOPED AREAS

The surface water drainage system consists of a combination of SUDS elements and a conventional below ground piped system.

At the building level, water butts are generally to be provided by the developer for water to be stored for use in gardens. Rainfall is collected by conventional rainwater systems where it is passed on to a piped system. From there it is discharged to a series of swales. Car parking courtyards and some adoptable mews or lanes will have permeable paving (subject to agreement of details with the highway authority). The overall drainage layout is shown in Figure 16.2.

The general nature of the immediate subsoil within the development area is slightly sandy clay (Glacial Lake Deposits) that has variable permeability. The water table is also variable and there is the possibility that groundwater will affect infiltration at certain times of the year. Therefore if the groundwater is high the swales act as ditches. Although infiltration will be significant during most rainfall events, the design of the swale system does not therefore assume infiltration and allowance has been made in the hydraulic design for groundwater inflow. The swale system design has therefore been based on conveyance /storage. The swales are predominantly about 10 m wide and 1.2 m deep with side slopes varying from 1 in 3 to about 1 in 5. Flow controls are orifice plates located in chambers or slots/steps in weirs.

In order to ensure that flow could discharge into swales, some pipes had to be laid at shallow depth, with a minimum cover of 800 mm. The highway authority required the use of minimum 300 mm diameter ductile iron pipes beneath the highway in such cases.

4. INTERACTION BETWEEN THE MINOR AND MAJOR SYSTEMS

The minor drainage system was designed such that no surface flooding occurred for rain events more frequent than the 1 in 30 year event (annual probability 0.033), though in practice the detailed design of the swales led to them achieving conveyance for larger events without overtopping.

The SUDS elements provide a series of “green corridors” through the development. The corridors also form a natural pathway for exceedance flows to be conveyed. In addition, some of the highways are available to act as above ground flood channels. Because of the range of drainage elements used in the development (including SUDS), interactions between the minor and major drainage systems are complex. They may be broken down into four categories:

- surface flow generated by limited inlet capacity. This includes drainage from conventional surfaces such as highways
- flow from permeable surfaces when infiltration is inhibited by high groundwater levels
- flow discharged from manholes and gully inlets due to surcharged sewers
- flow overtopping the banks of swales.

The design for conveyance and storage for exceedance conditions was carried out in stages. The first stage was to complete a conventional design for the building drainage, infiltration surfaces, pipe sewerage and swales, to meet the 1 in 30 year level of protection. An outcome of this was a hydraulic model of the drainage system capable of simulating its performance. This model was then used to perform a risk assessment of the drainage proposals for more extreme events. Finally any additional design for surface conveyance and storage of exceedance flow was undertaken. Details of the risk assessment and subsequent additional design are set out in the following sections.

5. RISK ASSESSMENT

A level 2 study of the performance of the designed drainage system was chosen based on the size of the drainage area (figure 16.1) and the complexity of the drainage system (Box 9.1). The model was used to simulate the performance of the drainage system. This allows the contributing areas, piped drainage components, and SUDS systems to be accurately represented. It also has the advantage of displaying outputs in GIS and 3D formats, so that results can be easily visualised.

5.1 Collecting data and building a hydraulic model

The landowners and consultants provided the outline design information (as listed below) to facilitate the modelling to commence.

- digital terrain data for the proposed development
- highway design details for major highways, with the centre line, camber, levels and kerb information
- routes of the swales and piped sewerage system.

Details of infiltration pavements were not available, and minor highways were not included. The swales were modelled without infiltration.

Figures 16.2 and 16.3 show details of the drainage model. Potential above ground flood pathways were identified by inspection using the model and digital terrain data. These included parts of the highway system and pathways formed by the swale system. These pathways were included in the model as open channels, as described in Section 9.3.3 and Appendix C. The piped sewerage system was modelled with a free outfall.

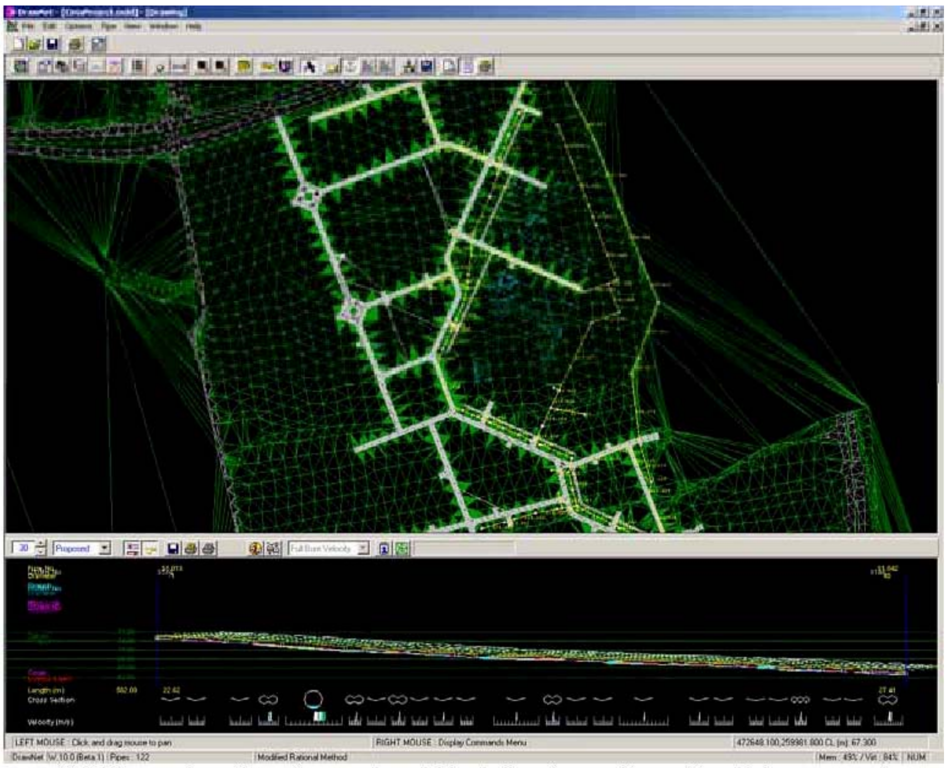

Figure 16.2 Plan and section of ground model including the position of the highways, swales and surface water pipe system *(courtesy MicroDrainage)*

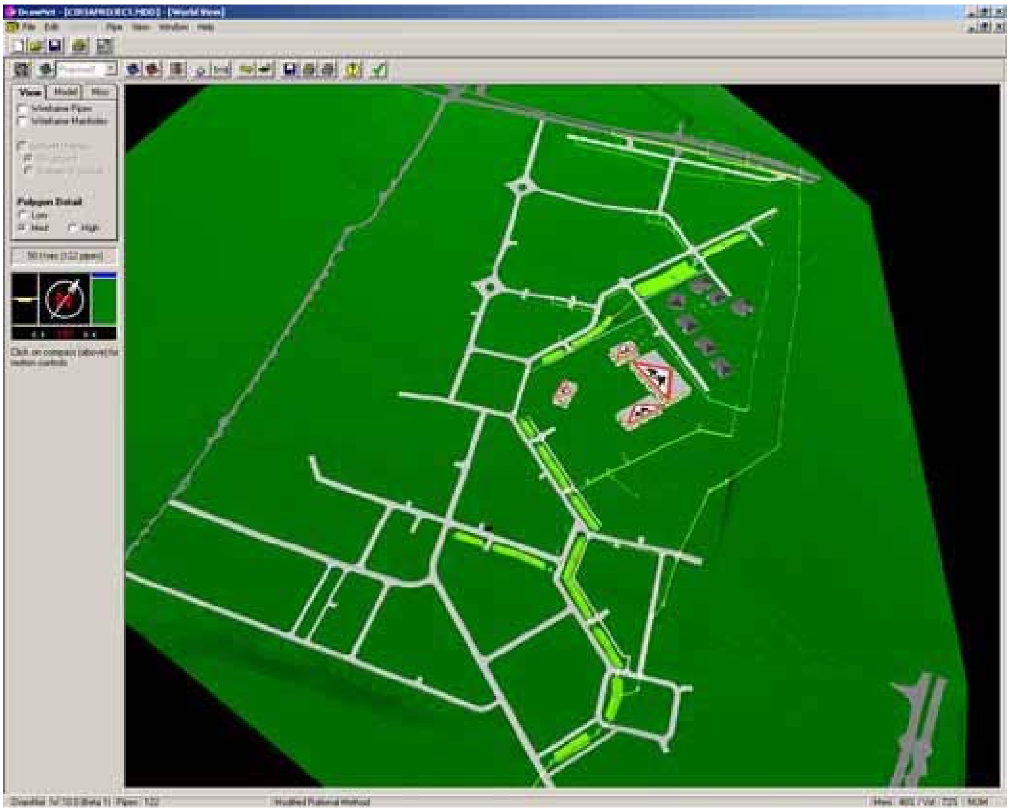

Figure 16.3 3D view of ground model with conceptual view of the school and some housing for illustrative purposes (courtesy of Micro Drainage Ltd)

5.2. Assessing system performance (1 in 30 year return period, 0.033 annual probability)

To test the performance of the drainage system (outline design), the model was used to assess what flooding would occur for the 30 year return period storm. Rainfall durations from 15 minutes to 24 hours for both summer and winter events were simulated.

No flooding was detected in the pipe system nor in the SUDS structures, and no flow was conveyed in the above ground flood channels. No properties or surface areas were affected. The design therefore met the requirement for a 30 year level of protection from flooding.

5.3. Assessing system performance (1 in 100 year return period, 0.01 annual probability)

The network model was then run with the 100 year return period storm event (probability of occurrence of 0.01). A range of durations was used for both summer and winter events to determine the most critical. Further simulations were undertaken with an allowance for climate change. Rainfall increased by 10 per cent as recommended in CIRIA publication C609 Sustainable drainage systems – hydraulic, structural and water quality advice (Wilson *et al* 2004).

In this case surface flooding was identified, with surface flows being conveyed in the above ground flood channels included in the model. The flow paths indicated that flooding would occur around the school and at the housing indicated on the right of Figure 16.4. It should be noted for the purposes of demonstration in this case study, the school's position had been moved to illustrate flooding implicitly and in its designed location would not have been affected. In addition to this, the terrain data was amended to produce flooding to the property as shown in Figure 16.4.

5.4. Assessment of risk outside school.

The highway (indicated by 'A' in Figure 16.4) acts as part of the major system for overland flow. It was necessary to confirm that the velocities and depths of flow did not pose a risk to traffic and pedestrians, particularly young children (as described in Section 10.5.5).
For the critical rainfall event, the rate, depth and velocity of the exceedance flow conveyed by the highway were computed. Details of the flood flow in this highway are shown in Figure 16.5. The surface flow was due to a combination of the minor system capacity being exceeded from the manhole upstream and surface flow that was designed to be conveyed in the highway as part of the highway drainage design. The maximum velocity was found to be 0.98 m/s at a depth of 50 mm (half kerb height). This was felt not to pose a significant risk to either parked or moving vehicles, or pedestrians.

The site is gently sloping and it is unlikely that the velocity and depth of flow in the landscaped areas would pose a high risk to pedestrians (see Chapter 10 and 11).

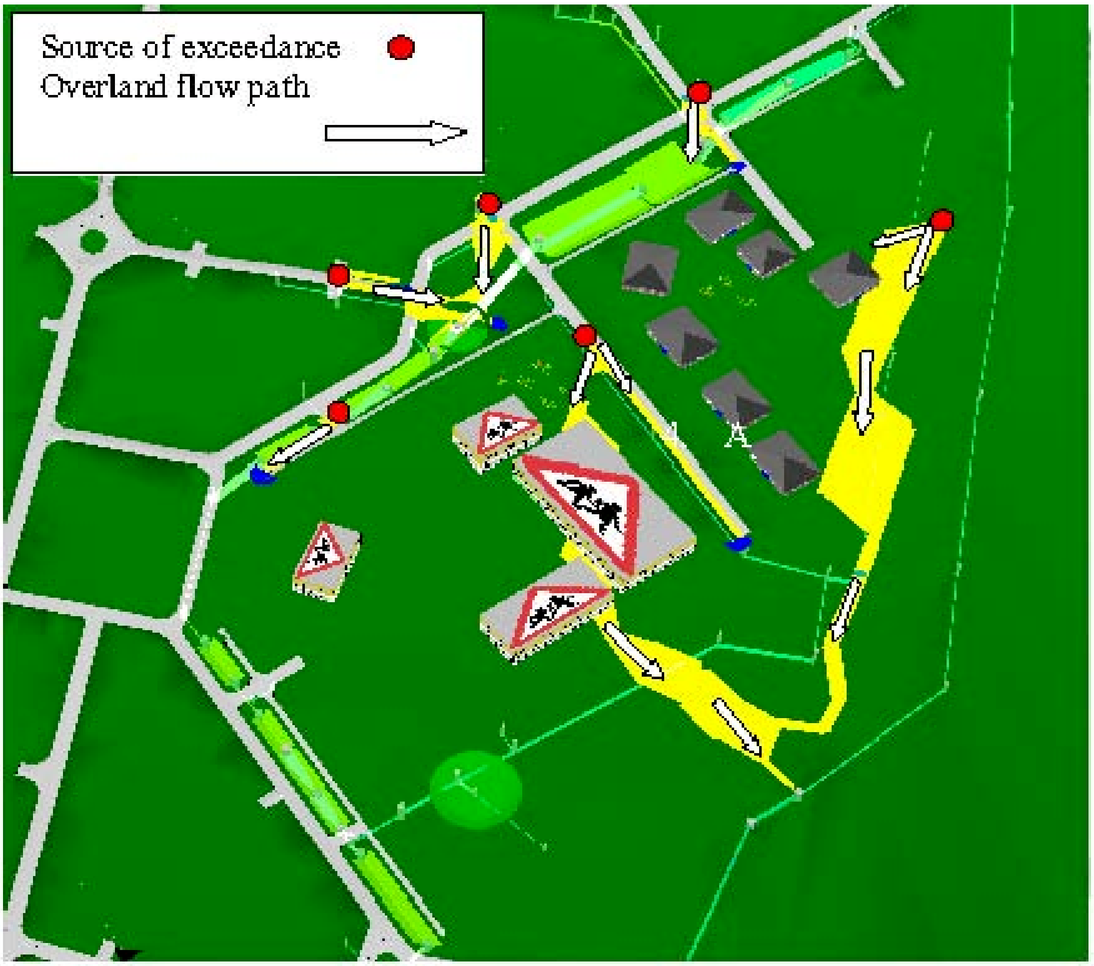

Figure 16.4 Flood flow paths for 100 year event with additional flooding due to climate change indicated by the lighter colour *(courtesy MicroDrainage)*

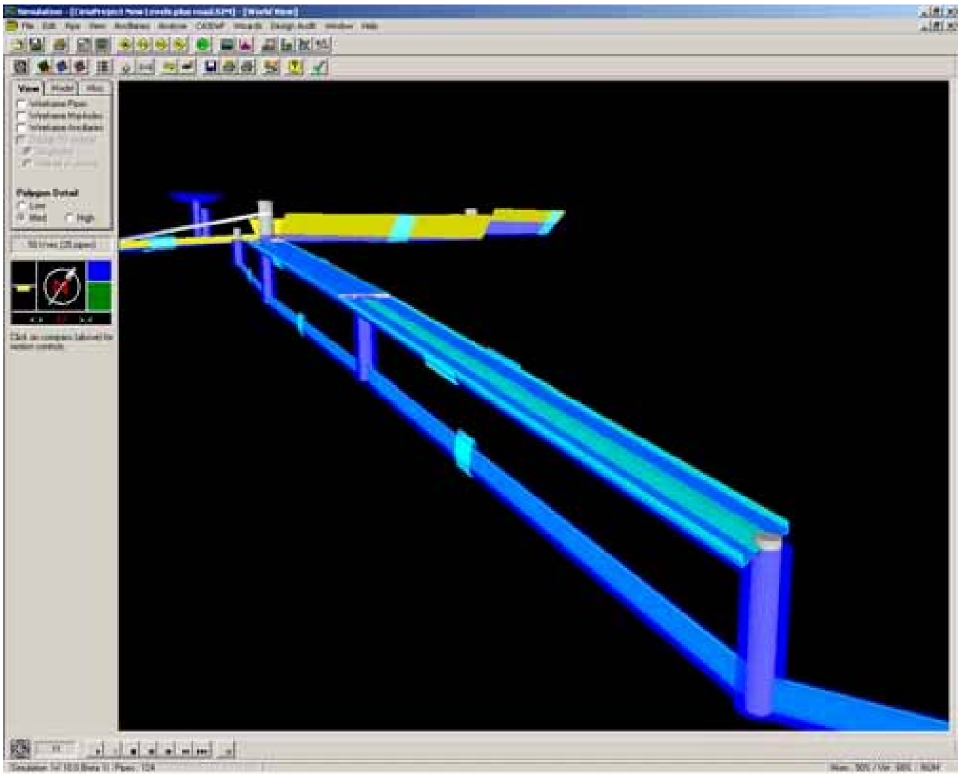

Figure 16.5 3D view of the modelling of surface flood paths and the inter-connections with the below ground sewerage system, in the vicinity of the school (courtesy Micro DrainageLtd)

6. BUILDING LAYOUT AND DETAIL

The “green corridors” provided by the swales and the principal highways provide the network of above ground flood pathways around the development. Local detailing of building layout and landscape is also important to ensure that when these systems operate in extreme events, individual property remains protected from flooding. Two potential problems had been identified in the risk analysis, the school and a single property in the vicinity, as illustrated in Figure16.4. The following sections describe the remedial measures undertaken to manage this risk.

6.1. Amending building layout and threshold levels

A number of options were available to prevent the flooding of the school and the housing. The proposed solution was to raise the threshold levels of the school. This forced the above ground flow to be retained within the highway, passing it safely downstream towards the outfall. The flooding of the individual property was tackled by re-profiling the ground locally, to create an above ground channel to convey flow away from the housing area. Other options considered were to locate storage in the area, raise ground levels, include an above ground conveyance channel such as a swale or highway, but these were considered to be less practical.

The option of raising threshold levels at the school would be combined with raised pathways enabling a safe means of escape from the building if it was occupied during an extreme event.
The model was then re-run with the modifications described and these were shown to have successfully alleviated the flooding (Figure 16.6).

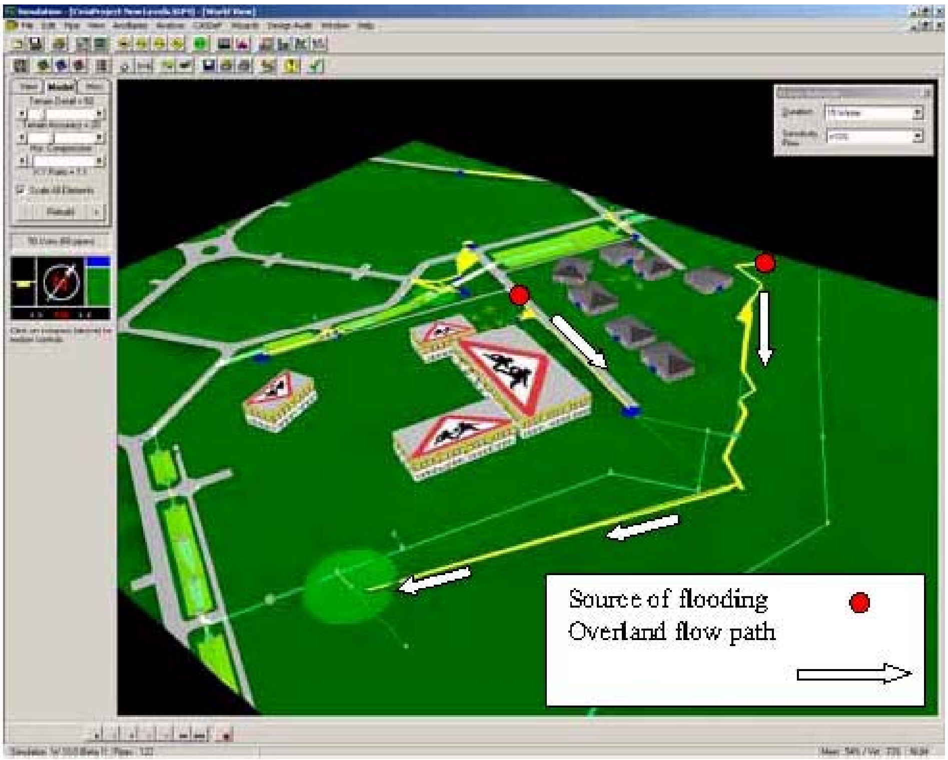

Figure 16.6 Modification to building layout with school threshold levels raised and ground re-profiling adjacent to housing. *(courtesy MicroDrainage)*

7. IMPACT ON DOWNSTREAM SYSTEM

Following a review of the Upper Nene catchment after the Easter 1998 flooding, which resulted in loss of life in Northampton, a development requirement was that there should be no impact on the downstream system resulting from events up to the 1 in 200year return period
(0.005 annual probability). An initial assessment of the site, following the procedures set out in Chapter 4, established the greenfield runoff. The proposed development, even allowing for effects of source control in the SUDS, would have had a significant impact on flood flows in the River Nene for the 200 year event.

To mitigate this effect, surface storage was planned, to attenuate exceedance flows on the surface. A suitable location for this was found in the grounds of the school. By reviewing the ground topography, and the level in the receiving river, the maximum depth of storage was determined. From this a suitable outlet control was designed to limit the discharge.

The storage pond was then incorporated into the model with an initial estimated volume. The data was entered to allow for the varying surface area with depth that would occur with the real pond. By successive trial and error the required volume that prevented overtopping for the 200 year event was determined. The whole of this volume could be accommodated below the level of the surrounding ground, so no special measures were required to protect an embankment in the event of overtopping. The location of the storage pond is shown in figure
16.6. Similar storage ponds were provided in other phases of the development.
As the storage has been provided in an open space, stores only surface runoff, and operates infrequently, there will be few requirements for clean up following an extreme event. Care needs to be taken in detailing such designs to ensure they do not pose a safety hazard when in operation. In this case careful attention to side slopes and the detailing around the flow control is required.

8. CONCLUSION

The case study demonstrates the importance of considering drainage design early in the development process, and also justifies early stakeholder involvement. It also shows that although SUDS can do much to mitigate the effects of flooding, they are insufficient on their own to mitigate the risk of flooding from extreme events.

By carefully identifying the paths for exceedance flood routes through a development, the damaging effects of flooding from extreme events can be mitigated. In this case the conveyance of the large resulting flood volumes is more cost effective than local storage. However, discharging these flows into the receiving river would have proved unacceptable due to the potentially damaging effects of consequential flooding downstream. The provision of local surface storage in a dual use area has in this case helped to mitigate these effects.

The use of suitable modelling software in this case considerably aided the design process. Although reference is made here to a particular software product, other products are available that can provide a similar function, and users should make their own judgement as to the most suitable.

The staged approach to modelling and flood risk assessment provides a useful framework by matching the level of effort and cost to the perceived risks. In this case it was relatively straightforward to add additional detail to the level 2 model in parts where additional information was required.

Overall the resulting design delivers a level of flood protection substantially above that provided in many new developments with little additional cost. This was highlighted by the need to amend the design to create a flooding problem. This design also demonstrates how the general recommendations of Sewers for Adoption 5^{th} Edition (Water UK and WRc 2001) can be delivered in practice.

> We would like to emphasise that the positioning of some of the buildings and ground levels were adjusted for illustrative purposes.
>
> The inclusion of a freeboard and the nature of the local topography means that some of the swales will actually provide protection up to the 1 in 200 year return period.

Acknowledgements:

English Partnership	Landowners and provision of case study
Pell Frischmann	Consultants and land use data
Micro Drainage	Modelling development