**SCARBOROUGH BOROUGH COUNCIL**

# Filey Town Flooding Investigation

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| | | | | | | |

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## GLOSSARY OF TERMS

| ***Term*** | ***Meaning / Definition*** |
|---|---|
| EA | Environment Agency |
| FEH | Flood Estimation Handbook |
| FTC | Filey Town Council |
| HydroWorks | A predecessor of InfoWorks |
| InfoWorks | Software for Hydraulic modelling of drainage networks, produced by Wallingford Software Ltd |
| NYCC | North Yorkshire County Council |
| SBC | Scarborough Borough Council |
| YW | Yorkshire Water plc |

# Executive Summary

## 1.1 Background

Parts of Filey have suffered from extensive and repeated flooding during severe summer storms affecting over 200 residential properties. Appendix 1 presents photographs together with a map of the affected areas to illustrate the severity of the events.

This Report details work undertaken by Atkins on behalf of Scarborough Borough Council as part of the Filey Flooding Working Group. This body was convened to investigate the problems and potential solutions to the repeated flooding. The Filey Flooding Working Group comprises the main client - Scarborough Borough Council (SBC) and also includes Yorkshire Water, North Yorkshire County Council, the Environment Agency, Filey Town Council, and some residents of Filey. Atkins was appointed to investigate the problems in an impartial manner and to recommend potential solutions to the various aspects of the flooding problems.

Damages following floods are disruptive, protracted and expensive. In certain cases repair costs have exceeded house values, while some residents have been forced out of their homes for up to a year whilst such repairs are undertaken. A number of residents are also experiencing difficulties in obtaining appropriate insurance for their homes.

The flooding comes from various sources which interact in a complex manner, making it difficult to find the specific causes. Technical solutions, whilst possible, are difficult to attribute due to the various organisations that may carry responsibility for the work.

## 1.2 Study Methods

The first part of the study was to gather the available information about the extent and nature of the flooding:

- What areas are affected?
- How often does it occur?
- Where does the floodwater come from?
- How long does it take for the floods to drain down?

A questionnaire distributed in 2002 and 2003 formed the basis of much of the above information, and a plan of the areas flooded in August 2002 was also produced by SBC and provided to Atkins.

Next, a computer model of the drainage network was constructed, including all the watercourses sewers, drains, and flood routes, using the latest software available – a programme named InfoWorks, produced by Wallingford Software Ltd. The programme simulates rainstorms, and follows the

### Technical note - Model Quality

This is described as a **calibrated** model. A further check can be made, in which a real rainstorm and the flows generated by it are measured and then compared to the flows predicted by the model for the same real rainstorm. This is known as Model Verification. The calibrated Filey model is believed to be sufficiently accurate for this phase of the project, but should not be used for detailed design until it has been **verified**. Thus, it should be noted that any proposed solutions may change after verification.

rainwater as it finds its way into the drains and sewers. It then tracks the performance of each manhole node and pipe in the system until the water from the storm has completely drained away. This computer model was adjusted until it showed the same pattern of flooding as had been experienced by the town. **(See box)**

By using the results from the model it is now possible to confirm that the flooding was a result of certain sections of the drainage system being overwhelmed during the heavy rain. Once this had been established, further investigations uncovered the different types of problems affecting different areas. These were land drainage issues and sewer incapacity and or a mixture of both. Once the problems had been identified it was possible to suggest ways to solve the problems and to test those suggestions against the computer model. Considering the model quality issues described previously, it is recommended that additional topographical and flow survey data be obtained in addition to a review of the accuracy of the sewer data utilised, to support any proposed solutions. (Flow surveys were not undertaken as part of the data gathering exercise.)

## 1.3 General Results

There are a number of interacting problems. Some relate to the watercourse and rainwater falling beyond the urban area of the town overwhelming the drainage system and others relate to the sewer system being under-capacity. These findings are summarised in the table below and presented in the Appendix.

| Location | Summary of problem | Solution |
|---|---|---|
| North Filey<br><br>(Filey Beck)<br><br>*(Watercourse problem)* | Tributaries of Filey Beck are unable to cope with rapid runoff and fill and flood north Filey.<br><br>The surface water from outside the urban area of the town overwhelms the existing town's drainage system.<br><br>The tributaries directly flood the town and water also fills and floods the local sewer system. | Surface water needs to be directed away from the town or stored and its flow controlled.<br><br>Sewer and surface water drainage systems could be upgraded. (It should be noted that while the existing sewer system receives land drainage flow there is no obligation on a water company to accommodate for such flows in new sewers) |
| Long Plantation Watercourse<br><br>(Watercourse problem) | The watercourse overflows into the Wharfedale Estate.<br><br>This is a surface water problem. Water overwhelms the watercourse and it floods into the rear of the properties and onto the streets. It goes on to exacerbate other flooding in the Wharfedale Estate and Muston Road. | This is being undertaken as a separate study so is not considered in detail in this report. |
| Wharfedale Estate<br><br>*(Sewer Problem)* | The existing sewer system does not possess sufficient capacity to deal with the rain falling in the immediate area for a 1 in 30 year return period event.<br><br>(Yorkshire Water have indicated that the current systems were probably designed for a 1 in 10 year standard.)<br><br>Additional flows entering the estate from Muston road and the Long Plantation Watercourse exacerbate conditions. | Sewer systems need to be upgraded. A more in-depth study is required to ascertain and refine detailed solutions.<br><br>(This is a sewerage problem in its own right, but requires solutions at the Long Plantation Watercourse and the sewerage problems at Muston Road.) |
| Muston Road<br><br>*(Sewer Problem)* | The existing sewer system does not possess sufficient capacity to deal with the rain falling in the immediate area for a 1 in 30 year return period.<br><br>(Yorkshire Water have indicated that the current systems were probably designed for a 1 in 10 year standard.) | Sewer system needs to be upgraded. A more in-depth study is required to ascertain and refine detailed solutions. |

In some areas, the flooding risk will continue until all of the interacting problems are resolved. Other discrete problems may be resolved by the responsible organisations without impacting upon other areas.

It is envisaged at this stage that the Watercourse improvements are a matter for the Environment Agency and/or Scarborough Borough Council, while the sewerage works will fall within the jurisdiction of Yorkshire Water.

Where residents and their representatives on the working group had put forward their own diagnoses of the problems, they were found to be broadly correct. There were two exceptions: flooding at Wharfedale is not a symptom of water backing from Dams Goit, and the flap valve on the sea wall is unrelated to the flooding of the housing estates.

## 1.4 Other Findings

Historically, Filey Beck used to run from the Dams area, under the railway line, cut across the northern part of the existing town, into the Ravine and to the sea. Most of this watercourse now flows thorough underground pipes (i.e the watercourse has been culverted). Thus it appears that Filey Beck used to collect the surface water draining from the fields to the north of the town via its tributaries. Now that it is culverted, this water has no easy route to the sea. This problem appears to be primarily a consequence of urbanisation encroaching on open land, rather than the flows from the agricultural areas in themselves.

The result is that runoff from the fields to the north of Filey overwhelms the existing tributary watercourses, and the small riparian culverts under houses are unable to drain them quickly enough. Therefore, floods arise and pass through the houses and several streets before eventually being drained by the surface water sewers and then into the culverted Filey Beck. This then outfalls into the main culvert in the Ravine.

In practice it is unlikely that residents will be easily able to improve the riparian pipes under their houses, and so any solution will most likely require intervention by Scarborough Borough Council or the Environment Agency. Even if the riparian pipes could be e enlarged, the culverted watercourse/surface water sewers to which they connect would be inadequate for this land drainage flow as they were not designed for such an input.

Minor independent problems such as flooding near Filey Senior School are isolated incidents of flooding that affect the highway only.

It is believed that the soil type in the Filey area is a type of clay that under certain conditions forms an almost impermeable surface. Combined with the sloping land this results in very rapid runoff, almost as if it were paved.

The existing InfoWorks model may provide the local authority with a basic tool to assist in the assessment of future development proposals. The model may also provide the starting point for the development of detailed solutions in the next phases of the project.

## 1.5 Summary of Solutions and costs

The table below outlines the various solutions that are possible with associated costs. The preferred options are underlined:

| Location | Solution | Appx. £ |
|---|---|---|
| Filey Beck | Upsizing of existing culverted watercourse and relevant surface water sewers and riparian pipes.<br><br><u>Local storage of floodwater.</u><br><br>Diversion via tunnelled pipeline skirting the northern boundary of the urban area to Ravine Road watercourse, or via a new sea outfall. | £1,206k<br><br>£164k<br><br>£2,319k |
| Long Plantation Watercourse | For this study assume watercourse and ditch improvements with a new flood bank to stop overflows into the estate. | - |
| Wharfedale Estate Sewers | <u>General upsizing of sewers.</u><br><br>General reinforcement. | - |
| Muston Road Sewer | Upsize sewer as far as Ravine Road.<br><br><u>Offline Tank near level crossing (With a non-return valve north of the railway, or All flows pumped across the railway).</u><br><br>Diversion to Pastures Crescent.<br><br>Offline tank at Pastures Crescent. | - |

## 1.6 Economic Appraisal of Filey Beck Solution

A broad estimate has been made of the cost of the construction works required by each option. The costs for the preferred Filey Beck proposals have been weighed against the benefits of the option. The estimated cost at £164,000 compares well against the present value of damages (if nothing is done) of £2.3m. (A similar cost benefit analysis will be carried out for the Long Plantation Watercourse as part of that separate study.). Using the Multi-coloured Manual procedures, this produces a cost-benefit ratio of 6.9. This assumes a £1k annual maintenance budget, a 50 year design life and 100 year standard of protection.

The results of the economic appraisal for Filey Beck have been used to calculate a Defra priority score. The Defra priority score is calculated using the number of properties currently at risk of flooding, the estimated cost of the scheme and the benefit cost ratio. For Filey Beck the Defra priority score is 22.8, which is highly favourable.

Cost benefit analyses have not been carried out for the other projects as those being based on sewerage problems will be appraised under different criteria by the relevant organisations concerned. The outcome of this appraisal has been developed into a prioritised schedule of preferred options.

## 1.7 Recommendations

The recommendations below have been based on the Economic Appraisal, but take account of the confidence levels of the various elements. In some cases the option which appears to be the lowest priced carries high risks of a change of scope that would increase the cost dramatically, or greater risks of conflicts with gas mains or water mains, or environmental risks.

Field Work Recommended

- A flow survey should be carried out to verify the model and a further stage of modelling should be carried out to test the proposals against the verified model. This will enable options to be designed more precisely and will contribute to more reliable cost estimates.
- Surveys of the sewer network to confirm the quality of data used in the model.
- In conjunction with the flow survey, a general ground investigation should be carried out to confirm the nature of the soil and its permeability. This will entail trial pits at various locations to establish its surface characteristics, and deeper boreholes to assist in appraising the behaviour of groundwater. Although this investigation would be primarily to establish the accuracy of the model, it would be beneficial to ensure that sufficient information is derived from this ground investigation to assist in the selection of appropriate construction methods, so that the costs of the various options can be estimated more accurately.

Further Investigations Recommended

- The separate study of the Long Plantation Watercourse should be completed as a matter of urgency, and its conclusions should be implemented at the earliest opportunity. This will prevent flooding of houses in the southern part of the Wharfedale estate, and will reduce the risks to those in the northern part of the Wharfedale estate and on Muston Road.
- The Filey Flooding investigation should proceed to the next stage as a matter of priority.

Specific Solutions Recommended

- In the Filey Beck area, flood banks should be constructed to collect and store runoff from the fields, and to release it slowly through the existing pipes under the houses. Manor Farm is too close to the cliffs and the ravine for this method, and should be relieved by increasing the size of the drains in Church Cliff Drive.
- To prevent flooding at Muston Road, a deep tank sewer made of large pipes should be laid in the highway to collect foul storm water and store it until it can be pumped back into the sewer once flows subside. A non-return valve should be installed on the far side of the railway to prevent backflow into the tank.
- The Wharfedale Estate requires general re-sewerage by online replacement with Responsibility for these various works should be determined in conjunction with the agencies concerned.
- Independent proposals should be carried out to prioritise the work according to organisational and financial parameters which is beyond the scope of this report.

## 1.8 Prioritisation of Proposals

The table below summarises the priority of the proposals that could be adopted, subject to the specific procedures of the various responsible bodies. The right column also expresses the relative proportion of Filey at risk as separated via the identified schemes. This is expressed as a percentage of the numbers of properties affected.

| Priority | Schemes | Proportion of Problems in Filey, expressed as numbers of properties |
|---|---|---|
| High Priority | 1. Filey Beck | 55% |
| | 2. Long Plantation Watercourse (not estimated in this study) | 9%<br><br>(Seriously affects a further 34%) |
| | 3. Muston Road | 12% |
| | 4. Wharfedale Estate | 22% |
| Medium Priority | Filey Senior School | 1% |
| Low Priority | Scarborough Road | 2% |

# *Appendix 1: FLOOD PLAN AND PHOTOGRAPHS*

# 2 Introduction

In every year since 1999, and in some years prior to that, Filey has been subject to flooding incidents during the summer or autumn. The events of 2000 and 2002 were particularly extensive, with 56 properties returning questionnaires reporting flooding and many others affected. Numerous roads and public spaces were inundated, and flood water combined with sewage flowed across private gardens and through the houses causing extensive and costly internal damage.

The floodwater was perceived by the public to come from a variety of sources, including ineffective gullies, inadequate sewers, and runoff from the fields, watercourses and ditches around Filey passing into the urban areas via private gardens and houses. In some instances inadequate riparian pipes were blamed. Some of the flooding was also believed to be caused by the diversion of the Dams Goit watercourse into the public surface water sewers at Pastures Crescent, with only a small overflow pipe to allow some flow to continue along the original channel. New developments are also felt to have added to the problem.

In view of the extensive nature of the flooding, the variety of perceived flood causes, and the number of organisations with potential liabilities, a working party was convened to investigate the flooding problems and to find ways to prevent its recurrence.

The working party comprised representatives of:

- Residents groups
- Filey Town Council (FTC)
- Scarborough Borough Council (SBC)
- The Environment Agency (EA)
- Yorkshire Water (YW)
- North Yorkshire County Council (in its capacity as the Highway Authority) (NYCC)

The working party agreed that Atkins should be appointed to impartially examine the nature and extent of the flooding, identifying its causes, and to propose potential solutions.

After the appointment of Atkins and the commencement of the study, a further storm occurred in August 2003, again resulting in extensive flooding through the same areas. This served to highlight the urgency of the investigation.

This report outlines the work undertaken as part of this study. This includes a summary of:

- the hydrological modelling of the overall catchment using the Flood Estimation handbook techniques;
- the hydraulic modelling of the existing system of watercourses, pipes, sewers, and overland flood routes;
- the options considered an economic assessment of each option; and
- full details of the preferred option.

# 3 Data Gathering

## 3.1 Existing Hydraulic Models

An old HydroWorks model of the combined sewer system from a drainage area plan made in 1993 was provided by YW, with an accompanying Hydraulic Model Audit prepared by Montgomery Watson in 1998. The report states "...exercise...[i.e. calibration for the audit]...does not make the model suitable for assessing problems within the catchment", and "the…model is fit for the purpose of predicting flows reaching the proposed storage and pumping station". The model included the areas of combined sewers, but did not include the separate areas. It appears to have been used in the design process for the storage tanks and pumping station that have been constructed on the promenade, but did not contain any details thereof.

It has been concluded that this model was unsuitable for the present study or broader flood alleviation, as it deals with the combined sewerage system only and focuses on the opposite side of the town.

It is believed that a more recent model exists, being held by Yorkshire Water's consultant, but this model was unavailable within the timescale of this study.

## 3.2 Letters and written reports

All relevant letters written by members of the public to the local authorities have been copied and passed to Atkins, including any attached sketches and photographs. In some cases letters were written directly to Atkins, and these have also been included in the investigation. A database was created to analyse the complaints, recording details of flood times, durations, depths, sources and effects.

The following plans were also provided:

- Gully locations (NYCC)
- Public sewers (YW via NYCC)
- Filey Flood Plan August 2002 (Compiled by Filey residents and presented by NYCC and SBC)
- The Pastures Filey – Proposed drain modifications (NYCC)
- Annotated plans showing locations of flooding attended by FTC 11/08/03

All of the above items are included in Appendix 2.

## 3.3 Questionnaire

Following the August 2002 floods, a questionnaire was issued by Filey Town council to 78 selected properties in the Wharfedale estate area. 57.7% of the questionnaires were returned, and these were passed on to Atkins.

Atkins also sent additional copies of the questionnaire to a number of other properties as requested, and those that responded were included into the investigation.

## 3.4 Topographical Survey

A topographical survey was commissioned to obtain ground levels for the following inter alia: -

- Longsections and profiles of watercourses and ditches, and also of Ravine Road
- A sample of manhole cover levels within the town.
- Threshold levels for a selection of flooded properties
- Topographical surveys to obtain contours in the fields north of Filey near Cherry Tree Close.

## 3.5 Site Visits

The site has been visited by members of the project team to gain familiarity with the locations and to review topography, interview residents affected by flooding, appraise catchment boundaries, watercourse and ditch profiles and overland flow routes, etc.

## 3.6 Mechanical Data

Yorkshire Water provided the following details of pumping stations and real time control installations, where known: -

- Pump start and stop levels
- Pumping rates.
- Inflow rates
- Sight of as-built drawings of the promenade storage tanks.
- Overflow levels
- Existence of a penstock to divert flows from Ravine Road into the tanks enabling use of the outfall for tank overflows in the case of extreme events

## 3.7 List of References Used

A list of the references used in this study is given below:


- *Flood Estimation Handbook – Procedures for Flood Frequency Estimation*, Duncan Reed, Institute of Hydrology, 1999.
- *WaPUG User Note 37 – RC Allitt, Richard Allitt Associates*
- *WaPUG Code of Practice for the Hydraulic Modelling of Sewer Systems version 3.001 Dec2002*
- *FCD PAG 3 March 2003 (“The Multi-Coloured Manual”)*

# 4 Flooding History

## 4.1 Historical Flooding Events

A number of sources have provided flood history information including:

- Letters sent to local councils
- A questionnaire was sent to properties believed to be affected, and over 55 were returned
- Verbal reports from residents during meetings of the working party
- Annotated plans from operatives of the councils and other bodies involved in the response to the flood incidents
- Photographs appended to the above items.
- Yorkshire Water's flooding register. Every water company is required by Ofwat to maintain a register of properties that are liable to flooding in very specific circumstances, which is used to develop periodic budget requirements and strategies at a company and national level. For commercial reasons it is confidential and permission has not been granted for its contents to be revealed in this study. It has been used to provide corroboration of the general pattern of flooding, and contained only four locations where flooding had not already been identified through other sources.

Appendix 2 includes tables and plans showing details of the flooding taken into consideration. They can be summarised as shown in table 3.1.

## 4.2 Summary of Flooding Incidents

Table 3.2 lists some of the storms that have given rise to recorded flooding. There may have been other storms that have caused flooding which has not been recorded, and there are properties which are known to flood for which no formal report has been made.

**Table 3.1 Summary of Historical Flooding**

| Area | Perceived Flooding Problem |
|---|---|
| **Filey Beck** | The watercourses along the southern, downhill boundaries of the fields north of Filey fill up. Small riparian pipes under the houses, which drain the watercourses into the surface water sewers (which ultimately link to a piped watercourse through the estates), are overwhelmed and the watercourses and ditches overflow through the houses into the estate. The overwhelmed sewers and the watercourse then flood other houses further downhill towards Scarborough Road.<br><br>Runoff from the country park and fields north of Church Cliff Farm overwhelms the surface water system in Church Cliff Drive. Floodwater drains through properties in Church Cliff Farm, causing extensive damage. |
| **Muston Road** | Runoff from the station yard is unable to enter gullies and overflows through the houses on the west side into Linton Close |
| **Wharfedale estate** | Extensive flooding from sewers |
| **Long Plantation Watercourse** | Watercourse overflows and floodwater runs through properties into the sewers in the Wharfedale estate |
| **Scarborough Road** | Flooding of the road impinges on some gardens. Work by the highway authorities has identified that tree roots contribute to the problem. |
| **Filey Senior School** | The school is connected to the public sewer upstream of a short length of 150mm diameter pipe, which forms a constriction. Flooding of the highway ensues. |
| **Town Centre** | Some of the properties in the water company flood register lie in this area. |
| **Ravine Road** | Runoff from flooding in the north Filey estates flows into and down Ravine Road. In some events lifting of covers on the sewers and watercourses has been reported. |
| **East Filey** | Scattered reports of isolated flood locations. |

| Date | Comments/Data Source |
|---|---|
| **1985** | Yorkshire Water Flooding Register |
| **1986/87** | Noted on questionnaire return from 1 property at Fewston Close |
| **Dec 1987** | Noted on questionnaire return from 1 property at Linton Close |
| **July 1992** | Noted on questionnaire return from 1 property at Muston Road |
| **7 Sept 1992** | Yorkshire Water Flooding Register |
| **14 Sept 1992** | Yorkshire Water Flooding Register |
| **23 Sept 1992** | Yorkshire Water Flooding Register |
| **24 Nov 1993** | Noted on questionnaire return from 1 property at Muston Road |
| **1994** | Noted on questionnaire return from 1 property at Linton Close |
| **1997** | Noted on questionnaire return from 1 property at Linton Close |
| **1998** | Noted on questionnaire return from 1 property at Wharncliffe Place |
| **Oct 1999** | Noted on questionnaire return from 1 property at Barden Place and 1 at Harewood Drive |
| **Oct 2000** | Noted on questionnaire return from 20 properties |
| **Nov 2001** | Noted on questionnaire return from 2 properties at Muston Road |
| **10 Aug 2002** | 42 properties made written reports of flooding, via questionnaire, letter to FTC, or letter to Atkins. Storm also noted in Yorkshire Water Flooding Register |
| **11 Aug 2003** | 11 properties and two specific highway locations plus other highway flooding noted on a plan, all passed to Atkins by FTC. |
| **23 June 2004** | 8 Properties (?) and highway flooding |

**Table 3.2 Summary of Flooding Incidents**

# 5 Summary of Hydrologic Modelling

## 5.1 General

The primary aims of the hydrological assessment are:

- to derive design flows for input into the hydraulic models (ISIS and InfoWorks) of the Filey Town system. This will subsequently enable the prediction of potential flood risk areas within the catchment.

- Selection of catchment descriptors, for use in the InfoWorks rainfall generator.

Design flow estimates have been derived for the 5, 10, 25, 50, 75, and 100 year return periods, with the principal return periods of interest being 100 years for land drainage issues and 1 in 30 years for matters relating to sewers. These are the standard criteria for these different fields of the water industry.

As an ungauged catchment, the methodology utilised for the hydrological assessment of Filey Town has been adopted to provide the most appropriate and rigorous hydrological analysis that can be achieved without verification data.

## 5.2 FEH Methodology

Design inflow hydrographs have been estimated for the Filey catchment in accordance with the Flood Estimation Handbook (FEH). Filey Town is an ungauged catchment, and therefore FEH procedures for ungauged (‘no-data’) catchments have been used to model catchment hydrology. The key stages in this analysis are outlined below:

- Use of FEH CD-ROM 1999 to determine catchment descriptors;

- Estimate of QMED (the median annual flood) from the FEH equation

- Application of FEH Rainfall-Runoff method to derive hydrographs for the various return periods using synthetic unit hydrographs;

The statistical method has not been adopted because of the relatively small catchments. This method uses analogue catchments but is only applicable for catchments larger than 0.5 $km^2$.

## 5.3 Rainfall Runoff method

The rainfall-runoff method predicts catchment flow by explicitly examining the relationship between rainfall and the hydrological response of a catchment to a storm event. Three key parameters are used by the rainfall-runoff model to define the hydrological characteristics of a catchment, determined on the basis of statistically derived catchment descriptors (FEH CD-ROM) in the case of an ungauged catchment. These include:

- Catchment response to rainfall (time-to-peak, $T_p$);

- Proportion of rainfall which directly contributes to river flow (percentage runoff, PR);

- Quantity of flow in the river prior to the storm event (base flow, BF).

Rainfall is defined in terms of duration, depth and distribution (over time), and may relate to either a probabilistic design event, e.g.: 1 in 100 year return period, or an observed storm event (for calibration purposes).

Where a design event is to be analysed, the storm duration (D) is determined as a function of catchment response (time-to-peak, Tp) such that:

$$D = T_p\left(1+\frac{SAAR}{1000}\right)$$

Rainfall depth is estimated for the return period of a given storm, and this is a function of the return period of the design flood in question. An areal reduction factor is subsequently applied, and the rainfall hyetograph (distribution over time) defined on the basis of a standard time profile.

## 5.4 Design Flows

A figure showing the catchment boundaries can be found in Appendix 4. Catchment descriptors for the northern catchments Filey_NW have been used for all of the northern catchments since this catchment was the closest catchment known by FEH. The size of the catchments was estimated by using isolines and by looking at the landscape during site visits. On this site visit it was also observed that not all of the Filey_NW subcatchment drains into Filey town as suggested by FEH, but actually falls in a north westerly direction to Newbiggin East Farm. This subcatchment is actually smaller and the area was therefore reduced.

The Urban extent was set to zero for all the catchments since rain falling in the town drain to the sewer and thus should not be included in the rainfall runoff as it is included in the sewer model.

The table below shows the peak design flow estimates from the Rainfall runoff method.

| Peak Design Flow ($m^3$/s) at critical storm duration (4.75 hrs) | | | | | |
|---|---|---|---|---|---|
| Return Periods | Rural Subcatchment | | | | |
| | Long_Plant | Filey_N_01 | Filey_N_02 | Filey_N_03 | Filey_N_04 |
| 5 | 0.5 | 0.04 | 0.12 | 0.19 | 0.08 |
| 10 | 0.6 | 0.05 | 0.15 | 0.23 | 0.10 |
| 25 | 0.8 | 0.07 | 0.20 | 0.30 | 0.13 |
| 50 | 0.9 | 0.08 | 0.24 | 0.37 | 0.16 |
| 75 | 1.0 | 0.09 | 0.26 | 0.41 | 0.18 |
| 100 | 1.1 | 0.10 | 0.28 | 0.44 | 0.19 |
| 200 | 1.3 | 0.11 | 0.34 | 0.52 | 0.23 |
| Theoretical Existing capacity * | 0.22 | 0.11 | 0.04 | 0.04 | 0.11 |

**assuming free discharge and no surcharge.*

Hydrographs were also calculated for storm durations of 30 minutes, 1 hour and 2 hours, to be used in conjunction with storms examining critical conditions within the urban area where the time of concentration for urban runoff contribution is very short.

## 5.5 Difficulties with the Methodology

These hydrographs were applied as inflow hydrographs to appropriate nodes on the watercourses and ditches in the InfoWorks model, subdividing them between two or three nodes along the watercourses and ditches where applicable. However, it was subsequently concluded that the FEH flows did not fully reflect the rate of runoff from the rural areas. Firstly in some areas of the model predicted flooding was very much less than observations. Secondly, North Yorkshire County Council provided anecdotal accounts of very rapid runoff attributed to the nature of the soil – a hard clay that forms an almost impermeable surface in certain conditions. Consequently, a revised model was produced in which the rural catchments were represented purely within InfoWorks, as large impermeable areas. This correction improved the correlation between observed and predicted flooding, and was used for the remainder of the modelling.

It is considered that the method of using FEH to produce hydrographs for inflows is theoretically more appropriate, and the representation of such large fields as 100% impermeable is extremely unusual. However, the better fit achieved by this approach cannot be disregarded. The proposed solutions to land drainage issues have been sized in accordance with this method, which gives very large runoff rates. These proposals are therefore likely to be conservative.

# 6 Summary of Drainage Network Modelling

## 6.1 Model Building

### 6.1.1 Software Selection

The software package 'InfoWorks' was selected to hydraulically model the drainage system, including the combined and surface water sewers, open and culverted watercourses, riparian pipes and ditches, and selected overland flow routes, and also some of the proposed options for solutions.

This package is widely used within the water industry for modelling sewer networks and drainage systems. Data are handled as database tables of nodes, conduits and subcatchments, and flows are simulated hydrodynamically using primarily the Colebrook-White equation. The user interface allows the model to be edited interactively on the computer screen and enables the results of simulation runs to be displayed in a tabular format and as longsections of pipe runs or 3D views of nodes. This enables the modeller to gain an intuitive understanding of the flows and appreciate the system and its sensitivities.

### 6.1.2 Base Data

The following information was used in building the model:

- Yorkshire Water Digital Sewer Records
- Ordnance Survey Landline plans
- Yorkshire Water pumping station and real time control data such as was available (see 4.5 above)
- Inflows from the FEH analysis of the catchment (see Section 5).
- Topographical data from surveys.

### 6.1.3 Model Build

Principles and criteria

The hydraulic model of the sewer network was built to the standard of a Type II Drainage Area Planning Model as described in the WaPUG Code of Practice for the Hydraulic Modelling of Sewer Systems. Given that the area is small and the software is now very powerful, there was no need to simplify the model by pruning or merging links. The parts of the model representing watercourses and ditches and overland flow routes only achieve the standard of Type 1 Skeletal Planning Models.

Sewer records import

The basic model was created by importing the electronic versions of the sewer records. The data was pre-processed using Microsoft Excel and MapInfo, to convert the sewer depths quoted in the supplied data into sewer invert levels by deducting depths from manhole cover levels. In view of inconsistencies in the data, this gave rise to some unrealistic levels. Every branch of the network was therefore viewed as a longsection, and where unrealistic values and profiles were observed these were substituted with assumed or interpolated data to give reasonable gradients.

Where manhole cover level data was missing, this was initially supplemented with levels assumed or interpolated by reference to nearby manholes and spot levels in the OS data. Later, survey information started to become available and this was inserted on receipt.

Conduit roughness was represented by equivalent grain sizes. This was taken to be 1.5mm for the majority of the piped sewer network.

Non-sewer conduits

The next stage of model building was the addition of watercourses and ditches, and riparian pipes. The line of each was selected to follow the appropriate lines on the OS data, based on approximate site observations. Some of these were later revised with survey information. Invert and ground levels were assumed based on observations during site visits – again these were revised where possible with survey data. Profiles of watercourses were based on site observations, photographs, and assumptions.

The Dams (a group of ponds associated with dams Goit and the Long Plantation Watercourse) was represented in the model as a single 'storage' node, with assumed areas, depths and levels. In view of the coarseness of data available, flood predictions at this node were disregarded.

The final stage of the network building was the addition of overland flow routes. Routes were created based on contours generated by InfoWorks, with reference to areas of reported flooding. The overland flow was represented as broad, shallow channels. Where the route lay mostly along a road, a channel width of 7m was selected to approximate the distance between kerbs, and a nominal height of 200mm was used. Where the overland flow route passed mostly over gardens, a broader 10m channel was taken, again with a nominal 200mm height. It was not considered possible to accurately measure or predict flows along these routes, in view of the number of obstacles such as fences, shrubs, sheds, raised patios, etc. The purpose of these channels was merely to identify instances of flow in them.

Where the overland flow routes meet the sewer and other networks, they were linked to the nodes (manholes) on those networks. The invert level in the overland flow route was set to equate to the ground level of the manholes. In order to prevent "pipe above ground" type error messages during the network validation process carried out by InfoWorks, the ground level at these manholes was artificially set 200mm high, to correspond to the nominal 200mm height of the overland flow routes. A consequence of this approach is that when results are presented by InfoWorks, water levels above the actual manhole cover level are not treated as flooding, since they are below the ground level. In this study the test of flooding at these locations has been the presence of flow in the overland link, and therefore this approach has been suitable. WaPUG User Note 37 suggests the use of an additional dummy node, and this may be beneficial in more detailed future stages of his investigation.

Representation of Runoff

Urban subcatchment areas were drawn onto the OS background map using the on-screen editing facilities in InfoWorks. The subcatchments are assigned to network nodes as part of this process, and contributing areas are calculated by the software. The runoff surfaces (commonly roads, roofs, and permeable areas) can be evaluated by similar automated procedures where the OS data identifies them as separate features. Unfortunately the OS data available was a single layer with no feature code to distinguish roads and roofs. A visual appraisal of the map divided the town into five basic zones in which the relative proportions of roads, roofs and permeable areas looked similar, and for each of these a sample area 50m square was measured in detail to establish the relative percentages of the runoff surfaces. These percentages were then applied to all subcatchments within the zone. Some subcatchments were later amended to reflect anomalies or better information.

Villages to the south of Filey, whose flows are pumped into this catchment, were represented by a dummy rectangular catchment draining to a pumping station whose pump rate was based on data provided by Yorkshire Water for flows into the promenade tanks. This area is remote from the flooding and did not require a detailed representation.

The modelling of rural subcatchments is described in section 5 above. Initially the subcatchments were represented by inflow hydrographs derived from FEH. A better fit was achieved by representing them as large InfoWorks subcatchments with 100% impermeability. The latter approach is justified by anecdotal descriptions of the behaviour of the soil, but would not otherwise be considered appropriate in absence of the correlation between observed and predicted flooding.

Mechanical and Electrical Plant

The Wastewater Treatment Works (WwTW) has not been modelled separately: The pumps in the promenade tanks that feed it are shown on the plan view as passing through the WwTW site for illustrative purposes, but the performance of the WwTW does not impinge on this flooding investigation.

Information from Yorkshire Water indicates that there is a penstock at the foot of the ravine, which in times of storm diverts flow into the tanks. The outfall is then used as an overflow for the tanks. The location and operating details of the penstock have not been provided, nor details of the pipework connecting it to the tank. These matters were not readily determined by observation of the sewer records. To model this penstock, a small pipe was placed in the Ravine watercourse in the approximate area, such that low flows would pass on through the outfall but storm flows would be forced to travel via links to the combined system into the tanks. This is an imperfect representation of the performance of the penstock, but creates a prediction of flooding at the foot of the ravine that corresponds to reports from council operatives of manhole covers being blown off in this area. Initial runs of the model indicate that this area has no influence on the main areas of flooding under consideration, and so a more detailed representation of the penstock has not been required in this phase.

Foul contributions

The default population density was assumed. This study investigates extreme storm events in which foul flows play only a minor role, and there was no need to model the foul flows in detail. In the separate areas, only surface water catchments were applied. This was partly an outcome of the relatively low importance of foul contributions to this study, but also enabled predicted flooding to be quickly identified by checking for operation of the Wharfedale and Thorn Tree Avenue pumping stations – any flow would indicate that surface water had entered the foul system. (In the model this would be via the overland flow routes, representing floodwater entering the fouls system through manholes in the road or via flooded kitchen gullies.)

New Development

Only one new development has been brought to the attention of Atkins. This lies in the area between the existing pastures Crescent estate and Cawthorne Crescent. Most of the housing would be on the sloping land between Pastures Crescent and The Dams, but an access road will connect to the end of Cawthorne Crescent. The drainage from the estate is subject to ongoing negotiations between the developer and the development control authorities. All possible outcomes of these negotiations have been accounted for either formally or informally in the model,

Miscellaneous

Land use types from the InfoWorks defaults were used.

The soil type was set to 2, based on the Wallingford procedure maps. The use of soil type 4 should be considered in any future verification, to reflect the local soil type as described above.

### 6.1.4 Selection of Design Storms

In absence of any hyetographs of actual rainfall intensities, standard design storms based on the FEH were used. Catchment descriptors from FEH were applied to the InfoWorks FEH rainfall generator, to give storms compatible with the inflow hydrographs. Spatially varied rainfall was not considered: in particular it should be noted that all storms were applied to the whole urban and rural catchment.

In a typical study of properties flooding as a result of hydraulic inadequacy of a sewerage network, owned by a water company and regulated by Ofwat, the critical storm duration for the locality would be selected by passing storms of all durations through the network and noting which storm generates the worst conditions at the flooding properties. This storm duration would then be used for storms of return periods up to 1 in 30 years. This approach can only be applied in part in the case of Filey. Some of the problems are attributable to sewers as described. Other problems lie in the domain of land drainage authorities where events with return periods of 100 and 200 years must be considered and slow runoff from fields across a wide catchment gives a much longer critical duration than rapid urban runoff. A further complication lies in the fact that when statistics are analysed it is found that storm return periods (rainfall events) do not match the associated river flow return periods, so. for example a 1 in 100 year flood event (river flow) is considered to be associated with a 1 in 140 year storm (rainfall) event.

Therefore the urban catchment was tested with relatively short duration storms to find the urban critical duration (60 or 120 minutes, depending on location), and the overall catchment was tested as part of the FEH analysis to give the much longer critical duration for the rural contributions. After the change of approach to modelling rural subcatchments within InfoWorks, the rate of rural runoff was very much quicker and a duration of 120 minutes was taken. The change also eliminated the need to consider unequal event and storm return periods.

Thus the performance of the existing system and the proposals were measured primarily for a 60 or 120 minute 1 in 30 year storm, and for a 285 minute 1 in 100 year event (140 year storm)

Although at a glance these figures would appear to indicate a much more onerous standard for the rural long duration events, in practice owing to reduction factors for area and duration (i.e. rainfall intensities over a wide area or duration are averaged out, giving lower values) the actual flow rates are very similar to the equivalent 30 year short duration storm.

Proposals for solutions which lie in the jurisdiction of the water company should therefore be tested against their industry standard 1 in 30 year storms with critical durations based on urban flows but taking cognizance of the rural contribution. Solutions which address issues of land drainage problems should be tested for the long duration 1 in 100 event (1 in 140 year storm) if the inflow hydrograph method is used and for a 100 year 120 minute storm for the InfoWorks subcatchment method.

### 6.1.5 Model Testing and Verification

Hydraulic verification of the model by means of a flow survey has not been carried out during this phase of the study.

For the historical verification, all the known flood locations and incidents were drawn onto MapInfo layers to be overlain on the OS plan and views of the model. Simulated design storms of 100 and 30 year return periods were then passed through the model, and the locations of predicted and recorded flooding were compared.

The pattern of flooding was very similar, with extensive problems throughout Muston Road, the Wharfedale estate, North Filey, Scarborough Road, etc. appearing on both the predicted and historical data. There is some underprediction by the model, where reported flooding does not appear to be supported by the model. Typical locations are Fir Tree Drive at the junction with Scarborough Road, and the upper part of Ravine Road. Possible causes of the discrepancies are: -

- The performance of gullies, which are not expressly modelled. It may be that overland flooding further up the hill in Fir Tree Drive is unable to return to the sewers because of blocked gullies, and continues to flow to this point, or it could be local rain that is unable to enter the sewers. Either of these would not show on the model, which assumes normal gully performance.

- The profile of Ravine Road may retain flows in the channels, preventing the return of flows to the sewer in areas where there are no gullies.

These problems were eliminated by using the approach of representing rural catchments within InfoWorks rather than as inflow hydrographs from FEH.

There is an apparent overprediction of flooding in the town centre, and in particular the central car parks. Possible causes of the discrepancies are: -

- Under-reporting of actual flooding. The presence of some of the properties listed on Yorkshire Water's flooding register in this area does indicate that there is indeed a problem. Additional incidents may not have been reported, or may have been reported to other organisations. The flooding information provided by Yorkshire Water focuses on internal flooding of properties owing to hydraulic incapacity, and incidents which do not fall into this narrow definition would not have been included. Alternatively, owing to the steeper topography, flooding may run off along streets without being perceived as excessive in the wet weather.

- The car parks have been represented as large subcatchments draining to single nodes – the only ones in the area shown on the sewer records. It is presumed that there is an actual private drainage system within the car parks which has not been possible to include in the model at this stage, but which would provide some additional storage. The car parks are also relatively level but with a degree of undulation which may give rise to ponding that would not be perceived as flooding. However, the predicted flood volumes at these nodes are high in relation to the remainder of the network and since this area may contribute to backflows into the Muston Road area it should be one of the foci of any future verification.

<u>Overall, despite the problems in the central car parks, the model is considered to give a fair representation of the performance of the network for the purpose of this study,</u> but it is recommended that expensive final solutions to the flooding problems should not be based on this model without a formal hydraulic verification by a flow survey.

## 6.2 Modelling Processes and Outputs

Modelling comprises three phases:

- Calibration and verification -
- Assessment of the performance of the existing system
- Development of Proposals

<u>Calibration and Verification</u>

The calibration phase was the longest phase, and includes the historical verification described above and overlaps into the second phase – assessing the performance of the existing system. The phase was prolonged by the intermittent receipt of different elements of data, each of which had to be added to the model and validated and measured against the known flooding incidents to assess the impacts of each change.

During the calibration and (historical) verification the performance of the model was compared against known historic flooding incidents, and this was the first step in appraising the performance of the existing system, confirming that the flooding was a consequence of hydraulic inadequacy of the pipework rather than simply a problem of rainfall not entering the sewer. But it was now possible also to appraise the sequence of events and appraise the reasons for the hydraulic inadequacy.

<u>Assessment of the Performance of the Existing System</u>

Using the Inflow Hydrograph approach to represent rural subcatchments, the following sequence of events was noted: -

*Muston Road*

The first location to experience difficulties is the low point of Muston Road, near the level crossing. The pipe under the railway is of inadequate capacity for the flow, and causes surcharge leading to flooding of Muston Road. Since the model indicates some backflow under the railway, a test was made imagining a free outfall from the sewer at this point, to test if the flooding was a consequence of the backflow. This test proved that the flooding originates locally and is only exacerbated by the backflow. Eyewitness reports state that flooding in this area runs off the station yard and is unable to enter the gullies – presumably because these are surcharged. The floodwater at this point runs along the overland flow route to Linton Close. This route was inserted to represent reports that flow passed through the gardens of Muston Road and into Linton Close, and the model does appear to confirm that this would happen.

*Wharfedale Estate*

The second effect to be noted is that the surface water sewerage network in the Wharfedale Estate becomes surcharged and floods. This is endemic to the whole estate, not just isolated pockets or constrictions. Floodwater passes along the reported overland flood routes that have been put into the model. In the Linton Close area it mingles with the floodwater from Muston Road. It enters the foul system at various points around the estate, and passes to the Wharfedale Pumping Station, confirming reports that it is involved in the flooding incidents. The Wharfedale Pumping Station is activated and pumps flow into Muston Road, which is already flooded. Thus the water circulates back to Linton Close.

*Dams Goit*

The Wharfedale surface water sewers combine at a point in Pastures Crescent, where the sewers cross the Dams Goit watercourse. The watercourse has been diverted into the sewers at this point, with only a very small overflow pipe connecting to the original watercourse downstream of this point. Atkins understood that proposals existed to enlarge the opening to the downstream watercourse and have included assumptions regarding these proposals in the investigation. The conclusion is that this work is not strictly necessary, but not harmful. The work has now been implemented, but not exactly as originally envisaged, and in any future phases of the project the model should be adjusted to reflect the work as built.

There is a perception amongst the residents that this diversion was a cause of the problem, and that the sewer was unable to cope with the flows from the watercourse in addition to those from the Wharfedale estate. It is true that all the manholes along the route surcharge, but this is a consequence of the inadequacy of the pipes to transport the flow rather than water backing up from the watercourse. If the watercourse was unable to drain into its diverted route, it would flood at the diversion point and the level pool would not reach high enough up the hill to cause flooding in the Wharfedale estate.

(Similarly, there is a perception that sections of Cawthorne Crescent have been protected from flooding by tarmac sealing the manholes. The model indicates that the absence of flooding in this section results from the top water level not reaching the ground level. If the model had indicated a top water level higher than the ground level, this would have been confirmed in reality by floodwater emerging from highway gullies in this section of Cawthorne Crescent.)

Since the rural flows take longer to concentrate than the rapid urban runoff, the peak flow in Dams Goit is not concurrent with the peak flow in the sewers. The sewers a short distance downstream of the diversion point are larger than those in the Wharfedale Estate and are of sufficient capacity to carry all the flows currently directed to them.

*Long Plantation Watercourse*

The next effect to be noted is that as the rural flows build up, the watercourses and ditches fill up and overflow. The Long Plantation Watercourse overflows through the houses and gardens and into the Wharfedale Estate where it eventually drains via the highway gullies into the surface water sewers. These are already flooded by local rainwater, and the floods are seriously exacerbated by the new water overflowing from Long Plantation Watercourse. In some locations up to 90% of the flood volume has its origin in the watercourse. The duration of the floods can also be extended from approximately 1 hour to 12 hours, resulting from a 2hr 'design' storm. Because the Wharfedale estate is linked to Muston Road by the Wharfedale pumping station and by the overland flow flood route between Linton Close and Muston Road, the effects of the Long Plantation Watercourse flooding can also be seen in exacerbated flooding in Muston road itself.

*Filey Beck*

In the north of Filey, the surface water system has hitherto been adequate. There are some instances of small volumes of predicted flooding, but it is felt that these reflect a combination of the model's limited accuracy and localised ponding that would be considered acceptable in such an extreme event.

As the rural flows build up, riparian drains linking the watercourses and ditches in the fields to the surface water system become overwhelmed. The watercourses and ditches fill and overflow through the houses and into the streets. The surface water system is not designed for these rural flows and surcharges and floods. Water follows the overland flood routes deeper into the estates until it reaches sewers that have not yet been filled. The sewers in this area drain to the piped watercourse through the estates, which in itself is of sufficient capacity to carry the storm flows.

The Country Park is a relatively recent development, which may have affected the flow regime in two ways. Firstly areas of the land have been paved for car parking, secondly the old ridge and furrow field system which stored runoff and directed it towards the sea has been levelled. The upper portion now runs off down Horn dale, while the lower part of the park drains to Church Cliff Drive. Here the surface water sewer is unable to cope. There are anecdotal accounts that gully problems are exacerbated by blockage resulting from agricultural detritus. The flow builds up and overflows through Church Cliff Farm – which has been converted to residential accommodation with a high proportion of elderly residents. The flow builds up rapidly and presents a danger to life and limb as well as causing damage to property

<u>Implications of revised rural catchment methodology</u>

Representing the rural areas as InfoWorks subcatchments, the rural runoff is much quicker and starts to flood into the town at an earlier phase. However, the separation of the interacting sewerage and land drainage problems discovered above remains valid. The solutions can be implemented with some degree of independence by the respective organisations, although Muston Road and Wharfedale will not be fully free of flooding until the sewerage solutions and Long Plantation Watercourse works have both been implemented.

## 6.3 Summary of Hydraulic Problems

The hydraulic problems of Filey confirmed by the modelling process are be summarised in table 6.1. This table may be compared to historical flooding in table 3.1.

## 6.4 Principles Used for Option Development

Options have been generated by considering the problems individually, seeking a solution to one, and then developing solutions for the remainder of the problems one by one assuming implementation of the solutions already derived for the first problems.

Alternative combinations of solutions may be feasible and should be considered in the next phase of the project.

The various major elements of these proposals are stand-alone solutions in the sense that they solve the local problem without reference to which particular solution is selected for the other problems.

**Table 6.1 Summary of Modelled Flooding**

| Area | Modelled Flooding Problem |
|---|---|
| **Filey Beck** | Watercourses and ditches along the southern, downhill boundaries of the fields north of Filey fill up. Small riparian pipes under the houses, which drain the watercourses and ditches into the surface water sewers (which ultimately link to a piped watercourse through the estates) are overwhelmed and the watercourses overflow through the houses into the estate. The overwhelmed sewers and the watercourse then flood other houses further downhill towards Scarborough Road. Some of these affects, especially those resulting from inflows at Cherry Tree Drive, were difficult to corroborate using the inflow hydrograph approach but were predicted well by the representation of rural catchments within InfoWorks.<br><br>Runoff from the country park and fields north of Church Cliff Farm overwhelms the surface water system in Church Cliff Drive. Floodwater drains through properties in Church Cliff Farm. |
| **Muston Road** | The combined sewer in Muston Road is of insufficient capacity and overflows through the houses on the west side into Linton Close. This is compounded by high water levels north of the level crossing, and (subject to confirmation of the modelling of the town centre car parks) there is backflow under the level crossing. |
| **Wharfedale estate** | The whole surface water sewerage system appears to be of insufficient capacity. |
| **Long Plantation Watercourse** | Watercourse overflows and floodwater runs through properties into the sewers in the Wharfedale estate |
| **Scarborough Road** | The surface water sewers appear to be overloaded. |
| **Filey Senior School** | The observed flooding mechanism was confirmed. |
| **Town Centre** | Flooding predicted in the town centre is more extensive than reported. Overland flow has not been modelled in this area. |
| **Ravine Road** | Flooding in Ravine Road was best predicted when using the method of representing rural catchments within InfoWorks. The insertion of a small pipe to coarsely emulate the penstock gave rise to flooding at the base of the hill corroborating reports of covers being blown off in this area. |
| **East Filey** | Scattered predictions of isolated flood locations, but not in exactly the same pattern as observations. There are many assumed ground levels in this area. |

# 7 Description of Remedial Options

The following options have been considered to alleviate flooding within Filey from the respective sewerage and watercourse/land drainage problems.

## 7.1 Long Plantation Watercourse

The Long Plantation Watercourse has been the subject of a Critical Ordinary Watercourses Study. It is assumed for the purpose of this report that the Long Plantation Watercourse will be provided with a flood bank on the Northern side of sufficient dimensions to prevent water from overflowing into the Wharfedale Estate. (**Option LPW**)

## 7.2 Filey Beck

The flooding in the estates in north Filey is from two sources: flows from the watercourse itself and runoff from the country park and the fields and on the hills north of Filey.

**Option F1** - To do nothing has the lowest capital cost, but will allow the ongoing situation of recurrent internal flooding of properties to continue.

**Option F2** is the enlargement of the existing watercourse from Cherry Tree Drive to Ravine Road as well as upsizing the Church Cliff Drive sewer to say 600mm diameter, conveying the flow away from the affected property and into the Ravine Road pipelines. It will also require the enlargement of the surface water sewers on the branches stretching back from the watercourses to the riparian pipes that drain the fields. These riparian pipes would also need to be enlarged. This option requires extensive pipelaying operations through residential areas. Difficulties may also be encountered in ensuring that the riparian works are carried out.

**Option F3** is the provision of a new route for the piped watercourse, constructed as a tunnelled pipeline of size ranging from 1200 to 1800mm diameter. The new route would pass to the north of the town under the fields from which much of the runoff originates. It would bring flows to a new outfall north of Coble Landing. Pipeline construction is expected to be largely in tunnel owing to the depths required by the adverse topography. For this option all of the work is off the public highway, and once consent is obtained for use of the land it would be of relatively low disruption. There may be some minor conflicts with major sewage pumping mains that follow a similar route. There would be some civil engineering complexity in bringing the new watercourse down the cliffs to the beach. A cascade was assumed for modelling purposes, but this could be unsightly and difficult to construct. Future phases of the project may seek to increase the gradient and depth of the tunnel such that it emerges at the foot of the cliff. This could additionally be beneficial in reducing pipe sizes, but would greatly increase shaft depth. Consideration should also be given to methods for collecting runoff from fields, with its load of suspended soil and agricultural detritus, into the new watercourse at an adequate flow rate without allowing sedimentation to occur in the tunnel. Increased gradients to the foot of the cliff could be beneficial in this regard as well. This option also includes the diversion of the flow to a new outfall North of Coble Landing. Option F3 has the advantage of allowing the riparian pipes to be abandoned.

**Option F4** is the provision of storage at the points of overflow through the residential properties. It is envisaged that the storage would be provided by excavating basins, but it could also be provided by raising embankments to allow fields to flood, or by providing deep civil engineering structures with to be drained by pumping. The volumes required are probably excessive for new basins, being of the order of 5000m$^3$ to 10000m$^3$. Storage provided for the runoff from the park within its boundaries would be a basin or underground structure of volume 43m3. However, the presence of stored water close to the top of the cliffs and ravine slopes would add to their instability, and so to protect Church Cliff Farm in this storage option the drains in Church Cliff Drive should be enlarged as in Option F2.

## 7.3 Muston Road

**Option M1** - To do nothing has the lowest capital cost, but will allow the ongoing situation of recurrent internal foul flooding of properties to continue.

**Option M2** – to upsize the sewer from Muston Road to Ravine Road to 600mm dia pipework will involve extensive disruption of the following streets: -

Muston Road

Station Ave

Scarborough Road

Ravine Hill

The disruption will include noise, dust, loss of profits to businesses affected by loss of access to the works, service diversions, vibration, road closure, etc.

In addition a crossing of the railway will be required, which will incur a protracted period for consultation with Network rail and the local train operator, and will involve high costs for supervision by their staff.

**Option M3** – to construct an offline tank sewer in Muston Road, will reduce all of the above considerations. The disruption will be more localised, business affected will be minimal. There will be no rail crossing, but the proximity of the work to the level crossing will still require some railway consultation and supervision.

The tank sewer will comprise 2100mm dia pipes laid off-line from number 40 to number 8 Muston Road at a depth of approximately 4.2m. It will be connected to the sewer system by overflows at each end and two intermediate positions, and will return flow to the sewer by pumps. These have been modelled as a low flow pump of 10 l/s and a main pump of 40 l/s, discharging to a point on the Muston Road sewer downstream of the connection from Gardners Court. The use of sensors to switch the pumps off while the Muston Road sewer is full is advocated to avoid simply recirculating the water.

This option also requires the insertion of a non return valve on the north side of the railway, to prevent backflow from that area from entering the tank.

**Option M4** has not been modelled. In this option the Muston Road sewer would be diverted (or an overflow from it provided) to drain along Wharfedale and into Pastures Crescent. From there it would follow the existing surface water system to the promenade. This is undesirable in that it would add combined sewage to the surface water network, which could unless controlled give rise to pollution at Dams Goit and on the beach. This pollution could be avoided by the complete diversion of Dams Goit into the same sewer, and then diversion of the piped watercourse in the Ravine into the tanks on the promenade. The volume of water pumped to treatment would thus increase. The advantage of Option M4 is that it could incorporate some of he upsizing of sewers required for the Wharfedale estate problems.

**Option M5** has not been modelled. In this option excess flow from Muston Road would be carried to a new offline storm attenuation tank in the open space adjacent to Dams Goit at Pastures Crescent. After storms, flow would be pumped back to Muston Road. This is seen as undesirable in that it does not deal with the problem at its location. It would however reduce the involvement of the railway.

## 7.4 Wharfedale Estate

**Option W1** - To do nothing has the lowest capital cost, but will allow the ongoing situation of recurrent internal flooding of properties to continue.

**Option W2** – To upsize the sewerage network throughout the estate appears to be the only solution. The problem of undersized pipes is not restricted to isolated locations, but affects every street. To develop this option, design commenced at the Dams Goit connection, beyond which pipe sizes are adequate. Pipe sizes were increased progressively up the various branches, and in some cases new loops were created, until flooding had been eliminated from the major branches. The particular layout modelled is not necessarily the optimum variant, and this should be subject to further modelling at future stages of the project.

It may be possible to construct parts of this option in combination with Option M4 above.

A variant of Option W2 is to reinforce the sewers by providing additional, parallel pipelines. Pipe sizes could then be smaller reducing costs, and the existing assets would continue to be used. This should also be modelled at the next stage. However, this variant has a greater risk of encountering problems with conflicting utility apparatus.

**Option W3** has not been modelled – in this option small amounts of storage would be provided at various locations around the estate. This is not expected to be a viable option, as there would still be difficulty in bringing flows to the storage given the small pipe sizes, and in draining the storage on completion of the storm because the existing sewers are generally fairly shallow.

## 7.5 Scarborough Road

At the western end of Scarborough Road flooding has been observed and is also predicted by the model. The Highway Authority has carried out work in this area to clear tree roots from the drains, and this is expected to ameliorate the problem. Consequently no proposals are put forward in this report. However, the situation should be monitored and re-included in further phases of this project if problems persist. It is envisaged that a solution would comprise online storage in upsized pipework (**Option S1**).

## 7.6 Filey Senior School.

There is a constriction in the public sewer immediately downstream of the connection from the school, where it drops from a 225mm diameter sewer to 150mm diameter for a short distance. The model indicates that if this short length were to be relayed at 225mm diameter the problem would be alleviated. (**Option FSS1**)

## 7.7 Town Centre

Predicted flooding in the town centre is subject to the accuracy of the flows from the car parks. However, it is noted that two of the properties on Yorkshire Water's flooding register would be relieved by Option M2 above.

## 7.8 Ravine Road

Observed flooding in the upper part of Ravine Road is expected to be relieved by the solutions to the North Filey Estates flooding, and no work is required locally.

Reports of manhole covers being blown off at the base of Ravine Road appear to be corroborated by the model but it should be noted that the penstock has not been modelled in detail. This area is considered to be outside the scope of this project to alleviate the general flooding of houses in the higher areas of the town, and no work is proposed. It is recommended that in any future phase of the project the penstock should be modelled in greater detail to assist with the model verification.

## 7.9 East Filey

There have been scattered observations of flooding in the eastern area of Filey, and the model also shows scattered flooding although it is not exactly co-incident with the observations. This is thought to be a result of assumed level information.

As for the lower part of Ravine Road, this area is considered to be outside of the general flooding problem in Filey and no work is proposed at this stage although better detail should be obtained for any future flow verification.

# 8 Assessment of Costs and Funding

## 8.1 Estimation methodology

To assess costs, node and conduit details of the works proposed for each option were copied from InfoWorks into an Excel Spreadsheet. Rates were then estimated for each item and summed for each option. Allowances were made for miscellaneous costs such as road closures, and 20% of the conduits estimated cost was applied as an allowance for service diversions where the works are in urban areas. A further 15% was applied for design and supervision. These estimates have not been compared to estimates from contractors or other databases, but illustrate the relative merits of the proposals in financial terms.

A summary sheet from the excel spreadsheet is included as Table 8.1

## 8.2 Discussion of Costs for Each Option

No ground information has been obtained. It is assumed that dewatering is not required in the soil conditions of Filey.

### 8.2.1 Long Plantation Watercourse

**Option LPW – Subject to another study.** The cost of this aspect of the work is not discussed here as it is the subject of a separate study.

### 8.2.2 Filey Beck

**Option F1 – do nothing** Zero cost for construction works. The social and economical costs of the ongoing risk of internal flooding to approximately 72 houses and external flooding to a further 42 properties, have not been assessed.

**Option F2 – upsizing through the estates** Cost is based on simple civil engineering works. It assumes that riparian pipes under houses are replaced as part of the project at the same linear rates as the remainder of the project – this may require further consideration. The upsizing in Church Cliff Drive has not been modelled and so the costs here are less reliable.

**Option F3 – diversion via new tunnel north of the town** Although the option is described as a tunnel the cost is based on open cut and allows £50000 for a structure to drop the flows to sea level. A steeper bored tunnel may be cost effective. Access for vehicles to sites in the fields may be difficult in wet conditions.

**Option F4 – storage at flooding points** The cost is based on the construction of an embankment to retain flood water in the fields north of the town, to drain through existing routes. To make the storage volume by scraping off the soil to a relevant depth could cost in the region of £304,000.

### 8.2.3 Muston Road

**Option M1 – Do nothing** Zero cost for construction works. The social and economical costs of the ongoing risk of internal foul flooding to approximately 15 houses and external foul flooding to a further 13 properties, have not been assessed.

**Option M2 – Upsizing through town** The cost is based on relaying the full length of Muston road right through the town centre to Ravine Road. The cost excludes the costs and delays associated with laying a new sewer across the level crossing of the railway.

**Option M3** – **tank on Muston Road** The cost includes an allowance of £60,000 for the deep shaft including pumps, short rising mains, installation of telemetry, power supplies, etc. It excludes any costs associated with proximity to the railway.

**Option M4 – diversion to Pastures Crescent** has not been modelled and the cost is therefore less reliable. The cost does not account for any possible overlap with the proposals for the Wharfedale estate, and assumes that no work is required beyond Pastures Crescent to accommodate the additional flow. This may be pertinent to arrangements at the penstock at the base of the ravine.

**Option M5 – Storage at Pastures Crescent** has not been modelled and the cost are less reliable. The figure is a ball-park all-in figure based on similar experience for other clients.

### 8.2.4 Wharfedale Estate

**Option W1 – do nothing** Zero cost for construction works. The social and economical costs of the ongoing risk of internal flooding to approximately 41 houses and external flooding to a further 14 properties, have not been assessed.

**Option W2 – General Upsizing** Cost is moderately reliable but subject to the final arrangement designed for the project.

**Option W3 – general reinforcement** Cost assumes a similar layout to W2, but offline. It assumes that since capacity exists in the current system the proposed pipes could all be one size smaller. The cost does not reflect the increased risk of conflicts with services for working off the line of the current sewer, and does not include for additional work in connecting to the existing system at numerous points throughout the network.

### 8.2.5 Scarborough Road

**Option S1** – local upsizing This option has not been modelled and the cost is therefore unreliable. It is based on upsizing to 600mm diameter for approx 360m.

### 8.2.6 Filey Senior School.

**Option FSS1 – local upsizing** This is the cost for simple short pipeline replacement.

## 8.3 Funding

### 8.3.1 Land Drainage Works

It is anticipated that work to resolve the land drainage issues will be funded by means of obtaining grants from DEFRA. Such grants are available where

- The watercourse satisfy the classification of Critical Ordinary Watercourses, and
- The Cost - Benefit analysis is satisfactory.
- The projects is successful in competing for the funds on a priority basis against other similar projects in the region and nationally

### 8.3.2 Sewerage Works

The sewerage works will be funded by the water company subject to the following

- Ofwat's triggers are met
    - Internal Foul Flooding of Properties

    - Two or more events in 10 years NOT caused by exceptional events (greater than 1 in 30 years magnitude)

- The project is successful in competing for the funds on a priority basis against other similar projects in the region

# 9 Conclusions

## 9.1 Status of Watercourses

The Long Plantation Watercourse and Filey Beck with its tributaries are watercourses that give rise to serious and extensive flooding problems including flooding of highways, gardens, fields, and internal flooding of properties. It is considered that they meet the criteria to be designated as Critical Ordinary Watercourses.

## 9.2 Methodology for Recommending Options

The following paragraphs discuss some of the relative merits of each option in terms of cost, buildability, disruption, etc. A recommendation is developed accordingly.

## 9.3 Discussion of Merits for Each Option

### 9.3.1 Long Plantation Watercourse

**Option LPW – Subject to another study.**

### 9.3.2 Filey Beck

**Option F1 – do nothing** See option M1 above.

**Option F2 – upsizing through the estates** The upsizing of sewers through the town is costly and disruptive. This option in particular requires enlargement of riparian pipes under houses.

**Option F3 – diversion via new tunnel north of the town** This option is apparently simple but would be costly and would involve relatively complex engineering problems in designing intake structures at the points of flooding and in designing the method for dropping flows to the beach level.

**Option F4 – storage at flooding points** This option is very much cheaper than major pipelaying operations and is the preferred option. However, consideration should be given to risks – if an embankment is overtopped or fails, catastrophic and life threatening flood surges could occur.

### 9.3.3 Muston Road

**Option M1 – Do nothing** In view of the level of suffering and reporting of problems the current situation should be resolved by all reasonable steps and the 'do nothing' option should only be followed in the case of a total absence of funding for the work. This comment applies equally to the 'do nothing' option for each problem, and is not repeated below.

**Option M2 – Upsizing through town** This option is costly, highly disruptive, and fraught with difficulties in crossing the railway. It would benefit some, but not all, of the properties on Yorkshire Water's Ofwat flooding register that lie in the town centre area. On balance, it is not considered to be the optimum solution.

**Option M3** – **tank on Muston Road** Proximity to the railway may be a problem, but to a lesser extent than for a crossing as in M2. This problem deals with the majority of the perceived problem at source, but does to resolve unconfirmed predicted flooding at the southern end of Muston Road. The project would be highly disruptive, but would probably be accepted by the public owing to the high profile of the flooding events. It is the second cheapest option, but the estimate for the cheaper, un-modelled option M4 is unreliable.

**Option M4 – diversion to Pastures Crescent** This proposal could result in contaminated water being discharged to the open section of dams Goit, and later onto the beach. Further alterations may be required to the pipework downstream to accommodate the extra flow, although there appears to be capacity up to the penstock. Here the contaminated flow should be diverted into the tanks on the promenade and treated as appropriate. This is the cheapest option, but is considered undesirable owing to uncertainty about the costs and questions about the destination of contaminated flows.

**Option M5 – Storage at Pastures Crescent** This option keeps traffic disruption on Muston Road to a minimum, but increases disruption in the Wharfedale Estate to resolve problems at Muston Road. It could therefore prove unpopular. The green space at Dams Goit would be impaired by the presence of the tank. This option is likely to prove more costly than the tank in Muston Road, but it has not been modelled and its required size has not been established. The cost may therefore increase or reduce.

### 9.3.4 Wharfedale Estate

**Option W1 – do nothing** See Option M1 above.

**Option W2 – General Upsizing** This is the recommended solution for this area. This option appears more expensive than Option W3 below, but this option does not require connections to the existing system, it poses less risk of conflict with services, and by following the line of the existing system is less likely to encounter conflicts with existing sewers.

**Option W3 – general reinforcement** This option preserves existing assets and is cheaper than option W2, but as described above could have a greater final cost with more difficulty on site.

### 9.3.5 Scarborough Road

**Option S1** – If flooding continues after tree root cutting, then this option will need to be modelled and implemented.

### 9.3.6 Filey Senior School.

**Option FSS1 – local upsizing** This small element of work will resolve the flooding of Filey Senior School.

# 10 Recommendations

## 10.1 Surveys

The following surveys are required to enable verification of the model.

Flow survey

Impermeable Area survey

Survey of the penstock at the foot of the ravine (flow parameters, switch levels, etc)

Topographical surveys

Interpolated and assumed levels

Rural subcatchment boundaries

Ground investigation

Trial pits to confirm soil type and permeability

Boreholes to assist in prediction of construction techniques and option selection

## 10.2 Modelling

The model should be formally verified using the data from the above surveys.

The verified model should then be used to confirm the viability of the options proposed herein, particularly those which have not yet been modelled. It may then also be used to confirm final designs.

The verified model should be utilised by the local Planning Authority for development control purposes.

## 10.3 Proposals

Subject to the remodelling above, the following works should be implemented

### 10.3.1 Long Plantation Watercourse

The proposals of the separate study must be implemented to prevent flood water overflowing into the Wharfedale Estate to negate the benefit of Options M2 and W3 above.

### 10.3.2 Filey Beck

Option F4 subject to embankment overtopping or failure risk assessment

### 10.3.3 Muston Road

Option M3 – Tank at Muston Road

### 10.3.4 Wharfedale Estate

Option W2 – General Upsizing of Sewers In The Estate.

### 10.3.5 Scarborough Road

Monitor the outcome of tree root cutting

### 10.3.6 Filey Senior School -

Short pipe replacement

## 10.4 Programming of Proposals

### 10.4.1 Parameters for Programming

Programming should account for the priority of the solutions in terms of the number of properties that will be protected by them, and should also account for the relationship between interdependent proposals.

### 10.4.2 Interdependent Works

The proposals that affect the Wharfedale Estate carry a high priority. These proposals should be carried out in the following sequence:

1 Long Plantation Watercourse Option LPW

2 Muston Road Option M3

3 Wharfedale Estate Option W2

### 10.4.3 Independent Works

The following works may be carried out in a sequence determined by priority and by organisational and financial constraints beyond the scope of this investigation

Filey Beck (High Priority)

Filey Senior School (Medium Priority)

Scarborough Road (low priority)

## 10.5 Responsibilities

Responsibility for the various proposals should be determined in conjunction with the agencies concerned.

# *Appendix 1: LOCATION PLAN*

# *Appendix 2: FLOODING DETAILS*

**(EXCLUDING COMMERCIALLY CONFIDENTIAL INFORMATION)**

# *Appendix 3: RURAL CATCHMENT BOUNDARIES FOR FEH ANALYSIS*

# *Appendix 4: DRAWINGS OF OPTIONS FOR MUSTON ROAD*

# *Appendix 5: DRAWINGS OF OPTIONS FOR WHARFEDALE ESTATE*

# *Appendix 6: DRAWINGS OF OPTIONS FOR FILEY BECK*

# Appendix 7: MISCELLANEOUS DRAWINGS