Communities Directorate

Technical and Property Services

Roads Division

Engineering and Design Services

Flood Risk Assessment

For

Edzell

	Signed	Date
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Reviewed and Approved By Walter Scott	WS	10 September 2014

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Executive Summary

Significant flooding occurred in Edzell from the Whishop Burn on 21st to 23rd December 2012. Subsequently Angus Council has developed a flood risk assessment to identify the flood mechanisms in operation. From this an options appraisal has been developed to identify which measures merit further consideration and more detailed development for implementation.

Once identified and implemented the measures will improve the quality of life of residents within Edzell by offering a greater level of protection from flooding. This will also ensure that the community can develop in a sustainable manner and the existing natural and built environment is protected.

The findings of the assessment and options appraisal are to be used to provide support to the recommendations made to the council for committee approval.

A full assessment of the flood mechanisms can be found within the Flood Risk Assessment section of this report. The technical assessment of all options is contained within the technical options appraisal and the appendices contain an assessment of the level of protection afforded by each option, the estimated cost and the Benefit Cost Ratio (BCR) of each option.

Angus Council has been working with the local community to ensure they are engaged within the development of the report. A two-way flow of information has taken place with Council employees clarifying technical queries and the flood group acting as a conduit for information. The queries and leads passed to the council for potential causes of flooding have been examined within the flood risk assessment.

Angus Council commissioned a quantitative report on the flood mechanisms within Edzell. This report has been used to assist in the development of the flood risk assessment and technical options appraisal of all potential mitigation measures. The measures identified within the technical options appraisal were assessed against several criteria including cost, buildability and residual risk.

Physical measures have been identified and appraised. There are options available which are considered feasible and affordable but need further development before implementation. These are summarised in Table 1. In addition, further property level protection is proposed, which relies on empowering local residents to take responsibility for protecting their own property. These measures provide differing levels of protection against the different storm events and flood mechanisms.

The options that have been identified and appraised as suitable for progression are works to increase the capacity of the Dunlappie Road culvert (£220,000) and further property level protection (£30,000). Other options considered suitable for progression are a package of multiple interventions

throughout the town itself (£220,000) and a western bypass of flows to the West Water (£720,000). Further detailed development will be required for these options, including checks on affordability and land agreements to access land and construct flood protection works.

Table 1 – Summary comparison of the proposed options

Options	Forecast Level of Protection (indicative return period)		Cost (including staff cost)	Benefit/Cost Ratio
	River (Fluvial)	Surface Water (Pluvial)		
Do nothing	Low (<1:10)	Low (<1:10)		
Dunlappie Road Culvert	High (1:200) (Localised)	Medium (>1:30-1:100) (Localised)	£220,000	1.22
Dunlappie Road Culvert + Upstream Measures	High (1:200) (Localised) Medium (>1:30-1:100) (Combined)	Medium (>1:30-1:100) (Combined)	£440,000	1.38
Western Bypass	High (>1:200)	Low (Indirect) (<1:30)	£720,000	1.49
Dunlappie Road Culvert + Western Bypass	High (>1:200) (Combined)	Medium (>1:30-1:100) (Combined)	£940,000	1.42
Property Level Protection	Low-Medium (1:10-1:30) (Combined)	Low-Medium (1:10-1:30) (Combined)	£30,000	>1
Eastern Bypass	High (>1:200)	Low (Indirect) (<1:30)	£1,085,000	1.19

1. Option Appraisal

This section considers each option presented in Section 3 of this report 'Optioneering' in terms of several factors including cost, buildability, land requirements and risk. Given the direction provided for the preparation of this assessment, the 'do nothing' option has not been accounted for. Each aspect is scored 1-6 to allow a traffic light system to be used. A score of 1 or 2 is deemed to be good and is assigned the colour green; 3 or 4 is an average score and is assigned the colour yellow; and 5 or 6 is deemed to be a poor score thus it is assigned the colour red. Two numbers have been used to represent each colour to allow a level of flexibility in representing the relative strengths and weaknesses of each measure.

This is an entirely qualitative assessment to allow a high level examination of the relative advantages and disadvantages of each option to be compared and examined. The assessment relies on the engineering judgement of the professionally qualified officers of the council. The scores have been totalled and these options colour coded, generally scores below 30 are green, 30 to 40 are yellow and above 40 are red. The exceptions to this rule are the embankment options; these have been scoped out due to the cost of these measures.

It should be noted that whilst the above assessment is presented in a numerical format, this does not negate the need for professional judgement to be applied in considering the 'best' options to take forward for detailed development.

									Raise Embankments				Other Measures					
	Culvert upsize		E Bypass		W Bypass		Proprietary Products		N Embankments		S Embankments		Drainage Installation		Managed Overland Flow Paths		Natural Flood Management	
Cost	4	Medium cost	5	High cost as per angus Council costing	4	See costing < £1m	1	Low cost, subsidised by Angus Council	6	See costing>£1m	6	Costing not carried out but similar to northern embankments	2	Cost is scalable to budget;	2	Low cost traffic calming intervention	2	Low cost, grants and subsidise available
Legal	3	Wayleave agreements required to maintain access.	4	Wayleave agreements required to maintain access.	3	Wayleave agreements required to maintain access.	1	No legal implications	5	Complex agreements and compensation	5	Complex agreements and compensation	1	all works within powers conferred by Roads Scotland Act	5	Traffic calming requires traffic order and public consultation	1	No legal implications
Land	3		3	Landowner agreement to be confirmed	4	Land held by one owner, no engagement as yet regarding feasibility	1	No land implications	4	Farmer agreement or compensation required	4	Farmer agreement or compensation required	1	All land within local authority control	1	No land implications	5	Works must be carried out with landowner agreement
Buildability	5	Very complex works	6	Deep excavations	1	Standard Civils works	1	No construction required	3	Due to size may have to be treated as reservoir and treated as such	2	Standard Civils works	2	Standard Drainage Works	1	Standard roads engineering works	1	Planting works
Maintainability	3	Specialists needed for inspection, non-visible failure possible	5	Specialists needed for inspection, non-visible failure possible	2	Regular maintenance needed to ensure capacity is maintained	1	Maintenance the responsibility of property owners	4	Due to size may have to be treated as reservoir and treated as such	2	Regular inspection required however easily maintained	2	Standard Drainage Works	1	Standard roads maintenance	1	
Disruption	5	Works in centre of town, through private gardens and public roads, extreme disruption for extended period of time	3	Medium disruption with closure of public areas and disruption to public roads	2	Works out with town so little impact to village	1	Demountable therefore no day to day disruption	2	Works out with town so little impact to village	2	Works out with town so little impact to village	5	traffic management and works in carriageway required	6	traffic management and works in carriageway required	1	No disruption to town
PU	5	Highly constrained works area due to public utility location.	4	Proposed route crosses water main and possibly other utilities. Liaison with statutory undertakers will be required	1	No impact to Public Utilities	1	No PU interactions	3	Excavations may impact public utilities	4	Power lines known to cross site, excavators may be limited in operation	4	May be some PU interactions, minimise risk through choice of product	1	No PU interactions	1	No Pus
Sustainability	3	Medium sustainability	5	Low sustainability piped solution	1	Above ground, green option. Highly sustainable	1	Highly sustainable	4	Maintenance required and crops damaged by Use of storage area	4	Maintenance required and crops damaged by use of storage area	6	Standard Drainage Works, low sustainability	2	Highly sustainable	1	Highly sustainable
Risk	5	Does not help flooding to north of town, may increase flooding of hotel, golf club house and B966	4	Medium risk due to maintenance and depth of excavation required.	1	Low risk, flows diverted away from village	3	Medium risk due to uncertainties regarding deployment and leakage	3	impounded water but waters kept away from village	5	High risk, waters impounded immediately adjacent to residential area	1	Low risk, standard drainage works	5	High risk due to failure consequences	6	High risk as level of protection unquantifiable
Level of Protection	4	Reduced risk to Dunlappie Road, no change to level of protection north of town, increased risk downstream	2	Protection predominantly from fluvial events	2	High level of protection afforded to entire town	1	up to 600mm protection for each property	2	High level of protection afforded to entire town from fluvial events	2	High level of protection afforded to entire town from fluvial events	4	Improved protection during short duration storms, no protection during flooding from Whishop Burn	4	Medium level of protection for Church Street	6	Variable level of protection and unquantifiable
Totals	**40**		**41**		**21**		**12**		**36**		**36**		**28**		**28**		**25**	

2. Flood Risk Assessment

2.1 Flood Mechanisms

This section identifies the flood mechanisms and assesses the risk of flooding from these mechanisms to properties in Edzell.

2.1.1 Tidal

Edzell is not at risk of tidal flooding.

2.1.2 River (Fluvial)

Edzell is bracketed by two watercourses: the River North Esk to the East of the village; and the Whishop Burn to the West of the village. The River North Esk is within a deeply incised valley and as such does not present a significant flood risk to the village; however the smaller Whishop Burn to the west can have a significant impact on the village.

The Whishop Burn's behaviour has been quantitatively modelled within the report commissioned by Angus Council (Grontmij, 2013), which provides a detailed analysis of the hydraulics and hydrology. The behaviour of the Wishop Burn is summarised as follows.

The modelling and anecdotal evidence indicate that during high flows there are two main flood mechanisms operating.

During high flows the burn breaches its banks north of Lethnot Road, this floods the Muir area then flows along Lethnot Road, Castle Gardens, Church Street and associated streets inundating gardens, garages and low lying properties.

The second mechanism occurs at Dunlappie Road as the culvert constricts flows and forces the burn 'out of bank', which leads to inundation of properties along Dunlappie Road and The Drive.

2.1.3 Surface Water (Pluvial) Flooding

Surface water flooding occurs when flood water reaches the ground surface. The source of this flood water may come from sewers and drains whose capacity has been exceeded; it may come from direct rainfall; and it may come from indirect overland flows from other flood sources that have not yet or are unable to discharge into sewers, drains or rivers.

2.1.4 Overland Flow

Overland flow is a fluvial mechanism that manifests on sloping terrain; when rain falls on impermeable or saturated ground it cannot infiltrate and therefore flows downhill. Under normal conditions this water will be quickly

picked up by drainage systems and directed to sewers, SUDs or a receiving water body depending on the local infrastructure. However during intense or prolonged storm events, where the capacity of the local infrastructure is already used, overland flow can cause or contribute to flooding.

The flooding of the north of the village is as a result of overland flow associated with fluvial flooding. The Whishop Burn breaches its banks to the north of the village on the Muir and flows south; this is then picked up by Lethnot Road and flows down Castle Gardens and Church Street using the roads as flow pathways.

Overland flow mechanisms are also in operation to the north of Dunlappie Road with water coming from the agricultural field and affecting properties. A low embankment has been raised by the property owners along the rear of their homes to protect against this mechanism and some homeowners have also constructed a wall.

2.1.5 Sewer

Sewer flooding is when excess water enters the foul system and causes flooding from contaminated water. Scottish Water has no record of sewer flooding within Edzell, however some road drainage appears to tie into the foul sewer which has limited capacity and this can contribute to pluvial flooding. However this is not flooding from the sewer.

Flooding by foul water directly from the sewer is the responsibility of Scottish Water and is often designed for lower return period events than for river of surface water flood protection. Due to the difficulties associated with sizing pipes for storm events, Scottish Water systems are only intended to carry the property flows from a 1:30 year rain event. However, this can sometimes be lower with older systems.

It is not considered that Scottish Water contributed directly to the flooding experienced in Edzell, although contamination of flood waters may have occurred once the foul sewer system was inundated by the river or overland flows.

2.1.6 Ponding

Ponding occurs when water cannot freely drain away. There are several areas in Edzell where this is known to occur. This form of flooding occurs within Edzell due to the nature of the surface water drainage system. Historically surface water and foul flows were drained within the same system. This combined drainage system is capable of conveying day to day flows of foul water and surface water from the curtilage of properties. However during high intensity rain events its capacity to take these volumes is overcome. When this capacity is exceeded water can no longer drain to the road gullies and ponding can occur.

Flooding is known to occur on Dunlappie Road during high intensity rain events and along the High Street. It is likely that large areas of Edzell are

vulnerable to this form of flooding due to the nature of the surface water drainage system.

2.1.7 Groundwater

Ground water is the existing level of water within a soil cross section. Groundwater flooding in isolation is caused when the water table rises. It can often occur in buried structures or in areas of limestone geology. There are no records of groundwater flooding occurring in this area however several groundwater mechanisms can contribute to the severity of a flood.

However, when groundwater rises very high it can prevent rainwater from soaking into the ground as it is already saturated. It is this mechanism that may have been operating within Edzell and contributed to flooding.

2.1.8 Infrastructure Failure

Flooding from infrastructure failure is caused by the catastrophic failure or collapse of artificially engineered structures that retain bodies of water. Structures such as dams, raised embankments and sea walls constitute flood protection infrastructure. The failure of these retaining structures can have catastrophic consequences as they enclose flood waters above the surrounding terrain.

Potential spills from the former Brechin water supply reservoir have been suggested as a mechanism that exacerbated the flooding within Edzell. This supply dates from the late 1800s and conveys water to Brechin through a cast iron water main.

Initial calculations indicate that under optimal conditions this pipe could deliver 0.042m³/s (42.2 l/s) to the electricity sub station. This is a conservative estimate erring on the side of caution; this calculation assumes that the pipe is in a straight line at a constant gradient. In reality it takes a meandering route and crosses several glens using non-return valves. The actual route and glen crossings would reduce the conveyance capacity below this value.

An increase of 0.042m³/s would not have a significant impact on flows at the village; it represents a 6% increase in flows during the 1:2 year high probability event and a 1% increase in the 1:200 year event. These increases also assume a direct point increase consisting of the entire volume of the capacity of the pipe. For this to occur the water main would have to discharge its entire volume directly into the Whishop Burn immediately north of the village which is not possible.

Angus Council are continuing to investigate the operation and management of this supply to ensure that it is properly managed and that any spills are acted upon.

2.2 Overview of Flood Risk Mechanisms

Flooding within Edzell occurs due to single factors or more often a combination of factors that contribute to flooding within the village.

Surface water flooding can occur within the village due to high intensity rain events, which can overcome the capacity of the combined sewer and road drainage, or be too intense to discharge into sewers, drains or rivers. This form of flooding can manifest quickly but equally will draw down and subside quickly once the rain storm has passed. These rainfall events are becoming more frequent and can be forecast but are less predictable and hence are difficult to defend. This type of flooding can have a significant impact on the roads infrastructure given the road system is largely hard surfacing. This is generally confined by kerblines and footway crossfalls. Where soft surfacing is present, e.g. gardens the risk is reduced. However, surface water flooding does present a specific risk to dwellings and buildings, and in particular low lying properties.

The second significant form of flooding that can occur within Edzell is fluvial flooding from the Whishop Burn. This generally occurs due to high duration rain storm events lasting several days, and more often than not over larger geographic areas than high intensity rainfall events. These storms tend to saturate the catchment and progressively increase the volume of water draining to the Whishop Burn, as the capacity of the ground to absorb water is lost. These rainfall events can be forecast but are more predictable, and hence are more readily defended, e.g. by deploying property level protection. The small size of the Whishop Burn catchment does not lend itself to a formal flood warning system. However, this does not preclude the use of local vigilance and monitoring to warn of flooding.

The Whishop Burn is a small but significant engineered channel, which has been straightened; it is constrained in several places along its upper length with several field and road crossings. These field crossings are likely to initiate turbulent flow conditions and flow constraints leading to out of bank flooding of the Muir, which leads to surface water flooding of the northern parts of Edzell. Lethnot Road then acts as a distributer for flood waters which then flow down Church Street and Castle Gardens. The second area of fluvial flooding is within the southern end of the town, with the onset of flooding in this area caused by the constriction of the Dunlappie Road culvert. When the capacity of the culvert is exceeded, flows progressively back up before overtopping the banks of the burn to the north of Dunlappie Road, and inundation of properties. Out of bank flows from the Whishop Burn downstream of the Dunlappie Road culvert is also a notable form of flooding, which impacts on the golf club and neighbouring properties before dispersing into Edzell Wood.

3. Optioneering

This section provides details of the various measures identified for mitigating the risk of flooding from the various sources identified in Section 2 'Flood Risk Assessment', and presents a technical appraisal of their merits.

3.1 Up-sizing of Culverts

Flooding at Dunlappie Road is caused by the culvert acting as a choke point and being unable to discharge freely. To reduce the onset of flooding the capacity of this culvert could be increased to allow greater flows. This would improve the situation during lower return period events, however sizing the culvert to convey higher return period flows is an option, which has been considered.

The capacity of a culvert is dependent on several factors. The main constraints in Dunlappie Road are the gradient and the cross sectional area. In this area the gradient is controlled by the level of the burn at the upstream and downstream end of the culvert. Therefore the only variable that can be altered to increase the capacity is to upsize the cross sectional area of the pipe. There are constraints to the upsizing of the pipe, as the pipe cannot be laid below the bed of the burn nor can it be laid just below the road surface.

The route of the culvert also presents challenges to be overcome.

An upsized culvert could not be laid on the line of the existing culvert due to extensions that have been built onto Station House. The demolition and re-construction of this extension would significantly increase the cost of any culvert on this route and as such is not considered feasible.

An alternative route is to divert flows through a new culvert to be laid in the gardens of properties on the south side of Dunlappie Road and The Drive. This route would need the demolition and rebuilding of two garages. The route and size of the culvert would be constrained by the locations of services in the area and excavations would have to take place in close proximity to the foundations of existing structures. It is though considered that the engineering constraints can be overcome.

The current capacity of the Dunlappie Road culvert has been calculated to be 0.74m³/s. The estimated flow from the 1:200 + cc event is 2.48m³/s. This represents a threefold increase in the current capacity of the culvert. Surveys carried out by Angus Council indicate that there is around a 1m depth available for extra pipes. These will require around 400mm of cover on top making the maximum diameter possible 600mm. Assuming these were set at the same gradient as the existing culvert, which is 1:238, each pipe would have a capacity of 0.44m³/s. This would require 4No additional 600mm diameter pipes or a 3m x 0.6m box culvert to be laid. However, this assumes ideal conditions and due to the pipe route and difficulties in constructing and

designing an intake structure that is hydraulically sound, a larger bore pipe may be required.

Upsizing of the culvert is an option that would relieve pressure on the Dunlappie Road area of Edzell. It may not be possible to size the culvert expansion to convey the total calculated flows and there would be several issues with the hydraulics of the culvert but a level of improvement would be gained.

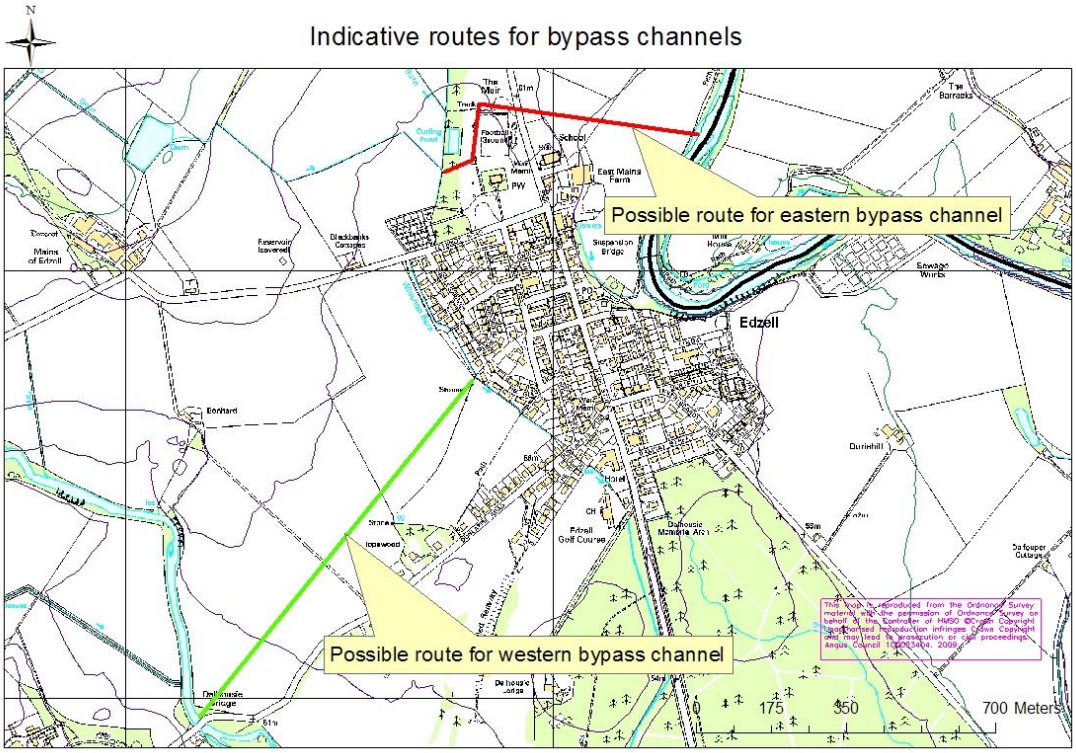
This option would protect properties in the vicinity of the Dunlappie Road culvert to a relatively high level however the properties to the north of the town would still be inundated by the Whishop Burn breaching its banks to the north of the town. This would mean that flooding would still occur and the culvert would be significantly oversized as the full flows of 2.48m³/s would not reach it as they had breached further upstream.

In summary, the exact capacity that could be created would be developed in the detailed design. The impact on the dwellings and need for reinstatement would need to be addressed, however, this option is considered feasible.

3.2 Bypass Channel

Another engineered solution to the flooding at Edzell would be to install a bypass channel to convey excess flows away from the village. This would reduce pressure on the Dunlappie Road culvert and pick up flows before they had the opportunity to breach the banks of the burn and inundate the village. Two possible routes for this channel have been appraised.

The eastern route picking up flows north of the town and conveying them with a pipe to the River North Esk. This is the shorter route for a bypass channel however it crosses the 60m contour twice requiring significant excavations. Preliminary work suggests the pipe will have to be laid at depths up to 6m. This level of excavation is significant, protection will be required to work at these depths and it is possible that rock may be encountered further complicating the works. This route would also require a road crossing and utility crossing which will require traffic management, reinstatement and support of services. This introduces further risk and complications to the construction of a pipe along this route.



The second possible route runs west and discharges to the West Water. The route for this channel is longer than the eastern proposal but may require less complex excavations and be in open cut. Supplementary works may also be required to the north of the town to ensure flooding does not occur prior to the flows entering the bypass channel.

Both options will require land agreements and approvals from the Planning Authority and SEPA.

Angus Council has carried out preliminary costing and cost benefit analysis for the eastern channel and estimates that it could be put in place for around £1 million; this cost does not include long term maintenance or land acquisition costs. The western route would have to be investigated further to allow an estimate of its feasibility for comparison to the eastern route. Current assessments indicate that the construction cost of the western bypass, albeit longer are less than western bypass. An overall cost estimate of £720,000 has been calculated (See Appendix 2).

3.3 Property Level Protection

Homeowners have a responsibility to protect their own property from flooding. Property level protection such as air brick covers and door guards can be retrofitted to properties and provide a level of protection. Gate guards across driveways are also considered to be feasible, particularly along Lethnot Road. These products reduce the impact of flooding but do not completely prevent the ingress of water. More permanent solutions can be designed into houses such as waterproof doors and automatic air bricks; these are more expensive but provide a better level of protection.

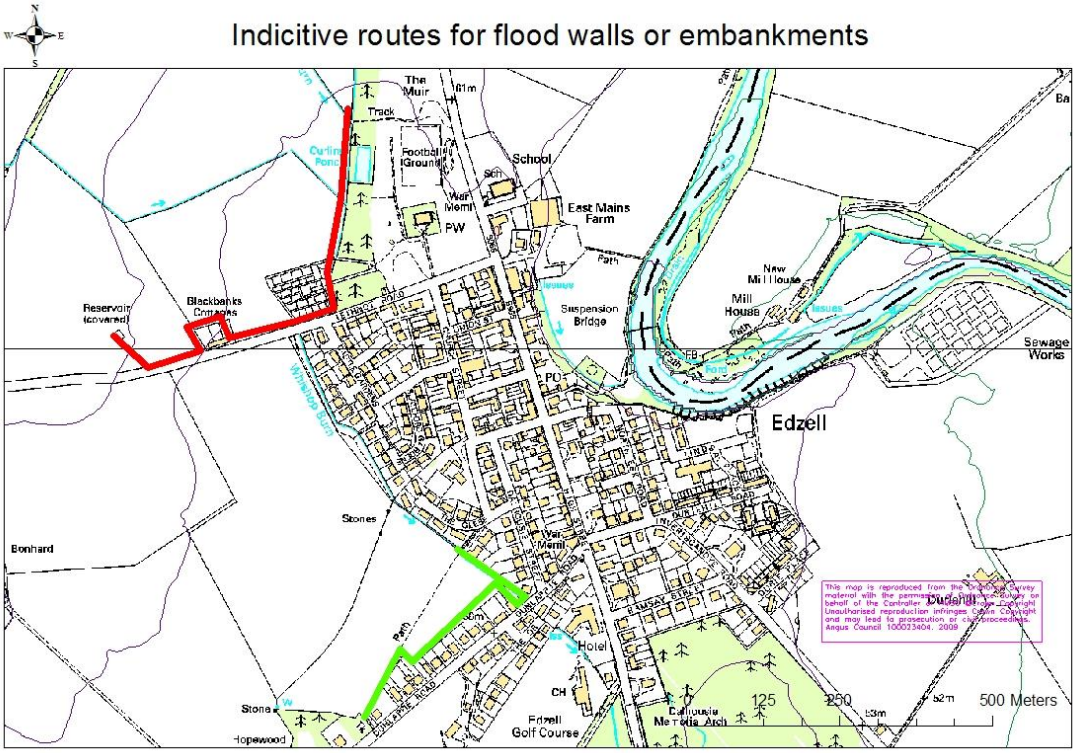
Property level protection offers the best level of protection for a range of events including both fluvial and pluvial flooding.

Angus Council have implemented a limited scheme for the purchase of airbrick covers. The option for widening the scheme to allow residents to take measures to protect themselves and their property against significant damage caused by flooding is considered feasible.

3.4 Raise embankments

A conventional solution to flooding is to raise embankments to either impound flood waters or direct it away from properties. There are several possible locations where walls and embankments could be used to reduce the frequency of flooding in Edzell. These would have to be installed in multiple locations throughout the village to ensure that flooding would not be exacerbated or caused elsewhere.

There are several options for the configuration of walls and embankments (see Figure 2) however these would have to be installed in an integrated manner throughout the town to ensure flooding is not directed elsewhere, as installation of walls ad-hoc or in isolation could actually increase flood risk.



The outline shown in red on figure 2 shows the possible line of an embankment or wall that would impound flood waters north of the village, this could take the form of a 1.5m high embankment with a clay core and reinforced concrete throttle structure to control the pass forward flows of the Whishop Burn in times of spate and cause the impounded area to flood. Around 5 ha

would be required to be flooded to a depth of 1.5m to provide sufficient attenuation (Grontmij, 2013).

The outline shown in green is the second alternative location for the construction of a flood wall and embankment. This could take the same form as the northern option shown in red with embankments and a throttle structure limiting the volume of water passed forward. Flood waters would be impounded north of Dunlappie Road and the culvert would be prevented from surcharging.

Option one would be preferred as it would prevent flooding to the north of and south of the village. Flood waters would be prevented from flowing out of bank, which would inundate the Muir and may lead to flooding of properties. Flooding at Dunlappie Road would also be prevented as the volume passed forward would be limited to the volume that the culvert was capable of conveying. Option two would also be impounding large volumes of water immediately adjacent to properties which is inadvisable due to the heightened risk in case of failure or overtopping due to an event of greater than 1:200 year probability.

Any area of impoundment would be of such a size that it could be considered a reservoir under the Reservoirs Act when at full capacity. As such it would have to comply with stringent design parameters and be designed appropriately; which has cost implications.

An alternative to the full solution storage area would be construction of a smaller area giving a lower level of protection from flows from the Muir. A smaller impoundment area of flood defence would reduce and redirect flows during events of lower return periods however the town would still be at risk of flooding during higher return period events such as the one experienced during December 2012. For this measure to be effective it would have to be implemented as part of a suite of other measures throughout the town.

3.5 Other Measures

3.5.1 Drainage Installation

Two types of flooding occur in Edzell: one is related to the Burn bursting its banks and inundating properties and the other is caused by the drainage systems being unable to cope during high intensity rain events. Improving the capacity of the roads drainage will not assist during flooding from the Whishop Burn but it will reduce the frequency of flooding from overland flows and surface water. The main issue with upgrading the roads drainage is that it is dependent on an appropriate outfall being available.

It is likely that the area that is suitable for upgrading the roads drainage will be limited to Dunlappie Road, The Drive and the southern end of High Street. Preliminary investigations regarding feasibility of installing extra drainage have been undertaken using the topographical survey and utilities drawings. It appears that conventional gully and piped drainage would not be feasible however kerb drainage could be installed, which would outfall into the

Whishop Burn. A non-return valve could be installed to prevent backflows from the culvert flooding the road during high flows in the burn.

The installation of kerb drainage would improve the rate at which surface water is discharged from the road. It would also increase the available capacity of the existing combined sewerage system. This would improve the drainage capacity of areas downstream as capacity that had previously been needed to convey flows from upstream would no longer be required. This would reduce the onset of roads flooding in areas downstream of the improved drainage scheme on Dunlappie Road. Improving the roads drainage and installing a potentially higher capacity outfall would also assist in the rate at which any flood events subside. As the roads drainage would have a free outfall to which they could discharge flood waters would be able to drain down as soon as the level of the burn had receded.

3.5.2 Managed Overland Flow Paths

In some situations it is an appropriate measure to manage flooding through the use of the road way as a flow path to direct flood water through a settlement or away from properties. Using topographical surveys and in some cases two dimensional modelling, flow routes can be identified and managed. Kerb lines, drop kerbs and traffic management features can direct or impound flows ensuring they do not impact on properties.

Measures can also be taken on private property to manage overland flow paths. These can take the form of raised drive ways and waterproofed boundary walls. These can act as a first line of defence to prevent the ingress of water onto the grounds of a property. Such measures can work in tandem with property level protection measures as detailed earlier in this report. Due to the nature of these measures and the need to maintain access to the properties these measures will not provide a high level of protection.

Another form of flow management involves keeping surface water within the footprint of properties. The replacement of solid impermeable paving within the boundary of a property allows rain that falls within the footprint of the property to soak into the ground. This reduces the strain on existing surface water drainage networks. Whilst this approach will not prevent or reduce the impact of the lower probability and more significant flood events, it can reduce the frequency of the lower impact events resulting from overloaded drainage systems.

Widespread implementation of permeable driveways may be an appropriate measure for adoption throughout Edzell, as could the raising of selected drives and property levels. However, this will have little impact on the larger return period flood events. One option for the management of overland flow paths would be the construction of traffic calming features at the northern end of Church Street and Castle Gardens. These would take the form of tabletops or speed bumps which would both act as traffic calming features and as physical barriers to overland flow. These would have to be installed along with upgraded road drainage to ensure that ponding does not occur.

3.5.3 Natural Flood Management

Natural Flood Management is the process of restoring the natural flow patterns to a catchment. These can include measures such as reforestation and restoring watercourses to their historic courses. Due to the agricultural nature of the Whishop catchment re-meandering is unfeasible and may not have a significant impact however several lower level interventions may be appropriate.

An assessment of the Whishop catchment indicates that there are two areas that are suitable for opportunistic intervention. The first option would slow the runoff response of the Hill of Edzell. The planting of shelter belts of trees at right angles to the slope would intercept and slow the response of watercourses in the area. A second option that has been identified is the opportunistic re-establishment of wetland areas. This would consist of forming small dammed areas in the upper catchment allowing them to flood during storm events. This will slow the response of the watercourse to large events and will improve the biodiversity of the catchment.

It is extremely difficult to quantify NFM and identify a numerical value to represent its benefits. This option will therefore not be costed nor will it be subjected to a BCR however it would be advantageous to implement some of these measures to improve the situation within the town and to slow the response of the Whishop Burn.

3.5.4 Dredging

The dredging of a watercourse involves widening and deepening the channel to increase conveyance capacity. Dredging also increases the speed at which water can flow through the system and can potentially concentrate flows downstream.

It may be advisable to implement a programme of targeted dredging and vegetation management south of Dunlappie Road to ensure free discharge from the Dunlappie road culvert.

Upstream it may be advisable to minimise the maintenance carried out to reduce the conveyance and speed of concentration of flows and the Dunlappie Road choke point. This approach would also encourage fields upstream to flood sooner and with a higher frequency further reducing the strain on the Dunlappie Road culvert. However it could put Lethnot Road at risk of flooding.

Most dredging works are the responsibility of the riparian landowner and any maintenance regime would have to be agreed as it is likely that the landowner would bear the burden of increased flood frequency. Angus Council as the flood authority also has the power to carry out works of clearance and repair under the Flood Risk Management (Scotland) Act 2009. However, exercising this power would still need to meet the requirements of the Controlled Activities Regulations.

Due to the uncertainty involved with the effects of this form of dredging and management it is difficult to quantify the benefits in either volumetric or financial terms. There would be a reduction in flood risk however the impact would only be during low return period events and properties would still be at risk during high return period events. This option will therefore not be costed nor will it be subjected to a BCR.

4. Conclusions

Edzell experienced severe flooding during December 2012 following which Angus Council initiated an investigation and report to ascertain the flooding mechanisms and options for reducing the risk. This report has found that there are several mechanisms at work operating in different areas of the town and during different conditions. No one option is capable of reducing the risk in all areas from flooding during all storm events.

The assessment has utilised the knowledge gained from hydraulic and hydrological surveys and modelling that has been undertaken. The assessment has also been advised by the local knowledge and investigations of contributing factors to the flood mechanisms in Edzell.

A high level analysis has been carried out of the costs and benefits of the proposed actions and the best options for development have been identified. These options will have to undergo further development and detailed design before being implemented.

In terms of affordability, this is dependent on the availability of funding to implement the options and the level of flood protection deemed appropriate. The existing budget allocations from Angus Council for dealing with flooding in Edzell have been applied to the consideration of affordability of each option and combination of options in this report. These considerations have led to the recommendations to progress the following options:

- Carry out phase 2 of the purchase of subsidised property level protection - These provide the best level of protection for the widest range of events.
- Further develop the upsizing of the Dunlappie Road culvert - This provides an increase in the level of protection locally for river and overland flow events.
- Further develop the western bypass route option and upstream other measures - This provides a 'full' level of protection for river events and an increase in level of protection for surface water events.

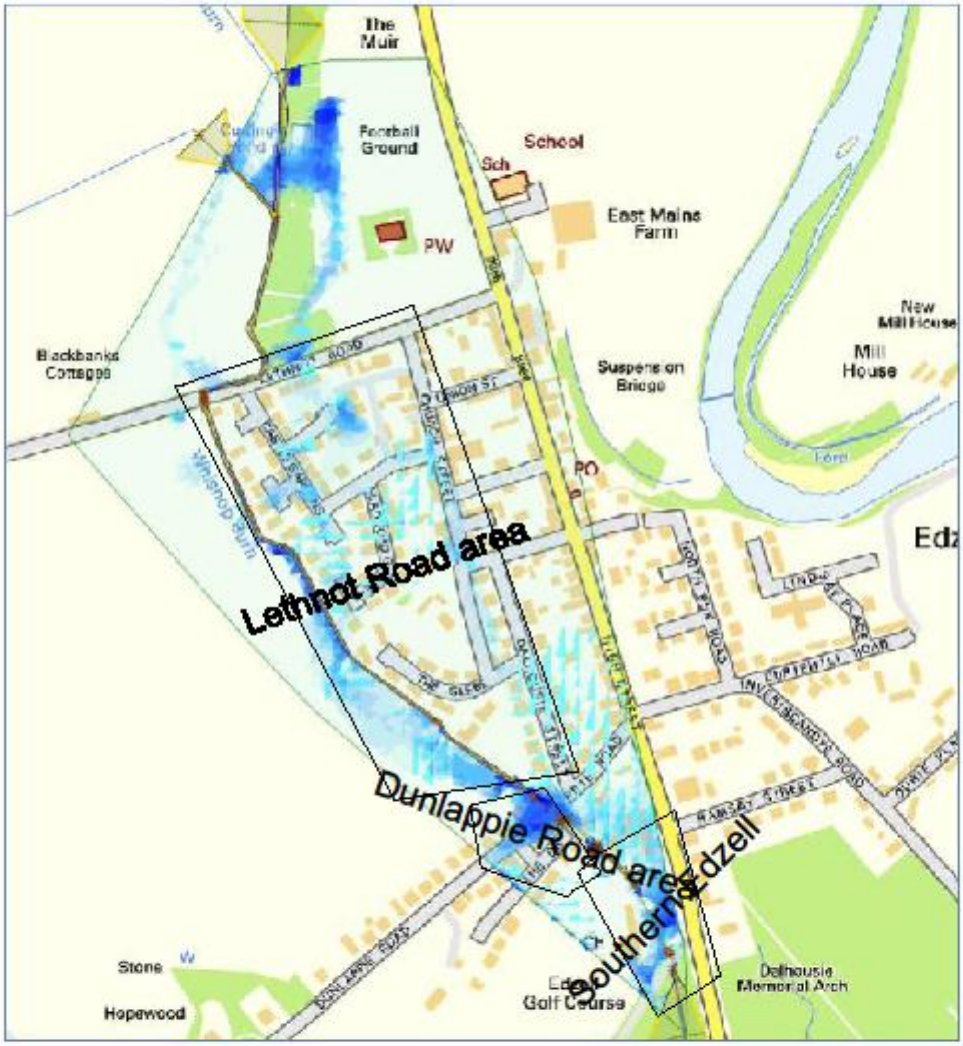
Based on currently available budgets, the recommendations to progress with the options are affordable; however, the budget would not be sufficient to implement all of the options. This will be reported to Angus Council for approval.

Appendix 1 Level of Protection

A qualitative assessment has been undertaken to asses the potential level of protection afforded by each option. This uses the same scoring system as the option appraisal section of the report with a value of 1 to 6 being assigned to each option. There is one significant difference in the scoring; 6* has been used to indicate where a measure may increase risk in an area.

To gain a clearer picture as to the relative benefits of each measure on different areas under different conditions Edzell has been split into three cells to represent the areas affected by separate flooding mechanisms. Two different flooding mechanisms have also been included to represent the two dominant threats to Edzell. The first is fluvial flooding from the Whishop burn, this is the response of the entire catchment directing flows towards the town and the capacity of the watercourse is overcome resulting in flooding. The second form of flooding results from intense rain over the town overcoming the capacity of the roads drainage.

Map 5 – 2D Modelling Results – 200 yr Design Event



Appendix A - Maps

						Raised Embankments		Other Measures		
		Culvert upsize	E Bypass	W Bypass	Propreitary Products	N Embankments	S Embankments	Drainage Installation	Managed Overland Flow Paths	Natural Flood Management
Lethnot Road	Fluvial (river/burn)	6	1	1	3	2	2	6	3	4
	Pluvial (ponding)	6	5	5	3	6	6	2	3	6
Dunlappie Road	Fluvial (river/burn)	2	3	2	3	2	2	6	6	4
	Pluvial (ponding)	4	6	5	3	6	6	2	3	6
Southern Edzell	Fluvial (river/burn)	6*	3	2	3	2	2	6	6	4
	Pluvial (ponding)	6	6	5	3	6	6	2	3	6
Totals		**24**	**24**	**20**	**18**	**24**	**24**	**24**	**24**	**30**
		Upsizing the Dunlappie Road Culvert will improve the situation in the central section however it will have no effect to the north and will worsen the situation to the south. 75% of the houses flooded during the 2012 event will be unaffected and still flood.	The Eastern Bypass will reduce river flooding in the town however the design submitted to planning for approval will not prevent flooding for the medium probability events.	The Western bypass will provide excellent protection from river flooding however it will have no effect on ponding.	Propriatry products will protect from all forms of flooding hower issues such as leakage and the need to deploy them prior to a flood can be an issue.	Embankments provide good protection from river flooding however they will have no effect on flooding resulting from heavy rain that causes ponding.	Embankments provide good protection from river flooding however they will have no effect on flooding resulting from heavy rain that causes ponding.	Drainage installation will reduce ponding but will not prevent it, it will have no effect on river flooding.	Managed overland flow paths will provide a level of protection to the north of the town for both fluvial and pluvial events however due to their nature they cannot be sized to come with larger rain events.	Natural flood management will reduce levels of runoff and the rate at which the Whishop responds to rain events, hovever this option cannot be employed in isolation and it will have no affect on flooding due to ponding.

A qualitative assessment has been undertaken to inform the expected level of protection afforded by each of the proposed measures. To assist in this assessment Edzell has been split into three areas that are affected by the same flooding mechanisms. The flooding mechanisms have also been divided into fluvial and pluvial.

The flooding areas are Lethnot Road, Dunlappie Road and Southern Edzell, see map 2 for a representation of these areas. Fluvial flooding (river/burn flooding) is flooding from the Whishop Burn and pluvial flooding (ponding) is flooding from intense rain that overcomes the drainage system.

Appendix 2 Costs for Measures

This section provides a high level assessment of the costs of each measure. These costings do not include costs for maintenance or staff time. The option for raising embankments has had a value of £575 applied year on year to represent the damages paid to the landowner, this value is not meant to represent the costs but is rather an annualised average damage, the value was calculated using guide values from the multi-coloured manual. The values estimated for the eastern bypass have altered slightly from those quoted within the addendum to the Grontmij report; this is due to the reduction in disposal costs to bring the estimate in line with the other options. An arithmetic error was also found in the estimation of the costs for the second pipe. These errors have not been significant enough to alter the cost benefit analysis.

This costing is based on unit costs from previous roads division construction projects; the Comprehensive Building Price Book – Major Works published by BCIS Wessex; and professional engineering judgment. 10% has been added to the estimates to account for costs associated with site supervision and 1% has been added to account for ground investigation works.

Eastern Bypass Preliminary Costing

Item	Description	Unit	Qty	Rate	Amount
1	**Excavation, backfilling and compaction of trench**				
	From CBPB: 1.35 x 3 m trench	*m*		*£66.31*	
	For 2.7 x 6 m trench multiply by 3	m	600	£198.93	£119,358.00
2	**Excavation in hard rock in trench, depth not exceeding 4m**				
	From CBPM	m^3	200	£191.01	£38,202.00
3	**Shoring moderate ground**				
	From CBPM: faces not exceeding 2m depth not exceeding 4m	*m^2*	*7200*	*£12.39*	
	Depth to 6m	m^2	7200	£17.00	£122,400.00
4	**Disposal of Excavated Material**	m^3	502	£12.70	£6,375.40
5	**Pipe work**				
	From CBPM: 600 mm diameter	*m*	*600*	*£49.71*	
	900mm	m	600	£85.00	£51,000.00
6	**Pipe Bedding**	m	600	£17.00	£10,200.00
7	**Chambers**				
	From CBPM: invert level 2.9m	*no*		*£1,763.97*	
	Depth to 6m	no	4	£3,527.94	£14,111.76
8	**Intake and outlet structures**				
	Allow plus contingencies				£100,000.00
9	**Reinstatement**	m^2	30	£233.30	£6,999.00
	Total Construction Cost				
13	Construction Management		10%		£46,864.62
14	Site Investigation		1%		£4,686.46
	To Grand Summary				£520,197.24
	Plus Inflation (not including 30% contingency)				**£702,266.27**

Item	Description	Unit	Qty	Rate	Amount
1	**Additional Excavation**	m	280	£198.93	£55,700.40
2	**Additional Shoring**	m	280	£17.00	£4,760.00
3	**Additional Pipe work**	m	280	£85.00	£23,800.00
4	**Pipe Bedding**	m	280	£17.00	£4,760.00
5	**Chambers**	no	2	£3,527.95	£7,055.90
	To Grand Summary				£96,076.30
	Plus Inflation				£129,703.01
	To Grand Summary (additional pipe plus 600m length not including 30% contingency)				**£831,969.28**

Raised Embankments Preliminary Costing

Item	Description	Unit	Qty	Rate	Amount
1	**Excavate 1m trench for seepage barrier**	m	800	£18.23	£14,584.00
2	**Import fill for embankment**	m^3	10,016	£20.69	£207,231.04
3	**Deposit fill in embankments**	m^3	10,016	£8.54	£85,536.64
4	**Compaction of fill**	m^3	10,016	£8.54	£85,536.64
5	**Disposal of material**	m^3	800	£12.70	£10,160.00
6	**Outlet Structure**	item	1	£50,000	£50,000.00
7	**Excavation of material within impoundment area (0.5m x 5ha)**	m^3	25,000	£18.23	£455,750.00
8	**Deposition of excavated material (0.5m x 5 ha)**	m^3	25,000	£8.54	£213,500.00
9	**10% Construction Management**				£112,229.83
10	**1% Site Investigation**				£11,222.98
	To Grand Summary				£1,245,751.14

Western Bypass Route

Item	Description	Unit	Qty	Rate	Amount
1	**Excavation**	m^3	12,375	£18.23	£225,596.25
2	**Disposal**	m^3	12,375	£12.70	£157,162.50
3	**Land acquisition**	ha	2.4	£10,000	£24,000.00
4	**Intake and outtake structures**	no.	2	£50,000	£100,000.00
5	**Crossings to maintain field access**	no.	5	£5,000	£25,000.00
6	**Fencing**	m	2,400	£10.00	£24,000.00
7	**Seeding**	m^2	16,000	£1.34	£21,440.00
8	**Regulatory approval (simple license)**	sum	1	£622	£622.00
9	**Regulatory Approval (Studies)**	sum	2	£10,000	£20,000.00
6	**10% Construction Management**				£59,782.08
7	**1% Site Investigation**				£5,978.21
	To Grand Summary				£663,581.03

Upsizing of Dunlappie Road Culvert

Item	Description	Unit	Qty	Rate	Amount
1	**3m x 0.6m Precast Box culvert section**	m	80	£1,180	£94,427
2	**Traffic Management**	no	1	£5,000.00	£5,000
3	**Concrete precast chamber**	No.	2	£1,000	£2,000
4	**Inlet and outlet structures**	No.	2	£5,000.00	£10,000
5	**Connections**	No.	4	£103.62	£414
6	**Demolition and reconstruction of garages**	item	1	£25,000.00	£25,000
7	**Type B drainage installation reinstatement**	m^2	87	£62.11	£5,404
8	**Contingencies to protect or move services (allow)**	item	1	£25,000	£25,000
9	**Contingencies for temporary works to support existing structures and excavations (allow)**	item	1	£10,000	£10,000
10	**Reinstatement of private areas (allow)**	item	1	£10,000	£10,000
11	**Concrete raft to protect pipes in road**	m^3	14	£300.00	£4,200
12	**10% Construction Management**				£9,701.81
13	**1% Site Investigation**				£970.18
	To Grand Summary				£202,117.24

Lower Level Interventions

Item	Description	Unit	Qty	Rate	Amount
1	**Upsize culvert**	no	1	£202,117.24	£202,117.24
2	**R.C Wall**	m	70	£407.09	£28,496.30
3	**Embankment**	m	100	£380.00	£38,000.00
4	**Kerb Drainage**	m	500	£138.50	£69,250.00
5	**Tree Planting**	no	1500	£5	£7,500.00
6	**Establish Wetlands**	no	1	£10,000	£10,000.00
6	**10% Construction Management**				£35,536.35
7	**1% Site Investigation**				£3,553.64
	To Grand Summary				£394,453.52

Appendix 3 - Benefit Cost Ratio Summary

A Benefit Cost Ratio has been carried out using the flood levels calculated in Grontmij's report. Angus Council's price estimates have then been applied to calculate a Benefit Cost Ratio (BCR).

To represent the lower level of protection offered by several of the options the benefit from areas protected has been reduced. The partial eastern bypass (option 2) values were calculated by Grontmij's model. For the upsizing of the Dunlappie Road Culvert (option 6) the benefits have been reduced by 75% as only 25% of the town will be protected. Due to the uncertainty associated with upsizing the culvert along with measures to intercept overland flows (option 7) it has been assumed that 50% of damages would be avoided. All other measures are assumed to provide a full level of protection.

Project Summary Sheet

Client/Authority		**Sheet Nr.**	1 of 21
Angus Council		Prepared (date)	06/08/2014
Project name		Printed	
Edzell Flood Prevention Scheme		Prepared by	NY
Project reference		Checked by	
Base date for estimates (year 0)	Aug-2014	Checked date	
Scaling factor (e.g. £m, £k, £)	£	(used for all costs, losses and benefits)	
Principle land use band	A	(A to E)	
Initial Discount Rate	3.5%		
Optimism bias adjustment factor	30.0%		

Costs and benefits of options

	Costs and benefits £							
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6	Option 7	Option 8
PV costs from estimates	24,853	702,266	831,969	1,262,348	663,581	202,117	394,454	865,698
Optimism bias adjustment	32,309	210,680	249,591	378,704	199,074	60,635	118,336	259,709
Total PV Costs for appraisal PVc	57,161	912,946	1,081,560	1,641,052	862,655	262,752	512,790	1,125,408
PV damage PVd	1,282,079	878,795	-	-	-	961,558	574,746	-
PV damage avoided		403,284	1,282,079	1,282,079	1,282,079	320,521	707,333	1,602,599
PV assets Pva								
PV asset protection benefits		-	-	-	-	-	-	-
Total PV benefits PVb		403,284	1,282,079	1,282,079	1,282,079	320,521	707,333	1,602,599
Net Present Value NPV		- 509,662	200,519	- 358,973	419,423	57,768	194,543	477,191
Average benefit/cost ratio		0.44	1.19	0.78	1.49	1.22	1.38	1.42
		-	-	-	**Highest b/c**	-	-	-

Brief description of options:

Option 1	Do Nothing	(Maintain existing infrastructure)
Option 2	Partial Solution	Partial pipe bypass to east
Option 3	Full Solution	Pipe design as per Grontmij recommendations
Option 4	Raised Embankments	Flood reservoir to north of town
Option 5	Western Bypass	Open watercourse discharging to the West Water
Option 6	Upsize Culvert	Increase diameter of Dunlappie Road culvert
Option 7	Upsize Culvert and works to north	Increase diameter of Dunlappie Road culvert and controll overland flow to north
Option 8	Upsize Culvert bypass to west	Increase diameter of Dunlappie Road Cuvert and install western bypass

Original Notes:

1) Benefits will normally be expressed either in terms of damage avoided or asset values protected. Care is needed to avoid double counting
2) PV damage avoided is calculated as
PV asset protection benefits are

PV benefits calculated as PV damage avoided + PV asset protection benefits
3) Incremental benefit/cost ratio is calculated as: (PVb(current option) - PVb(previous option))/(PVc(current option) - PVc(previous option))

Calculation Options:		**Assumed Floor Level (m AOD)**	
- Include Hotel? (Y/N)	Y		
- Include Care Home? (Y/N)	Y		
	Y		
	Y		(N=treated as residential property)
- Residential Freeboard :	0	mm	(must be 1000mm or less)
- Non-residential Freeboard:	0	mm	(must be 1000mm or less)
- Increase In Option Costs (for sensivity testing)	0%		(set to 0% for normal calculation)

(NB: All Excel files in this directory must be concurrently open to apply any changes to these options)