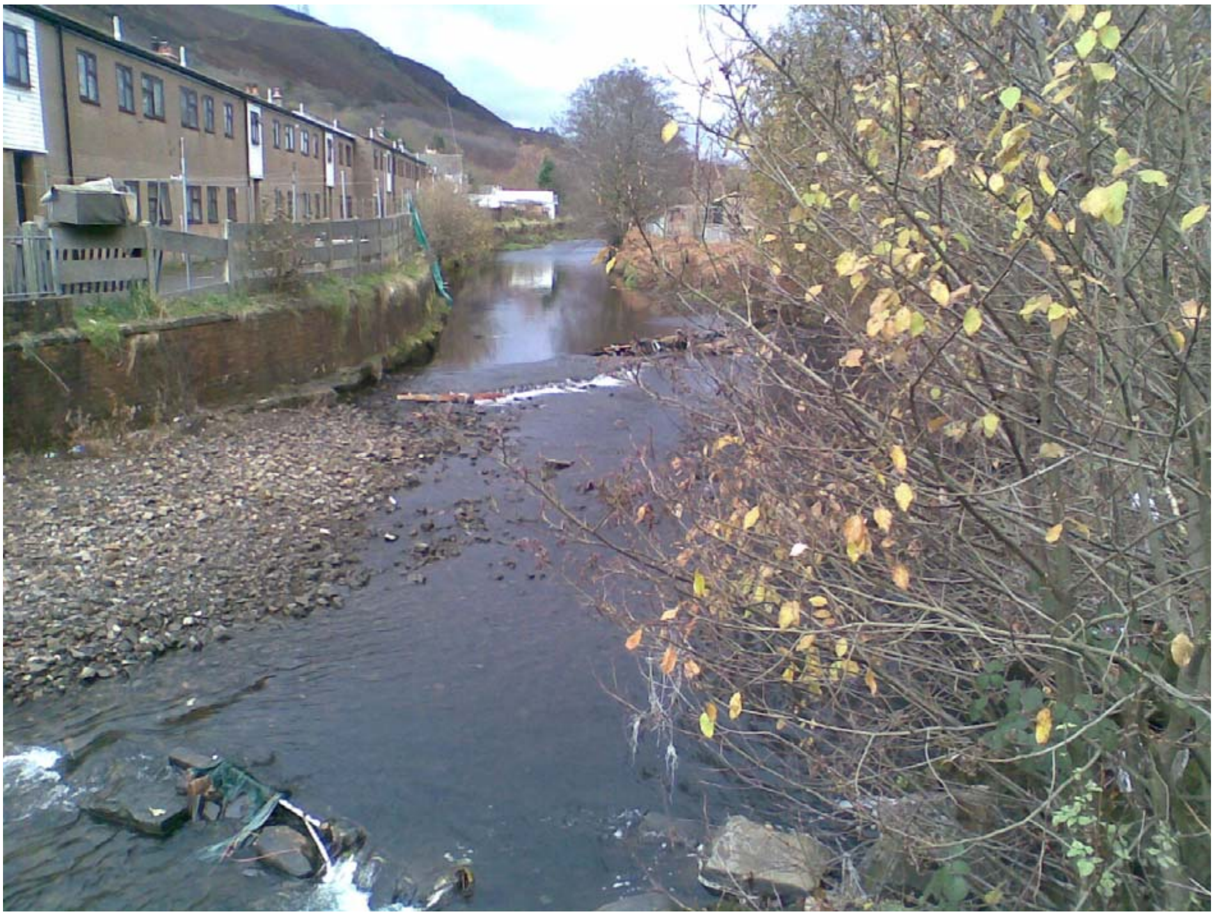
WAS042 – Waste Minimisation Design Review Case Study

New Tredegar Flood Alleviation Scheme



Design review report for the Environment Agency flood defence project at New Tredegar, Rhymney, South Wales. Potential for waste savings of 110 tonnes, cost savings of £50,000 and 400 tonnes of embodied carbon savings through design changes to minimise waste.

Project code: WAS042
Research date: January 2008
ISBN: 1-84405-381-4
Date: March 2008

WRAP helps individuals, businesses and local authorities to reduce waste and recycle more, making better use of resources and helping to tackle climate change.

Front cover photography: River Rhymney at New Tredegar, credit BioRegional Consulting Ltd

Key facts

- New Tredegar is situated on the River Rhymney, 20 miles north of Cardiff.
- New Tredegar Flood Alleviation Scheme comprises raised flood defences and raising of Birchgrove Bridge.
- New Tredegar Flood Alleviation Scheme protects private houses and sheltered accommodation for the elderly.
- Construction cost £2.6m.
- The project team comprises of the Environment Agency (EA) (Client), Atkins (Designers), Birse (Contractors).
- EA existing waste minimisation requirements:
    - National target of less than 25% waste to landfill across all of their projects.
    - Draft site waste management plans are required at feasibility stage for all Environment Agency projects.
    - Carbon calculation for all EA projects will be mandatory from April 2008.
    - National target to achieve over 70% use of recycled or secondary aggregates across all of their projects.
- Waste minimisation opportunities already identified on the project:
    - Standard form, standard layout and standard materials.
    - Reduced design complexity.
    - Re-use of site won facing stone.
- Waste minimisation opportunities to be taken forward on the project:
    - Off site manufacture of pre-cast brick wall units.
- Potential project cost savings through waste minimisation £50,000.
- Potential project waste savings of 110 tonnes, embodied carbon savings of 400 tonnes through waste minimisation.
- Potential savings through waste minimisation on typical EA projects.
    - Potential cost savings of 10%.
    - Potential waste savings of 1 tonne of waste / £4,600 construction cost.
    - Potential carbon savings of 1 tonne of carbon / £1,300 construction cost.

Typically 65% of these savings will already be included in designs through the EA's resource efficiency requirements.

Overview

A design review of the Environment Agency's New Tredegar Flood Alleviation Scheme in South Wales has been conducted to facilitate the actions required to adopt appropriate waste minimisation design solutions to deliver waste savings within the project.

New Tredegar is situated on the River Rhymney, 20 miles north of Cardiff. Flooding from the River Rhymney affects private houses, sheltered accommodation for the elderly and the only leisure facility available to the community. Following a detailed feasibility study a flood alleviation scheme is proposed for the village to increase the standard of flood defence from a 33% (1 in 3) annual chance event to a 1% (1 in 100) annual chance event. The scheme comprises of raising Birchgrove bridge and constructing raised defences throughout the low lying areas through a combination of sheet pile and reinforced concrete flood walls. The overall project cost was calculated to be £4.4m, with construction accounting for £2.6m.

An initial assessment of the project highlighted that the biggest opportunities for waste minimisation came through the concrete flood defence walls of the scheme. The flood defence walls proposed are typical of many Environment Agency (EA) flood alleviation projects, solutions devised for this scheme could be applicable to many other EA schemes. The analysis in this case study focuses only on the concrete flood walls and facing brickwork

The estimated cost of the four main construction materials used; concrete, formwork, reinforcing steel and brick facing for the concrete flood defence walls of New Tredegar flood alleviation scheme will be £198,940. Using the proposed construction approach it is anticipated that 2,630 tonnes of materials will be ordered, of which 360 tonnes will be wasted, Appendix 2 contains the assumptions and detailed calculations.

Key Opportunities and benefits

A long list of waste minimisation opportunities was developed specific to the New Tredegar scheme based on WRAP guidance document WAS004-005 'Achieving effective waste minimisation through design'. These options were analysed for their applicability to this project. From the long list, six options were short listed for further discussion and analysis:

1. (a) In situ concrete flood wall; pre-cast concrete units.
   (b) In situ concrete flood wall; pre-cast brick units.
2. Alternatives to facing brickwork to concrete flood wall.
3. Re-use of site won materials.
4. Early contractor involvement, at design stage, to reduce over ordering of materials on the scheme.
5. Standard form, standard layout and standard materials.
6. Communication and procurement.

The results for the options demonstrating potential waste savings are presented in Figure 1 below. A number of the waste minimisation options assessed were already included in the design, for example standard form, layout and materials, reduced design complexity and the re-use of site won materials.

Engineering design decisions are made for a number of reasons, waste is intuitive in this decision making process as well as driven by the tools provided by the Environment Agency (including site waste management plan requirement at design stage and use of carbon calculation tool commencing in April 2008). As contractors create waste and bear its cost, they are well placed to influence design decisions to incorporate low waste options. This was seen on this project through the early contractor involvement for example through the contractor approach to over ordering.

	Waste generated	Cost of waste	Embodied carbon of materials and waste	
Baseline	360 tonnes	£105,000	2,100 tonnes	
Option	**Waste saving**	**Waste cost saving**	**Embodied carbon saving**	**Adopted by the project**
1(a) In situ concrete wall; pre-cast concrete	110 tonnes	£93,990	825 tonnes	No
1(b) In situ concrete wall; pre-cast brick	42 tonnes	£30,515	270 tonnes	Yes (partially)
3. Re-use of site arisings	46 tonnes	£9,840	40 tonnes	Yes
4. Over ordering	49 tonnes	£19,110	180 tonnes	Yes (partially)
Total potential savings (option 1(b) + option 3 + half of the savings for option 4)	**110 tonnes**	**£50,000**	**400 tonnes**	

Figure 1 Comparative difference in cost, waste saving and carbon saving through adopting the waste minimisation options proposed

A number of proposed waste minimisation options were not taken forward on the scheme because of reasons other than waste minimisation, for example pre-cast concrete walls and alternatives to facing brickwork. The primary reasons were planning requirements, logistics and time. Cost was also a driver, but complex logistics and increased time will add cost to the project, which in many cases outweighs the cost of additional materials and waste disposal. To overcome the planning barrier requires early identification of waste minimisation within the project process, so that the planning submission incorporates the lowest waste option. Major changes to the scheme, as a result of this study, were not possible due to the timing, as the planning consent has already been acquired.

Overall the study identified the potential for waste savings of 110 tonnes, cost savings of £50,000 and embodied carbon savings of 400 tonnes through design changes.

Communications and potential savings across the Environment Agency

A communications plan to roll out the lessons learnt to the Environment Agency (EA) has been developed with the EA National Capital Programme Management Service (NCPMS) Environmental Technical Adviser. This will target both internal project managers and the Environment Agency framework consultants and contractors (12 major UK engineering and contracting companies). Figure 2 demonstrates the potential savings that could be achieved on a typical EA project, based on the findings at New Tredegar. However this is a very approximate estimate as the waste saving potential in Figure 2 is for concrete flood walls, typical EA projects include other elements such as earth bunds and sheet piling which are likely to generate less waste than flood walls.

Total cost of waste	£50,000
Total construction cost of project element	£500,200
Total waste saving potential	110 tonnes (70 tonnes had already been included in the designs prior to testing of WRAP guidance)
Total embodied carbon saving potential	400 tonnes
Potential percentage cost saving through waste minimisation	10%
Potential waste saving through waste minimisation	1 tonne of waste / £4,600 construction cost
Potential carbon saving through waste minimisation	1 tonne of carbon / £1,300 construction cost
Percentage of project adopting waste minimisation measures without the influence of the WRAP study	65%

Figure 2 Cost and waste savings inferred for typical Environment Agency projects

Lessons Learnt

The key lessons learnt through this project were:

1. In construction projects waste minimisation must be an important issue in options appraisal and design but there are other factors that can be equally if not more important e.g. Health & Safety, cost, legislative/planning requirements, CO_2 footprint, ongoing maintenance requirements etc.
2. Resource efficiency and sustainability drive decision making, the carbon impact of transporting pre-cast units long distances, may in some cases outweigh the carbon savings achieved through use of pre-cast units. This is an important factor in the adoption of low waste solutions.
3. Guidelines on options that are more wasteful than others should be followed from the earliest stages of a project.
4. Design decisions made at an early stage in the process affect waste production on site.
5. Some over ordering is unavoidable.
6. Waste of time and resources is a bigger cost and risk than waste of construction materials.
7. Early contractor involvement helps to refine design options to reduce waste.
8. Modern methods of construction and offsite construction (MMC/OSC) are restricted by access constraints for large panels. The ideal application of MMC for flood defence projects is where long, large lengths can be used to save waste and time, and reduce the number of joints required.
9. Waste minimisation of different design options is not easily quantifiable.
10. WRAP guidance on waste minimisation provides a useful guidance document for designers to consider waste minimisation options, it would be useful to have a summary checklist of the generic 'long list' of opportunities for design teams to use.

Contents

List of Acronyms

EA	Environment Agency
FAS	Flood Alleviation Scheme
GRP	Glass reinforced plastic
MMC	Modern methods of construction
NCPMS	National capital programme management service
OSC	Offsite construction
Spons	Civil Engineering and Highways Price Book 2007, Davis Langdon
WRAP	Waste & Resources Action Programme

1.0 Background

WRAP have produced guidance on designing out waste for construction clients, design teams and contractors called 'Achieving effective waste minimisation through design' (WAS004-005). WRAP have commissioned a number of design review projects to assess their guidance document, this case study is one of a number of similar reports.

1.1 The Project – New Tredegar Flood Alleviation Scheme

New Tredegar is situated on the River Rhymney, 20 miles north of Cardiff. Flooding from the River Rhymney affects private houses, sheltered accommodation for the elderly and the only leisure facility available to the community.

Following a detailed feasibility study a flood alleviation scheme is proposed for the village to increase the standard of flood defence from a 33% (1 in 3) annual chance event to a 1% (1 in 100) annual chance event. The feasibility study considered a number of alternative options with 'Raised defences and Raising Birchgrove Bridge' being the preferred option. This option comprises of demolishing and rebuilding Birchgrove bridge and constructing raised defences throughout the low lying areas through a combination of sheet pile and reinforced concrete flood walls. The requirements of the proposed scheme are to raise the height of the flood defences, the details of specifically how to do this were being worked out during the period of this study i.e. where to use concrete walls rather than sheet pile walls. At this stage the overall project cost was calculated to be £4.4m, with the construction work costing £2.6m.

A planning application was submitted in September 2007 and the detailed design work for the proposed scheme commenced in October 2007 and is due to be complete in March 2008. The project is due to commence on site in May 2008.

Figure 3 Raised water levels and flooding in New Tredegar as a result of heavy rain, source Atkins

The scheme proposed in the planning application comprises of 7 areas of work:

- Greenfield Street; 17.5m long earth embankment.
- Bowling Green; 100m in situ concrete flood defence wall with brick facing.
- Leisure Centre; 125m of in-river flood wall comprising of sheet pile wall clad in a combination of patterned concrete and bricks, with a cast in situ concrete pile cap flood wall above clad with facing bricks.
- Birchgrove Bridge; raising of bridge and highway works to improve access.
- Residential Home; 103m demolition of existing stone wall and replacement with cast in situ concrete flood wall clad with the natural stone from the demolition.

- Birchgrove flats; 176m of in-river flood wall comprising of sheet pile wall clad in a combination of patterned concrete and bricks, with a cast in situ concrete pile cap flood wall above clad with facing bricks.

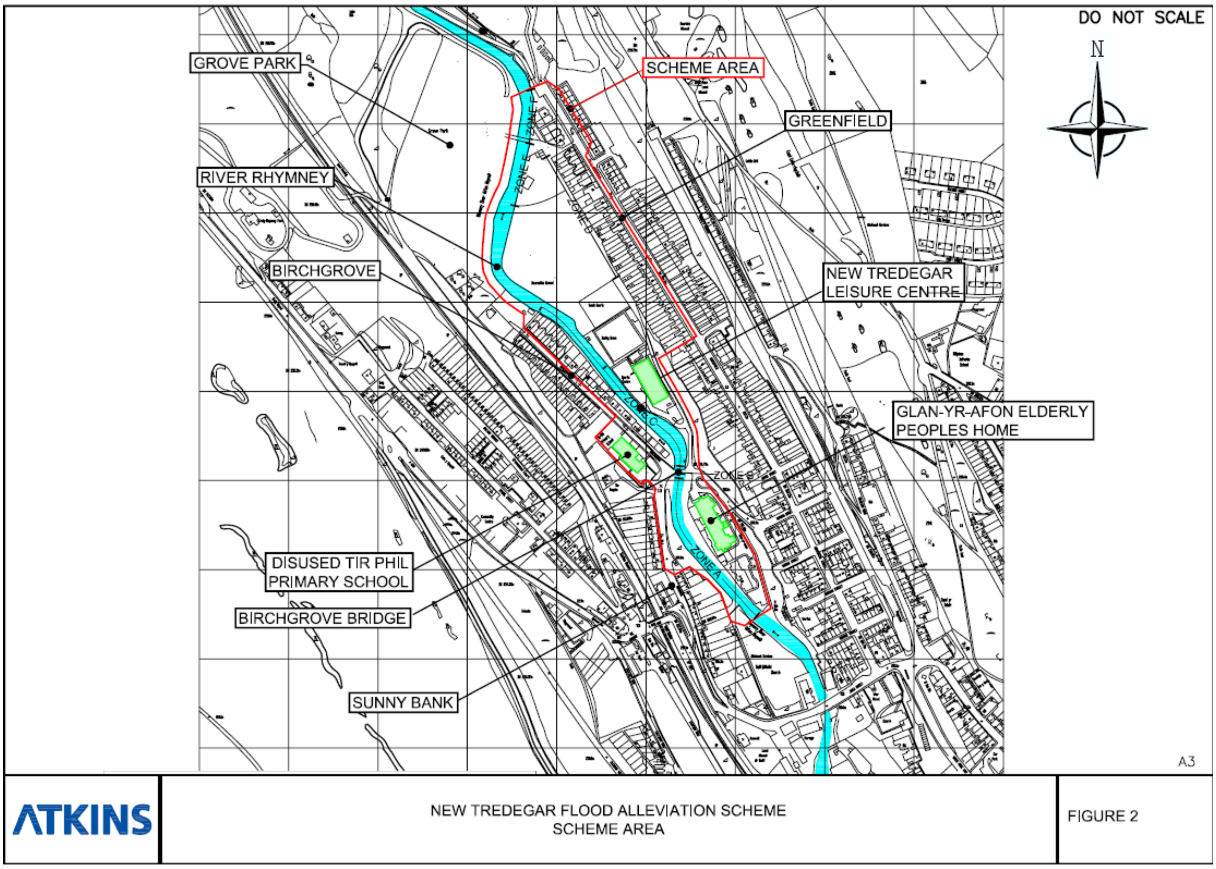


Figure 4 New Tredegar Flood Alleviation Scheme; Scheme Area

2.0 Project Structure

The New Tredegar project team comprises the Environment Agency, their framework consultants Atkins and their framework contractors Birse. BioRegional Consulting Ltd conducted the waste minimisation design review and analysis.

BioRegional conducted two waste minimisation workshops with the design team, to discuss options, prioritise opportunities and present findings. Between the workshops BioRegional conducted a period of analysis of potential waste savings for the options presented here.

3.0 'Long list' of opportunities

The Environment Agency has existing requirements for their framework consultants and contractors to improve resource efficiency, and hence minimise waste, within their construction portfolio, as outlined below.

- National target of less than 25% waste to landfill across all of their projects.
- Draft site waste management plans are required at feasibility stage for all Environment Agency projects.
- Carbon calculation for all EA projects will be mandatory from April 2008.
- National target to achieve over 70% use of recycled or secondary aggregates across all of their projects.

The project team have developed design solutions based on the existing EA requirements, the 'long list' below highlights both the existing and new opportunities that have arisen through this study.

3.1 Design Development Opportunities

During the development of the design it is important to raise the profile of waste, the long list opportunities are:

New Tredegar Opportunity / Issue
Change management: The design process has not adopted design freezes.
Design with existing resources ■ There could be an opportunity to use site won material for the flood embankment and flood wall facing outside the old people's home. ■ The demolition arisings from the adjacent school are proposed for the site compound area.
Design for site conditions: The primary site condition that the design has to accommodate is access to the site along narrow roads, and into the river.
Putting waste on the agenda ■ EA national target of <25% waste to landfill ■ Draft site waste management plan required at feasibility stage for all EA projects. ■ From April 2008, it will be mandatory for all projects to conduct a carbon calculation for their project, which aims to drive resource efficiency and minimise waste.

3.2 Design options

As the project is at the detailed design stage, most design elements are fixed. The design options follow the value engineering logic of delivering the same (or more) for less, in this instance for less waste.

New Tredegar Opportunity / Issue
Fundamental design decisions ■ 'Raised defences and raising Birchgrove Bridge' provided the best cost benefit in terms of flood protection and environmental enhancements. ■ The primary goal of the project is to save lives and protect property by providing flood protection.
Standard form and layout ■ The project is simple, the cross section of the wall along its length is similar, comprising of; sheet pile (where required), reinforced concrete and facing. ■ Formwork: the simple design will enable standard lengths of high quality timber ply formwork with a glass reinforced plastic (GRP) impressed liner for the concrete finish to be re-used (up to 50 times) on the scheme
On site reuse of materials ■ Demolition of school adjacent to site; materials have been stored for reuse by the EA. ■ Natural stone wall adjacent to the old peoples home; proposals to re-use the stone for facing the new flood wall in this area. ■ Opportunity to use site won material in the flood embankment. ■ Opportunity to use recycled aggregates and cement substitutes in concrete.

New Tredegar Opportunity / Issue
Standardised building materials ■ Wall solutions; only two wall materials concrete and sheet piling. ■ Wall facing solutions; use of two facing solutions; predominantly new bricks and re-use of natural stone wall.
Modern methods of construction ■ Pre-cast concrete flood walls; considered but access is an issue. ■ Panellised units for bricks e.g. concrete panels with brick wall effect. ■ Brick slips, to replace brickwork for the facing to the flood wall. ■ Tunnel form techniques for the concrete flood wall.
Ground works and enabling works ■ Temporary works designed to use only site won materials; arisings from adjacent school demolition will be used for hardstanding for site compound. ■ Opportunities to reuse excavated materials in flood embankment are being investigated.

3.3 Communication and Procurement

The key to waste reduction is a change in mindset and communication throughout the supply chain. Waste can be reduced through adequate planning and thought throughout the design process.

New Tredegar Opportunity / Issue
Appointments ■ The EA appoints contractors and consultants through national frameworks. There are stringent environmental requirements for organisations to be appointed on the framework. ■ EA national target to achieve over 70% recycled or secondary aggregates across all of their projects.
Project briefing: EA projects begin with a pre-feasibility study, followed by a feasibility study resulting in a project appraisal report. The feasibility study has a requirement to complete a draft site waste management plan, which asks the design team to consider the sources of waste arising on the project.
Early contractor involvement: Early contractor involvement arises through the EA framework.
Procurement: This is a traditional design then build contract. Procurement is through the NEC[1] contracts using pain/gain sharing[2]. The pain/gain could be linked to the project KPIs, of which waste generation and minimisation on site could be one, although this is not currently the case.

4.0 Revised list of solutions

The long list of options was discussed with the project team in a waste minimisation workshop, November 2007. A number of specific options were discussed in greater detail and short listed:

1. In situ concrete flood wall; (a) pre-cast concrete units and (b) pre-cast brick units.
2. Facing brickwork to concrete flood wall.
3. Re-use of site won materials.
4. Over ordering.
5. Standard form, layout and materials.
6. Communication and procurement.

5.0 Cost-benefit analysis

The short listed options were analysed looking at the cost of the materials required for construction (including wastage and over ordering in these costs), quantity of waste generated and the cost of that waste including both the disposal cost and the cost of the materials. A comparison has been made between the design options and

[1] *NEC: New Engineering Contract*

[2] *Option C of the NEC is a contract based on target cost, agreed between client and contractor. If the cost of the project exceeds the target the pain is shared between client and contractor and if below the target price the gain is shared. The pain or gain is capped.*

alternative proposed lower waste options to identify the savings achieved through adopting the options. A cost benefit analysis for options 5 and 6 has not been conducted.

5.1 Baseline

Waste will arise from the major elements of the scheme, listed below, the major sources of waste are:

- formwork,
- over ordered, broken and wasted materials (applies to all materials used),
- packaging from supplied materials, and
- excavations and demolition.

The major elements of the scheme that will generate waste are:

- In-situ reinforced concrete flood walls; comprising concrete, reinforcing steel, formwork.
- Sheet pile flood walls; steel sheet piles.
- Facing brickwork; bricks, mortar, pallets and straps on bricks, cement bags.
- Excavations; site won topsoil and subsoil.
- Flood embankment; graded earth and topsoil, plants, geotextiles.
- Birchgrove bridge; pre-cast concrete beams, road construction materials (Type 1, tarmac, kerbs etc).
- Temporary works; use of built up river shoals for in river working platforms, demolition materials from the adjacent school available for the site compound (which may be a permanent feature as the council require additional parking provision in the village).

The quantities of waste likely to be generated have been calculated only for the in-situ concrete flood walls and facing brickwork as outlined in Figure 5. Details of the assumptions made and details of scheme elements that have not been included in the detailed calculations are contained in the appendix.

Material	**Quantity of materials**	**Maximum quantity of waste generated**
Concrete for in-situ concrete flood walls	702m^3	92m^3
Steel	89 tonnes (115m^3)	9.5 tonnes
Formwork (timber)	50m^3	50m^3
Bricks	129m^3	17m^3
Demolished natural stone wall	27m^3	27m^3
Total quantities	**1,020m^3 (2,630 tonnes)**	**360 tonnes**
Total cost of materials	**£198,480**	**£88,710**[3]
Packaging	280 pallets + shrink wrap and straps for bricks. Cement bags (for on site mortar for brickwork).	
Disposal cost[4] - Standard industry practice		£16,120
Disposal cost – Typical EA practice		£6,850
Total Cost		**£105,000**
Embodied CO_2 of materials	**2,100 tonnes CO_2**	**60 tonnes CO_2**

Figure 5 Sources and quantities of waste generated at New Tredegar

5.2 In situ concrete flood wall

There are two major opportunities for changing the design to achieve significant waste saving with regard to the in situ concrete floodwall:

1. Pre-cast concrete units; replace in situ walls with pre-cast concrete flood walls.
2. Pre-cast brick units; use a brick faced pre-cast concrete panel as permanent formwork to the exposed face.

The design proposals discussed below address waste minimisation through design change. Waste minimisation could also be achieved through use of recycled aggregates and cement substitutes in concrete (both for on and off site concrete elements). Use of these materials do not minimise waste generation on site, however they do minimise material going to landfill, reduce embodied carbon and hence carbon footprint and save on finite resources; currently the project team is looking into the opportunity to use both recycled aggregates and cement

[3] *The cost of materials is high because of the cost of formwork and the fact that all of the formwork is waste. Steel and concrete waste materials are only a small percent of the total steel and concrete materials costs, whereas the cost of formwork waste is the same cost as the total materials cost.*

[4] *Includes landfill tax and gate fees*

substitutes on this project, use of these materials will be considered as an environmental bonus rather than a direct waste saving.

5.2.1 Replace with pre-cast concrete flood wall units

In this option all of the in situ concrete flood walls would be replaced with pre-cast units. These units would be manufactured off site to the required specification and delivered to site. Units could be supplied with a patterned and coloured finish if required eliminating the need to face the walls with bricks, or anything else. It would also be possible to use recycled aggregates and cement substitutes in the concrete mixes; this minimises waste going to landfill in the UK and reduces the embodied carbon of the concrete mix.

Advantages

1 Quicker installation.
2 Shorter supply chain less sub contractors involved, eliminates the need for steel fixers and carpenters.
3 Reduced time working in the river.
4 Reduced waste; manufacturing units in a controlled environment practically eliminates waste as the correct quantity of concrete can be used and any additional concrete can be re-used in future concrete mixes.

Disadvantages

1. Access to the site from the A469 is a major barrier to the success of this option. It would not be possible to bring a 29 tonne articulated lorry down either of the two access roads through the village to the works areas. One possibility would be to unload the lorry at the edge of the village and use a tractor and trailer to move the units down to the site. This would introduce added labour and plant costs to the option.
2. Pre-cast units will be heavy and awkward to move around the site, it may be necessary to use a small crane to manoeuvre the units in to place, this is entirely unpractical for two reasons; small narrow roads and long length of scheme requiring multiple crane set ups.
3. Pre-cast units introduce joints, which create potential leakage routes for water. Flood defence projects are designed to create impermeable barriers to contain water within a managed flood area, introducing leakage routes into the scheme creates a potential future problem. Due to the confined space of the site it would be necessary to manufacture short pre-cast units (2 – 3m long) therefore multiple joints would be required for a pre-cast option. It would be better to use pre-cast concrete units on schemes without access restrictions where 20m long units can be manufactured thus reducing the number of joints and reducing the risk of failure and leakage. Currently there are no engineering solutions to overcome this issue.
4. Coloured concrete finishes fade quickly and are unlikely to meet the stringent requirements of the planning authority with regard to the aesthetic finish to the flood walls.
5. Unless a more local pre-cast concrete supplier can be found the transport impact of bringing pre-cast concrete units from Cornwall to South Wales would add a significant carbon impact from the project.

Cost

Cost data obtained from Spons and contact with suppliers is as follows.

Total cost to supply materials only for in situ flood walls:	Spons[5]:	£198,480
Total cost to supply pre-cast concrete units to the site;	Average from suppliers contacted:	£535,680

The cost data only accounts for direct materials costs, installation costs for the walls has not been included. The installation costs for the two options will be significantly different.

Installation of in situ flood walls:	labour and plant for reinforcement, formwork, casting concrete, brickwork
Installation of pre-cast concrete walls:	labour and plant to place units

The waste, transport and carbon costs for the two schemes are outlined below.

Waste

Total waste for in situ concrete flood walls:	110 tonnes; £88,170
Total waste for pre-cast concrete flood walls:	0 tonnes[6]
Waste saving:	110 tonnes; £88,170

[5] *Spons Civil Engineering and Highway Works price book, 2007, Davis Langdon*

[6] *Waste generated on site is assumed to be zero, waste will be generated in the pre-casting process, however it is assumed that most of this waste will be reabsorbed into the manufacture of further units.*

Cost of waste disposal for in situ concrete flood walls:	£5,280
Cost of waste avoided (materials and disposal):	£93,990

Carbon[7]

Total embodied CO_2 for in situ concrete flood walls:	2,100 tonnes CO_2
Total embodied CO_2 for pre-cast concrete flood walls:	988 tonnes CO_2
Embodied CO_2 saving:	1,110 tonnes CO_2

These savings are achieved through eliminating formwork and bricks.

Transport (from supplier to site, excluding transport of raw materials to suppliers)[8]

Transport distances for in situ concrete flood walls:	5,700 miles
Transport distances for pre-cast concrete flood walls:	17,600miles
CO_2 associated with transport for in situ concrete flood walls:	3 tonnes
CO_2 associated with transport for per-cast flood walls:	9 tonnes

This analysis shows that even though the carbon impact for transporting pre-cast units to site is greater than for transporting the in-situ materials the overall carbon impact of the pre-cast units is lower than the in-situ units. However the transport assumptions do not include supply of raw materials through the supply chain to the final supplier, it only looks at transport from final supplier to site. Inclusion of this data is likely to have more of an impact on increasing the carbon impact of the in situ concrete flood walls than the pre-cast flood walls. However it highlights the importance of considering transport and resource efficiency in design decisions, and not solely focussing on the benefits of waste minimisation.

This option was discussed during the workshop in February 2008; it will not be taken forward for the following reasons:
- Access to and moving units around the site.
- Leakage routes created at the joins between the units.

5.2.2 Use of pre-cast brick units as permanent formwork to the exposed face(s)
Numerous companies manufacture brick faced pre-cast concrete panels. These units are typically made by hand in a factory and comprise of a brick skin (usually half brick thick) laid in a mould backed with concrete. This creates a unit that is as durable as a brick wall. Units are typically available up to 9m long and 4m high, thickness varies between 150 – 300mm and can be manufactured to suit. It is possible to manufacture units with sloping edges and various heights and depths as each unit is made by hand.

These panels can then be used as permanent formwork for the exposed face(s) of the flood defence wall. Use of these panels would reduce the quantity of formwork required and slightly reduce the volume of concrete required on site. There would still be a requirement to pour some in situ concrete and to use some formwork. Panels would be fixed in place using a similar technique to traditional timber formwork using dividat bars. Moving units around the site would require the same access as moving formwork; however the units would be heavier than formwork.

As the panels are manufactured in a factory environment there is very little waste, half bricks are used to make the facing, and each single brick makes two half bricks. Exact quantities of concrete can be used, and waste concrete can be re-used in the next concrete mix.

Advantages
The same advantage as pre-cast concrete units.

Disadvantages
1 This option does not eliminate use of in situ concrete on site.

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[7] *Source of carbon data: Environment Agency carbon calculator*

[8] *Transport analysis based on location of local supplier information provided by Birse contractors*

2 Use of traditional brickwork to face the floodwall following a meandering river can be easily shaped to the form of the river. Long panels may not fit with the curvature of the wall alignment along the river. However it may be possible to overcome this through use of additional bricks, or shorter panels to smooth the joints.
3 Efficient use of brick laying gang, once brick layers are in a rhythm long lengths of wall can be completed in a short space of time, especially for long straight walls e.g. alongside the rugby pitch. Contractors achieve cost and time savings on their brickwork sub-contracts compared with in-river work.
4 Access to the site from the A469 down the minor roads into the site is an issue, although it is not as big an issue as the pre-cast concrete units, as the pre-cast brick units are smaller and lighter.

Cost

The cost comparison between the baseline proposal and the option of replacing exposed faces with pre-cast brick units as permanent formwork is outlined below. It has been assumed that waste reductions will be achieved through using less material (i.e. half brick rather than a full brick for the pre-cast walls) and eliminating 30% of the timber formwork

Cost data obtained from Spons and contact with suppliers is as follows.

Total cost to supply materials only for in situ flood walls:	Spons:	£198,480
Total cost to supply pre-cast concrete units to the site;	Average from suppliers contacted:	£250/m^2

The cost data only accounts for direct materials costs, installation costs for the walls has not been included. The installation costs for the two options will be significantly different.
Installation of in situ flood walls: labour and plant for reinforcement, formwork, casting concrete, brickwork
Installation of pre-cast brick units: labour and plant for the above, but with less formwork required and no requirement for brick layers.

The waste, transport and carbon costs for the two schemes are outlined in the table below.

Waste

Total waste for baseline:	89.8m^3; £88,710
Total waste for pre-cast brick option:	55.8m^3; £59,890
Waste saving:	34m^3; £28,820
Waste disposal for baseline:	£5,280
Waste disposal for pre-cast brick option:	£3,580
Waste disposal saving:	£1,700
Cost of waste saving (materials and disposal):	£30,520

Carbon

Total embodied CO_2 for in situ concrete flood walls:	2,100 tonnes CO_2
Total embodied CO_2 for pre-cast concrete flood walls:	1,811 tonnes CO_2
Embodied CO_2 saving:	270 tonnes CO_2

These savings are achieved through using less material (i.e. half brick rather than a full brick for the pre-cast walls) and eliminating 30% of the timber formwork.

Transport

Transport distances for standard brick face concrete walls:	5,700 miles
Transport distances for pre-cast brick option:	9,000 miles
CO_2 associated with transport for standard brick faced concrete:	3 tonnes
CO_2 associated with transport for pre-cast brick option:	5 tonnes

In principle the project team think this could be taken forward on the scheme in some areas particularly for long straight wall sections alongside the rugby pitch. However there are reservations outlined in the advantages and disadvantages section above, especially regarding the curvature of the river wall. Birse agreed to look into this option further and assess whether they could create a pleasing visual affect with panels. The use of shorter panels (perhaps 2 – 5m long) may get round the problem of following the river line.

5.3 Alternatives to facing brickwork to flood wall

Eliminating the facing brickwork from the scheme could be achieved through one of the following options, saving not only cost and materials, but also eliminating the waste generated from constructing brick walls on site:

- Imprinting a brick pattern onto the concrete wall
- Growing vegetation in front of the wall instead of brick

Patterned concrete

A GRP impressed concrete liner integral to the timber formwork will be used to construct patterned concrete facing to sheet pile walls. This impressed concrete liner will be used up to 50 times.

A liner could be manufactured to create a brick effect, however it would be impossible to use coloured concrete to create a brick and mortar effect.

Vegetation

There are two main types of planting required;

1. In river planting.
2. Planting around the rugby pitch.

In the interim while the plants are growing, local children could be involved in painting a mural of the proposed plants, or similar, on the wall. It would be advised that this painting is directed by a local artist but involves the local children as an opportunity to include the local community in the scheme. This will also eliminate the aesthetic and visual problems of residents seeing exposed concrete surfaces whilst the plants are growing and for deciduous species over the winter.

This option cannot be taken forward for the following reasons:

1. EA flood asset management staff would not accept the maintenance burden of vegetated walls.
2. Access for spectators along the rugby pitch is required and planted areas would not be welcomed.
3. In channel planting would have to be soft stemmed, during times of high water these plants would be flattened leaving an exposed concrete wall.

5.4 Re-use of site arisings

The following site won material will be available:

1 Excavation will be required on site for access to the river and to create working areas for the in river work.

2 Demolition arisings from demolition of a school adjacent to the site have been saved for re-use on the EA project.

3 Demolition and replacement of the stone wall adjacent to the old peoples home will generate natural stone.

Reuse of the demolition arisings and natural stone have already been identified; with the demolition arisings being used for the temporary site compound (and retained in the long term for a car park for rugby fans) and flood embankment (the embankment will still require an impermeable clay core or membrane to provide an impermeable barrier to flood waters). It is proposed to use the natural stone to provide the facing stone for the replacement wall.

A further opportunity to substitute the concrete flood wall for an earth embankment around the rugby pitch was proposed at outline design stage and discarded due to the alignment of a trunk sewer pipe. In mid February the design team made a change to the design to eliminate approximately 40m of concrete flood wall around the bowling green and to replace it with a newly aligned earth embankment. The design team are looking into the options of using either imported clay or an impermeable liner for the core, using site won material for the bund and reclaiming the top soil for the outer layer of the bund. This change in the design demonstrates the project team's commitment to identifying resource efficient solutions and continually looking for ways to reduce waste.

The proposals for the scheme involve demolishing the existing natural stone wall in front of the residential home and replacing it with a 102.5m long in situ concrete flood wall and re-using the stone to face the new wall. This option reduces waste being sent off site for recycling or to landfill and eliminates the need to import brick or another type of facing material for the wall. There is an added benefit of retaining the character of this length of flood wall.

Materials saving achieved through not importing brick facing:	27m^3 (46 tonnes)
Cost saving achieved through not importing brick facing:	£9,839
Embodied carbon saving achieved through not importing brick facing:	40 tonnes
Transport saving through not importing brick facing:	840 miles

Figure 6 Existing natural stone wall, re-use of the stone will retain the character of the area and save waste.

5.5 Early contractor involvement, at design stage, to reduce over ordering

Over ordering on construction sites occurs for a variety of reasons including:
- Inaccurate or surplus ordering of materials that don't get used.
- Allowing for damage of materials through handling errors or inadequate storage.
- Inefficient use of materials.
- Rework due to low quality of work.
- Incorrect ordering of materials due to inaccuracies in design drawings or design changes.

The New Tredegar project has the benefit of early contractor involvement which can help to reduce over ordering on the project. Early contractor involvement ensures that the design drawings are clear and provide accurate information for the contractor to use for procuring the materials on the project.

Over ordering can be reduced by creating a culture change within the procurement team to reduce the margin that is added to procurement quantities . However this will only occur if the site management supports this through a well managed storage compound, use of 'just in time' delivery, training all staff and promoting and championing good workmanship. Birse contractors create a culture of promoting good practice among site staff through championing examples of good practice and developing a materials ordering strategy. The key points from the Birse material ordering strategy include:
- Sheet piles ordered to minimum lengths necessary, number of piles ordered equates to the length of the wall rounded up to the next pair.
- In situ concrete; last load of concrete for each pour will be kept on hold until the engineer has checked the exact requirements, excess concrete will be used for blinding in following sections of wall (prepared prior to the concrete pour). Concrete will be discharged directly into formwork or pumped to minimise spillage and waste.
- Quality formwork to maximise number of uses.
- All non standard pallets will be collected and stored after use for return to supplier on their next delivery lorry.
- Standard pallets will be used to create a pallet wall to divert the river and keep working areas dry.
- Use crushed demolition waste from adjacent school for granular fill.

This plan reflects good quality design information provided to the contractor.

The impact of over ordering by 10%, excluding wastage, is demonstrated below.

Material	Baseline materials		Over ordered materials	
	Quantity	Cost	Quantity	Cost
Concrete for in-situ concrete flood walls	702m^3	£45,648	61m^3	£3,969
Steel	89 tonnes	£33,277	7.9 tonnes	£2,967
Formwork	50m^3	£73,131	5m^3	£6,648
Bricks	130m^3	£46,474	11.3m^3	£4,401
Total		**£198,480**		**£17,626**
Waste disposal			49 tonnes	£1,484
Overall Total				**£19,110**
Embodied carbon	**2,100 tonnes**		**180 tonnes**	

Figure 7 Waste figures for over ordering

The total cost of this over ordered waste is £19,110. The data contained in Figure 6 demonstrates the worst case for over ordering on this project. Whilst it may be possible to reduce over ordering as outlined through Birse's material ordering strategy, it is unlikely to be able to completely eliminate this cost to the project. These figures may be slightly misleading as the over ordered materials are often used as a resource, for example over ordering concrete will be minimised, but any extra concrete that arises during a pour will be used for blinding the next section of the flood wall. This requires the contractor to plan ahead for this and prepare the area for blinding. Additionally over ordered steel is typically in the form of 2m long T16 bars that can be bent and cut on site as required. As this steel is of a useable size and length any remaining steel at the end of the job could be moved to another site for re-use.

5.6 Standard form, layout and materials

New Tredegar Flood Alleviation Scheme comprises a simple solution to flood defence for the village. The use of sheet piled and concrete flood walls throughout the scheme provide a solution that is repeated along the length of the defence. The repeatability introduces savings in both materials and time for the construction process and time savings in design. A standard cross section shape is used throughout although heights and widths do vary along the length. The floodwall is a simple design.

The use of standard concrete walls means that the same formwork can be re-used 50 times, rather than the typical re-use of 8 times as outlined in Spon's Civil Engineering and Highway Works Price book, 2007.

The use of patterned concrete minimises the need for additional materials (and hence waste) to face the concrete as facing can be constructed in a single pour for the wall.

5.7 Communication and Procurement

The EA Framework for contractors and consultants promotes waste minimisation informally through encouraging sustainability in design and construction and seeking to reduce cost (which inherently drives contractors to reduce waste). Use of early contractor involvement on all projects also streamlines design to reduce waste, as well as many other benefits to the project and client. Design teams are required to produce draft site waste management plans (SWMP) for project feasibility studies and from April 2008 will be required to conduct a carbon calculation for their projects. Both the SWMP and the carbon calculation aim to drive waste and resource efficiency up the agenda and ensure that designers consider waste during project feasibility. Contractors are required to monitor waste generated on site. The overall national target for the Environment Agency is to achieve less than 25% of waste generated going to landfill.

Through using framework suppliers the EA can encourage performance improvement through repeat work with both consultants and contractors, this helps to drive a culture of sustainability within these organisations.

6.0 Action and communications plan

Whilst there are no direct Key Performance Indicators (KPIs) for waste minimisation, the KPIs and contractual requirements of the EA framework contracts are related to the existing EA policies (draft SWMP required at feasibility stage, less than 25% waste to landfill and use of carbon calculation tool). The existing EA policies and tools are designed to improve resource efficiency, therefore in future specific requirements within the frameworks relating to waste minimisation could be developed.

6.1 Project Communications

There was no additional design required to incorporate the waste minimisation options, the options taken forward were the responsibility of the contractor in their scope of works for design development. Therefore no additional personnel time was required.

Following BioRegional's involvement in the project Birse are to investigate use of pre-cast bricks for the flood wall alongside the rugby pitch and possibly for the river wall, although this section is less likely due to the aesthetic reasons. The project team agreed that on future projects they would investigate some of the waste minimisation options proposed throughout this process in detail.

In mid February the design team made a change to the design to eliminate approximately 40m of concrete flood wall around the bowling green and to replace it with a newly aligned earth embankment. The design team are looking into the options of using either imported clay or an impermeable liner for the core, using site won material for the bund and reclaiming the top soil for the outer layer of the bund. This change in the design demonstrates the project team's commitment to identifying resource efficient solutions and continually looking for ways to reduce waste.

6.2 Environment Agency NCPMS communications

This project was chosen as it provides a case study of a 'typical' Environment Agency flood alleviation project under their national capital works programme (NCPMS). The capital allocation for 2007/08, which covers existing commitment as well as new allocations was approximately £200m, it is anticipated that the 2008/09 allocation will be similar.

The lessons learnt through this design review process will be rolled out to the EA NCPMS project teams through a communications package comprising the exemplar case study and a short article highlighting the key lessons and learning points. The communications package has been drawn up by BioRegional to be used by the EA NCPMS Environmental Technical Advisor for the UK and is outlined below. Andrew Powell will co-ordinate the roll out of lessons learnt throughout the Environment Agency.

Environment Agency Communications Plan

Actions to be taken

- The Environment Agency will promote the case study and its findings, through adding the case study to its extranet (shared with their framework contractors and consultants, 12 national companies).
- The EA will email a short article to all NCPMS project team managers (PTMs), including feasibility study PTMs and detailed design/construction PTMs. This will be part of monthly health, safety and environment update circular.
- The Environmental Subgroup, is an established forum for environmental and sustainability initiatives, the Case Study report will be raised at this meeting.
- The EA will promote the case study and lessons learnt through a short article in 'Current' magazine; a publication for all their framework consultants and contractors (12 national engineering design and contracting companies).
- EA PTMs will be emailed a reminder to put waste minimisation on the agenda at their next team meeting.
- EA to consider incorporating specific waste minimisation requirements alongside their existing resource efficiency policies (draft SWMP required at feasibility stage, no more than 25% waste to landfill (across their portfolio, and use of carbon calculation tool from April 2008).

7.0 Constraints to prevent adoption

The main barrier to adopting waste minimisation solutions was that design decisions were made for reasons other than to minimise waste. It was noted that a number of low waste solutions were identified during the feasibility stage of the project, but these were discounted due to other technical, sustainability and economic reasons.

Option proposed	Constraint to option
Pre-cast concrete units	Physical site constraints, access, leakage
Earth bund using on site won materials rather than concrete wall	Trunk sewer located under only possible location of the bund
Painting walls rather than using bricks	■ Planning requirement to create acceptable aesthetics through use of bricks ■ Asset management issue
Growing vegetation in front of the wall rather than using bricks.	■ Planning requirement to create acceptable aesthetics through use of bricks. Also soft stemmed vegetation in the river gets flattened at times of flood, exposing the concrete wall. ■ Asset management issue

Figure 8 Constraints to options proposed in the design review

It is not possible to overcome the physical constraints of the site at this stage in the design, other than through an alternative flood defence solution, discussed below. The planning objections could be overcome through education and discussion with the local planning department, however to be successful these discussions should be held at the earliest stages of the planning process, and in this case it is considered too late to change the planners mind. However the planning authorities respond to local objections, therefore alongside changing the view of planners is a need to educate local people about the impacts of waste and potential savings through adopting alternative solutions as well as the links between waste and climate change and climate change and flooding.

8.0 Conclusions

8.1 Key Opportunities and benefits

A long list of waste minimisation opportunities was developed specific to the New Tredegar scheme based on WRAP guidance document WAS004-005 ‘Achieving effective waste minimisation through design’. These options were analysed for their applicability to this project. From the long list, six options were identified for short listing for further discussion and analysis:

1. (a) In situ concrete flood wall; pre-cast concrete units.
   (b) In situ concrete flood wall; pre-cast brick units.
2. Facing brickwork to concrete flood wall.
3. Re-use of site won materials.
4. Early contractor involvement, at design stage, to reduce over ordering of materials on the scheme.
5. Standard form, standard layout and standard materials.
6. Communication and procurement.

The results for the options demonstrating potential waste savings are presented in Figure 9 below. A number of the waste minimisation options assessed were already included in the design, for example standard form, layout and materials, reduced design complexity and the re-use of site won materials.

Engineering design decisions are made for a number of reasons, waste is intuitive in this decision making process as well as driven by the tools provided by the Environment Agency (including site waste management plan requirement at design stage and use of carbon calculation tool commencing in April 2008). As contractors create waste and bear its cost, they are well placed to influence design decisions to incorporate low waste options. This was seen on this project through the early contractor involvement for example through the contractor approach to over ordering.

	Waste generated	Cost of waste	Embodied carbon of materials and waste	
Baseline	360 tonnes	£105,000	2,100 tonnes	
Option	**Waste saving**	**Waste cost saving**	**Embodied carbon saving**	**Adopted by the project team**
1(a) In situ concrete wall; pre-cast concrete	110 tonnes	£93,990	825 tonnes	No
1(b) In situ concrete wall; pre-cast brick	41.5 tonnes	£30,515	270 tonnes	Yes (partially)
2. Facing brickwork to concrete wall	Various options assessed.			No
3. Re-use of site arisings	46 tonnes	£9,840	40 tonnes	Yes
4. Over ordering	49 tonnes	£19,110	180 tonnes	Yes (partially)
Standard form layout and materials	Not possible to quantify the impact.			Yes
Communication and procurement	Not possible to quantify the impact			Yes
Total potential savings (option 1(b)+option 3+50%*option 4)	**110 tonnes**	**£50,000**	**400 tonnes**	

Figure 9 Comparative difference in cost, waste saving and carbon saving through adopting the waste minimisation options proposed

A number of proposed waste minimisation options were not taken forward on the scheme because of reasons other than waste minimisation, for example pre-cast walls and alternatives to facing bricks. The primary reasons were planning requirements, logistics and time. Cost was also a driver, but complex logistics and increased time will add cost to the project, which in many cases outweighs the cost of additional materials and waste disposal. To overcome the planning barrier requires early identification of waste minimisation within the project process, so that the planning submission incorporates the lowest waste option. Major changes to the scheme, as a result of this study, were not possible due to the timing, as the planning consent has already been acquired.

Overall the study identified the potential for waste savings of 110 tonnes, cost savings of £50,000 and 400 tonnes of embodied carbon through design changes.

A communications plan to roll out the lessons learnt to the Environment Agency (EA) has been developed with the EA National Capital Programme Management Service (NCPMS) Environmental Technical Adviser. This will target both internal project managers and the Environment Agency framework consultants and contractors (12 major UK engineering and contracting companies).

8.1.1 Summary of influence for EA portfolio

Figure 9 demonstrates that this project has identified the potential to design solutions that prevent 110 tonnes of waste arising on the site, which could save the project £50,000 and 400 tonnes of embodied carbon.

Figure 10 demonstrates the potential waste savings that could be adopted for a typical Environment Agency project. However this is a very approximate estimate as the waste saving potential is for concrete flood walls, typical EA projects include other elements such as earth bunds and sheet piling which are likely to generate less waste than flood walls.

Total cost of waste	£50,000
Total construction cost of project element	£500,200
Total waste saving potential	110 tonnes (70 tonnes had already been included in the designs prior to testing of WRAP guidance)
Total embodied carbon saving potential	400 tonnes
Potential percentage cost saving through waste minimisation	10%
Potential waste saving through waste minimisation	1 tonne of waste / £4,600 construction cost
Potential carbon saving through waste minimisation	1 tonne of carbon / £1,300 construction cost
Percentage of project adopting waste minimisation measures without the influence of the WRAP guidance	65%

Figure 10 Cost and waste savings inferred for typical Environment Agency projects

8.2 Lessons learnt

The key lessons learnt through this project were:

1. In construction projects waste minimisation must be an important issue in options appraisal and design but there are other factors that can be equally if not more important e.g. Health & Safety, cost, legislative/planning requirements, CO_2 footprint, ongoing maintenance requirements etc.
2. Resource efficiency and sustainability drive decision making, the carbon impact of transporting pre-cast units long distances, may in some cases outweigh the carbon savings achieved through use of pre-cast units. This is an important factor in the adoption of low waste solutions.
3. Guidelines on options that are more wasteful than others should be followed from the earliest stages of a project.
4. Design decisions made at an early stage in the process affect waste production on site.
5. Some over ordering is unavoidable.
6. Waste of time and resources is a bigger cost and risk than waste of construction materials.
7. Early contractor involvement helps to refine design options to reduce waste.
8. Modern methods of construction and offsite construction (MMC/OSC) are restricted by access constraints for large panels. The ideal application of MMC for flood defence projects is where long, large lengths can be used to save waste and time, and reduce the number of joints required.
9. Waste minimisation of different design options is not easily quantifiable.
10. WRAP guidance on waste minimisation provides a useful guidance document for designers to consider waste minimisation options, it would be useful to have a summary checklist of the generic 'long list' of opportunities for design teams to use.

9.0 Bibliography

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- Designing to encourage waste minimisation in the construction industry, A Keys, A Bladwin and S Austin, CIBSE
- WAS004 – 001 Efficient construction logistics, WRAP, March 2007
- WAS003-001 Current Practice and Future Potential in Modern Methods of Construction, WRAP, Jan 2007
- WAS003-003 Waste Reduction Potential of Off site concrete manufactured off site
- Setting a requirement for waste minimisation, WRAP
- The Small Environmental Guide for Construction Workers, SEPA and CIRIA
- Spon's civil engineering and highway works price book, 2007
- A guide to modern methods of construction, NHBC Foundation
- Modern methods of house construction, A surveyors guide, BRE Trust
- Demonstrating waste minimisation benefits in construction, CIRIA, 2001

Appendix Assumptions made in waste and cost calculations

The main assumptions used to obtain the results are outlined below. These assumptions were based on design details taken from the design drawings and discussion with the project team:

- Timber formwork to concrete walls will end up as waste; each section of formwork is re-used 8 times.[9]
- Formwork 10mm thick timber.
- Wastage minimum 2.5%, maximum 5% for concrete and bricks[10]
- Wastage minimum 1%, maximum 2% for reinforcing steel[11]
- Over ordering of minimum 5% to maximum 10% on all materials[12]
- Mortar used on brickwork not included in calculations
- Temporary works (other than formwork) not included in calculations.
- No allowance made for blinding concrete.
- Waste reduction and disposal looks at industry standard practice. For comparison typical EA waste management practice has been included i.e. waste concrete is used for blinding, all materials are segregated and recycled where possible. For comparison industry standard practice has been included

During the February workshop Birse indicated that they would be using a formwork mould made from timber that could be reused 50 times made from high quality timber ply and using a glass reinforced plastic (GRP) impressed liner for the concrete finish, this waste saving has been incorporated in the option analysis below.

Sources of waste excluded from the calculations

1. Works at Birchgrove Bridge have been excluded from the analysis for the following reasons;

- the flood walls and embankments proposed throughout the New Tredegar scheme are typical for many EA flood defence projects and waste minimisation opportunities identified here could be relevant to many other projects in the EA portfolio, whereas the bridge works are bespoke to this project;
- within the timescale of this design review it was not possible to analyse all elements of the scheme so the focus was on the elements most relevant for roll out; and
- use of pre-cast beams for the bridge demonstrates a good practice waste minimisation option.

2. Quantities of waste generated by sheet piling have not been analysed in detail either as the waste is expected to be minimal, waste will arise due to anomalies in the ground conditions, preventing the piles from being driven to full depth and requiring cutting off. The quantity of waste generated would be difficult to predict accurately even with detailed borehole data. It should be noted that through Early Contractor Involvement on the project, Birse Contractors have already identified a material saving by reducing the overall length of the piles from 6.5m to 4m by incorporating ground anchors. The principal driver for this design change was noise and vibration. Birse also conducted detailed investigations into the feasibility of using designed off-cut sheet pile sections from another near by project into the New Tredegar scheme, however due to the timing of the two projects, introducing a requirement to store the sheet piles for a long period of time, it was not possible.

3. Excavation of site won materials has not been included in the assessment. This will form a major element of the material arisings. The EA have been stockpiling river shoals over the last couple of years to create temporary in-river working platforms, ordinarily the river shoals would be removed on an annual basis. There is no way to calculate the exact volume of material arising without a thorough topographical survey. The EA seek to make use of any excess site won material from one site to make flood embankments at other sites, therefore it can be used as a resource for other projects. Site won demolition materials have been addressed in Section 5.4.

Cost Analyses Assumptions

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[9] Based on assumptions used in Spons Civil Engineering and Highway Works Price Book, 2007, Davis Langdon

[10] Wastage rates assumed in Spons Civil Engineering and Highway Works Price Book 2007, Davis Langdon

[11] Typical wastage rates discussed with Birse Contractors

[12] Birse contractors stated that 10% over ordering is typical practice, they are striving to reduce this to 5% on all of their projects

Cost data has been obtained from Spon's Civil Engineering and Highway Works Price Book 2007 for the proposed design drawings Revision A received on 29 November 2007. These drawings were the drawings submitted for planning, they are outline drawings and some dimensions have been scaled off the drawings, this only provides an approximate assessment of the dimensions. The detailed calculations contained in Appendix 2 identify where dimensions have been scaled.

For the alternative proposals outlined below, cost data has been obtained from suppliers (outlined in Appendix 3). This provides the materials costs, and in some cases delivery to site. For comparison only the direct materials cost have been compared as labour and plant costs for the alternate proposals are unknown.

Landfill costs from April 2008 are £32/tonne for non-hazardous material or £2.50/tonne for inert materials.

Waste Analyses Assumptions

Quantities of waste generated on site have been calculated for the following:

- Wastage; considered minimum 2.5% – maximum 5% (Concrete, bricks)[13]
- Wastage minimum 1%, maximum 2% for reinforcing steel[14]
- Over ordering; minimum 5% to maximum 10% (concrete, steel, bricks)[15]
- Formwork; all formwork used on site is waste, assumed to be timber, each formwork is used 8 times[16]
- Packaging; pallets for delivering bricks to site, shrink wrap to bricks

Carbon Analyses Assumptions

The EA have recently developed a carbon calculator tool designed to be used on all their flood defence projects to calculate embodied CO_2 of the construction project. This project is one of the first EA projects to use the tool and will therefore not only be an exemplar project in terms of design approach to waste minimisation but also in terms of carbon calculation.

Embodied carbon has been calculated for the construction materials and waste disposal. Plant, personnel transport and portakabins have not been included in the calculations as the carbon impacts are based on the time that the project is on site, which at this stage is unknown.

Transport Analyses Assumptions

Transport of materials from the supplier to the site has been assessed. No assessment of transport of raw materials to suppliers has been made as there was insufficient data available. Details of locations of suppliers, size of lorry and quantity of material per load for each material and option are contained in Appendix 2, it has been assumed that all deliveries are made by road and the total distance travelled by the lorry is for a return journey to the supplier. A carbon emissions factor of 0.0003174tCO_2/km has been assumed for the total distances.

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[13] Wastage rates assumed in Spons Civil Engineering and Highway Works Price Book, 2007, Davis Langdon

[14] Typical wastage rates discussed with Birse Contractors

[15] Birse contractors stated that 10% over ordering is typical practice, they are striving to reduce this to 5% on all of their projects

[16] Based on assumptions used in Spons Civil Engineering and Highway Works Price Book, 2007

Rates Used for Cost Analysis

Spons Civil Engineering and Builders Price Handbook, 2007 Edition

Concrete	***Materials cost***	***Total cost***	***Unit***
Class F: Standard mix sulphate resisting C30, 20mm aggregate	£88.03		/m3
Birse concrete rate	£65.00		/m3
Placing concrete; reinforced: Bases, footings and pile caps 300 - 500mm thick		£19.23	/m3
Placing concrete; reinforced: walls 300 - 500mm thick		£24.04	/m3
Reinforcement			
Class G: Concrete ancillaries deformed high yield bars to BS4449 16mm nominal size	£373.70	£1,083.49	tonne
Formwork			
Class G: Formwork: Fair Finish for concrete components of constant cross-section to walls 1.5m high thickness 300mm	£31	£158.81	/m
Class G: Formwork: Fair Finish for concrete components of constant cross-section walls 1m high thickness 250mm	£21.27	£117.13	/m
Brickwork			
Class U: facing bricks in plasticised cement mortar, vertical facing to concrete	£36.92	£75.82	/m2

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