# SCARBOROUGH BOROUGH COUNCIL

## Newby Flood Alleviation Assessment

## Final Report

## May 2004

## Notice



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# GLOSSARY OF TERMS

| ***Term*** | ***Meaning / Definition*** |
|---|---|
| Agency | The Environment Agency |
| AOD | Above Ordnance Datum (Newlyn) |
| Atkins | WS Atkins Consultants Ltd. |
| BF | Base Flow (FEH term) |
| CH | Chainage |
| CIRIA | Construction Industry Research and Information Association |
| COW | Critical ordinary Watercourse |
| Defra | Department for Environment, Food and Rural Affairs (*Formerly MAFF)* |
| EA | The Environment Agency |
| FEH | Flood Estimation Handbook |
| ISIS | Mathematical modelling package |
| MCM | Multi Coloured Manual<br>*A manual published by the Flood Hazard Research Centre at Middlesex Polytechnic containing data and costs for flood damage to a variety of properties in different scenarios.* |
| POS | Public Open Space |
| PR | Percentage Runoff (FEH term) |
| SBC | Scarborough Borough Council |
| $T_P$ | Time to peak flow (an FEH term) |

# Executive Summary

Atkins were commissioned to undertake a preliminary feasibility assessment of the mechanisms of flooding in the Newby area. In addition, this feasibility report was required to determine whether the project was feasible to proceed to the more detailed assessment and modelling stage.

Historically, the area of Newby has flooded frequently from the watercourse that flows through it via culverts and open channel sections. The main reason for flooding is the incapacity of the culverts and channel sections that are required to take flows from a flashy, urbanised catchment.

A 100 year flood envelope has been estimated from historical data and has found to encompass 63 properties with approximately 9 properties at risk for a 5 year event. This substantiate Scarborough Borough Councils designation of Newby watercourse as a Critical Ordinary Watercourse.

Three options have been assessed to alleviate flooding: replacement of the main 220m long culvert (Option A); providing a storage solution upstream of the aforementioned culvert (Option B); and diversion of the main 220m culvert (Option C). Cost benefits of the schemes were found to be robust and favourable. Option B was found to be the most favourable scheme, with Cost Benefits ranging from 2.9 to 4.8 and a Defra Priority score of 12.1. Costs included channel widening/regrading and regular maintenance.

It is, therefore, recommended that this scheme is progressed to the detailed modelling and assessment phase.

The risks associated with this assessment are mainly due to the estimated 100 year flood envelope, although as this is based upon historical data combined with the robust benefit cost ratio, it is felt that this risk is within manageable limits. A detailed modelling exercise in the next phase would more accurately define the flood envelope and determine flood defence levels.

# 1 Introduction

## 1.1 Aims and objectives

WS Atkins (Atkins) were commissioned by Scarborough Borough Council (SBC) to undertake a feasibility study for a section of the Newby watercourse. This assessment is designed to collate and analyse information such that a determination can be made whether to undertake a more detailed study to submit a scheme to DEFRA for grant funding.

## 1.2 Methodology

For this stage the following information was collected and analysed:

- A topographic survey of the critical areas for the study
- Site visits and a photographic survey
- A questionnaire sent to residents and relevant groups
- An initial consultation exercise to relevant environmental organisations

Using the above information, flood mechanisms and the extent of potential flooding were assessed and preliminary engineering and economic appraisals undertaken.

## 1.3 Catchment Description

The route of the Newby watercourse and its key hydraulic / drainage features have been assessed from three main sources: the published OS data, a walkover inspection, and a limited topographic survey. A location and study reach is presented in Figure 1.1.

Newby Beck is a small watercourse flowing in a north-westerly direction and is located in the north-west quarter of Newby – an area on the northern outskirts of Scarborough. The watercourse starts in the back gardens of the properties on Scalby Road and Newby Primary School. At The Green it goes into a 125 metre culvert and emerges at in the public open space north of Newby School playing field. Newby Beck then re-emerges, running alongside a path within the playing fields at the end of Linden Road, before being culverted again for about 220m under the gardens of Lawrence Grove, under the allotment gardens on Moor Lane, and under Hackness Road. Finally, the watercourse re-emerges and runs along private land adjacent to residences Hackness Road, before feeding into Sea Cut through flap valves.

# 2 Data collection & review

## 2.1 Data collected

As no previous studies have been carried out on Newby Beck catchment, data for this report has been obtained from site visits and information from residents and SBC.

## 2.2 Site Walkover

A site visit and walkover inspection was undertaken by experienced river engineers in October 2003. The main objectives of the watercourse walkovers were to:

- Assess the general characteristics of the catchment;
- Identify hydraulic controls on the watercourse;
- Make an initial assessment of the likely limit of the floodplain and flood risk areas;
- Identify locations for which topographic survey data will be required.

Properties that were potentially at flood risk or were known to have flooded in the past were identified during the walkover survey, and a flooding questionnaire was delivered to the properties following approval from SBC.

Photographs of key features of the watercourse/catchment were taken during the site visit and can be found in Appendix A.

## 2.3 Topographic Survey

A topographic survey for Newby Beck was carried out by Survey Operations Ltd during November & December 2003.

This survey incorporated structure data for identified bridges and culverts which were identified to be potential hydraulic constrictions. In general all hydraulic structures were surveyed as follows :

- One cross-section immediately upstream of the structure;
- Details of the structure and of any flood relief arches across the floodplain: shape, width, height, length, pier details (dimensions and shape), soffit level, deck level, springing levels, shape of weir, width of the weir crest, internal diameter;
- Ancillary equipment such as trash screens : general shape and details of the screen (skew angle, diameter of bars, space between bars).

The Newby Beck survey also included property threshold in specified areas. The threshold level is defined as the lowest point where water can flood the property (e.g. basement window, brick grill, and front/back doors). This data was required in order to assess the extent of flooding and the number of properties likely to be affected by internal flooding during a high flow event. The survey locations and results are presented in Figure 2.1.

## 2.4 Planning and development issues

The Scarborough Local Plan allocates land at Newby School Playing field (to the rear of The Close) for sports facilities – all weather and grass pitches. Scarborough Rugby Club are also investigating possibly culverting the watercourse in this area. Atkins met with Scarborough Rugby Club and discussed their general plans as to how the area can be sympathetically developed without adversely affecting the flood regime. This could involve channel diversion and partial culverting. The rugby club were also advised that this playing field is likely to be in the floodplain and may be required to be utilised for storage as part of a flood alleviation scheme.

## 2.5 Consultations

A number of organisations were contacted to determine whether they had any interests regarding Newby Beck. The list of bodies contacted and their responses are reproduced in Appendix B and summarised in Table 2.1.

| Organisation | Response |
|---|---|
| Scarborough Rugby Union | An additional Rugby pitch is proposed upon partly derelict land which lies between the existing Rugby club pitch and Scalby School playing fields. Newby Beck runs through the area and it is acknowledged that works could be required to deal with potential floodwater at this location. The Rugby Club were advised by Atkins that an open channel diversion would be more beneficial. |
| Scarborough Borough Council (Highways) | No response. |
| Scarborough Borough Council (Planning) | The Scarborough Local Plan allocates land at Scalby School Playing field (to the rear of The Close) for sports facilities – all weather and grass pitches. Scarborough Rugby Club are investigating culverting the watercourse in this area. |
| Scalby & Newby Parish Council | The Parish Council are concerned that flow into Newby Beck from a new culvert draining the Linden Road/Moor lane area has caused the beck downstream of Linden Road to be under capacity. They feel the additional volume of water has damaged the culvert flowing behind Lawrence Close and Hackness Road and due to this caused flooding of properties in Hackness Road.<br>A list of residents to contact was provided. |
| Yorkshire Water | No response. |
| The Countryside Agency | No comment to make at this stage, would welcome being kept informed as the study progresses and reaches completion. |
| RSPB | No specific comment. |
| Yorkshire Wildlife Trust | No response. |
| Environment Agency | No formal response received. The watercourse is not designated as a critical ordinary watercourse be the Environment Agency. |
| English Nature | No comment to make at this stage. |
| English Heritage | No response. |
| National Farmers Union | No response received. |

***Table 2.1 – Responses from Consultees***

The major consultees felt that there was no need for further consultation until proposals for works on flood defence were at a more mature stage.

## 2.6 Responses from residents

Questionnaires were delivered to properties identified to be at possible risk of flooding as described above. A summary of the key information obtained is presented below and in Figure 2.2.

(i) In the Scalby Road area the residents reported that their back gardens flood every year. The residents at numbers 364 and 370 Scalby Road believe that the cause is the culvert being under capacity. The back garden and offices of the Nursing home at 374 Scalby Road were flooded. On the other side of the

water course Newby Primary School on the Green reported that the School field floods every year.

(ii) The residents at Gatesgarth Close reported that they had never experienced flooding on their premises.

(iii) The residents of 21, 22 and 27 The Close reported that their back gardens flooded approximately every 6 months. The fields behind The Close also flood frequently.

(iv) Linden Road is reported to flood regularly. The back gardens and the end of Linden Road flood annually. The resident of 41 Linden Road stated that the houses 41 and 43 Linden Road flooded on August 10th 2002, however the resident at 43 Linden only reported that the back garden was flooded. The resident at 39 Linden Road reported that 37 and 49 Linden Road flooded August 10th 2002 however, the resident at 37 Linden Road only reported flooding of the road. The resident at 35 Linden Road reported that their own house as well as the house at 33 Linden Road flooded.

(v) The resident at 9 Lawrence Grove stated that the house at the corner of Hackness Road and Lawrence Grove flooded in August 2002 and the resident at 6 Lawrence Grove reported that the houses at 3 and 5 Lawrence Close flooded and floodmarks could be seen at window level. This resident also reported that surface water drainage was in the area of Linden Road was redirected in 2002 and that this might have coursed the problem. Many of the residents reported that their back gardens were flooded in the August 2002 event.

(vi) Many of the residents at Moor Lane reported that Moor Lane and Hackness Road flooded at the junction in the August 2002 event. Some residents also stated that this happens approximately every year and that the Allotment Gardens flood approximately every 6 months. The resident at 3 Moor Lane stated that the gardens flooded because of incapacity of the culvert flowing through the gardens.

(vii) The Allotment gardens were reported to have flooded by many residents. Properties on Hackness Road at numbers 57, 59, 61, 63, 65 were reported to have been affected by flooding in August 2002. The resident at 59 Hackness road reported that 2 properties flooded in September 2000 although they did not specify which properties these were. The occupier also reported that his own property flooded in August 2002 and again in November 2nd 2002 due to the un-repaired garden wall that collapsed in the August 2002 event. During both these events the fire brigade came and pumped water out of the properties. It was also stated that flooding of the properties in this area occurs approximately every year. Several of the questionnaires stated that Hackness Road floods approximately every 6 months.

(viii) The residents of 5 Glynndale Drive reported that their house was flooded on the 10th August 2002 and that the house was not inhabitable for 10 months following this. The gardens of 3, 4 and 5 Glynndale Drive were flooded on the August 2nd 2002 as well as Glynndale Drive. A telephone conversation January 30th 2004 with the occupant of 4 Glynndale Drive determined that the flooding of Glynndale Drive came from the Newby watercourse and not from overtopping of the banks of Sea cut. It also determined that the area behind the back gardens used to be Marsh land and therefore in the past was utilised as flood storage.

Table 2.2 below summarises the problems in the area as reported by the questionnaire responses.

| No. | Location | Properties affected by Flooding | Frequency | Cause of Flooding |
|---|---|---|---|---|
| 1 | 57, 59, 61, 63, 65, 69 Hackness Road | Residential properties and Hackness Road flooded | Many properties at risk annually. The road floods every 6 month | Incapacity of culvert |
| 2 | 1, 3, 4, 5 Glynndale Road | Road and garden. | Annually | Insufficient capacity and drainage to sea Cut |
| 3 | 3, 7 Moor Lane | Gardens Flooded | Annually | Incapacity of culvert |
| 4 | 41, 43 Linden Road | Residential properties and Gardens | Residential flood happened once. Road and gardens 3-4 times annually | Incapacity of culvert |
| 5 | 44 Linden Road | Rear garden | Annually | Incapacity of culvert |

*Table 2.2 – Summary of Historical Flooding Information*

## 2.7 Recent flooding

The dates of incidents reported by local residents are listed below:

- 2nd August 2002. This event flooded many properties. Properties on Hackness Road, Scalby Road, Linden Road and Glynndale Drive were flooded.
- 10th August 2002. Roads flooded.
- September 2002. The properties on Hackness road flooded again due to unrepaired garden walls protecting properties.
- 2nd November 2002, Roads flooded.
- March 2003. Roads flooded.
- 28th September 2003. Roads flooded.
- November 2003. Roads flooded.

It is clear that flooding in the area is frequent and that a fundamental weakness of the drainage system is culvert incapacity.

# 3 Hydraulic and Hydrological Calculations

## 3.1 Culvert Capacities

To analyse the capacity of the culverts the Culvert design guide (CIRIA) was utilised. The method used was standard circular inlet controlled culverts which estimates the flow for various water levels upstream of the culverts.

## 3.2 Hydrology

Rainfall runoff models were constructed using FEH boundary units within ISIS hydraulic modelling software. The catchment area is determined using the catchment boundaries suggested by FEH-CDROM. The rainfall-runoff method estimates flows 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. These are: Catchment response to rainfall (unit hydrograph time-to-peak, Tp); Proportion of rainfall which directly contributes to river flow (percentage runoff, PR); Quantity of flow in the watercourse prior to the storm event (base flow, BF). Figure 3.1 shows the catchment boundaries from FEH which suggests that Newby water course actually follows Scalby Road until it discharges into Sea Cut. In reality the watercourse turns west towards Newby Primary School. The catchment area estimated by FEH is approximated and the fact that the downstream part of the watercourse is not in the estimated catchment does not affect the catchment area significantly.

Since there is no flow gauge in the catchment, the parameters are derived using digital FEH catchment descriptors. This is quite appropriate and a standard approach to use under these circumstances. Rainfall is defined in terms of duration, depth and distribution (over time), and may relate to either a probabilistic design event, eg: 1 in 100 year return period, or an observed storm event (for calibration purposes).

The following conclusions were made comparing the FEH run off estimation with the culvert capacities estimated.

- The bank full capacity of the channel going from the back garden of Moor Lane and Hackness Road is estimated to be 0.5 $m^3/s$. This culvert has the smallest dimension and is, therefore, believed to be main hydraulic restriction along the watercourse with a non-surcharged capacity of 0.4-0.5$m^3/s$..
- The FEH rainfall run off method estimates the 1 in 2 year event at this point to be approximately 0.8 $m^3/s$. This , implying that this culvert and associated channel is clearly under capacity.

It should also be mentioned that the above calculations exclude channel blockages and restrictions which can be seen from recent events to significantly reduce the capacities of the channel and culverts. The return period flows from FEH are presented in Table 3.1 below, although it should be noted that being an un-gauged catchment, reliable figures are best gained from a long period of flow readings.

| Return Period (yrs) | 2 | 5 | 10 | 25 | 50 | 75 | 100 |
|---|---|---|---|---|---|---|---|
| Flow Rate $m^3/s$ | 0.8 | 1.1 | 1.3 | 1.8 | 2.1 | 2.4 | 2.7 |

**Table 3.1 FEH Flows for varying return periods**

Figure 3.2 presents the flow/stage relationship at the culvert under Lawrence Grove and Hackness Road (CH 375). It also indicates the return period that the level corresponds to. The approximate threshold level for the houses around Newby watercourse are also shown on figure 3.2. Threshold level for the houses around the culvert is 43.0 -43.5 m AOD for houses on Linden Road and 44.0 – 44.5 m AOD for the houses on Lawrence Grove. According to the theoretical curve in figure 3.2 these houses should flood approximately every other year. It should be noted that these calculations do not take storage into account and the return period at which the houses flood, are therefore, considered to be underestimated. However this figure does highlight the frequency of flooding that this undersized culvert is causing in this area.

# 4 Assessment of Flooding Mechanisms

## 4.1 Historical Flooding

A number of properties and numerous gardens and roads are inundated as determined through historical accounts. A number of properties are currently inundated by this watercourse and houses, roads and gardens flood frequently in this area. A map indicating areas of recent reported flooding is presented in Figure 4.1.

## 4.2 The 100 year predictive flood outline

The catchment for this watercourse is very urban and steep. The presence of a hill to the west of the watercourse combined with the large paved area results in a rapid runoff regime, putting the drainage system under considerable strain. The culverts in the area do not appear to be designed appropriately to accommodate the degree of flow experienced and are consequently severely surcharged. This, combined with the incapacity of the open channel sections provides the main reason for flooding. A predictive 100 year flood outline is also presented in Figure 4.1, indicating that approximately 63 properties are at risk in this scenario for a 100 year return period event.

## 4.3 Hydraulic restrictions present

To demonstrate the problem more graphically, figure 4.2 presents the long section of the watercourse. From this figure it can be seen that the most upstream surveyed section (CH 810) is where the smallest 500mm diameter culvert is located. However, the most severe flooding problems are at the long culvert going under Lawrence Grove which is 600mm diameter. This second culvert is too small to convey storms in excess of a five year return period and begins to surcharge at a 1 in 2 year event. An additional hydraulic problem is that the culvert turns $90^{o}$ in the vicinity of the allotment gardens which further restricts its already limited capacity.

The event in August 2002 flooded many properties and the culvert going under Lawrence Grove and Hackness Road burst due to the water pressure and therefore water escaped from the culvert under pressure and flooded the allotment gardens and properties on Hackness Road.

It is possible that the sewer draining the Throxenby catchment joins Newby watercourse at the upstream end of Newby watercourse. This means that the design flows might be underestimated. However it is also understood that a high percentage of the runoff from the Throxenby catchment in severe events does not discharge into the sewer system but flows north into other parts of Scarborough.

Sea Cut has not been reported overtopping in the area near Glynndale Drive. However it is likely that if the water level in Sea Cut is high the flapped outfall from Newby watercourse may inhibit discharge. This could cause ponding on Glynndale.

# 5 Proposed flood alleviation schemes

Three main options have been assessed to limit flood damage to the houses and roads. These are listed below and presented in Figure 5.1:

- Option A – replace 220m long 600mm diameter culvert from public open space with a larger culvert along same route.
- Option B – construct an embankment around the public open space (POS) and utilise as a storage area to restrict flow into 220m long culvert.
- Option C – Construct a new culvert to replace the 220m long culvert using an alternative route under Linden Road and Hackness Road.

(Note that all the above options require the 125m 600mm diameter culvert at the upstream end of the watercourse to be replaced with a larger culvert and widening of the open channel sections along most of the route.)

Within the three options replacement of the culvert under bridge at the back of Newby Primary School and replacement of the 125 metres culvert going under The Green and re-emerging in the Public Open Space. In the August 2002 event the nursery on 374 Scalby Road and it is believed that more properties will flood in a bigger event.

The two areas that require protection are the region around Hackness Road and the area on Glynndale Drive. A solution that provides protection to both areas would be advisable. The options proposed are described in detail in the sections below.

## 5.1 Option A – Replace Culvert

In this option, it is proposed that the 220m culvert section be replaced/upgraded with a larger one. This will allow increased flows from the public open space, through the Allotment gardens and under Hackness Road. This option may require the enlargement/regarding of the open channel section leading to Sea Cut although without detailed modelling, the nature of this work cannot be determined at this time.

There is also a possibility of de-culverting stretches of the watercourse to promote ecology, although at this stage it appears that such an option may be detrimental to the solutions. However, this should be considered at the next stage of work.

## 5.2 Option B – storage in the POS

This option provides a solution to the incapacity of the 220m culvert via the storage of water in the POS. This will entail the construction of flood protection walls to protect the properties on Lawrence Grove, Lawrence Close and Linden Road. This option will also require the regarding of the POS and the reconstruction of the culvert entrance to ensure the controls will work effectively. It is noted that there are currently plans of making a Rugby ground in this area, and it is not certain that this option can be made to work with that proposal.

Figure 5.2 shows the hydrographs for the 2, 10, 50 and 100 year event. The volume of water needed to be stored in this artificial reservoir will be the area under the graph but over the capacity of the existing culvert. Table 5.1 below shows the volume required to store flood water.

| Return Period (years) | 2 | 10 | 50 | 100 |
|---|---|---|---|---|
| Volume required | 792 $m^3$ | 2,621 $m^3$ | 5,880 $m^3$ | 8,124 $m^3$ |

**Table 3.1 Volume calculations**

Thus, a total volume of 8,124 m3 of water is estimated to be required for this solution which corresponds to a water depth of approximately 70 cm within the area marked on Figure 5.1.

There are safety implications to this option which would probably require the creation of large areas of ponds and raised embankment/walkways. This will ensure that members of the public are not put in any danger.

## 5.3 Option C – New culvert

This option proposes the construction of a by-pass culvert to effectively replace the existing 220m culvert. The route of the new culvert follows Linden Road, turns south at Moor Lane and along Hackness Road discharging into Sea Cut.

# 6 Cost Benefit Assessment

Table 6.1 presents the Benefit Cost Ratios for the proposed schemes using the MCM manual. It should be noted that costs of flooding of roads are not included in the scheme costs and these would have the effect of increasing the benefit cost ratios. As part of a sensitivity assessment, a range of costs (minimum and maximum) were assessed to ascertain the robustness of the benefit cost ratios.

| Option | | Damage Prevented | Scheme Summary | Scheme Costs - £k | | Benefit Cost Ratios | |
|---|---|---|---|---|---|---|---|
| | | | | min | Max | min | Max |
| All | Replace the culvert under bridge at Newby Primary School and replace the culvert going under the Green and re-emerging in POS | | | £675 | £1,013 | - | - |
| **A** | Replace 220m Culvert on same route | 9 homes every 5 years and 63 Properties in a 100 year event | Replace 220m culvert under Lawrence Close and Hackness Road | £2,244 | £3,366 | 1.9 | 2.9 |
| **B** | Flood Storage and Flood protection | | Build flood protection wall around properties at Lawrence grove and Hackness Road and use POS as storage | £1,338 | £2,222 | 2.9 | 4.8 |
| **C** | New Culvert Bypass to replace 220m culvert | | Divert 220m Culvert along Linden and Hackness Road | £4,619 | £6,928 | 0.93 | 1.4 |

Table 6.1: Benefit Cost Assessment Summary

The costs have been determined as presented in Appendix C, with maintenance of £1,000 per year allowed for and a contingency of 25% on the overall costs. The average annual damage has been calculated as £239k with a present value of total damages of £7.1m.

It is advisable that schemes with a benefit cost ratio greater than 2 are worth presenting to DEFRA for grant aid assistance. On this basis options A and B are worth considering to be taken forward to a more detailed assessment.

A DEFRA prioritisation score assessment has also been undertaken (LDW14) and this provides scores for Options A and B of

# 7 Conclusions & Recommendations

The schemes proposed have been shown to be robust with benefit cost ratios ranging from 0.9 and up to 4.8. The DEFRA scheme prioritisation score of 12.1 has been achieved for Option B (flood storage option). It is, therefore, recommended that these schemes are taken forward to the next more detailed assessment phase. This would involve detailed mathematical modelling to confirm the flood outlines and check the technical feasibility of the proposals. The following items should be noted in this regard.

(i) The detailed assessment will require a mathematical modelling exercise, including additional topographic survey. The modelling would provide design information for storage options, channel widening/regarding and requirements for and levels for various flood defences (i.e. floodwalls) proposed.

(ii) It should be noted that the 100 year flood envelope has been determined using historical flood information and without detailed mathematical modelling and may be subject to change.

(iii) The consultation phase of this project could be lengthy depending upon the solution adopted. This is due to the character of the area, the local interest in use of the land plus the land ownership issues that would need to be resolved for some of the options.

(iv) There may be some requirements for a habitat survey and consultations with EN and EA, although at this stage, the initial consultations have suggested that these key consultees would only like to be kept informed. It should e noted though that there is a general philosophy of de-culverting wherever possible.

(v) Renewal of the sewer outfalls into the Sea Cut would require further investigation into the hydraulic and hydrological nature of the Sea Cut the Section 105 modelling of this watercourse would be required to be inspected.

# Figures

# *Appendix A: PHOTOGRAPHIC SURVEY*

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# *Appendix B: RESULTS OF CONSULTATIONS & QUESTIONNAIRES*

# *Appendix C: COST BENEFIT SPREADSHEETS*