Almondbank Flood

Management Options Report

March 2006

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Contents

Document Control Sheet....2

Contents....3

1 Introduction....4

2 Background Information....5

2.1 History of Scheme....5

2.2 Economics of a Flood Defence Scheme....7

3 Flood management Options....9

3.1 The River Almond....9

3.1.1 Diversion Channel....9

3.1.2 Online Storage....11

3.1.3 Offline Storage....13

3.1.4 Flood Embankments and Flood Defence Walls....14

3.2 Pow Burn....14

3.2.1 Diversion Channel....15

3.2.2 Online Storage....15

3.2.3 Offline Storage....18

3.2.4 Flood Embankments and Flood Walls....19

3.3 Summary of Flood Management Options....20

4 Discussion....21

Appendix A – Drawings....26

1 Introduction

This report is written to outline various options for managing flooding conditions through the village of Almondbank near Perth in Scotland. Options for the sustainable management of floods are considered first for the Almond, then for its tributary, Pow Burn.

The report is born out of Mouchel Parkman's involvement in the Environmental Impact Assessment (EIA) for a flood defence scheme for the village. This scheme was developed by a succession of consulting engineers across various reports. However in order to fulfil the criteria required for the EIA, different options of flood defence scheme needed to be considered. The previous engineering reports do not seem to explore these options, suggesting only one type of flood management scheme; hard defences using flood walls and embankments. The study outlined in this report aims to develop information presented in previous reports, together with observations made on site to investigate the feasibility of different flood defence options. An assessment of these possibilities has been made based on the topography, flow regime, observed features, environmental impact, financial implications and confirmed with simple calculations and hydraulic modelling.

2 Background Information

2.1 History of Scheme

Almondbank is a small village, probably built up around a bridging location of the River Almond. The historic village is built along the road on either side of the stone arch bridge crossing the river whilst more recent developments have taken place slightly further downstream of the crossing point. Here the land is flatter and developments have been built right up to the edge of the Almond. At present there are no existing flood defences in the town, despite the town having suffered significant flooding in the last few years. This is likely to be a reflection of the developments adjacent to the Almond being more recent than the last set of major flood events. This development is referred to in one of the Babtie Reports, and was known as the Almond Valley Village. The new developments are essentially at top bank level, so are more prone to flooding than the historic village, which is built up the steep slopes of the valley and is above the flood level.

The worst flood in recent times occurred on 16th January 1993 with a peak flow of 273m^3/s. This event has been estimated as a 1 in 50 year return period event and caused widespread damage within the village. Figure 1 shows the extents of flooding caused by this event. In addition, the footbridge in the centre of the village known as the Black Bridge was washed away.

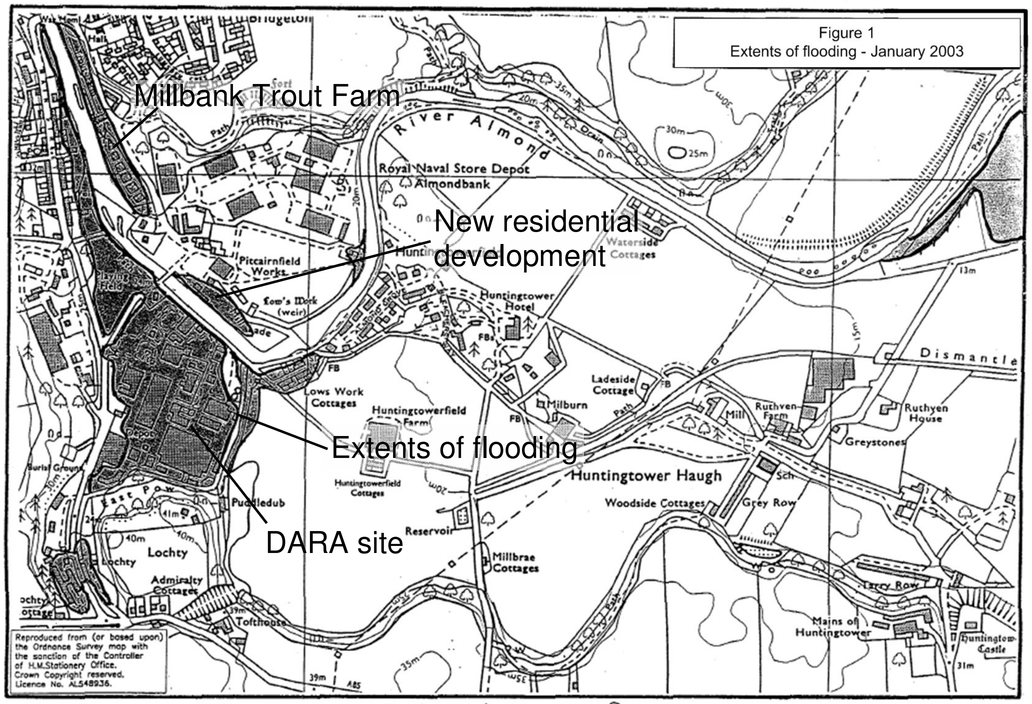


Figure 1 taken from the Babtie Report "Almond Valley Village: Final Report on Flood Risk Assessment" annotated by Mouchel Parkman

This shows the flood event inundating both the residential sites along the left hand bank and also the industrial sites in the town; the Defence Aviation Repair Agency (DARA) site and Millbank Trout Farm. This damage is considered in the economic appraisal of flood damages in order to make an economic case for a flood defence scheme. It was this flood event that led to Tayside Regional Council to commission Babtie to undertake a flood study for the village.

Babtie delivered their first report in February 1994 investigating flooding from the River Almond and included elements of hydraulic modelling and a preliminary economic appraisal of flood damages. This was followed by a more detailed analysis of the economic impact of both flooding and potential flood defence schemes by Ove Arup & Partners who submitted their report in March 1996. Further flood studies were then undertaken by Babtie into flooding in Pow Burn (1998), a Flood Risk Assessment for the new development at Almond Valley Village (1998) before they reappraised the Flood Defence scheme for the River Almond in March 2000. This report looked over the same elements of flooding as the 1994 report, but applied more recent economic appraisal techniques building a much stronger case for flood defences. This work was then taken forwards to develop a flood defence scheme by Royal Haskoning who produced their report in March 2004. This detailed all the elements of a proposed flood embankment scheme, including economic appraisal to justify the scheme. Royal Haskoning provided an outline design of the flood defence schemes including a draft of a flood prevention order, although it is understood that this was not submitted. We have had access to all of these reports whilst undertaking an assessment of the different options for flood management.

2.2 Economics of a Flood Defence Scheme

It is intended that funding for the Almondbank flood prevention scheme should be sought from the Scottish Executive through an application for a Flood Prevention Order. In order to do this, any scheme under consideration must be proven to be economically viable. The economic damage is assessed by calculating the probable average annual damage for the level of protection being provided by the scheme. This is found by plotting the anticipated damage for each return period against the reciprocal of the return period and then calculating the area enclosed from the design return period, as shown in Figure 2. This annual average damage is then discounted annually at the present rate of inflation over the proposed design life of the scheme. This is them summated to give the total present value damages (PVd). This is used to calculate the benefit cost ratio for a particular level of protection.

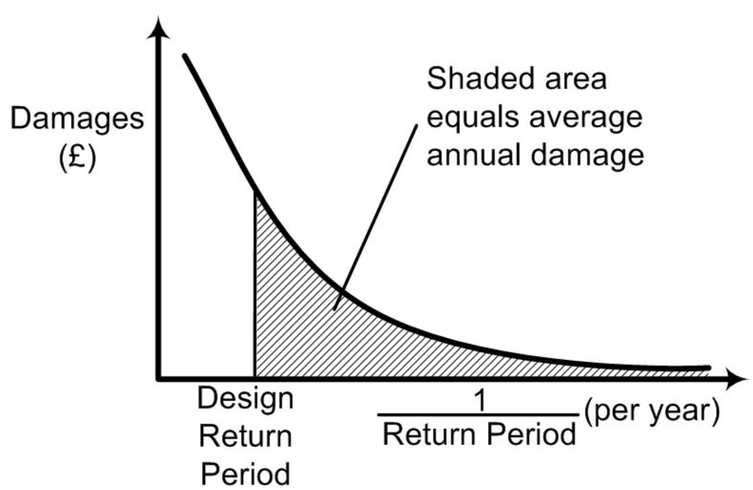


Figure 2: Annual Average Damage Calculation

This process was undertaken by Royal Haskoning for the flood defence scheme proposed in their report, a summary of which is included in Table 1 below.

	Costs and benefits £k	
	No Defence Scheme	Royal Haskoning Scheme
Total Present Value Damage (PVd)	5,105	542
Damage Avoided	0	4,563
Total Present Value Costs (PVc)*	0	3,771
Benefit Cost Ratio (B/C)	-	**1.21**

* Estimated cost including an optimism bias adjustment factor of 30.0%

Table 1: Summary of Royal Haskoning's economic appraisal

In order that a scheme be accepted by the Scottish Executive and receive funding, it must have a benefit cost ratio greater than 1. Theoretically, using the same optimism bias adjustment factor for other flood management options, a flood management scheme could cost up to £3,573,500, including maintenance for a period equal to design flood return period (i.e. 200 years).

The inclusion of maintenance costs for a scheme is very important as it allows any financial judgement to be based on the design life of the structure. This allows the benefit of the scheme to be judged fairly since proper maintenance is the only way of ensuring the scheme is able to protect the development during the design flood. For the scheme evaluated by Royal Haskoning, £2,820,000 was allowed for the initial construction of the scheme with a sum of £300,000 set aside for maintenance across a 100 year period. The maintenance sum is then equated to a present value cost, and was found to be £81,080. If the same ratio is allowed for maintenance costs, for a scheme with the minimum cost benefit ratio of 1, a maintenance sum of around £100,000 should be allowed, reducing the funds available to construct a scheme to £3,475,500. The assessment of the economic viability of alternative schemes must be made with this figure in mind. It must be considered that this value is only true for schemes with similar maintenance requirements as the flood embankment and wall scheme proposed by Royal Haskoning.

3 Flood management Options

3.1 The River Almond

The River Almond at Almondbank is changing from a river flowing in a steep sided valley, to a wider more open valley. The channel carries flow from Glen Almond and consequently is a wide, fast flowing channel to cope with the high flows. The most influential hydraulic feature on the river, in terms of local flooding, is a rubble weir, Low's Work, situated at the downstream end of the village. The influence of this feature is discussed in light of various flood defence options below.

3.1.1 Diversion Channel

The desk study undertaken before the site visit suggested that it may be possible to employ a diversion channel to avoid the peak river flood flow passing directly through the centre of Almondbank. The peak flow from a storm event is diverted into a different channel, limiting flow in the main channel to a flow which can be safely passed forward with no flooding.

The route that appeared to be possible was a diversion from slightly downstream of Cromwellpark, upstream of the centre of Almondbank leaving from the left hand bank of the river and heading east away from the main river channel to a smaller, un-named water course. This smaller channel flows around the north-east of Almondbank, discharging into the Almond downstream of the almond valley village development. This route is shown in drawing 315500/022/001 in appendix A of this report.

The first difficulty with this route is a problem with the topography around the proposed diversion location. The River Almond flows at the bottom of a relatively steep sided valley, as such it is difficult to carry the flow from the river into the receiving water course. There is around 10-20m level difference between the two water courses, illustrated in Figure 3. This is very difficult to overcome and would require very costly engineering works to be undertaken. Since the stage in the river does not approach the difference in height between the water courses, some form of retention structure would be needed to sufficiently raise the water level to allow water to gravitate to the receiving water course. This has obvious implications for the natural flow in the River Almond as it would significantly change the flow regime. However, in addition, the increased depth of flow in the Almond would result in flooding at Cromwellpark, just upstream of the diversion point. In fact, in order to overcome this bank height, at least 2kms of the upstream valley would need to be flooded to cause the stage to rise high enough to flow by gravity into the receiving water course. At this point, the scheme would have a greater volume of storage than the online storage scheme described below, rendering the diversion channel superfluous.

This problem could be overcome by constructing a far smaller impoundment scheme than is outlined above, coupled with a pumping station to carry water to the top of the hill. The pumping rate we have assumed is half of the peak flow rate for the one in two hundred year return period. This is calculated as $168m^3/s$. This rate was used as the peak flow itself is only experienced for a brief moment. In order to maintain this pumping rate, an area must be set aside to impound water before it is pumped into the channel. This will allow the pumps to operate at a constant rate, despite the variable flow rate in the channel. Whilst the operating head of 20 to 30m is a fairly average operating head for a pump, the flow rate required is extremely high. This will require multiple pumps to be installed along with a large pumping line.

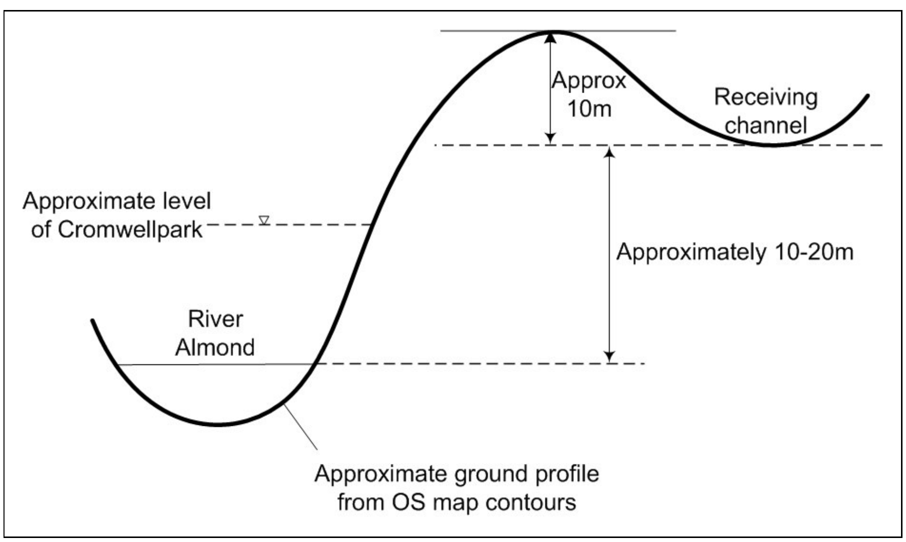


Figure 3: Approximate levels of River Almond and potential diversion channel

In addition to the difficulties of getting flow into the diversion channel, the capacity of the receiving water course must be sufficient to accommodate the flows. Using the pumping rate suggested above, the diversion channel would need to carry a flow of $168m^3/s$ in addition to the normal flow in the channel in order to prevent flooding in Almondbank. This is an extremely large flow and the receiving water course would not be able to carry this magnitude of flow without significant works to improve it. Without these works, the small village of Pitcairngreen would be at risk from flooding and the diverted flow would simply transfer the flooding problems from Almondbank to Pitcairngreen.

In summary, the use of a diversion channel, fed by pumping or gravity, to prevent flooding in Almondbank would be too expensive an option to be employed. Both the initial capital and subsequent maintenance costs would be far greater than those outlined in section 2.2. The construction of suitable infrastructure on the Almond to allow water to enter the diversion channel is likely to be financially unviable before one considers maintenance costs or the wide ranging environmental impacts of building and operating such a scheme.

3.1.2 Online Storage

Online storage involves the creation of a restriction in the channel forcing flow to back up into a suitable geographical feature. The steep sided valleys of the upper Almond catchment are particularly suitable for online storage schemes, as a relatively narrow, but tall, restriction will result in a large area of retention storage. The restriction is designed to restrict flow to the downstream capacity of the channel, storing any additional flow upstream of the restriction.

To determine the storage required, the capacity of the downstream channel is assessed, the largest flow that can safely be passed forward is allowed to flow down the channel. Any flow in excess of this threshold is retained until the flow drops below this threshold and is slowly released until the river stage returns to normal. Since 200 year return period event the peak flow is so much higher than the annual maximum flow in the River Almond, any online storage scheme would need to have a very large capacity in order that flooding downstream can be eliminated.

The online storage scheme would be controlled by a water retaining structure built across the valley floor. This would need to have a penstock or similar flow control device built into it, allowing water to pass freely through the structure at low flows. This would then form a constriction at higher flows, causing water to back up, flooding the valley upstream of the structure, allowing the water downstream to flow in bank along the River Almond.

If the same estimation was taken as above, reducing the 200 year event to the same level as the annual maximum flood level, the diagram below shows a simple estimation of the flood storage required. Across a period of 2.2 hours, flow would need to be attenuated, holding back a volume of 3,182,400m^3 (see Figure 4) of water. Making an assumption that the channel is approximately 200m wide when it is flooded, and will have an average depth of 15m, around 800m of the channel will need to be flooded. To give an idea of scale, an indicative flood area is shown in drawing 315500/022/002, included in appendix A of this report.

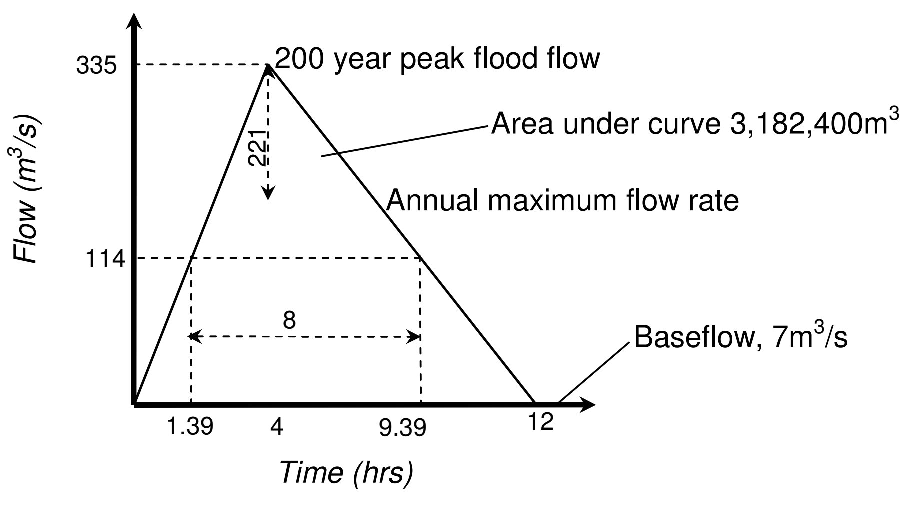


Figure 4: Estimated volume of flood water to be stored on the River Almond

Objections to this scheme are likely to come principally on environmental grounds, particularly in light of the high ecological quality of the water course. The River Almond is classified as an A2 water quality watercourse and provides a habitat for a wide variety of fish and birds. A scheme large enough to protect Almondbank would have a very significant effect on the quality of the watercourse due firstly to the extent of construction required and secondly to the potential changes to the flow regime up and downstream of the control structure.

It is likely that such a scheme can also be discounted on the grounds of cost, since a structure capable of retaining a depth of water in the order of 20m (in order to provide an average depth of 15m), whilst still passing forward a large flow will be very expensive to build. In addition, the structure would require regular maintenance to allow it to operate correctly throughout its life. This would include inspection after every flood event, removal of debris and a walk over the area used as storage upstream. This could prove relatively onerous, as the effects of smaller storm events would need to be determined to ensure the defence scheme was in a suitable condition to operate effectively during a large storm event. Since the planned storage volume exceeds 25,000m^3, this storage option would classify the flood management option as a reservoir under the Reservoirs Act (1975). This has further implications in terms of the maintenance and safety precautions which must be taken. Annual inspections must be made and reported by a Reservoirs Act appointed Supervising Engineer in order that maintenance requirements are identified and fulfilled. At less regular intervals a Panel Engineer must inspect the reservoir. Again, this may lead to further maintenance being required. These engineers are required to be specialists in dam construction and maintenance in order that any potential problems with the dam can be identified and dealt with quickly. The Reservoirs Act also stipulates that the water retaining structure must have an overflow structure designed to pass the probable maximum flood. This design criteria is necessary due to the proximity of the Almondbank community downstream of the retaining structure.

3.1.3 Offline Storage

The topography of the Almond catchment does not present many sites suitable for offline storage schemes. The most obvious sites are at the downstream end of Almondbank, where the valley begins to open out. Unfortunately these sites have either been developed already or are too far downstream to prevent flooding in Almondbank itself. This is due to the influence of Low's Work. Flow backs up from this point triggering flooding upstream, and reducing the flood flow's influence downstream of the weir. It is not possible to alter Low’s Work as the structure is listed by Historic Scotland and controls flows into the Mill Lade which flows to Perth. This means that any scheme must be designed around the flow regime imposed by the weir.

3.1.4 Flood Embankments and Flood Defence Walls

The River Almond flows within a steep banked channel through the centre of Almondbank. These natural channels will entrain the river for small storm events, but the banks are breached by larger events – such as the 1993 flood event. A simple solution to the flooding problems is to study the flood paths and build appropriate defences to prevent these paths being operated. This is the approach taken by Babtie in previous studies undertaken for the catchment. Through hydraulic modelling of the catchment, it is possible to see the extents of flood defence walls required. Whilst this work has not been checked in the extents of our study, we believe that the work undertaken represents a viable option to provide flood defences for the centre of Almondbank. As discussed in section 2.2, economic appraisal of the scheme has demonstrated that there is a benefit cost ratio greater than 1 and as such the development of the scheme can be promoted under the Flood Prevention (Scotland) Act (1961).

It is not clear whether any assessment has been made of an increased flood risk down stream due to the removal of natural floodplain in Almondbank. However, the loss of flood plain is small in comparison with the peak flood flows. This would need to be assessed at detailed design stage.

3.2 Pow Burn

Pow Burn is a tributary of the Almond, joining the main channel slightly upstream of Low’s Work. The burn drains an area to the south of the main Almond catchment, and is a less steep catchment than the receiving watercourse. The channel at Almondbank is a narrow, steep channel with supercritical flow regimes dominating much of the reach. The flow conditions in the tributary are likely to be affected by the Low’s Work weir just as much as the upstream reaches of the Almond. Investigations using a development of Royal Haskoning’s hydraulic model indicate that a high stage in the River

Almond at Low's work will cause flooding along the last 200m of the channel before the confluence with the River Almond, even at nominal flows of 2m^3/s in Pow Burn itself.

Relative to the flows in the River Almond, the flows in Pow Burn are very small. Whilst peak flood flow in the River Almond is estimated to be 335m^3/s for a 200 year return period flood event, flow in Pow Burn for the same event is only 35m^3/s. Accounting for approximately 10% of the flow in the River Almond, any flood management measures on Pow Burn will have a negligible effect on flows in the River Almond. As such, the options laid out below should be considered in isolation from the Almond catchment flood management schemes.

3.2.1 Diversion Channel

As Pow Burn flows into the Almond through Almondbank, the options for a flood diversion channel are somewhat limited. One consideration may be to divert flow around the weir and avoid some of the problems associated with flow backing up in the Pow, however, the line of Mill Lade, the small channel running off from the Almond by Low's Work, prevents this from being possible. As no feasible route can be suggested, the possibility of a diversion channel should be discounted.

3.2.2 Online Storage

The geometry of Pow Burn lends itself to small online storage options being employed on the channel. For a large stretch upstream of Almondbank, the burn flows within a sunken valley amongst agricultural land. As such it would be possible to build a small constriction in this area, allowing flow to back up within the channel. Such a scheme on Pow Burn could be acceptable since the channel appears to have been straightened along some of its reach. As such, there has already been human interference in the flow regime of the channel.

However, what needs to be established is how effective such a scheme would be in preventing flooding in Almondbank. As discussed above, it is safe to assume that flooding along the main river channel will not be alleviated by a storage scheme on the Pow. What must be established is whether the flooding at the downstream end of Pow Burn will be eased by reducing flows in Pow Burn with an online storage scheme. If flooding at the downstream end of Pow Burn is as a result of flow backing up in the Pow due to high levels in the Almond, then flooding would not be averted even with an upstream storage scheme.

In order to test this, we obtained a copy of Royal Haskoning's hydraulic model of the burn. This had been built using the U.S. Army Corps of Engineers' hydraulic modelling system, HEC-RAS, using initial data and survey information from Babtie's mathematical model. Before undertaking simulations with the model, it had to be evaluated and compared to our own site observations. The first problem was that there appeared to be a bridge included on the Haskoning model which we had not observed on site. The difficulty is that this bridge is apparently situated on the length of the river channel we were unable to walk over. Reference to our site photos, maps and aerial photos were unable to prove that the bridge was definitely present, however, since leaving the bridge in the model represented a more conservative design approach than removing it, we left it in.

Additionally, a cross section needed to be added at the downstream end of the channel to allow the bridge to be modelled correctly. This is due to the way HEC-RAS models the bridge, it cannot use the same cross section down stream of the bridge as is used for the downstream boundary. This was the only minor change made to the model to allow further calculations to be undertaken.

In order to test the possibility of an online storage scheme, the model was operated with a high water level in the River Almond and normal depth at the upstream end of the catchment. The levels chosen represented a two hundred year return period flood event in the River Almond, and a minimal flow of 2 m^3/s in Pow Burn. This did not lead to any flooding issues at the upstream end of the reach, but did cause flooding at the downstream end, due to inundation from the River Almond. The water level was high enough that the Pow came out of bank on both sides of the channel. This means flood defence operations numbered 15-20 on Royal Haskoning's drawing

9M6952/PD/0001 would still be necessary, despite the online storage scheme.

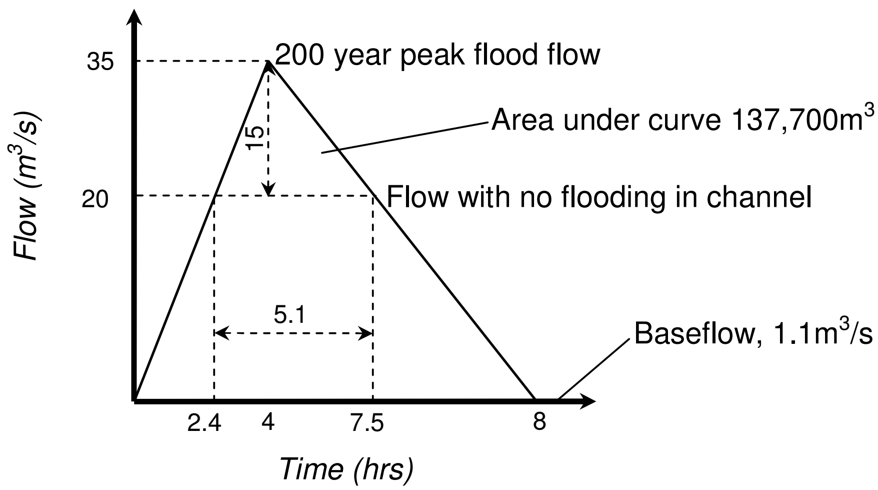


Figure 5: Estimated volume of flood water to be stored on Pow Burn

Using the hydraulic model, the bank full flow for Pow Burn was found to be 20m^3/s. This flow rate did not stop the backing up of flow from the confluence with the River Almond, but did prevent flow from leaving the main river channel anywhere else along the reach. From this an approximate volume of required storage was determined. This calculation is shown in Figure 5, and a volume of 137,700 m^3 would be required to remove the necessity of the flood defence operations 21-25. Such a site would not be available within Almondbank, particularly within the length of the burn included in the hydraulic model, however a site may be available upstream of the settlement. Here, the ground opens out into farmland used to graze animals with the burn flowing in a sunken channel, where an embankment feature, with a suitable flow control structure, could be used to produce an online storage system. This would cause water to back up, flooding the sunken channel before the water flows out of these banks and floods the surrounding farm land.

Such a scheme would have to be carefully maintained in order that the flow control structure is kept free from debris, without this maintenance, the channel may flood in smaller storms, causing unnecessary flooding to the surrounding farmland. The difficulty in implementing such a scheme would come from the very flat farmland on either side of Pow Burn. Once the water level in the burn rises above the top of the banks of the sunken channel, it will spread very quickly and shallowly over the surrounding farmland. This would require an embankment to be built around the area of farmland that is allowed to flood in order to prevent water spreading onto land it is not intended to. Without this embankment, it would not be possible to provide sufficient storage volume to alleviate flooding along Pow Burn within Almondbank. Again, due to the volume of storage required to prevent flooding along Pow Burn this type of scheme would be classified as a reservoir. This means that that an online storage scheme would be subject to the same maintenance requirements as a reservoir, these are outlined in the section 3.1.2 on online storage for the River Almond.

As there is still a requirement to construct a separate flood defence scheme at the downstream end of Pow Burn, adjacent to the confluence with the River Almond, it is our opinion that this type of scheme would prove uneconomic. This would be due to both the very high capital cost of building a scheme and also the high maintenance costs associated with the scheme due to its classification as a reservoir. As such it such it cannot be recommended for further development.

3.2.3 Offline Storage

The most obvious location for an offline storage scheme is the agricultural land on the right bank towards the downstream end of the burn. However, this solution would not alleviate flooding upstream of the storage area, furthermore, the areas downstream would still need to flood in order that flow would back up and cause the offline storage to become operational. As such, the practical difficulties of the site outweigh the benefits. The best employment of offline storage would be to couple it with an online storage scheme and flood farmland adjacent to a controlled obstruction. However, as discussed above, due to the flat ground on either side of Pow Burn, this type of scheme would require the construction of a large embankment to control where the flood waters are allowed to spill. This would render the option financially unviable.

3.2.4 Flood Embankments and Flood Walls

Due to the backing up of flow at the downstream end of Pow Burn, this approach seems the best course of action for the burn. It allows flow to be held within the river channel, and builds on work already undertaken to provide erosion protection to the left hand river bank alongside the DARA site. The flood operations suggested in the Royal Haskoning report seem to address the issues that were observed on site and were subsequently observed in the results of the hydraulic model, they have been proven to be financially viable in the economic appraisal.

The difficulty with a hard defence scheme is that the effect of flooding is often passed on to a different section of the river as the flow rate downstream will increase and flow upstream can back up. Upstream of the proposed defences is an area of farmland. From an economic point of view, flooding at this location, rather than within Almondbank, is more favourable. Downstream of the defences, flow passes into the River Almond. Due to the relative sizes of these water courses, outlined in the introduction to this section, the impact of this additional flow from Pow Burn in isolation will not cause further problems.

3.3 Summary of Flood Management Options

Flow Condition	River Almond	Pow Burn
200 year flow	35 m^3/s	335 m^3/s
Bank full flow	114 m^3/s (mean annual maxima flow)	20 m^3/s (flow determined in hydraulic model)
Flood management Options		
Diversion Channel	Topography and capacity make available routes uneconomic	No available route
Online Storage	Extremely high storage volume required renders scheme uneconomic	Flooding due to inundation from the River Almond renders online scheme on the Pow uneconomic as downstream flood defences are still required
Offline Storage	No Available Site	Site within Almondbank would not alleviate flooding in channel, upstream sites do not alleviate flooding around confluence with River Almond
Flood Walls and Embankment	Economically viable scheme demonstrated by Royal Haskoning report	Economically viable scheme demonstrated by Royal Haskoning report

Table 2: Summary of flow conditions and flood management options

4 Discussion

The flood defence schemes outlined in this report are all aimed at solving the flooding issues within Almondbank with a single solution on each of the affected water courses, Pow Burn and the River Almond. The principal difficulty in providing a sustainable solution is the magnitude of the flows on the River Almond. Any solution taking flow from the river channel must cope with such a large volume of water that it becomes extremely expensive to solve the problem. Whilst the damage in Almondbank is extensive in relation to the size of the village, the damage in relation to the river is relatively small. This discrepancy colours the options available for flood defence within Almondbank as large schemes are not economically viable. The use of embankments and flood walls seems to be the only financially justifiable choice, however their use does need to be considered in light of SEPA's concerns.

Under the Water Framework Directive and the Water Environment and Water Services Act (Scotland) 2003, SEPA have a responsibility to control works which may influence the morphology of watercourses as well as their water quality. It is SEPA's concern that the scheme proposed for Pow Burn is in danger of compromising the morphology of the river due to its inclusion of a large length of flood walls, sheet piling and gabion baskets. These concerns need to be addressed before the option can be considered further, despite its status as the only economically viable option.

Ideally work would be done to prevent or at least limit the flood volumes through careful management of the catchment, reducing the need for the flood defences. However the problems through Almondbank stem from the high volume of water being conveyed in the rivers. Additional catchment management options within the Almond and Pow catchments would have such a small effect on the overall flows that they could not be considered effective enough options to undertake in isolation. However it would be recommended that catchment wide practices such as afforestation, good farming practices and sustainable drainage systems be adopted where practical.

The downstream reach of Pow Burn has already had significant works done to it which would influence the future morphology of the river channel. The river banks have already been reinforced using gabion baskets on both the left and right hand banks. These are used to reinforce the banks where erosion has historically been a problem. The main difficulty along the channel is the proximity of buildings and roads along its length. This provides very little scope to allow the channel to flood naturally, holding water within a controlled flood plain. This issue is further complicated by the flooding mechanism in the downstream section of the channel. Since flow backs up into the channel from the River Almond, it is not possible to alleviate flooding along the entire river channel by controlling flows in Pow Burn.

Because flow backs up in the burn, the construction of flood walls along the banks near to the confluence with the River Almond is necessary to ensure human safety and water quality. The flood wall on the left hand bank would prevent flood waters entering a sewage treatment works owned and operated by Scottish Water. The flood wall on the right hand bank protects the property known as Brockbank. According to local residents spoken to during the site visit, this property has flooded three times in the last ten years due to high flows in the River Almond backing up in Pow Burn, coming out of bank and inundating the property. These flood events have all been lower than a 50 year return period, and one might reasonably argue that during a higher return period event, human safety might be at risk. No other works on Pow Burn could prevent this type of flooding.

The flood prevention works upstream of the confluence are those which SEPA may object to more strongly. Royal Haskoning's outline designs make use and expand existing gabion basket walls. These are built up to protect the river bank from erosion and to provide a level of flood defence by incorporating a sheet pile wall at the back face of the gabions. This solution would raise an objection from SEPA as it takes the river channel away from its natural river bank and does not provide a suitable habitat for water dwelling wildlife. The gabion structures were suggested to stabilise the river bank and to provide flood protection for houses and buildings on the DARA site located adjacent to the burn. Ideally SEPA would favour a solution which removed the gabions from the channel and returned the channel to its natural state, however the requirement to protect the existing development adjacent to the Burn coupled to the narrow strip of land available to construct suitable flood defences make this impossible.

The suggested structure comprising Gabion baskets could be developed to provide the appropriate level of flood defence whilst retaining the look of a high river bank. This will encourage the river channel's biodiversity as it matures. Whilst the gabions and sheet piles could provide the basis for the flood defence structure, they would be naturalised by imposing a simple slope over them. This can be achieved using a variety of materials over the top and in front of the gabions. These techniques have successfully been applied to other river restoration projects where bank erosion has been a problem. The slope of a river bank can be recreated using a geotextile layer and is far more resistant to erosion than a natural soil slope. These slopes can then be planted to allow vegetation to grow adjacent to the channels. This is illustrated in Figure 6 and Figure 7 below, although it should be noted that the technique can be applied to slopes much steeper than that shown below.

Figure 6: Geotextile being used to create an erosion resistant river bank

Figure 7: Established river bank founded on a geotextile slope

Alternatively a technique called willow spilling can be employed to provide stable banks (illustrated in Figure 8). Here, wooden stakes are driven into the river bed and live willow branches are woven between them to form a simple retaining structure. Then, as the willow branches grow the river bank becomes a living habitat for wildlife.

Figure 8: Willow Spilling banks

The final option is to include planting cages within the gabion structure (shown in Figure 9). These allow plants to be securely fixed to the gabion structure preventing them from being washed away or coming loose from the structure.

Figure 9: Planted gabion cages to soften the gabion structure

The choice of system to soften the gabions should be chosen in consultation with SEPA. It must be borne in mind that including planting options could increase the required maintenance for the scheme as plants grow and develop. However, this would be a necessary mitigation measure in order to promote an acceptable flood defence scheme. The flood defence options can be justified in terms of ensuring human safety, but it is the nature of these defences that may need to be explored with SEPA.

Given the constraints imposed by the topography in and around Almondbank, coupled with the high peak flows, the embankment and flood wall scheme selected by Royal Haskoning, provides adequate protection within Almondbank and is economically viable. The fine details of how this scheme is integrated into the environment needs to be discussed with SEPA, however it is felt that sufficient options are available to allow a scheme to be constructed without compromising the long term quality of either the River Almond or Pow Burn.

Appendix A – Drawings

The following drawings are included in this appendix:

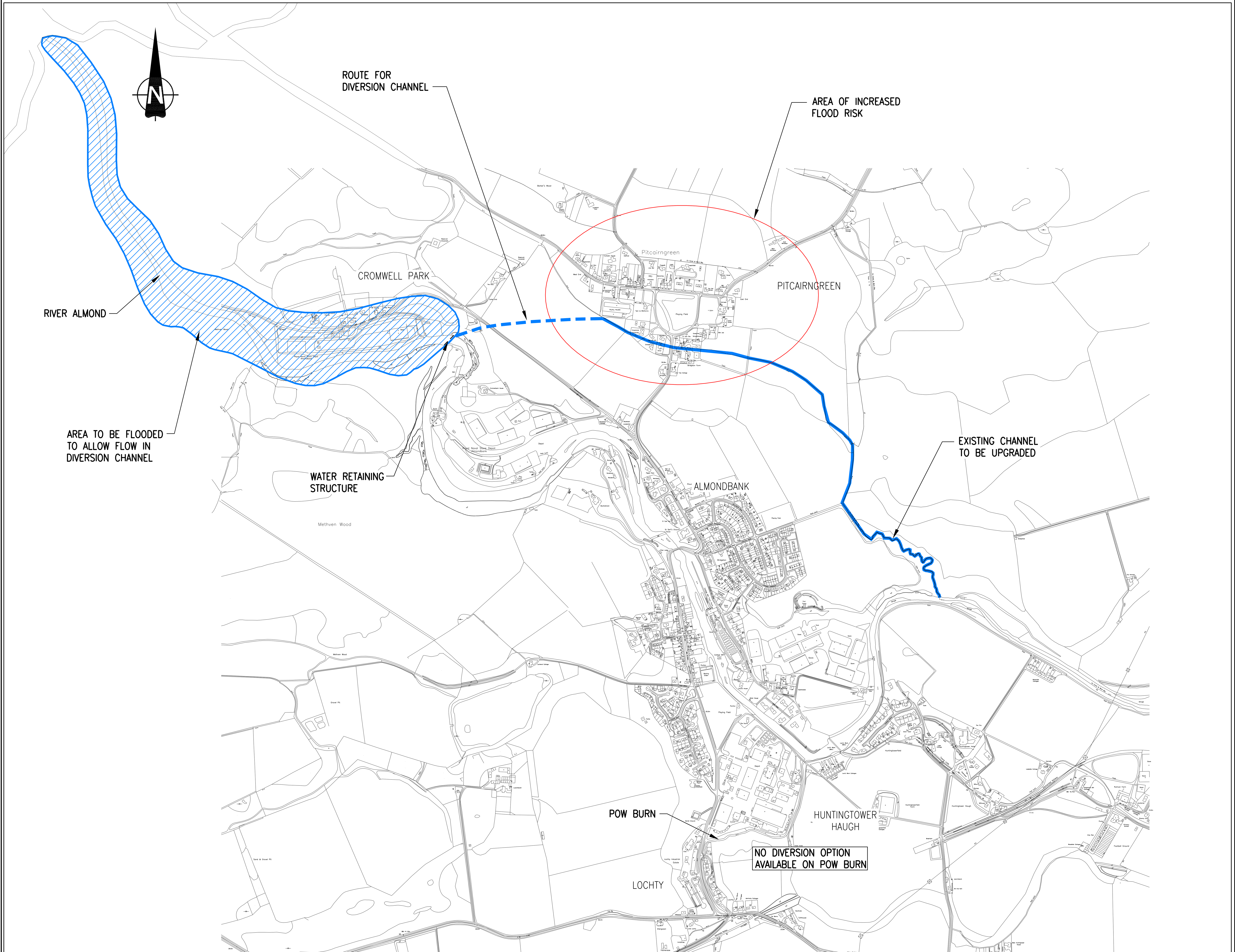
Mouchel Parkman Drawings

315500/022/001	Flood Diversion Channel Option General Arrangement
315500/022/002	Online Storage Scheme General Arrangement

Royal Haskoning Drawings

9M6952/PD/0001	General Arrangement Operations 17-25 Preliminary Outline Design Sheet 1 of 3
9M6952/PD/0002	General Arrangement Operations 6-19 Preliminary Outline Design Sheet 2 of 3
9M6952/PD/0003	General Arrangement Operations 1-8 Preliminary Outline Design Sheet 3 of 3

Notes



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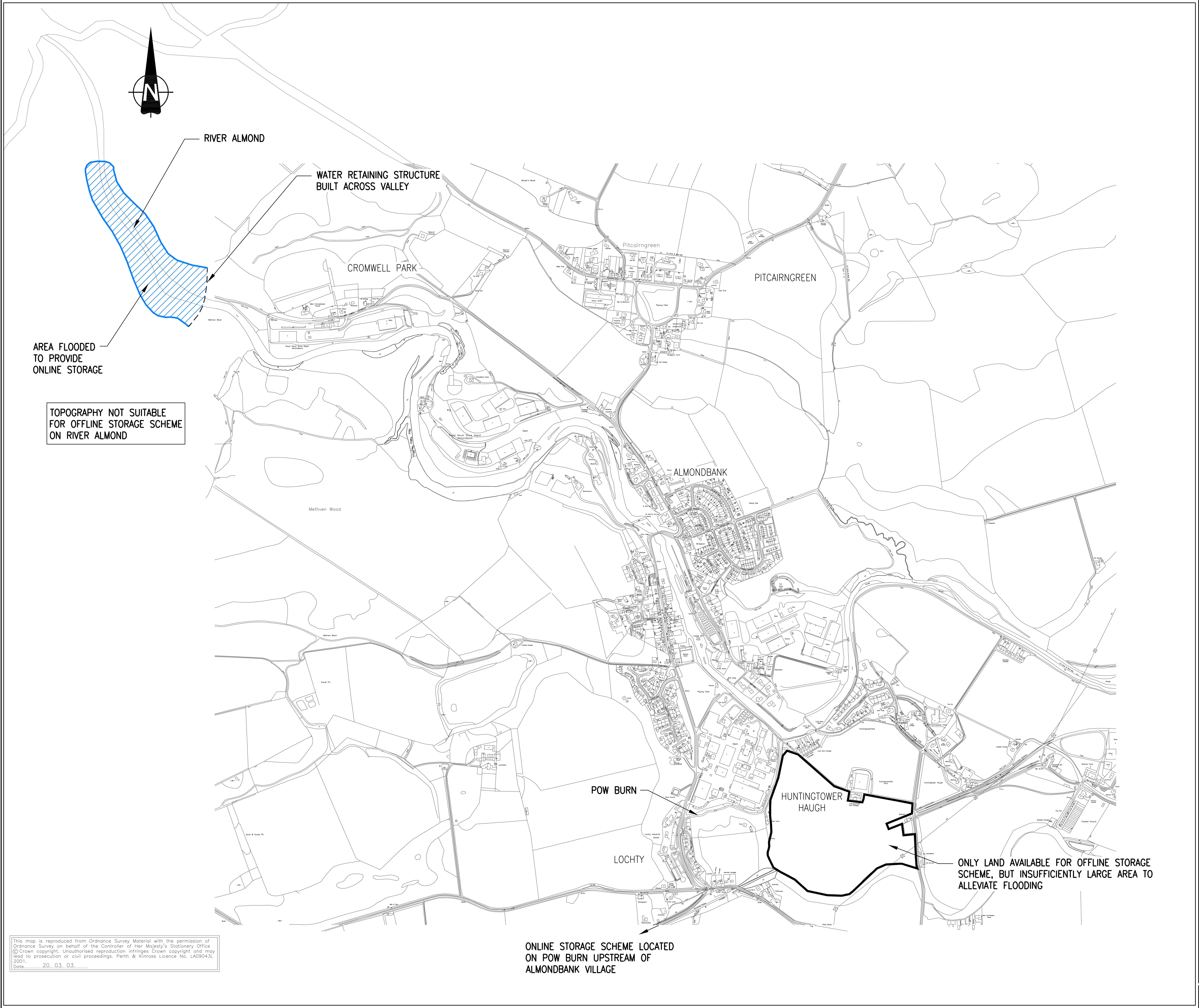
Version	Amendment	Originated by and date	Checked by and date	Approved by and date
A	FIRST ISSUE	M Chambers 15.03.06	A Stinson 15.03.06	P Swift 15.03.06

mouchelparkman

Client	PERTH & KINROSS COUNCIL
Project	ALMONDBANK FLOOD MANAGEMENT OPTIONS
Purpose	INFORMATION
Drawing Title	FLOOD DIVERSION CHANNEL OPTION GENERAL ARRANGEMENT
Draft / Issue	●
Scale (at A1 size)	NTS
Issuing Office	LIVERPOOL
Telephone	0151 242 7777
Drawing Number	315500/022/001
Version	A



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Version	Amendment	Originated by and date	Checked by and date	Approved by and date
A	FIRST ISSUE	M Chambers 15.03.06	A Stinson 15.03.06	P Swift 15.03.06

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Client	PERTH & KINROSS COUNCIL	
Project	ALMONDBANK FLOOD MANAGEMENT OPTIONS	
Purpose	INFORMATION	
Drawing Title	ONLINE STORAGE SCHEME GENERAL ARRANGEMENT	
Draft / Issue	Issue ●	
Scale (at A1 size)	NTS	
Issuing Office	LIVERPOOL	
Telephone	0151 242 7777	
Drawing Number	315500/022/002	
Version	A	

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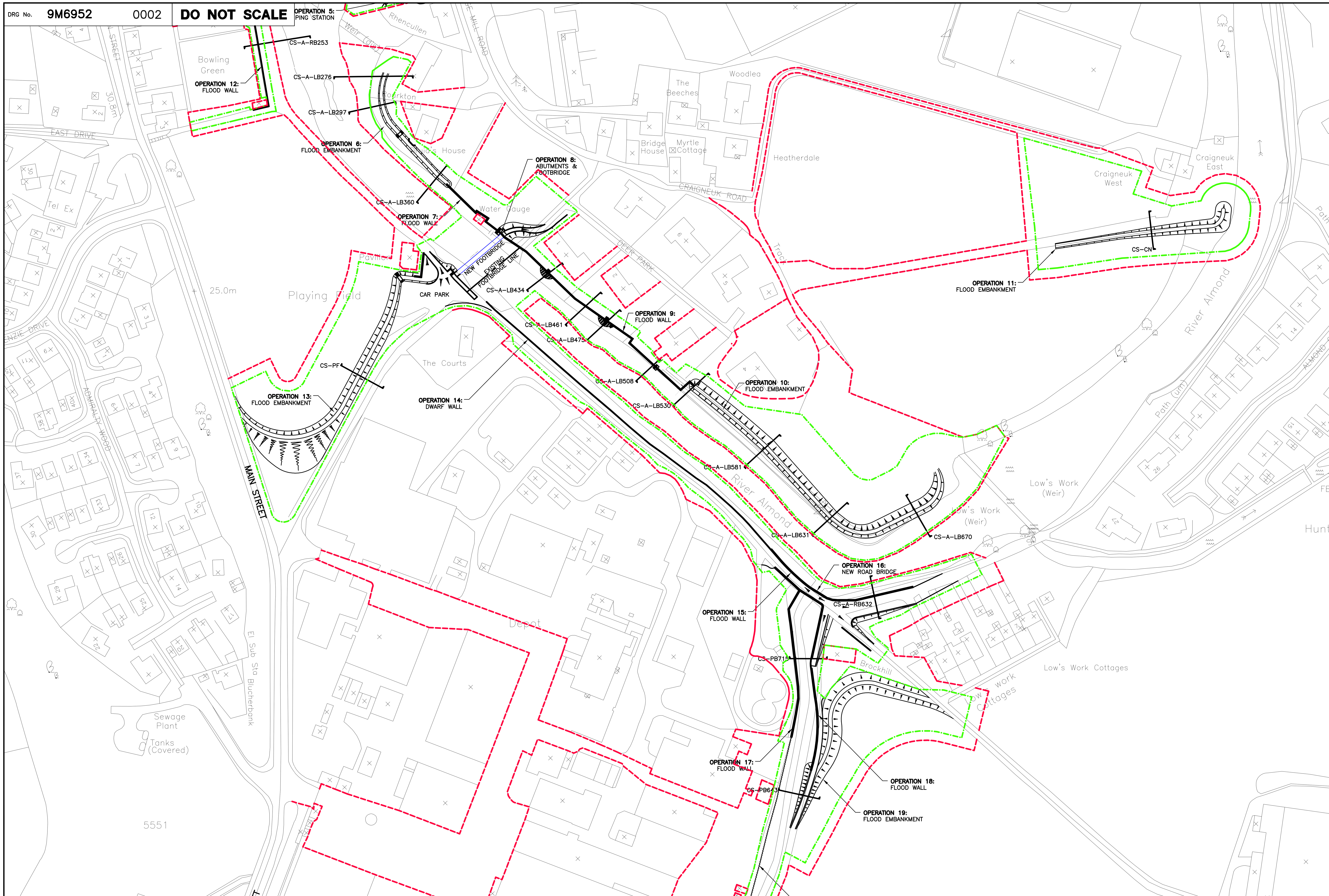

NOTES

1. ALL DIMENSIONS ARE IN MILLIMETRES UNLESS STATED OTHERWISE.

2. ALL LEVELS ARE IN METRES RELATIVE TO ORDNANCE DATUM.

3. FOR CROSS SECTIONS REFER TO PLANS 9M6952/PD/2000 TO 9M6952/PD/2002.

4. THE LIMIT OF VERTICAL DEVIATION WILL BE THE TOP OF FLOOD DEFENCE WALL OR EMBANKMENT +100mm.

5. OPERATIONS ARE FULLY DESCRIBED IN PARAGRAPH 3 OF THE SCHEME TEXT.

6. "CS-PB643" MEANS CROSS SECTION ON POW BURN AT CHAINAGE 643

KEY

— · — LIMITS OF LATERAL DEVIATION.

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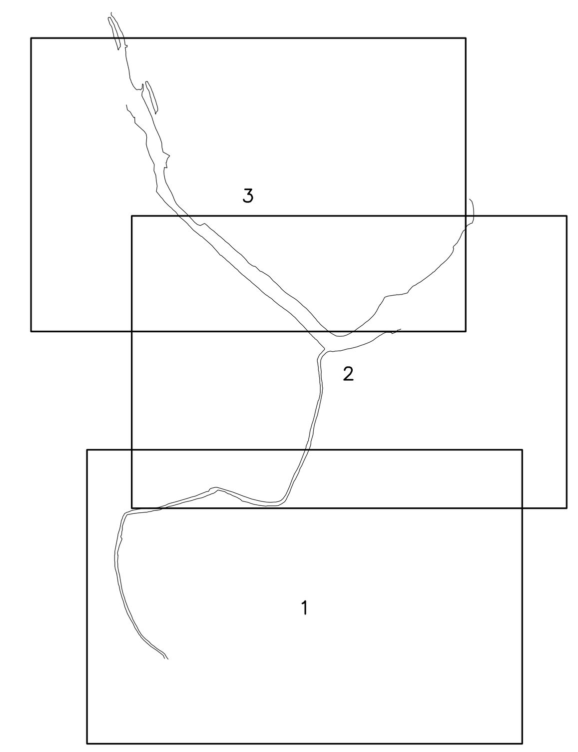

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A	08/03/04	AMENDMENTS S.E. COMMENTS. FOR DISCUSSION ONLY	CRS	NR	MJN
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ALMONDBANK FLOOD PREVENTION SCHEME 2004

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GENERAL ARRANGEMENT
OPERATIONS 6 – 19
PRELIMINARY OUTLINE DESIGN
SHEET 2 OF 3

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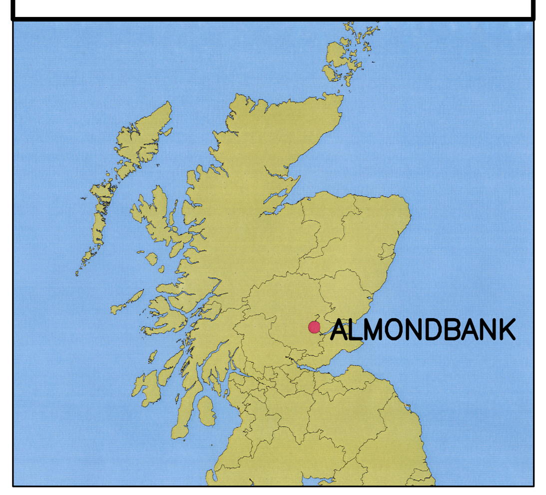

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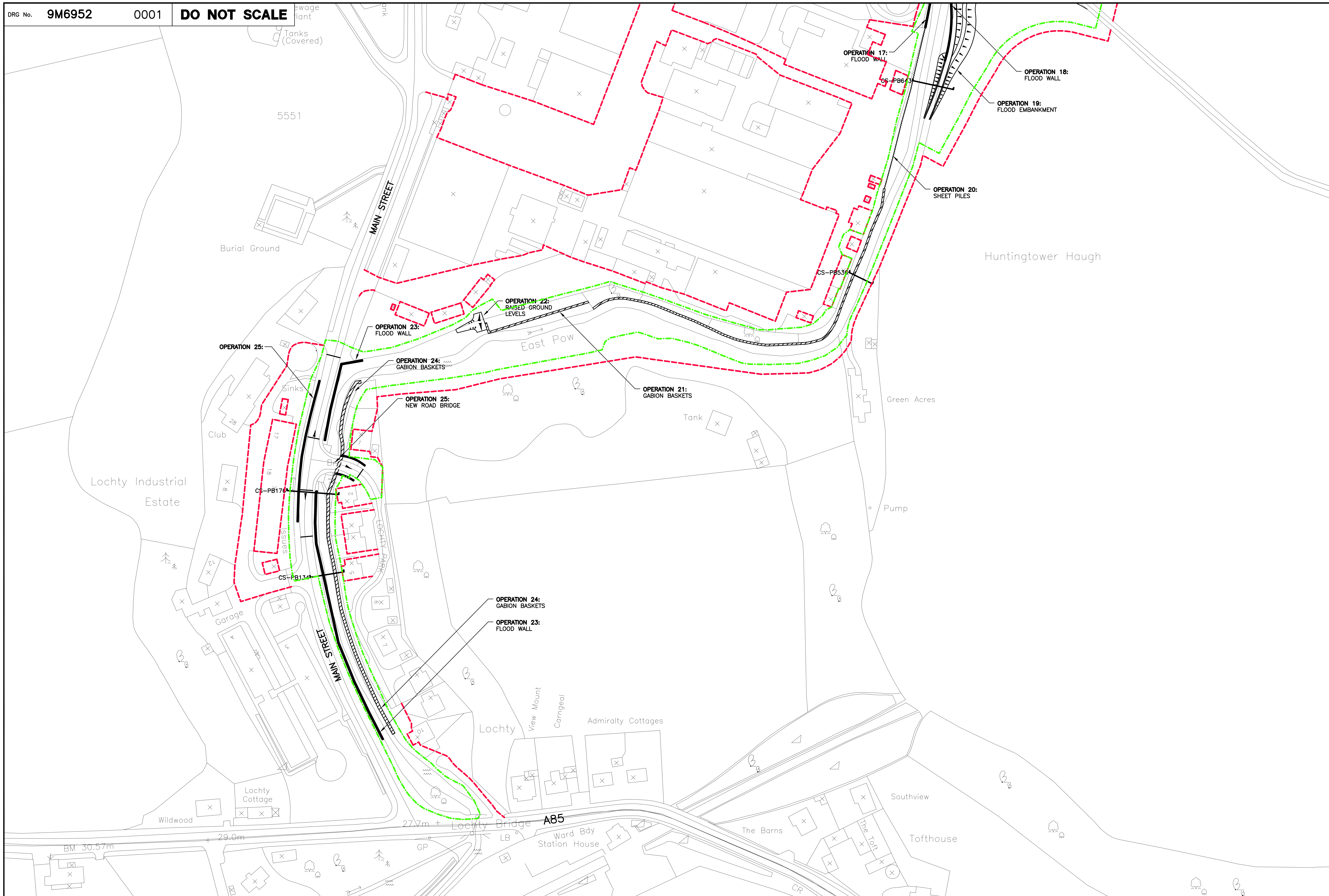

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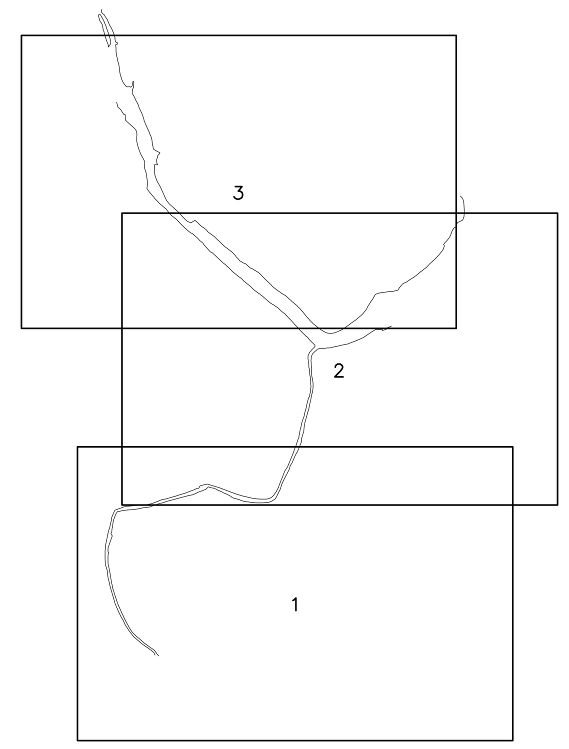

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ALMONDBANK FLOOD PREVENTION SCHEME 2004

TITLE

GENERAL ARRANGEMENT
OPERATIONS 17 – 25
PRELIMINARY OUTLINE DESIGN
SHEET 1 OF 3

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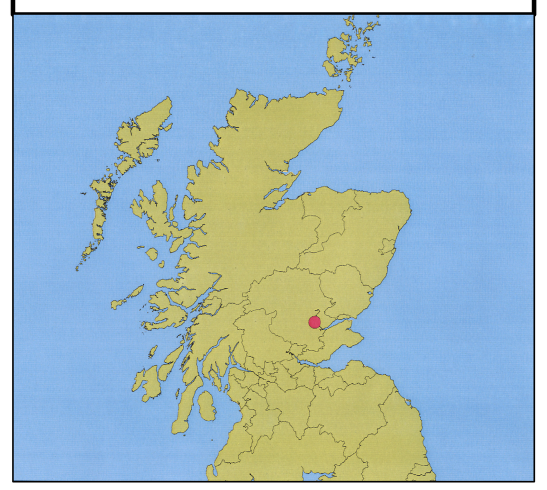

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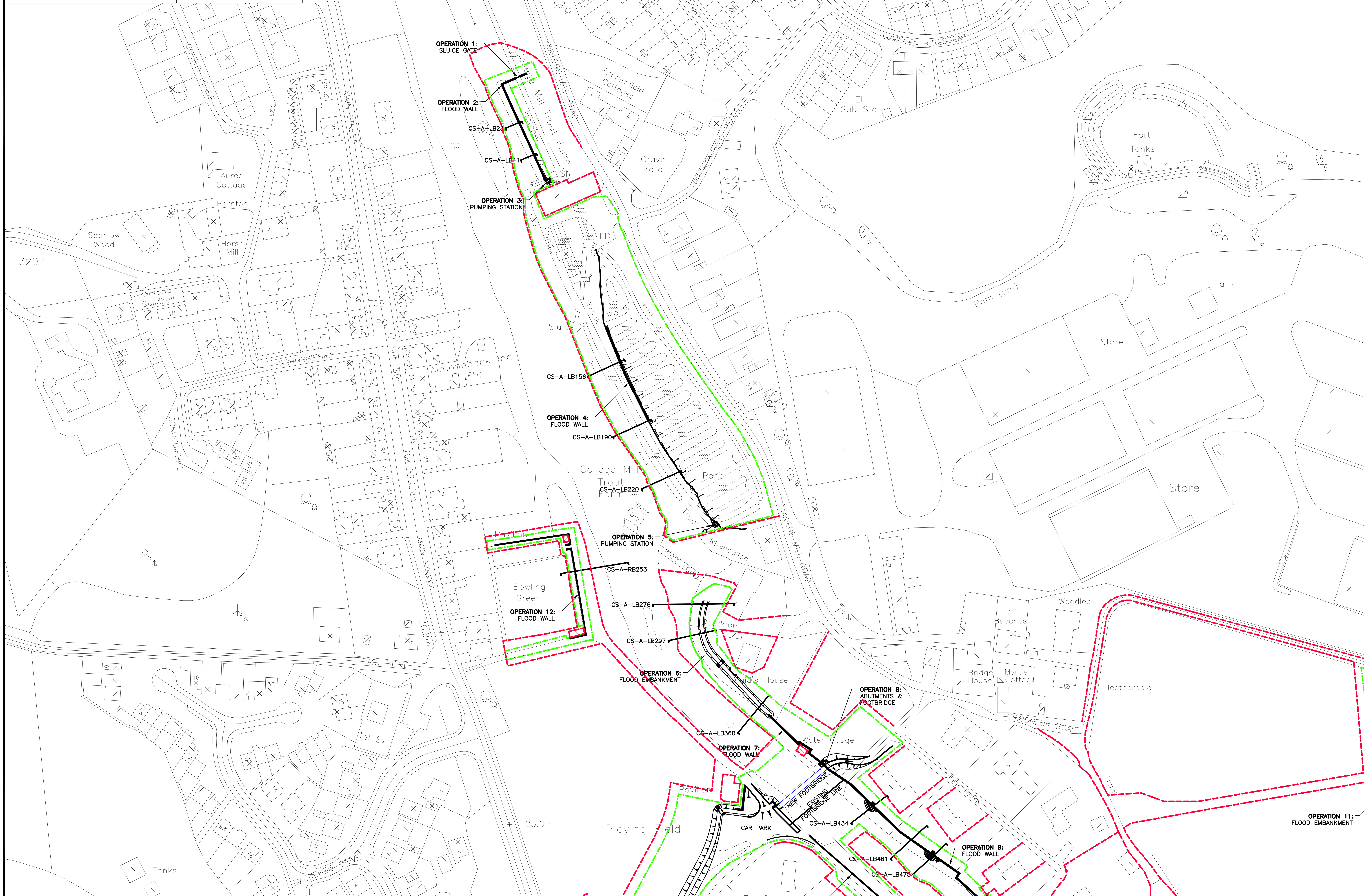

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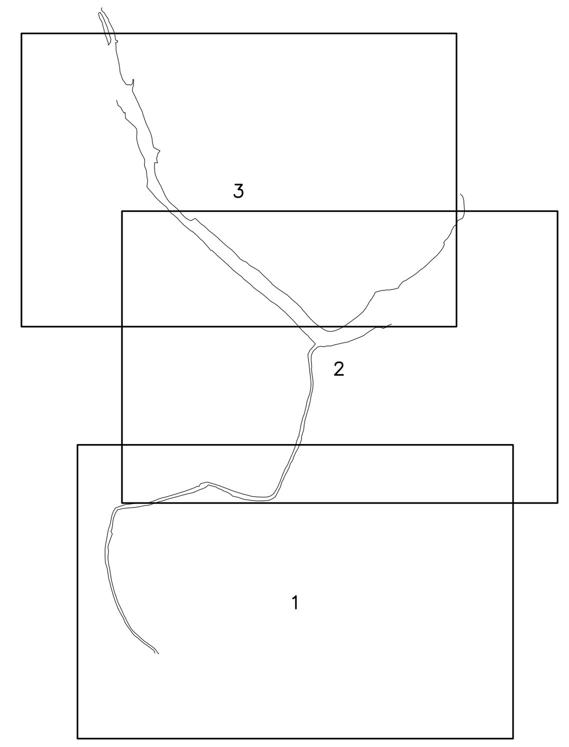

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Planning and Transportation

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TITLE

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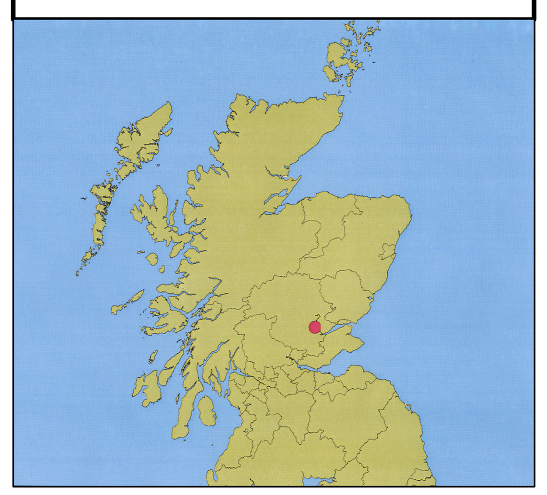

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