Galway County Council

Dunkellin River & Aggard Stream Flood Relief Scheme

Description of the Proposed Works

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REPORT

PROJECT: **Dunkellin River and Aggard Stream Flood Relief Scheme**

CLIENT: **Galway County Council,**
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Document Amendment Record

Client:	**Galway County Council**
Project:	**Dunkellin & Aggard Stream Flood Relief Scheme** **Technical Description for EIS**
Title:	**Technical Description for EIS**

PROJECT NUMBER: 6408				**DOCUMENT REF:** **6408-Works Description Section for EIS Revision K**			
K	Proposed Scheme	CK	Aug 14	MMcD	Sept 14	MMcD	Sept 14
Revision	**Description & Rationale**	**Originated**	**Date**	**Reviewed**	**Date**	**Authorised**	**Date**
TOBIN Consulting Engineers							

NON TECHNICAL DESCRIPTION

The extent of the overall study area for the proposed *Dunkellin River and Aggard Stream Flood Relief Scheme* has been divided into two distinct channels. These channels are:

1. the Dunkellin/Craughwell River from approximately 200m upstream of Craughwell Village to the sea at Kilcolgan just upstream of where the river enters Galway Bay.

2. the Aggard Stream and Monksfield River from the townland of Cregaclare (near Ardrahan), to its outfall at the confluence of the Dunkellin and Craughwell Rivers.

It is proposed to undertaken flood relief works along the Dunkellin in three reaches of the river:

a. in the vicinity of Craughwell Village,
b. locally at Rinn Bridge and
c. from a location just upstream of the Dunkellin Bridge to the N18 at Kilcolgan.

The works consist of channel deepening (not widening) in Craughwell village to the confluence of the Aggard Stream, local channel widening at Rinn Bridge, out of channel maintenance downstream of the Rahasane Turlough to Rinn Bridge (i.e., limited to trimming back of terrestrial bank vegetation such as trees and low hanging branches and removal of encroaching vegetation such as brambles and scrub) and channel widening from the Dunkellin Bridge to the N18.

It is not proposed to undertake any significant arterial drainage works along the Aggard Stream. The proposed works associated with the Aggard Stream will be limited to the replacement of field wall crossings which are blocked or have collapsed, together with maintenance works, including the non-invasive trimming of bank-side vegetation and the removal of areas of accumulated silt along the full length of the channel.

It is not proposed to undertake works within or adjacent to the Rahasane Turlough cSAC, NHA and SPA or within the Galway Bay Complex SAC.

The requirement for the proposed works are to relieve flooding generated from rainfall events similar to those that occurred in January 2005 and November 2009 which flooded properties in Craughwell Village and a number of townlands along the river including Rinn, Dunkellin and Killeely Beg. To place these works in context the following is a synopsis of the flooding that occurred in region in November 2009.

During the period 17th to 24th November 2009, daily rainfall amounts on Wednesday 19th were recorded as 26.7mm and 29.4mm at the Shannon and Claremorris Weather Stations, respectively. This peak rainfall was followed by peak flood levels :

a. upstream of Craughwell village along the R349 (Loughrea to Athenry Road) at approximately midday on Thursday 20th November,
b. at the Craughwell River/N6 road crossing during Thursday afternoon (road closed in afternoon resulting in significant traffic disruption), and
c. downstream of Craughwell at Rahasane Turlough during Friday 21st November.

The following photography, taken by the OPW & Central Fisheries Board, during the period Thursday 20th to Saturday 22nd November 2009, shows the extent of flooding which occurred in late November 2009.

Photograph A
November 2009 Event.
Looking Upstream from Craughwell

Note the relatively small area (approximately 1.2ha) and therefore volume of flooding in Craughwell village when compared with the extent of lands flooded at the Rahasane Turlough (>350ha) in Photographs B and C.

Photograph B
November 2009 Event.
Looking downstream from Craughwell

Note the relatively small area (approximately 1.2ha) of flooding in Craughwell in the foreground when compared with the extent of lands flooded at the Rahasane Turlough (>350ha) in background.

Photograph C
November 2009 Event.
Looking northwards across the Rahasane Turlough

The width of flooding shown is approximately 0.75 to 1.0km..

The proposed scheme aims to reduce the impact of similar extreme floods, on existing properties, while having minimal impacts, short term only impacts or no impact on local ecology or other sensitive designated areas such as the Rahasane Turlough and Galway Bay Complex.

The proposed scheme has used a series of computer models to establish the design of the excavations required and to also estimate the depth of flooding that may occur if events like January 2005 and November 2009 were to be repeated in the future.

The computer models have used recorded and locally gathered evidence of extreme flooding to establish the extent of the proposed flood relief works that are needed to protect, where possible, long established residential housing and commercial premises in the area.

Table A – Summary of the proposed Proposed Scheme

Location	Proposed Scheme
Main Channel (Craughwell Village)	The main channel shall in general be deepened by 0.6m with a localised maximum excavation of 1.0m.
Bridge Work in Craughwell	Both existing road bridges will require engineering works on each abutment to facilitate proposed channel deepening. Similarly the railway bridge will also require foundation works for the same purposes.
Bypass Channel (Craughwell Village)	The bypass channel is to be cleaned and excavated to alleviate flooding in Craughwell Village.
Rahasane Turlough	It is Not Proposed to Complete any Works within or adjacent to the main body of the Rahasane Turlough cSAC.
Channel Works between the Rahasane Turlough and Rinn Bridge and Works at Rinn	Out of channel maintenance downstream of the Rahasane Turlough to Rinn Bridge (i.e., limited to trimming back of terrestrial vegetation such as trees and low hanging branches and removal of encroaching vegetation such as brambles and scrub) with provision of new flood relief eyes to be constructed on one bank of the river in association with two stage channel widening 50m upstream and 50m downstream of the existing Rinn Bridge.

Channel Works beginning upstream of Dunkellin bridge	Works will commence approximately 175m upstream of the Dunkellin bridge and consist of the construction of a high level channel typically 20m in width along the left bank (as one looks downstream) of the river.
Channel Works from Dunkellin Bridge to Kilcolgan Bridge	Out of channel maintenance (limited to trimming back of bank side terrestrial vegetation to 1.0m to 1.5m above high flood levels) in association with the higher level “Two stage channel works” will continue from Dunkellin Bridge to Kilcolgan Bridge with a typical additional channel width of up to 20m.
Works at Dunkellin Bridge	In conjunction with localised channel widening the existing flood eyes shall be replaced with 2 new box culverts each measuring 13m wide x 2.3m deep. Existing stone from the bridge will be reused to match the retained main stone arch.
Works at Killeely Beg Bridge	In conjunction with channel widening a new bridge shall be provided with an 18m span.
Salmon Counter	The salmon counter will be relocated to a position upstream of Kileely Beg bridge as part of the river enhancement works

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DESCRIPTION OF THE PROPOSED SCHEME

1 GENERAL DESCRIPTION OF THE SCHEME

Following the invitations to tender from Galway County Council, in conjunction with the OPW, in January 2011, and the submission of Tender proposals by TOBIN Consulting Engineers and the RPS Group, both firms (the Design Team) were commissioned by the Council to undertake two service contracts, namely;

Service Contract 1: *"Dunkellin River and Aggard Stream Flood Relief Scheme - Engineering Consultancy Services",* a contract being undertaken by TOBIN Consulting Engineers,

and

Service Contract 2: "Dunkellin River and Aggard Stream Flood Relief Scheme - Environmental Consultancy Services", a contract being undertaken by the RPS Group.

The brief required TOBIN Consulting Engineers to review the proposed flood alleviation measures, contained in the report entitled *"Study to Identify Practical Measures to Address Flooding on the Dunkellin River including the Aggard Stream"* and dated June 2010, with a view to establishing a series of viable technical solutions, which address the environmental constraints which emerged as part of the planning stage and from the public consultation process undertaken in May 2011.

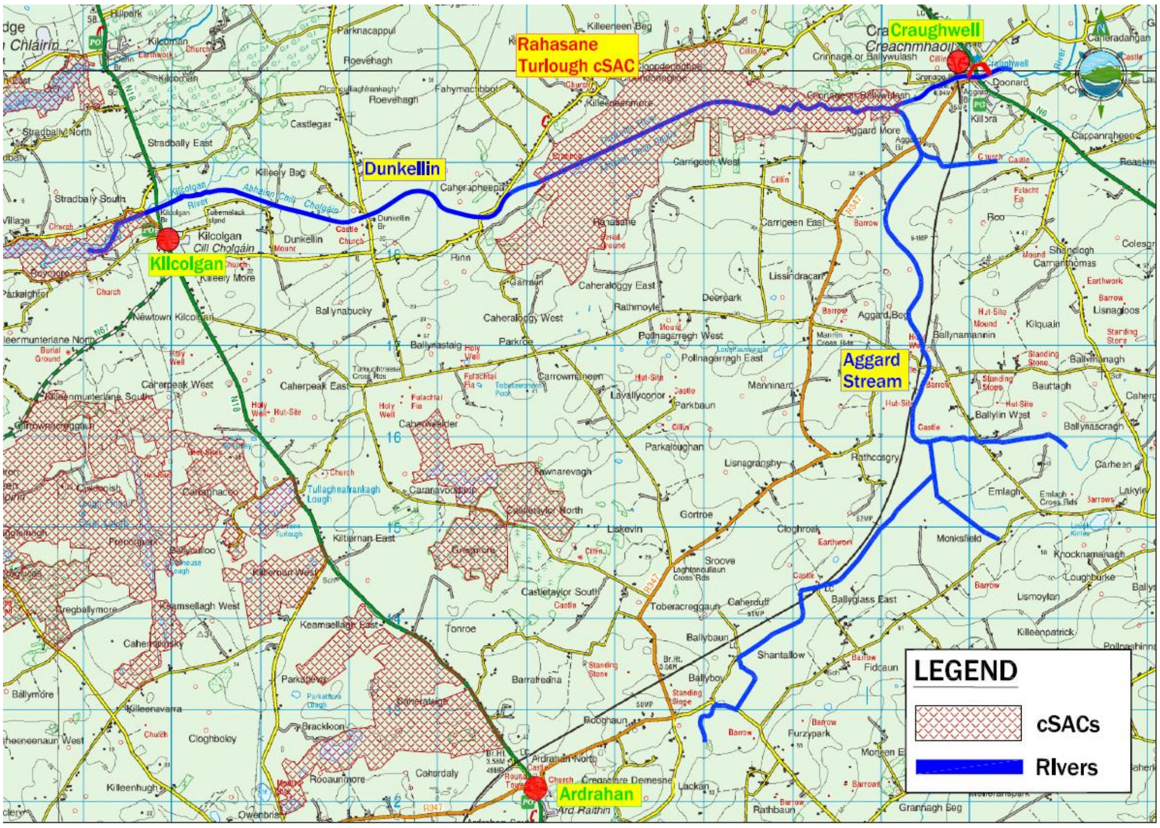


Figure 1-1 – Extent of the Study Area

The extent of the overall study area, as shown in Figure 1-1, has been divided into areas contributing to two distinct channels. These channels are:

3. the Dunkellin/Craughwell River from approximately 200m upstream of Craughwell Village, through the Rahasane Turlough cSAC, NHA and SPA, to the sea at Kilcolgan just upstream of where the river enters the Galway Bay Complex SAC.

4. the Aggard Stream and Monksfield River from the townland of Cregaclare (near Ardrahan), to its outfall at the confluence of the Dunkellin and Craughwell Rivers.

Whilst the Dunkellin River drains a significant area of lands to the east, northeast and south of Craughwell village (>200km^2), the particular reaches of river considered in this project are:

1. approximately 11km of the Dunkellin River which runs in a westerly direction from Craughwell Village to the sea at Kilcolgan.
2. approximately 7.5km of the Aggard Stream which flows in a northerly direction from Ardrahan to Craughwell.

It is not proposed to undertake any significant arterial drainage works along the Aggard Stream. The proposed works associated with the Aggard Stream will be limited to culvert replacement and the replacement of field wall crossings, together with maintenance works, including the non-invasive trimming of bank-side vegetation and the removal of areas of accumulated silt along the full length of the channel.

The Dunkellin River and its tributaries, rise at a number of locations to the east of Craughwell, and drain a number of population centres, including Woodlawn (Raford or Dooyertha River) and New Inn (Craughwell River), Cappataggle and Lough Rea (St Cleran's River) to name a few. Flows from each of the upper sub-catchment areas, combine to form the main channel reach at Craughwell Village, where the discharge is recorded at an OPW gauging station (Station No. 29007) on the main R446 (formerly N6) Road Bridge.

Figure 1-2, shows the extent of the Dunkellin River, from Craughwell Village to Kilcolgan, and the positions of the major hydraulic controls along this particular stretch of river.

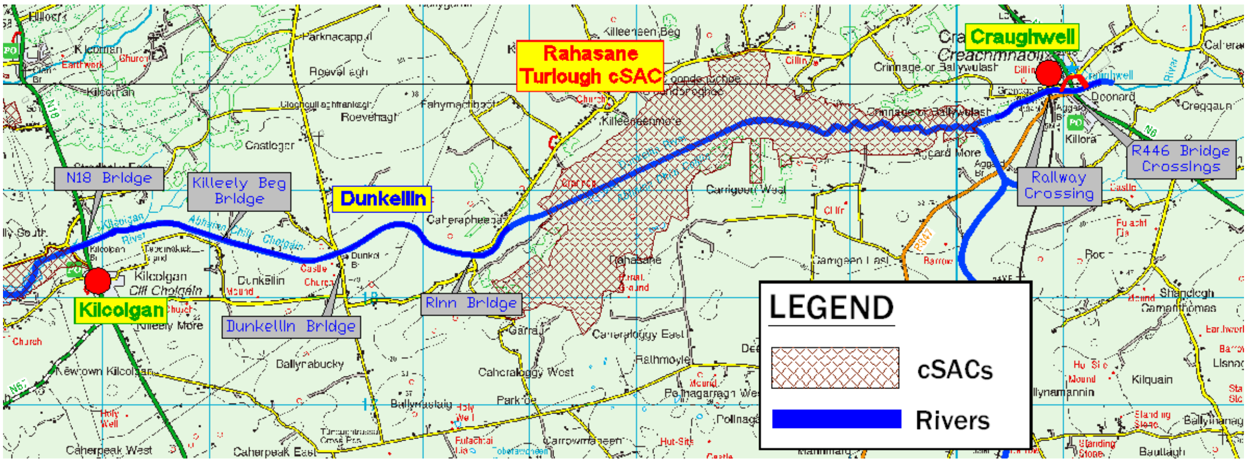
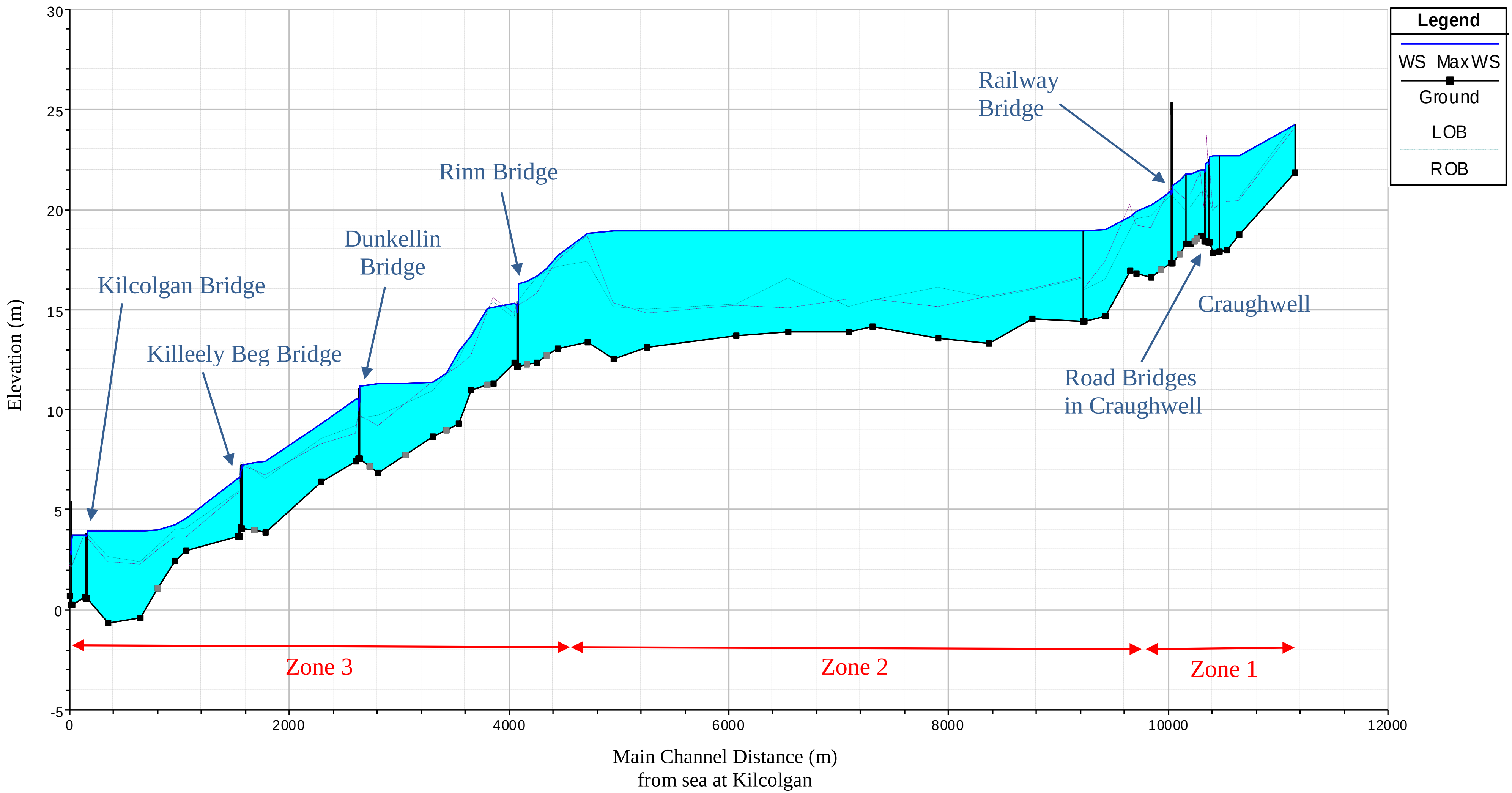


Figure 1-2 – Dunkellin Catchment from Craughwell to Kilcolgan

Figure 1-3, shows the longitudinal section of the Dunkellin River, from Craughwell Village to Kilcolgan, which was modelled using the hydraulic software package, HEC-Ras. It details the estimated surface water profile for the November 2009 event and compares this with the channel bed, left bank (LOB) and right bank (ROB).

Figure 1-3 – Longitudinal Section of the Dunkellin River from Craughwell to Kilcolgan



The depth of the main Dunkellin River channel varies quite considerably throughout its course. Natural embankments formed from excavated spoil, significant rock cuts and large flat flood plains, are predominant physical features of this channel.

The bed profile of the Dunkellin River, from Craughwell to Kilcolgan, as shown in Figure 1-3, ranges from a level of 22.29mOD (Malin Head) in Craughwell village, to 0.88mOD at Kilcolgan Bridge, and has three (3) zones along its length.

Zone 1 – Craughwell River, which has a relatively steep gradient in bed level at Craughwell Village.

Zone 2 – Rahasane Turlough cSAC, NHA and SPA, which has a gentle undulating bed level.

Zone 3 – Lower reach of the Dunkellin River, which has steep gradients in bed level from upstream of Rinn Bridge, to the sea at Kilcolgan.

These zones are described in more detail in the following sections and are used throughout this section to discuss the proposed flood relief measures.

1.1 ZONE 1 – CRAUGHWELL RIVER

This particular stretch of the Craughwell River in the village of Craughwell, consists of two distinct channels, namely,

a. the main channel and
b. the bypass or overflow channel.

During normal flow conditions, surface water flows are restricted to the main Craughwell River, coloured blue in Figure 1-4, and pass under two bridge crossings namely; the main R446 Bridge (formerly N6) and the old multi-arched stone bridge.

However, when flow conditions dictate excess surface water flow is directed around the main bridge crossing via an overflow channel and a further bridge crossing of the R446, highlighted in red on Figure 1-4. The effectiveness of this overflow channel (bypass channel) is limited, as it is not fully connected to the Craughwell River at its upstream location. High flows must follow a short section of overland flow before entering the overflow channel.

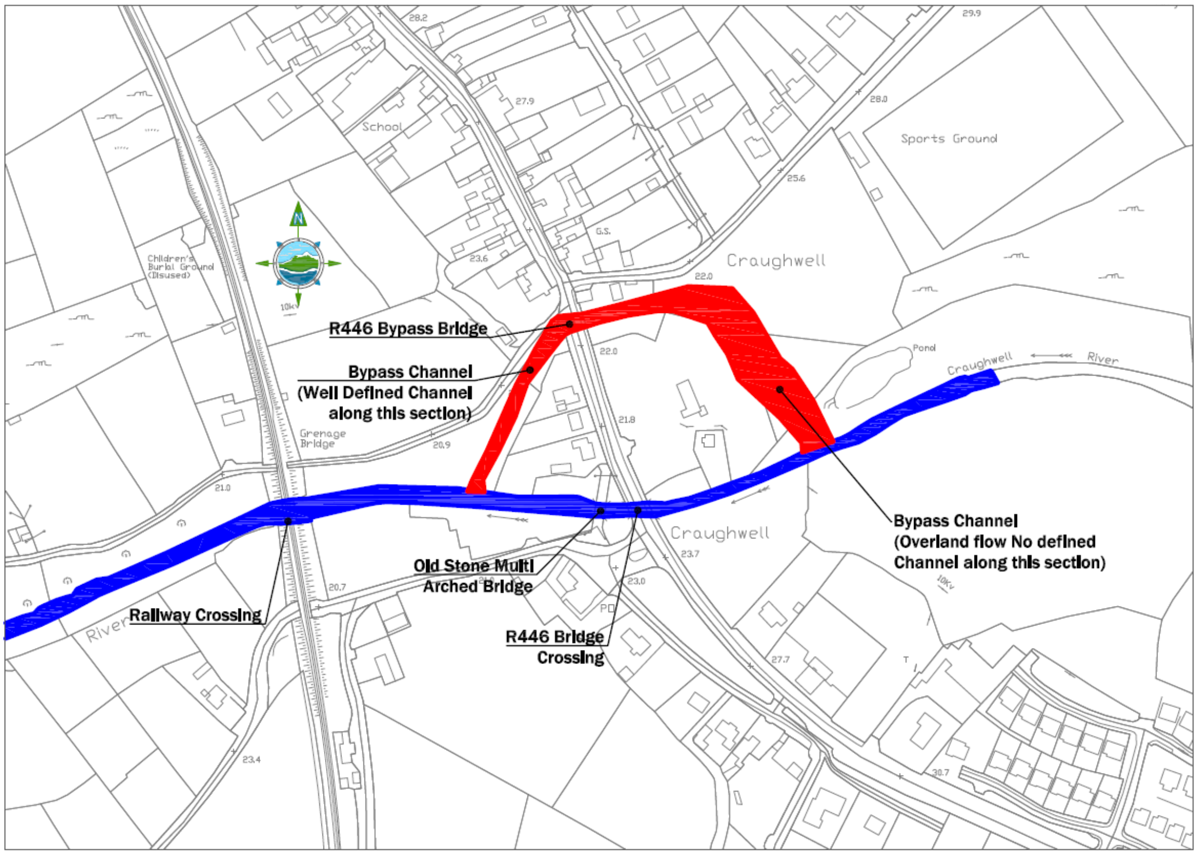


Figure 1-4 – Zone 1 Craughwell River at Craughwell Village

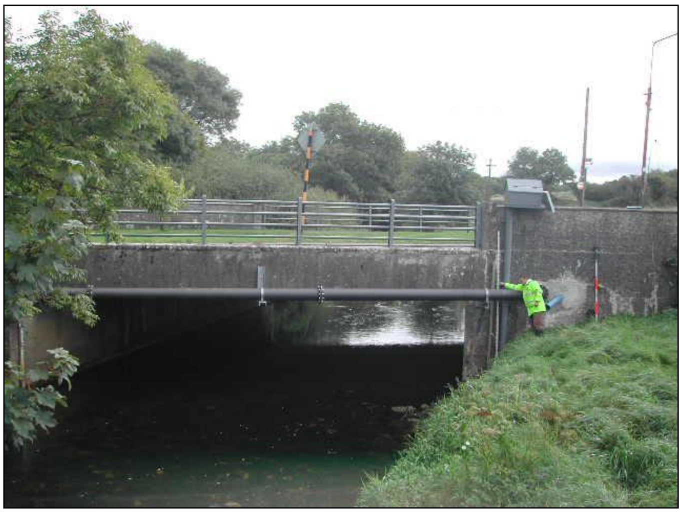
The channel along this stretch of the Dunkellin River, is of the order of 1.4m to 2.0m deep and the bed level gradient varies considerably, with a change in bed level occurring within Craughwell Village at the three bridge crossings.

There are a number of hydraulic controls along this stretch of the river. These controls are shown in the following photography and are :

a. The overflow or bypass channel within Craughwell Village (Photograph No. 1),
b. The two road bridges (Photograph No's. 2 and 3),
c. The old multi-arched stone bridge (Photograph No. 4) and
d. The railway bridge (Photograph No. 5).

Photograph No. 1

Overflow or Bypass Channel looking upstream from the R446 bridge crossing



Photograph No. 2

Main R446 Bridge Crossing along the main channel looking upstream from the multi-arched stone bridge crossing shown in Photograph No. 3

Note : Full span of bridge available for flow and the water main located on the downstream face does not impede flows.

Photograph No. 3
Bridge crossing of Bypass Channel looking upstream towards the channel shown in Photograph No. 1

Note : Unlike the Main R446 Bridge crossing, this structure has a central pier/support which reduces the overall effectiveness of the bridge.

The water main is located on the downstream face of the bridge and does not impede flows.

Photograph No. 4

Muli-arched Stone Bridge looking downstream from the main R446 bridge Crossing shown in Photograph No. 2

Note : Low Flows generally restricted to the main arches on the right of the photo. Only in times of high flows are the arches on the left utilised due to high bank levels.

Photo No. 5
Railway Bridge looking downstream through the stone arch.

Note : Water marks on the bridge abutments indicate that the full capacity (arch height) of this bridge is not hydraulically used.

1.2 ZONE 2 – RAHASANE TURLOUGH

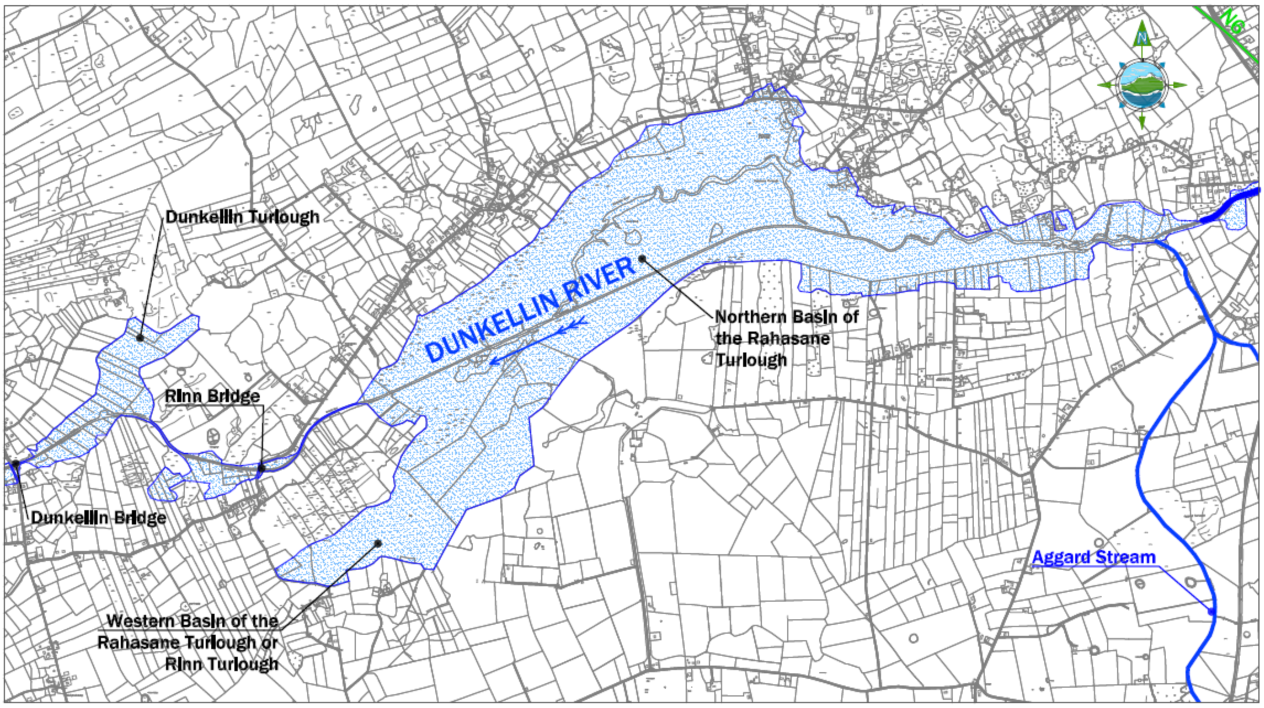
Water passing downstream of Craughwell Village, flows in a westerly direction for a distance of approximately 1km, where the Craughwell River and Aggard Stream combine to form the Dunkellin River.

During low flow conditions, surface water flows are restricted to the main Dunkellin River, which, following an Arterial Drainage Scheme in the 1850's, can be described as being "canalised" for a significant portion of its length. Along this particular stretch of the Dunkellin, the gradient of the channel bed is relatively flat, approximately 1 in 3,000.

During low flows, the channel varies in width from 10m to 30m. However, during periods of high flow, the Dunkellin River overflows its banks and floods the adjoining lands to form the Rahasane Turlough cSAC. The Rahasane Turlough cSAC is considered to be one of the largest turloughs in Europe and is of particular significance in an ecological context in that it is "one of only two large turloughs which still function naturally" (Site 000322 – Site Synopsis). The Rahasane Turlough cSAC is a rare habitat type of major conservation importance. This habitat type (turloughs) is listed in Annex 1 of the Habitats Directive.

The Rahasane Turlough (circa 4km in length) lies in gently undulating land and consists of two basins which are connected at times of flood but separated as the waters decline (Drew & Daly, 1996). These basins are detailed in Figure 1-5.

Figure 1-5 – Zone 2 Rahasane, Rinn & Dunkellin Turlough Complex



The larger of these, the northern basin, is described as the Rahasane Turlough proper. The Rahasane Turlough was formerly the natural sink of the Dunkellin River, but now an artificial channel takes some of the water further downstream. Water escapes the artificial channel to flood the northern basin where it flows into an active swallow hole system (NPWS, Site : 000322 - Site Synopsis).

The second of these basins, the western basin, known as the Rinn Turlough, is orientated north-south and is connected to the main Rahasane Turlough by a raised channel (circa 0.5m above the floor of the Rahasane Turlough). This Rinn Turlough is an overspill basin to the main turlough (Drew, 1986).

During flood conditions the width of the “Dunkellin River”, or the flood plain, increases quite significantly, as can be seen in Photograph No. 6.

In a number of locations along Rahasane Turlough cSAC, the flood plain can be greater than 1km wide and, at its highest levels, can extend to cover an area of over 300ha.

Photograph No. 6
Rahasane Turlough

Taken in November 2009 looking northwards

The Rinn Turlough (Western Basin) is in the foreground.

The Rahasane Turlough (Northern Basin) is shown in the upper portions of the image.

Typical bed levels of the channel within the Rahasane Turlough cSAC are of the order of 13.0mOD Malin Head (TOBIN Topographical Survey 2010) with other localised depressions, or sinkholes, having levels of 11.0m OD Malin Head (Drew 1986).

Downstream of the Rahasane Turlough cSAC, flow is westerly toward Rinn Bridge, through a well defined canalised channel, measuring up to 3.3m in depth, and 15 to 20m in width. The section of channel downstream of the turlough is shown in Photograph No. 7. This section of the channel is formed in a rock cut, for a significant portion of its length, and the gradient of the channel bed is typically 1 in 200.

Photograph No. 7
Dunkellin River looking upstream from Rinn Bridge

1.3 ZONE 3 – RINN BRIDGE TO KILCOLGAN

The main channel exiting the Rahasane Turlough (Photograph No. 7) and the Rinn Bridge (Photograph No. 8), which is located approximately 800m downstream of the turlough, are the main downstream features impacting on the hydraulic control of the river.

Downstream of the Rinn Bridge, and during low flow conditions, surface water flows are restricted to the main Dunkellin River, which again, following the Arterial Drainage Scheme completed in the 1850's, can be described as being "canalised" for a significant portion of its length. During these low flows, this particular stretch of the river varies in width from 10m to 15m and, the gradient of the channel bed is approximately 1 in 300.

Photograph No. 8
Rinn Bridge taken from the upstream left bank

Note the central pier dividing the two spans

The bed level at this structure and the upstream channel control the normal flood levels in the Rahasane Turlough.

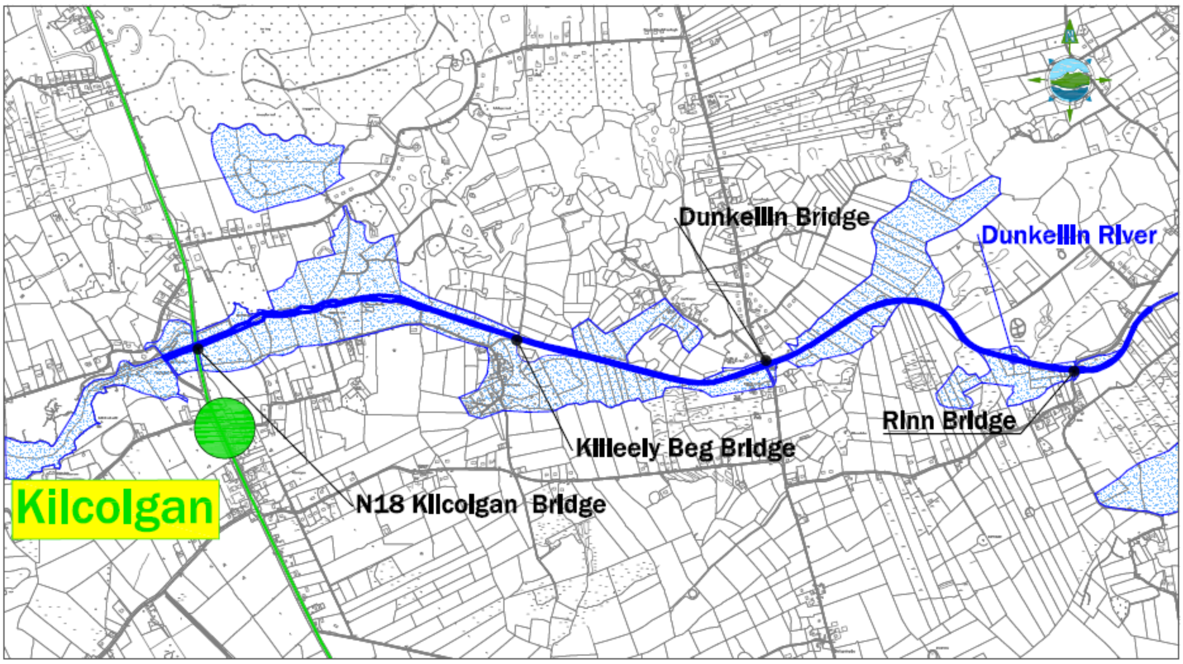


Figure 1-6 – Zone 3 Rinn Bridge to Kilcolgan

During high flows, the Dunkellin River also overtops its banks approximately 750m downstream of the Rinn Bridge and flood waters enter the Dunkellin Turlough as shown in Photograph No. 9.

Photograph No. 9
Dunkellin Turlough

Facing upstream with the Dunkellin Bridge in the centre of the image with a cluster of houses on each of the right and left banks

Photograph No. 10
Upstream face of the Dunkellin Bridge showing the main arch and flood eyes on the left bank

Low Flows at this location are restricted to the main channel and stone arch visible on the right of the photograph.

High flows overtop the channel and pass under the roadway via the three visible (smaller) arches.
However, restrictions, such as the trailer and piles of stone reduce the effectiveness of these flood eyes.

Downstream of the Dunkellin Bridge, the Dunkellin River continues for a further 2.5km to the sea via the Killeely Beg Bridge, the Kilcolgan Road (N18) Bridge and a local road bridge (stone arch). The lands and main channel within the vicinity of the Kilcolgan Road Bridge are tidal. Downstream of Dunkellin Bridge, the Dunkellin River continues to follow a well defined canalised channel, with gradients of between 1 in 300, and widths ranging from 10 to 30m, until it reaches the sea at Kilcolgan.

1.4 AGGARD STREAM

The Aggard Stream, as shown in Figure 1-7, discharges into the main Dunkellin channel at the confluence of the Craughwell and Dunkellin rivers approximately 1km downstream of Craughwell Village. The stream rises in the townland of Cregaclare, where water entering the channel, via surface contributions and ground water springs, flows in a northerly direction for a distance of approximately 4km in the townland of Monksfield. At this location, the channel discharges into the Monksfield River which, after a further 3.5km, enters the Aggard Stream. The channel flows almost parallel to the western railway corridor and crosses this railway at three locations.

Unlike the Dunkellin River, there are no designated sites (cSAC's, NHA's or SPA's) along the route of the Aggard Stream and Monksfield River.

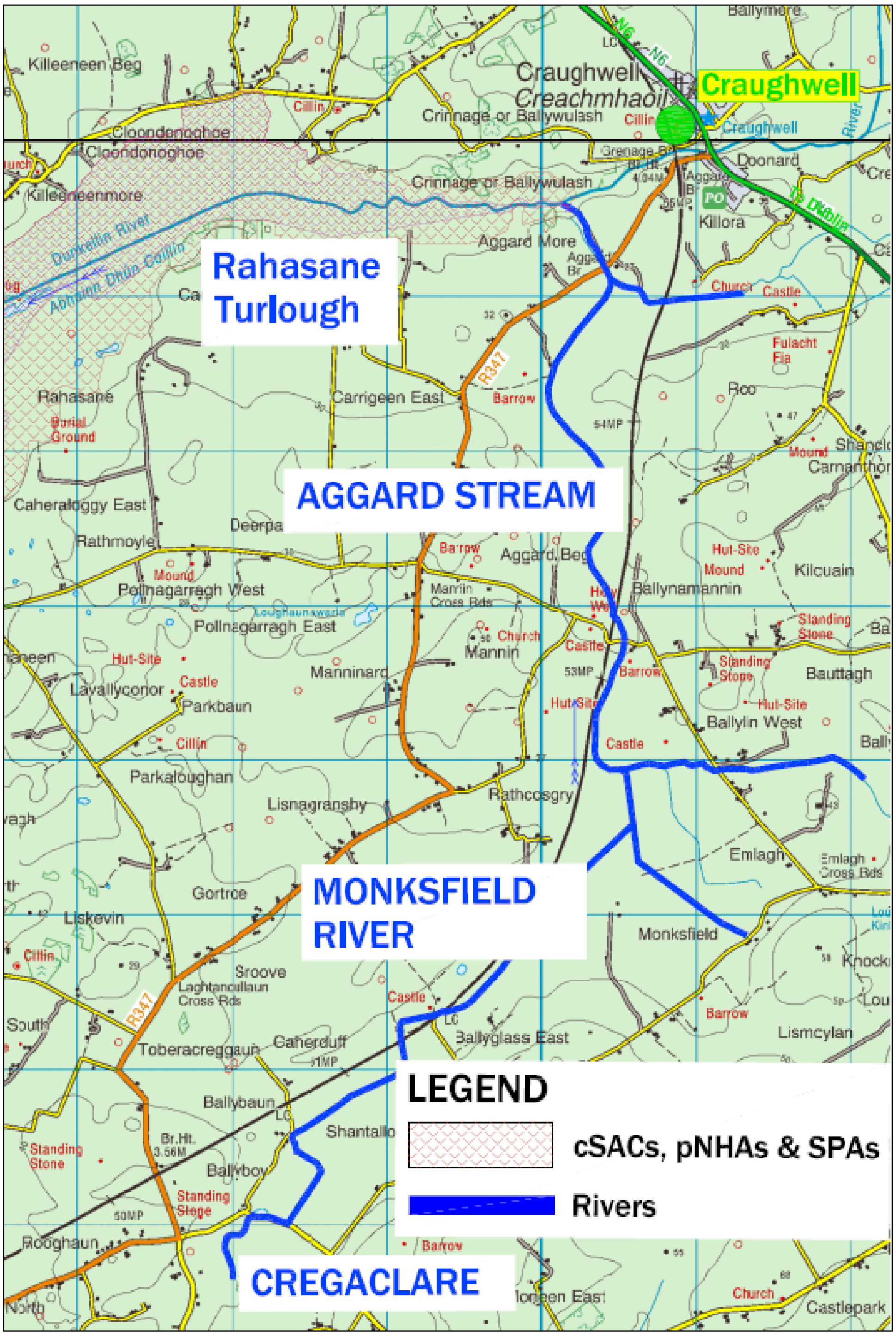


Figure 1-7 – Aggard Stream & Monksfield River

The bed profile and right/left bank levels along the Aggard Stream and Monksfield River from the townland of Cregaclare to the Dunkellin River are shown in Figure 1-8.

Along this channel, the bed profile ranges from a level of 32.5mOD (Malin Head) in its upper reaches, in the townland of Cregaclare, to 16.6mOD at the confluence with the Dunkellin River approximately 1km downstream of Craughwell.

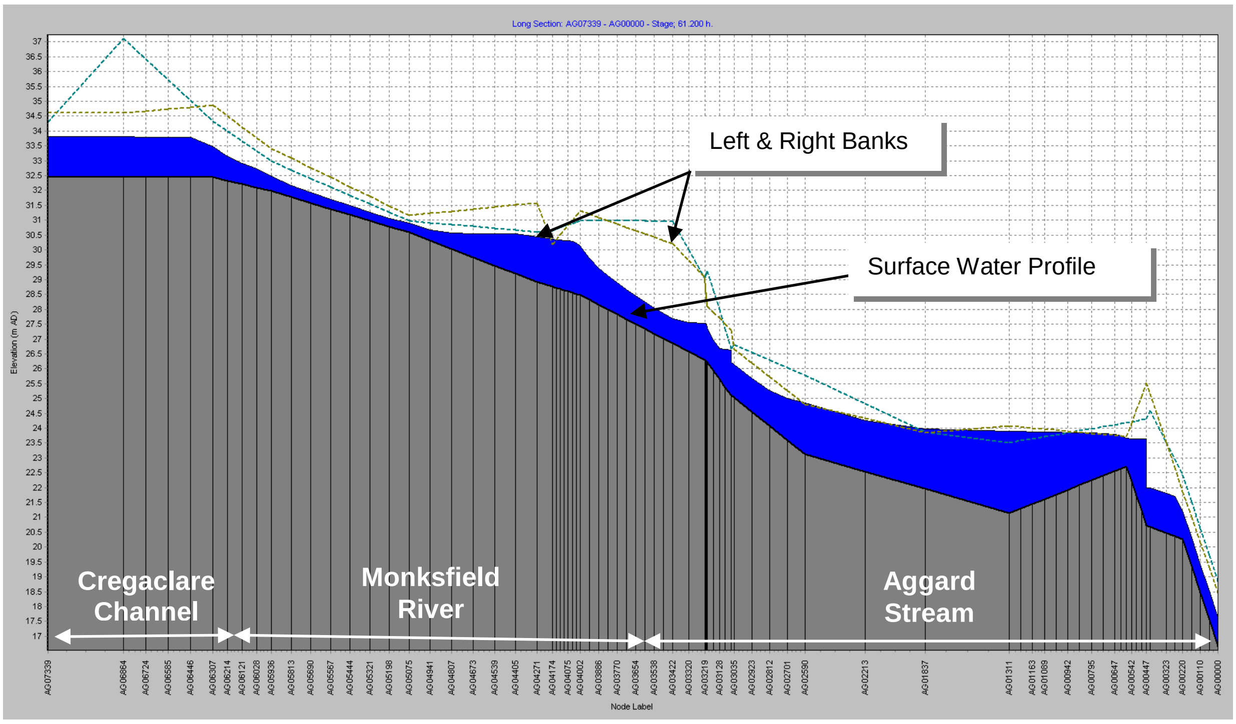


Figure 1-8 – Long Section of the Aggard Stream

The base width and side slopes of the Monksfield River and Aggard Stream are quite variable throughout its length.

In its upper reaches, along the Cregaclare Channel, the width of the stream is relatively narrow with some sections being 2.0 to 2.5m wide where the water depth is also quite shallow and stagnant as a result of the very flat gradient in bed level.

Along this stretch of the channel, field boundaries and local access crossings, as shown in Photographs 11 and 12, also impede the flow in the channel.

Photograph No. 11
Typical Boundary Crossing along the Aggard Stream in Cregaclare

Note : boundary wall traverses the channel without any pipework crossing to improve conveyance

Photograph No. 12
Typical Field Crossing along the Aggard Stream in Cregaclare

Dense weedy growth is also a significant feature of the upper reaches of this channel

Downstream of the Cregaclare Channel, in the townland of Ballyglass and Monksfield, the channel width becomes more pronounced and is typically 3.0 to 5.0m. The bed profile also steepens to a gradient of approximately 1 in 500. Along this stretch of the Monksfield River, the hydraulic control features are also more defined with concrete culverts and stone arch bridges used to traverse the railway line.

2 OVERALL DESIGN PHILOSOPHY

2.1 NEED FOR THE PROPOSED SCHEME

One of the most recent, and prior to November 2009, the highest recorded flooding event on the Dunkellin River, recorded by the gauging station in Craughwell (Station No. 29007), took place on the 10th of January 2005.

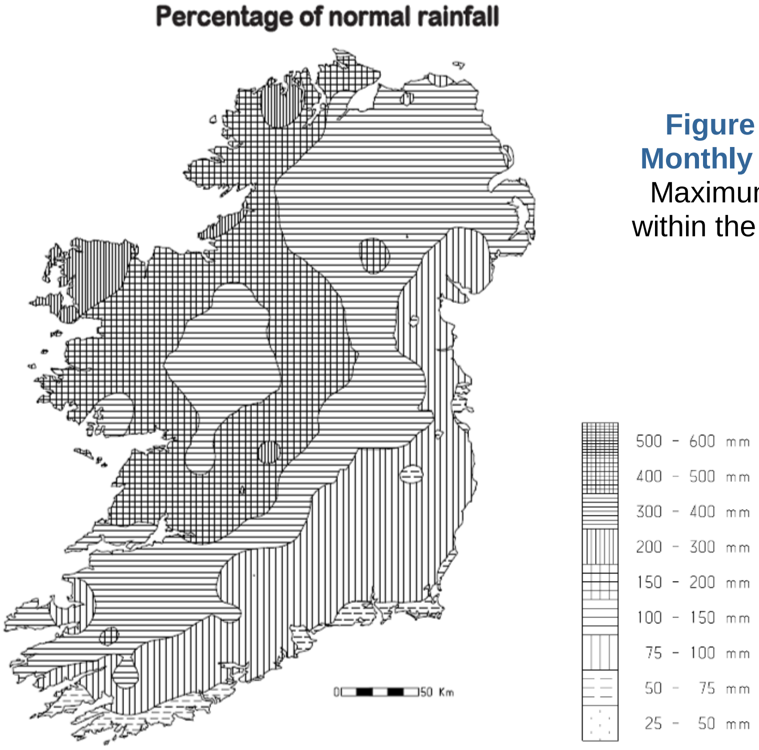


Figure 2-1 Extract from Met Eireann Monthly Weather Bulletin January 2005
Maximum Recorded Percentage Rainfall within the Dunkellin catchment ranged from 100% to 150%

The maximum level recorded on 10th January 2005 corresponded to a staff gauge reading of 2.83m, or a water level of 21.53mOD Malin Head.

Digital records, along with aerial photography for this flooding event, were documented by the OPW and the following photographs highlight some of the flooded lands, to the west of Craughwell, a number of days after the event has passed.

Photograph No. 13 January 2005 Event looking downstream to the west of Craughwell towards the Rahasane Turlough on 12th Jan 2005

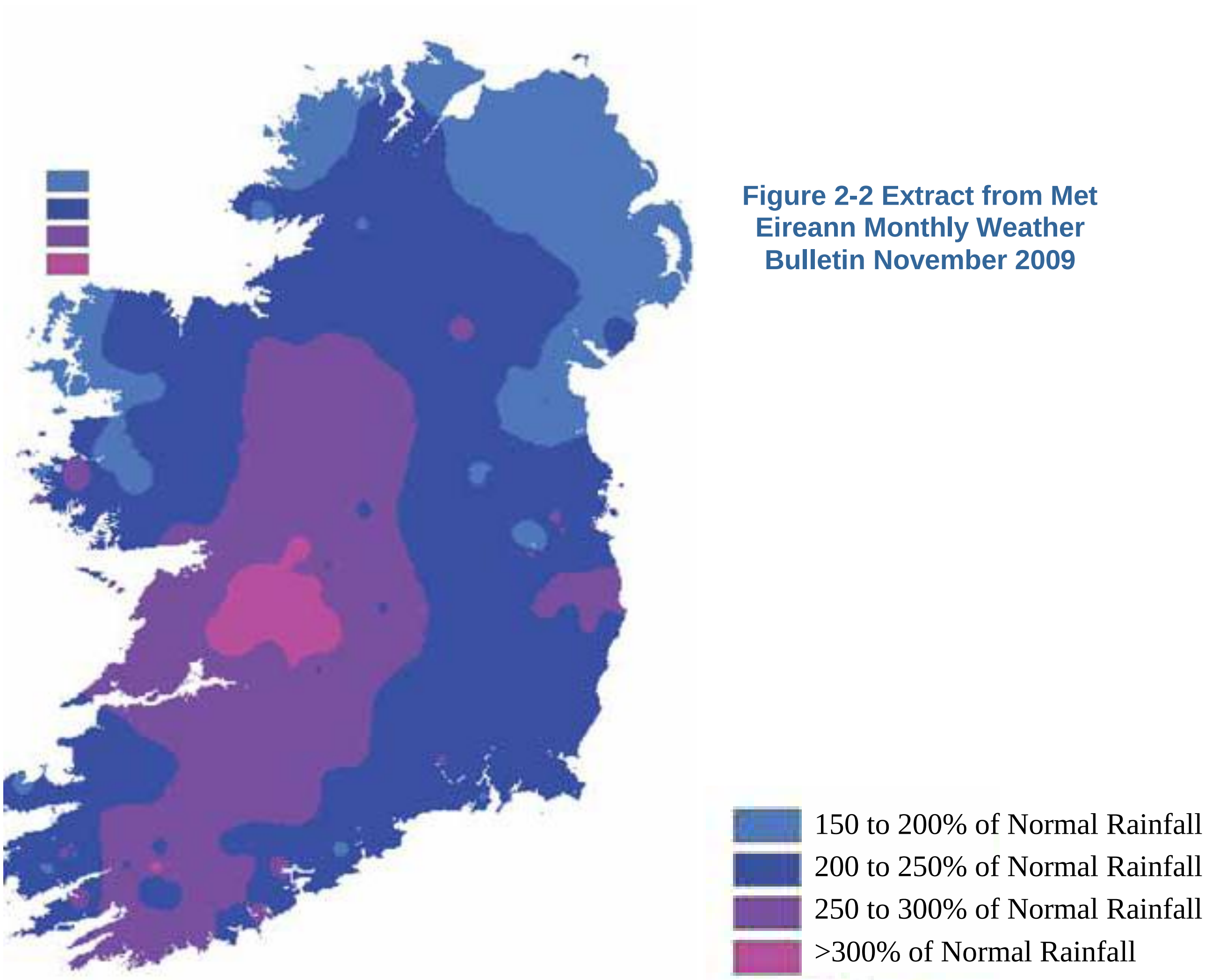
**Photograph No. 14
January 2005 Event
looking upstream towards
Craughwell from the
Rahasane Turlough on 12th
Jan 2005**

The width of the flood at this location was approximately 375m

A number of weather events occurred across Ireland, during the first three weeks of November 2009, which resulted in record rainfall and high water levels being recorded in many parts of Galway. The flooding which occurred at Craughwell, and downstream at Rinn Bridge, Dunkellin Bridge and Killeely Beg Bridge, was as a result of several days of persistent rain over the country which, when combined with high winter water tables, resulted in water levels which exceeded those normally encountered in many rivers during the same period.

During November 2009, the weather station at NUI Galway recorded a monthly total of 329.4mm of rain, which represents 286% of the average November rainfall for the period 1961 to 1990. Leading up to this flooding, a peak daily rainfall of 60.8mm was recorded at NUI Galway on the 17th November 2009.

Figure 2-2 Extract from Met Eireann Monthly Weather Bulletin November 2009



During the period 17th to 24th November 2009, daily rainfall amounts on Wednesday 19th were recorded as 26.7mm and 29.4mm at the Shannon and Claremorris Weather Stations, respectively, but based on the rainfall data recorded at NUI Galway, it is clear that localised heavier rainfalls occurred in the Galway Area. This peak rainfall was followed by peak flood levels :

d. upstream of Craughwell village along the R349 (Loughrea to Athenry Road) at approximately midday on Thursday 20th November,
e. at the Craughwell River/R446 road crossing during Thursday afternoon (road closed in afternoon resulting in significant traffic disruption), and
f. downstream of Craughwell at Rahasane Turlough during Friday 21st November.

The following photography, taken by the OPW & Central Fisheries Board, during the period Thursday 20th to Saturday 22nd November 2009, shows the extent of flooding which occurred in late November 2009.

Photograph No. 15 Flooding in Craughwell at the Main R446 crossing on 20th Nov 2009

The extent of dwellings flooded, or at risk from flooding, in the village is evident .

Turbulent flow crossing the R446 is also evident in the lower left foreground where both the bypass (lower left) and main N6 bridge crossing (centre) were overtopped.

The R446 (formerly N6) Road was closed for 4 days during this event.

Photograph No. 16 Rahasane Turlough downstream of Craughwell on 23rd Nov 2009

The Kilcolgan Road with ribbon development is visible in the upper portions of the photograph. This road was closed for 10 days during this event and properties were flooded along this stretch of the Dunkellin River

Photograph No. 18
Flooding at Dunkellin Bridge on 23rd Nov 2009

View facing upstream with the Dunkellin Bridge in the centre of the image with a cluster of houses on each of the right and left banks

The Dunkellin Turlough is also visible in the background

Photograph No. 17
Flooding in townland of Killeely Beg on 23rd Nov 2009

The "canalised" Dunkellin River is a straight section of channel in this location. The channel breaks its banks and follows the natural contours of the adjacent lands and ultimately bypasses the Killeely Beg Bridge in the centre of the photo (surrounded by trees).

Note : extent of dwellings flooded, or at risk from flooding, in this location

Following a review of aerial photography of the November 2009 event and by establishing an account of local anecdotal evidence, the estimated flood plain during the November 2009 event can be established. This flood plain is shown in Figure 2-3.

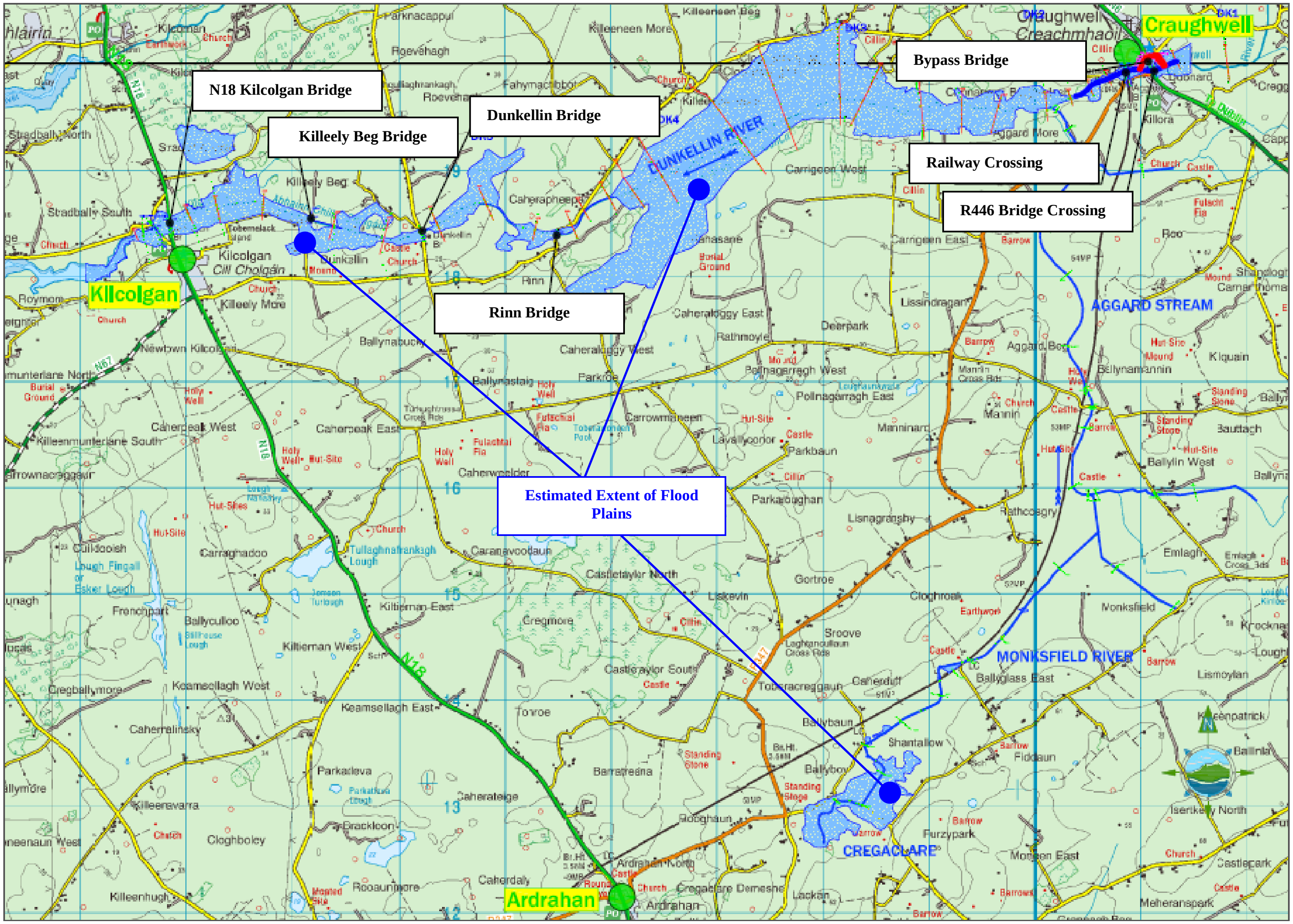


Figure 2-3 – Estimated Flood Plains along the Dunkellin and Aggard Stream based on Photography of the Nov 09 Event and local anecdotal evidence

From the recorded hydrographs of the event, aerial photography, measured wrack levels, direct observation from local residents and the estimated flood plain contained in Figure 2-3 it can be observed that:

1. Flooding upstream of Craughwell along the R349, (Athenry to Loughrea Road) north of Craughwell, occurred in advance of the flooding on the R446 within the village.

2. The R446 road bridges (2 No. flat deck concrete structures and 1 No. old stone arched bridge) are significant hydraulic restrictions, as both the main bridge and the additional "bypass/overflow" were overtopped.

3. The railway bridge, with a smaller effective cross sectional area, is also a significant restriction and an influencing factor on the upstream flooding within Craughwell.

4. The main channel downstream of the railway bridge and upstream of the Aggard/Dunkellin confluence, despite its steep bed gradient is also causing a restriction on flow.

5. The channel exiting the Rahasane Turlough cSAC and the Rinn Bridge have insufficient capacity to cater for this event.

6. The Dunkellin Bridge and Killeely Beg Bridge, and the channel upstream and downstream of these structures, also have insufficient capacity to cater for this event.

These observations, further analysis of the recorded river flow data, possible flood alleviation measures, and the mathematical modelling of these measures are discussed later in this section.

The following aerial photography details a number of locations where dwellings and commercial properties were flooded during the November 2009 event.

Photograph No. 19 Craughwell Village

Three dwellings were flooded in Craughwell, located in the centre of the photo and to the left of the R446 roadway. The R446 was also closed for 4 days during this event.

Two commercial properties were also flooded including the underground car park of the new development in the top left hand portion of the image.

Whilst the dwelling on the right of the photo was not flooded the surrounding gardens were inundated with flood waters.

Photograph No. 20 Rahasane Turlough

A number of properties were flooded at a number of locations along the northern shores of the Rahasane Turlough.

Whilst this image was taken after the flood had subsided, the threat to the Kilcolgan road is evident in this image.

Photograph No. 21 Killeely Beg Townland

A total of five dwellings were threatened by flood waters in the townland of Killeely Beg when the Dunkellin River broke its left bank and travelled along what appears to be the natural contour of an old channel.

2.2 FLOOD RELIEF DESIGN STANDARDS

It is generally accepted by the Office of Public Works (OPW) and Local Authorities that, where possible, a flood relief scheme should accommodate the 100-year design flood.

A significant amount of Hydrometric Data was received from the OPW for several hydrometric gauges within the study area. Figure 2-4 shows the location of the OPW hydrometric stations used in this study. The data consists of:

- Annual maximum series of recorded water levels and estimated flows for the Data Logger Stations, on the Dunkellin Catchment listed above, for the period of records dating from the commissioning of the hydrometric station to January 2010.

- Instantaneous 15 minute water level and flow data for the flood period 01/11/2009 to 15/01/2010 for each hydrometric station listed above, with the exception of Rahasane Turlough Station where the data logger was inundated during the November 2009 flooding event resulting in no data being available beyond 07:30hrs on the 19/11/09.

- Station rating equations and rating periods

The Environmental Protection Agency, Hydrometric Office, Castlebar has also provided data of measured flow for the November 2009 flooding event at Craughwell Station 29007, where measurements were carried out on the 21/11/2009 one day after the peak of that flood event.

The OPW have also undertaken a review of measurement records of the Hydrometric Station at Craughwell (Station No. 29007) and in doing so have considered the quality assurance and accuracy of data presented for this gauge. The mathematical review of the recorded data using both the EV Type I and EV Type II extreme value distributions have shown that due to:

a) partial blockages of the old Craughwell bridge
b) debris blockages
c) reduced conveyance (caused by gravel movements, weed growth, over hanging woody vegetation
d) bridge skew, and
e) bypassing flow (bypass channel)

careful consideration of the return period estimates is required.

In completing the review of the hydrometric data the OPW have estimated that the November 2009 event, at a flow of 84.8 m^3/sec has a return period of 122 years.

The estimated return period floods have also been established by the OPW. These are presented in Table 2-1.

Table 2-1 – Summary

Flow (m3/s)	Return Period (years)	EV1	EV2
28.6	1	-	-
34.0	2	0.37	-
42.0	5	1.50	1.72
49.3	10	2.25	2.77
60.5	25	3.20	4.32
70.3	50	3.90	5.66
81.4	100	4.60	7.16
94.0	200	5.30	8.86
98.4	250	5.52	9.45
113.2	500	6.21	11.45
130.0	1,000	6.91	13.71

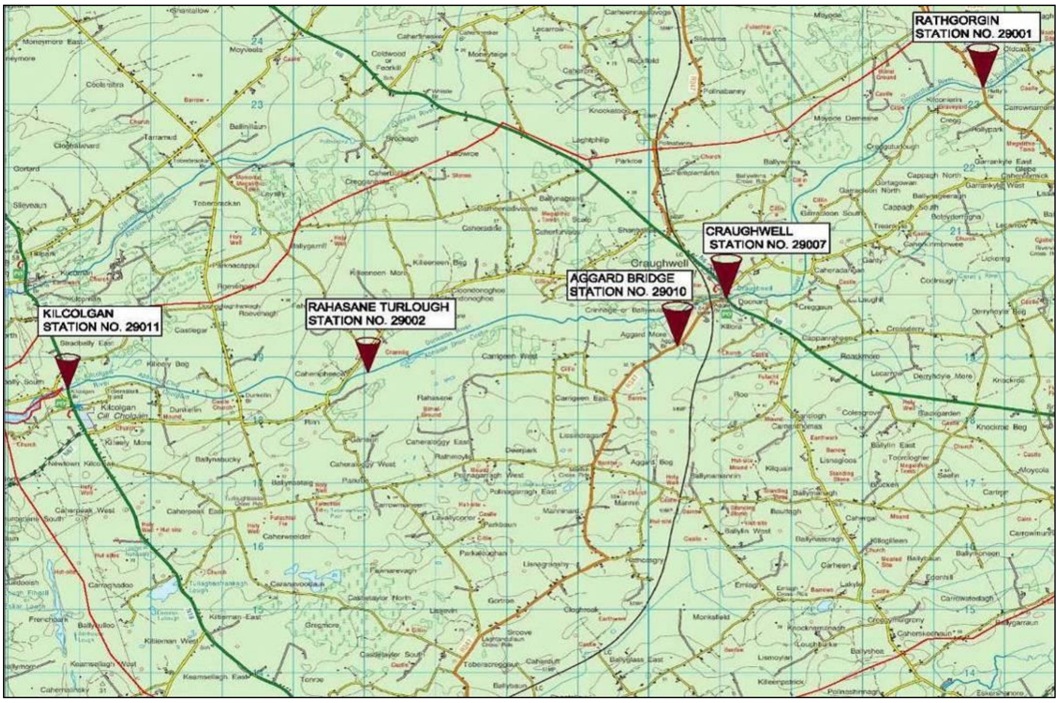


Figure 2-4 – Location of Hydrometric Stations in Dunkellin Catchment

2.3 CLIMATE CHANGE & FUTURE FLOW SCENARIOS

Two broad approaches are considered when implementing a proposed flood relief scheme.

These are:

(1) Design based on historic records

This approach considers historic flood and water level data and while climate change impacts are investigated, no allowance is made for climate change in relevant design parameters.

(2) Design for Climate Change

Designing for climate change is an approach where the level of proposed defences or the size of the proposed channel works are such that future climate change predictions are considered.

Whilst the design of the proposed works along this stretch of the Dunkellin River takes into account a series of environmental river enhancement works, the proposed approach to implementing the Dunkellin & Aggard Flood Relief Scheme is to design for climate change.

The document entitled *"Assessment of Potential Future Scenarios for Flood Risk Management"* and published by the OPW in August 2009 has been reviewed as part of this planning stage design.

This document states that :

"To provide an adequate understanding of the potential implications of the predicted impacts of climate change and other future changes, with due consideration of the significant uncertainty associated with such predictions, the OPW recommends that a minimum of two potential future scenarios are considered."

The two minimum scenarios are referred to as the :

"Mid-Range Future Scenario (MRFS) which it is intended to represent a 'likely' future scenario, based on the wide range of predictions available and with the allowances for increased flow, sea level rise, etc. within the bounds of widely accepted projections."

And

"High-End Future Scenario (HEFS), is intended to represent a more extreme potential future scenario, but one that is nonetheless not significantly outside the range of accepted predictions available, and with the allowances for increased flow, sea level rise, etc. at the upper the bounds of widely accepted projections."

The allowances, in terms of numerical values, for future changes which should typically be used for each of these scenarios, are set out in Table 2-2.

Table 2-2 – Allowances for Future Scenarios (100 year time horizon)

	Mid-Range Future Scenario MRFS	High-End Future Scenario HEFS
Extreme Rainfall Depths	+ 20%	+ 30%
Flood Flows	+ 20%	+ 30%
Mean Sea Level Rise	+ 500 mm	+ 1000 mm

In developing the mathematical model for the study area, the Mid Range Future Scenario (MRFS) has been adopted to establish the possible impact that the increases may have on the recommended flood alleviation measures.

The estimated 100 year return flow at each gauging station, the allowance for future scenarios and the November 2009 event are summarised in Table 2-3.

Table 2-3 – Estimated Design Flows used in the development of the Proposed Flood Relief Works

	Craughwell 29007	Aggard Stream 29010
Estimated 100yr Return Flow	81.4 m^3/s	18.00m^3/s
Allowance for Mid-Range Future Scenario	16.28 m^3/s	3.6 m^3/s
Estimated Future Scenario	**97.68 m^3/s**	**21.6m^3/s**
Estimated Peak Flow November 2009 Event	84.8 m^3/s	21.46 m^3/s

2.4 HYDRAULIC MODELLING AND TESTING OF THE PROPOSED FLOOD RELIEF SCHEME

2.4.1 Hydraulic Modelling

The modelling software used for the purposes of this study is HEC-Ras, a 1 dimensional (1D) hydraulic model. The model is based on cross-sections of the water course, surveyed as part of this study and supplemented, where required on a limited basis, with additional cross sectional information from the original OPW Arterial Design which was completed in the mid 1950s. All of the topographical information, particularly level information, is based on the Malin Head datum. The extent of the survey cross sections used in the hydraulic model were determined by analysing the November 2009 flood event and selecting critical locations where flood level information was available from automatic gauging stations and anecdotal evidence from local representatives.

The modelled reach of the Dunkellin River is approximately 10.8km long, and starts approximately 780m upstream of the Main N6 bridge Crossing in Craughwell.

The modelled reach starts with an elevation of approximately 24 m.OD Malin, in Craughwell and ends with an elevation of 0.8 m.OD Malin, in Kilcolgan.

The downstream extent of the model is approximately 125m downstream from the N18 Bridge Crossing at Kilcolgan and this downstream boundary is in a tidal reach. The downstream boundary used in the hydraulic model is a high tide of 2.9mOD.

A number of assumptions have been made with regard to the model build for this study. These are summarised as follows:

- Surface features such as walls, buildings, isolated trees, fences and hedges have not been included in the model. These features may affect flows along the floodplain that are not accounted for in the model.
- Default weir, culvert and bridge loss coefficients have been used.
- All structures included in the model have been assumed to be in good condition and will withstand a flood event without damage.
- The model used in this study is a one-dimensional mathematical model, which has some limitations.
- Roughness co-efficients were based on Manning's 'n' values as derived from Chow (Open-Channel Hydraulics, McGraw-Hill, 1959).
- The hydraulic model was calibrated using the November 2009 event and the depth of water encountered along the river and through the Rahasane Turlough. This event was recorded at the Craughwell & Aggard gauging stations and has also been estimated to be greater than a 1% AEP (i.e., 1 in 100 year return period) event.
- The base model used the flow recorded at the Craughwell gauge as a Q-T (flow-time) input, and compared the model's calculated flow with the recorded flood depths along the channel reaches. The flow recorded at Aggard Bridge was also included in the model build and calibration.

3 DETAILED DESCRIPTION OF THE PROPOSED SCHEME

3.1 INTRODUCTION

Initially, three broad modelling designs or Strategic Schemes were examined in the development of the preferred flood relief scheme and following consultation with key environmental stakeholders a fourth and final “Preferred Scheme” was developed.

The first scheme examined a package of coherent, effective works, which concentrated on channel improvements and reconstruction of those structures whose removal would be essential in an effective scheme of works. This first scheme known as “Strategic Scheme No 1” examined the impact of works associated with :

1. deepening particular lengths of the channel between bridge structures,
2. the use of flood eyes or bypass/over culverts at the Dunkellin Bridge and Rinn Bridge,
3. removal of the old multi-arched stone bridge crossing (pedestrian bridge) in Craughwell, and
4. deepening of the bed level at the Railway Crossing and R446 (formerly N6) bridge in Craughwell Village.

The second scheme known as “Strategic Scheme No. 2” examined the incremental benefit of more extensive bridge replacement, including :

1. the impact of channel widening, in lieu of deepening as examined under Strategic Scheme No.1,
2. the complete replacement of the Killeely Beg and Dunkellin Bridges,
3. the use of bypass culverts at the Railway Bridge in Craughwell,
4. removal of the old multi-arched stone bridge crossing (pedestrian bridge) in Craughwell, and
5. the complete replacement of the bridges on the R446 in Craughwell with larger span structures.

The third scheme known as “Strategic Scheme No. 3” examined the benefit of more extensive main channel deepening (Dunkellin River) in Craughwell and the deepening of the bypass channel in Craughwell, including :

1. the impact of channel widening in the lower reaches of the Dunkellin River at Kilcolgan,
2. the complete replacement of the Killeely Beg Bridge,
3. the provision of flood embankments between Killeely Beg and Dunkellin Bridge
4. the provision of two large bypass culverts at the Dunkellin Bridge,
5. the use of three bypass culverts at Rinn Bridge downstream of the Rahasane Turlough cSAC,
6. channel works downstream of the Rahasane Turlough and upstream of Rinn Bridge,
7. deepening of the main channel at the Railway Bridge in Craughwell, the deepening of the main channel in Craughwell including underpinning of the railway bridge in Craughwell,
8. the deepening of the main channel in Craughwell to facilitate retention, by underpinning, of the old multi-arched stone bridge crossing (pedestrian bridge) in Craughwell, and
9. the deepening of the main channel in Craughwell to facilitate retention, by underpinning, of the bridge crossing on the R446 in Craughwell, and
10. the deepening of the bypass channel in Craughwell to facilitate retention, by underpinning, of the bridge crossing on the R446 in Craughwell.

The fourth scheme known as "Strategic Scheme No. 4" or ultimately the proposed "Preferred Scheme" examined the benefit of the main channel deepening in Craughwell, as detailed in Strategic Scheme No. 3, but reduced the extent of the proposed excavations between the Rahasane Turlough and Rinn Bridge limiting works to out of channel maintenance downstream of the Rahasane Turlough to Rinn Bridge (i.e., trimming back of terrestrial vegetation such as trees and low hanging branches and removal of encroaching vegetation such as brambles and scrub) and bypassing of the Rinn Bridge. The proposed works downstream of the turlough (at Rinn Bridge) have been designed so as to limit the predicted impact on water levels within the Rahasane Turlough.

The hydraulic models of the Strategic Schemes, combined with early public and stakeholder consultation, consultation with Galway County Council and the OPW, indicated that the particular selection of flood alleviation measures, included in "Strategic Scheme No. 4" would produce the "Preferred Scheme".

The proposed works strike a delicate balance at Rahasane Turlough cSAC. Extreme floods would be passed through the Turlough where possible, by limited excavations downstream of the turlough and adaptations at Rinn Bridge, which would deliberately minimise the predicted changes in water levels within the turlough so to maintain the ecologically critical water level range.

The impact of this change in hydraulic control, downstream of the turlough, and the predicted change on normal water depth levels, means that the full benefits of flood relief, expected under "*Strategic Scheme No. 3"* cannot be achieved. The model predicts that the November 2009 flood level of 18.9mOD, within the Rahasane Turlough, will not be reduced and further alternative and localised flood protection measures (subject to consultation with local residents) may be required along the northern shore of the turlough.

The proposed engineering measures, working from the downstream location at the Kilcolgan Bridge on the N18, included in Strategic Scheme No. 4 or the ***"Preferred Scheme"*** and as detailed in Table 3-1, can be summarised across three zones as follows:

Zone 3 – Rinn Bridge to Kilcolgan:

Works to be undertaken downstream of the Rahasane Turlough from the townland of Rinn to the N18 at Kilcolgan.

Zone 2 – Rahasane Turlough:

No works to be undertaken along/within the Rahasane Turlough.

Zone 1 – Craughwell Village:

Works to be undertaken from Craughwell Village to the confluence of the Aggard Stream.

In addition to the engineering measures detailed above, additional works will be undertaken within the river channel to aid the passage of fish up the river. This will involve the construction of river enhancement works. These works will be developed further at detailed design stage through consultation between the Design Team, the Inland Fisheries Ireland, Galway County Council, the OPW and other relevant authorities.

Table 3-1 – Summary of the proposed *"Preferred Scheme" in Zones 1, 2 &3*

Zone	Works item No.	Description of Location	Proposed Scheme
1	1	Main Channel (Craughwell Village)	The main channel shall be deepened from 17.85mOD (35m u/s of the road bridge in Craughwell) to 14.66 mOD (610m d/s of the railway bridge)
	2	R446 Bridge	The channel shall be deepened by approximately 0.6m at the R446 Road Bridge (underpinning of the bridge will be required)
	3	Masonry Arch Pedestrian Bridge	The channel shall be deepened by approximately 0.6m at each arch (underpinning of all arches will be required).
	4	Bypass Channel (Craughwell Village)	The channel shall be graded from an u/s level of 18.5 to a d/s level of 18.0 mOD. (The bypass bridge will require underpinning to match proposed bed levels)
	5	Railway Bridge	The channel shall be deepened by up to 0.75m. (underpinning/scour protection of the railway bridge will be required)
2	6	Works at Rahasane Turlough	It is Not Proposed to Complete any Works within or adjacent to the main body of the Rahasane Turlough cSAC.
3	7	Channel Works at Rinn	A two stage channel typically 20m wide will be constructed from approximately 50m upstream of Rinn bridge to approximately 50m downstream of the bridge. Strictly out of channel maintenance works aimed at the removal of encroachment of terrestrial vegetation, removal of fallen/instream trees, with no dredging and no channelization/arterial drainage works. Terrestrial vegetation along the river banks would be managed (i.e. trimming back of brambles and scrub) rather than being removed.
	8	Works at Rinn Bridge	Three flood eyes will be provided each measuring 3.1m wide x 2.1m deep
	9	Channel Works beginning upstream of Dunkellin bridge to Kilcolgan Bridge	Maintenance works aimed at the removal of encroachment of terrestrial vegetation, removal of fallen/instream trees. Vegetation along the river banks would be managed (i.e. trimming back to 1.0m to 1.5m above high flood levels or top of bank) rather than being removed. Flood relief works will commence approximately 175m upstream of the Dunkellin bridge and consist of the construction of a two stage channel typically 20m wide.
	10	Works at Dunkellin Bridge	In conjunction with localised channel widening to facilitate the proposed bridge works (30m), the flood eyes shall be replaced with 2 new box culverts each measuring 13m wide x 2.3m deep
	11	Channel Works from Dunkellin Bridge to Killeely Beg Bridge	Two stage channel works continue from Dunkellin Bridge to Killeely Beg Bridge with a typical channel width of up to 20m.
	12	Works at Killeely Beg Bridge	In conjunction with localised channel widening to facilitate the proposed bridge works (14m), a new bridge shall be provided with an 18m span and a soffit level of 7.80 mOD.
	13	Salmon Counter	The salmon counter will be relocated to a position upstream of Kileely Beg bridge as part of the river enhancement works
	14	Channel Works from Killeely Beg Bridge to the N18 Bridge	Two stage channel works will continue from Killeely Beg to the N18 Bridge with a typical channel width of up to 20m. From a distance of 400m upstream of the N18 Bridge the two stage channel will be tapered back to match existing channel widths.
	15	Works at Kilcolgan & N18 Bridges	No Works Proposed

3.2 PROPOSED WORKS DOWNSTREAM OF THE RAHASANE TURLOUGH CSAC (ZONE 3)

3.2.1 Works Item No. 15 – Works At Kilcolgan Bridge

It is not proposed to undertaken any engineering measures at the Kilcolgan Bridge on the N18.

3.2.2 Works Item No. 14 – Channel Works from Killeely Beg Bridge to the N18 Bridge

The proposed works from upstream of the Kilcolgan Bridge at the N18 (Chainage 956m) to Killeely Beg Bridge (Chainage 1,529m) will consist of two-stage channel works whereby the top width of the channel will be increased from an average of 14m to a proposed average width of 34m. A 500m long embankment shall also be constructed on the left bank, from Killeely Beg Bridge with a maximum height of 3.0m above existing ground level. The proposed works will not involve excavation within the existing channel (in river works) and it is not proposed to alter the existing bed levels. This method of construction means that average annual flow can be contained within the existing channel and excavation can be undertaken along the bank with minimal interference to the water quality.

Maintenance works aimed at the removal of encroachment of terrestrial vegetation, removal of fallen trees and other obstacles will be undertaken along the river bank where flood relief works are not undertaken. Terrestrial vegetation along the river banks would be managed (i.e. trimming back to 1.0m to 1.5m above high flood levels) rather than being removed.

However, while it is proposed to undertake excavations along the left bank of the Dunkellin River, and that these works can be undertaken in dry bank conditions, such excavations have the potential to impact on the water quality of the river whereby silt may enter the river. This risk can be reduced or eliminated by operating in the dry conditions along the river bank.

Figure 3-1 provides an illustration of a typical cross section of the works to be undertaken along this section of the Dunkellin River.

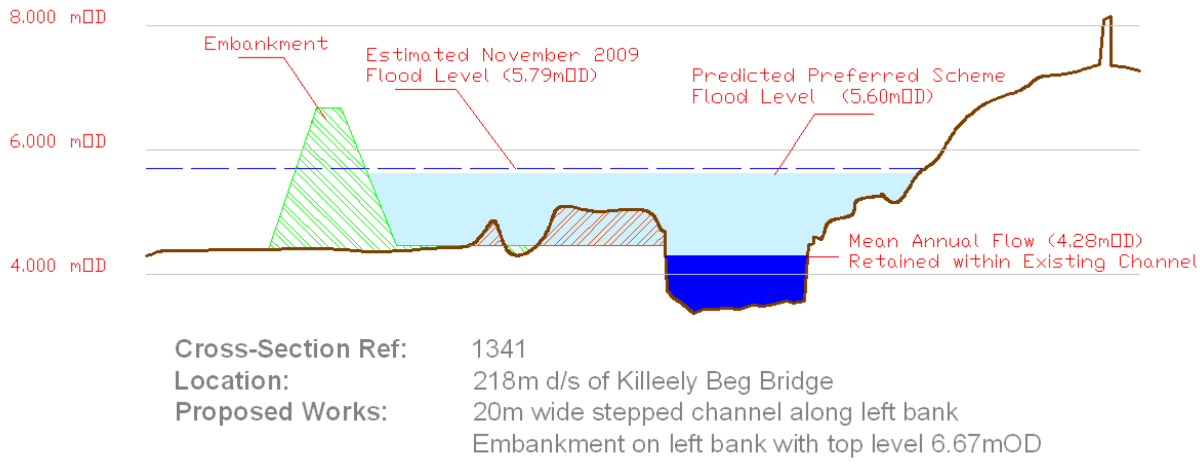


Figure 3-1 – Typical Cross Sectional Detail downstream of Killeely Beg Bridge

3.2.3 Works Item No. 13 – Relocation of the existing Salmon Counter

The existing salmon counter, shown in Photographs No. 22 and 23, is impacting on the high level water surface profile in the vicinity of Killeely Beg Bridge and is resulting in high water levels upstream of the bridge. Following consultation with the Inland Fisheries Ireland and other local parties, it is proposed to relocate this structure to a location upstream of the Killeely Beg Bridge. The proposed structure will be similar in all aspects to the existing concrete structure.

Photographs No. 22 and 23
Existing Salmon Counter

It is proposed to replicate the existing structure at a location upstream of the Killeely Beg Bridge. Note : change in depth of flow at this structure

The proposed salmon counter will be constructed in cast-insitu concrete and this will be undertaken in two halves, utilising cofferdam type construction whereby flow can be restricted to one half of the channel width allowing the civil engineering works to be undertaken in the dry conditions of the other half. This method of construction reduces the risk of wet concrete and other construction debris entering the river.

3.2.4 Works Item No. 12 – Works at Killeely Beg Bridge

Engineering works in the townland of Killeely Beg will include the complete replacement of the existing stone arched bridge. The existing bridge is approximately 8.2m wide and is a hydraulic constraint causing flooding upstream of the existing bridge.

It is proposed to replace this existing structure with a new bridge with a clear span of up to 18m and the proposed indicative bridge works are illustrated on Figure 3-2.

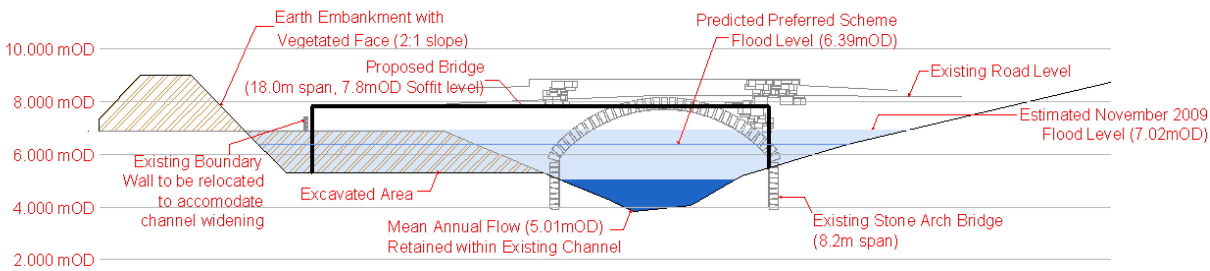


Figure 3-2 – Proposed Works at Killeely Beg Bridge

It is expected that the new bridge will be constructed from precast bridge beams resting on new concrete abutments on each river bank. It is also proposed to retain stone from the existing facades to construct the parapets of the proposed precast bridge.

The works will require the closure of the existing access road which is utilised for land access only and traffic disruption will be minimal. The proposed channel widening and bridge works will also require the realignment of the existing access road where suitable excavated material from the channel works can be utilised as fill material.

3.2.5 Works Item No. 11– Channel Works from Dunkellin Bridge to Killeely Beg Bridge

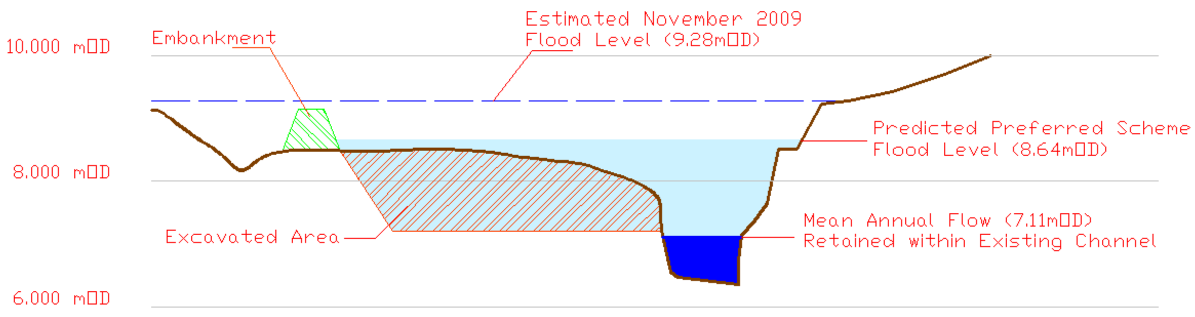
The proposed works from the Killeely Beg Bridge (Chainage 1,566m) to Dunkellin Bridge (Chainage 2,628m) will again consist of two-stage channel works whereby the top width of the channel will be increased from an average of 13m to a proposed width of 35m. The proposed works will not involve excavation within the existing channel (in river works) and it is not proposed to alter the existing bed levels. This method of construction again means that average annual flow can be contained within the existing channel and excavation can be undertaken along the bank with minimal interference to the water quality.

It is also proposed to construct an embankment on the left bank to a height above the predicted flood level. This flood embankment and two stage channel works will control and contain the extent of floodwater which had previously bypassed Killeely Beg Bridge (November 2009) and flooded numerous properties in Killeely Beg. It is proposed to use excavated material to form the embankment where possible.

However, while it is proposed to undertake excavations along the left bank of the Dunkellin River, and that these works can be undertaken in dry bank conditions, such excavations have the potential to impact on the water quality of the river whereby silt may enter the river. This risk can be reduced or eliminated by operating in the dry conditions along the river bank.

Maintenance works aimed at the removal of encroachment of terrestrial vegetation, removal of fallen trees and other obstacles will be undertaken along the river bank where flood relief works are not undertaken. Terrestrial vegetation along the river banks would be managed (i.e. trimming back to 1.0m to 1.5m above high flood levels) rather than being removed.

Figure 3-3 provides an illustration of a typical cross section of the works to be undertaken along this section of the Dunkellin River.



Cross-Section Ref:	2286 (Adjacent to DK31)
Location:	334m d/s of Dunkellin Bridge
Proposed Works:	20m wide stepped channel along left bank Embankment on left bank with top level 9.14mOD

Figure 3-3 – Proposed Works Channel Works from Killeely Beg Bridge to Dunkellin Bridge

3.2.6 Works Item No. 12 – Works at the Dunkellin Bridge

Engineering works in the townland of Dunkellin will include the provision of bypass culverts to one side of the existing main stone arch. The existing structures at this location consist of a stone arched bridge spanning the main channel with five flood eyes located along the left bank of the channel. The existing flood eyes are insufficiently sized to cater for predicted flood flows and as such it is proposed to provide two new bridge structures each with a clear span of 13m and both located on the left bank. The construction of the proposed structures will require demolition of the existing flood eyes on the left bank and it is proposed to retain stone from the existing facades to construct the parapets of the proposed precast bridges.

The proposed indicative bridge works are illustrated on Figure 3-4.

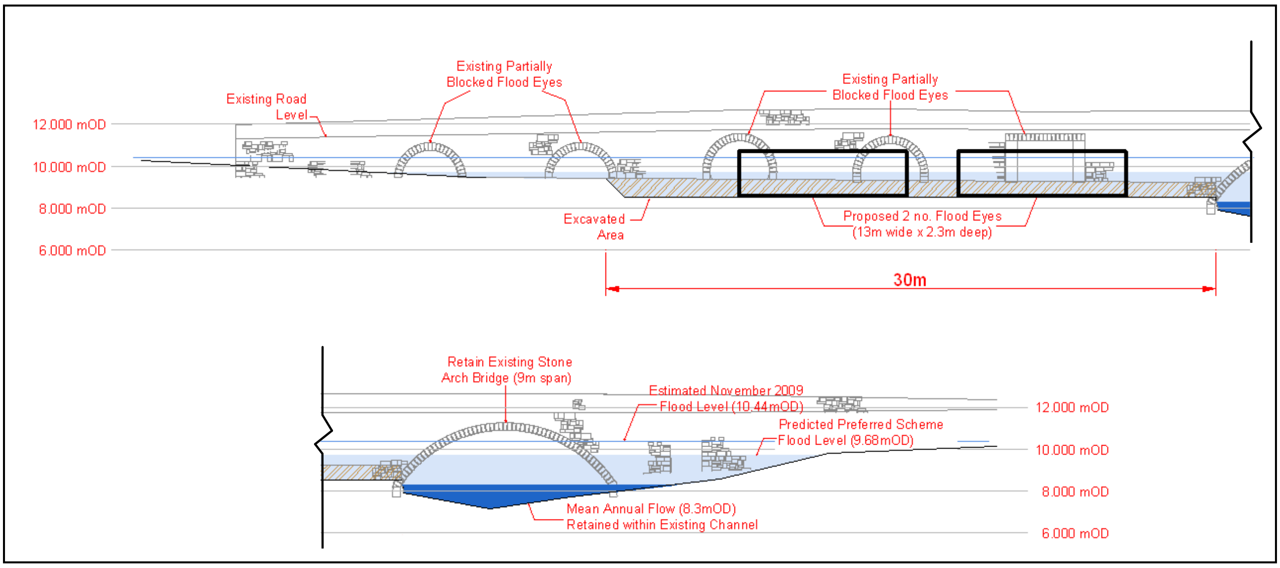


Figure 3-4 – Proposed Works at the Dunkellin Bridge

It is expected that the new bridge structures will be constructed from precast bridge beams resting on new concrete abutments.

The works will require the closure of the existing public road and therefore traffic disruption will be encountered. However road diversions can be put in place on the northern approaches at Roveagh and along the southern approaches at Madden's Forge with local access, to the northern and southern sides of the river, being maintained throughout the works.

3.2.7 Works Item No. 9 – Channel Works from the Dunkellin Bridge to Rinn Bridge

The proposed works from the Dunkellin Bridge (Chainage 2,634m) to Cross Section 3053 (419 metres upstream) will again consist of two-stage channel works whereby the top width of the channel will be increased from an average of 15m to a proposed width of 37m. The proposed works will again not involve excavation within the existing channel (in river works) and it is not proposed to alter the existing bed levels.

This method of construction again means that average annual flow can be contained within the existing channel and excavation can be undertaken along the bank with minimal interference to the water quality.

However, while it is proposed to undertake excavations along the left bank of the Dunkellin River, and that these works can be undertaken in dry bank conditions, such excavations have the potential to impact on the water quality of the river whereby silt may enter the river. This risk can be reduced or eliminated by operating in the dry conditions along the river bank.

Figure 3-5 provides an illustration of a typical cross section of the works to be undertaken along this section of the Dunkellin River.

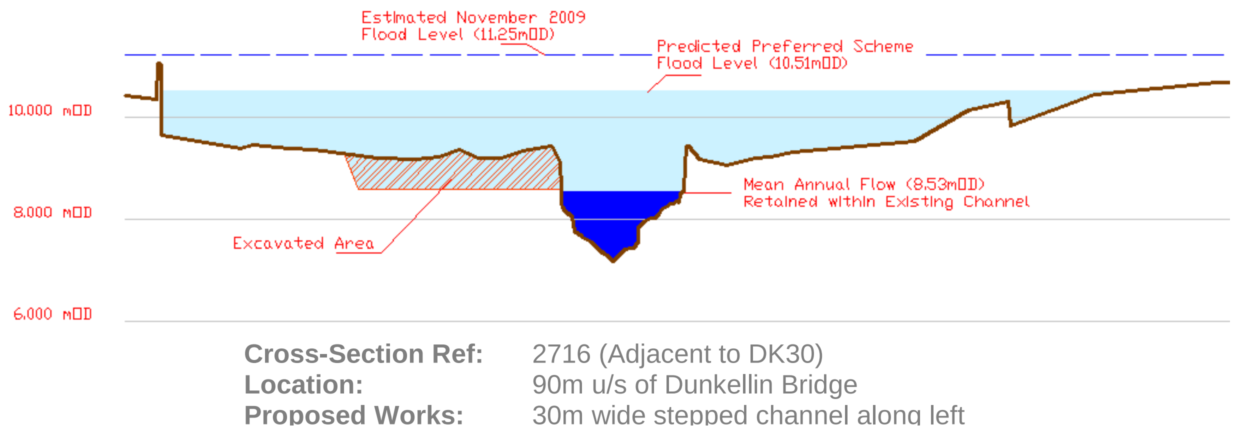


Figure 3-5– Proposed Works Channel Works from Dunkellin Bridge to Rinn Bridge

3.2.8 Works Item No. 8 – Works at Rinn Bridge

Engineering works in the townland of Rinn will include the provision of three bypass culverts on the left bank of the existing main concrete bridge. The existing structure at this location consists of a concrete flat deck bridge spanning the main channel with a single support located in the centre of the existing channel. It is not proposed to undertake any works on the existing bridge as the bed level of this bridge is considered to be a significant factor in controlling the water levels in the Rahasane Turlough cSAC. It is however proposed to provide three precast by pass culverts on the left bank of the existing channel. The culverts will consist of three precast concrete units measuring 3.1m wide by 2.1m high.

The proposed indicative bridge works are illustrated on Figure 3-6.

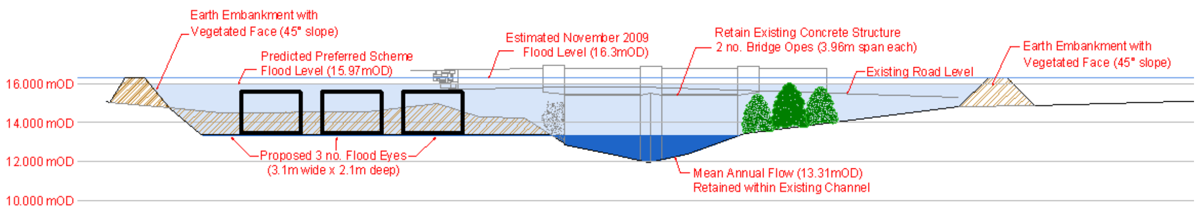


Figure 3-6 – Proposed Works at the Rinn Bridge

The construction of the proposed structures will require excavation of the existing road and will therefore require the closure of the existing public road and traffic disruption will be encountered.

However road diversions can be put in place on the northern approaches at Craughwell and along the southern approaches at Rinn and Madden's Forge with local access, to the northern and southern sides of the river, being maintained throughout the works.

3.2.9 Works Item No. 7 – Channel Works at Rinn Bridge

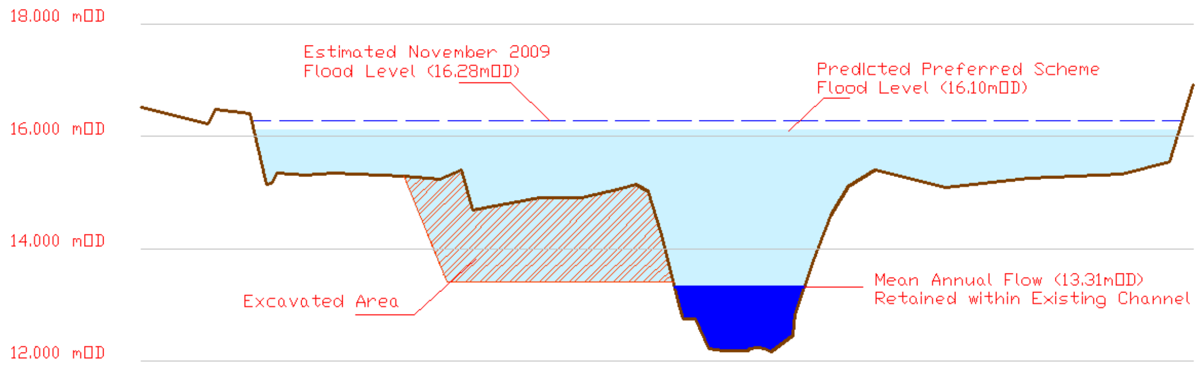
The proposed works at Rinn Bridge also include for the construction of two stage channel works for a distance of approximately 50m upstream and downstream of the bridge whereby the top width of the channel will be increased from an average of 21m to a proposed width of 41m. The proposed works will again not involve excavation within the existing channel (in river works) and it is not proposed to alter the existing bed levels. It is proposed to limit the extent of excavation in this section of channel to a maximum of 50m upstream of the bridge but also avoid excavation within the existing channel, so as to provide a natural hydraulic control for water levels in the turlough.

Strictly out of channel maintenance works aimed at the removal of encroachment of terrestrial vegetation, removal of fallen trees will be undertaken along the river bank where flood relief works are not undertaken. Terrestrial vegetation along the river banks would be managed (i.e. trimming back to 1.0m to 1.5m above high flood levels) rather than being removed.

However, while it is proposed to undertake excavations along the left bank of the Dunkellin River, and that these works can be undertaken in dry bank conditions, such excavations have the potential to impact on the water quality of the river whereby silt and other construction debris may enter the river. This risk can be reduced or eliminated by operating in the dry conditions along the river bank.

These proposed works will not enter the Rahasane Turlough cSAC.

Figure 3-7 provides an illustration of a typical cross section of the works to be undertaken at Rinn Bridge.



Cross-Section Ref:	4069 (Adjacent to DK26)
Location:	2m u/s of Rinn Bridge
Proposed Works:	20m wide stepped channel along left bank

Figure 3-7 – Proposed Works Channel Works from Rinn Bridge to the Rahasane Turlough

3.3 THE RAHASANE TURLOUGH CSAC (ZONE 2)

3.3.1 Item No. 6

Following development of Strategic Scheme No. 3, where channel deepening within the environs of Craughwell and channel & bridge widening downstream of the Rahasane Turlough were considered, it was found that proposed works would have an impact on the normal depth ranges of water within the turlough. This impact was thought to be environmentally significant and have the potential to impact on the normal hydrological and thus ecological regimes within the turlough. A fourth scheme, “Strategic Scheme No. 4” was therefore considered.

This fourth scheme considered the use of flood embankments or walls along the shore of the turlough without the need to change the depth of flooding within the turlough.

While offering flood protection on a theoretical basis, this proposal may not:

1. provide the necessary flood protection (from the Rahasane Turlough) due to the variable karstic nature of the bedrock in the region and the unpredictable potential movement of water beneath the flood protection wall or embankment (bringing a risk of “burst up” due to differential pressure of approximately 2.2m head across the wall), and

2. allow the drainage of surface/ground water, from lands along the northern boundary of the water body, behind the proposed wall, into the Rahasane Turlough, to occur naturally. This movement of water may be due to surface water flow or ground water movement in rock fissures or other unknown karstic features. Attempts to detail flexible pinch valves/flap valves to permit unidirectional drainage from behind the wall are unsound from a flood protection viewpoint, because such valves inevitably become blocked by debris in a partly open position.

Considering these risks the construction of flood embankments or walls in this karstic region were not considered viable and are therefore not proposed. However, the Craughwell to Kilcolgan Road and properties along the northern shore of the turlough will continue to be at risk of flooding during the extreme design flood events.

3.4 PROPOSED WORKS UPSTREAM OF THE RAHASANE TURLOUGH (ZONE 1)

3.4.1 Works Item No. 1 – Channel Deepening from the Aggard Stream to Craughwell Village

The proposed works, from a location approximately 600 metres downstream of the Railway Bridge in Craughwell (Chainage 9,426m) to a point 35m upstream of the R446 Road Bridge in Craughwell (Chainage 10,373m), will consist of channel regrading whereby the existing bed level will be lowered by 1.0 to 1.5 m over an approximate length of 950m. A summary of these works is given in Table 3-2. The proposed works will involve excavation within the existing channel (in-river works) and as such have the potential to impact on water quality in the area.

Table 3-2 – Craughwell channel works

Chainage	Location	Proposed Works
9426	Approximately 600 m downstream of Railway Bridge	Deepen Channel to 14.66 m.O.D. using side slope of 1:2
9426-10037	Downstream of Railway Bridge	Grade Channel from 14.66 m.O.D. to 16.83 m.O.D.
10037	Railway Bridge	Deepen Channel to 16.83 m.O.D. using side slope of 1:2
10037-10123	From Railway bridge approximately 127 m upstream	Grade Channel from 16.83 m.O.D. to 17.51 m.O.D.
10123-10373	Craughwell Village	Grade Channel from 17.51 m.O.D. to 17.85 m.O.D.
10373	Approximately 35 m upstream of Craughwell R446 Road Bridge	Deepen Channel to 17.85 m.O.D. using side slope of 1:2

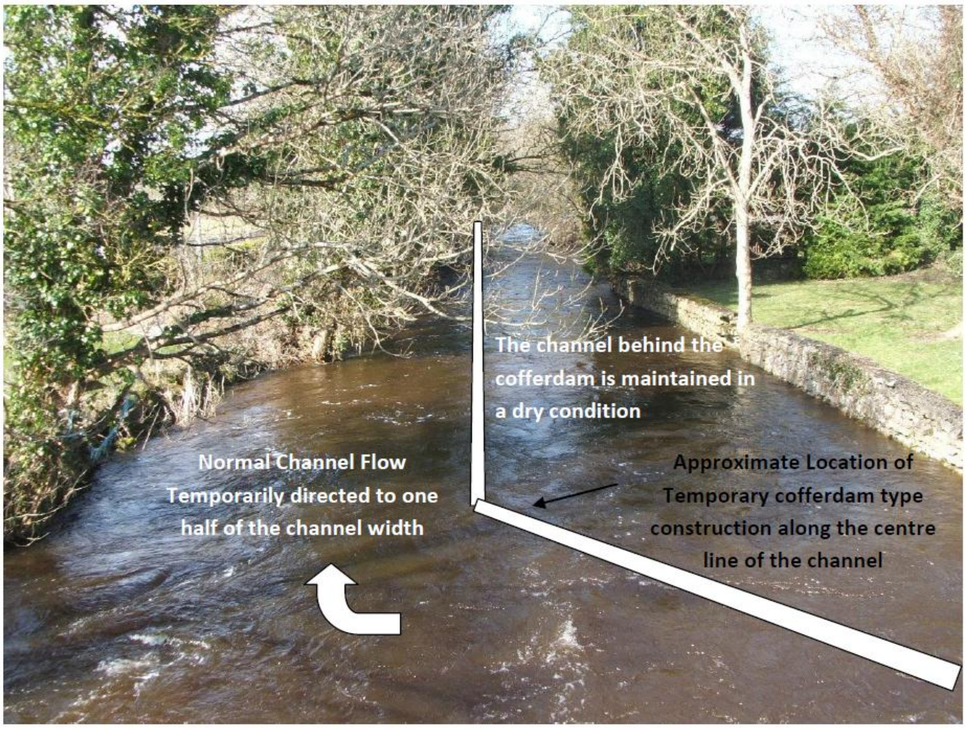


Figure 3-8 provides an illustration of a typical cross section of the works to be undertaken along this section of the river in the vicinity of Craughwell Village.

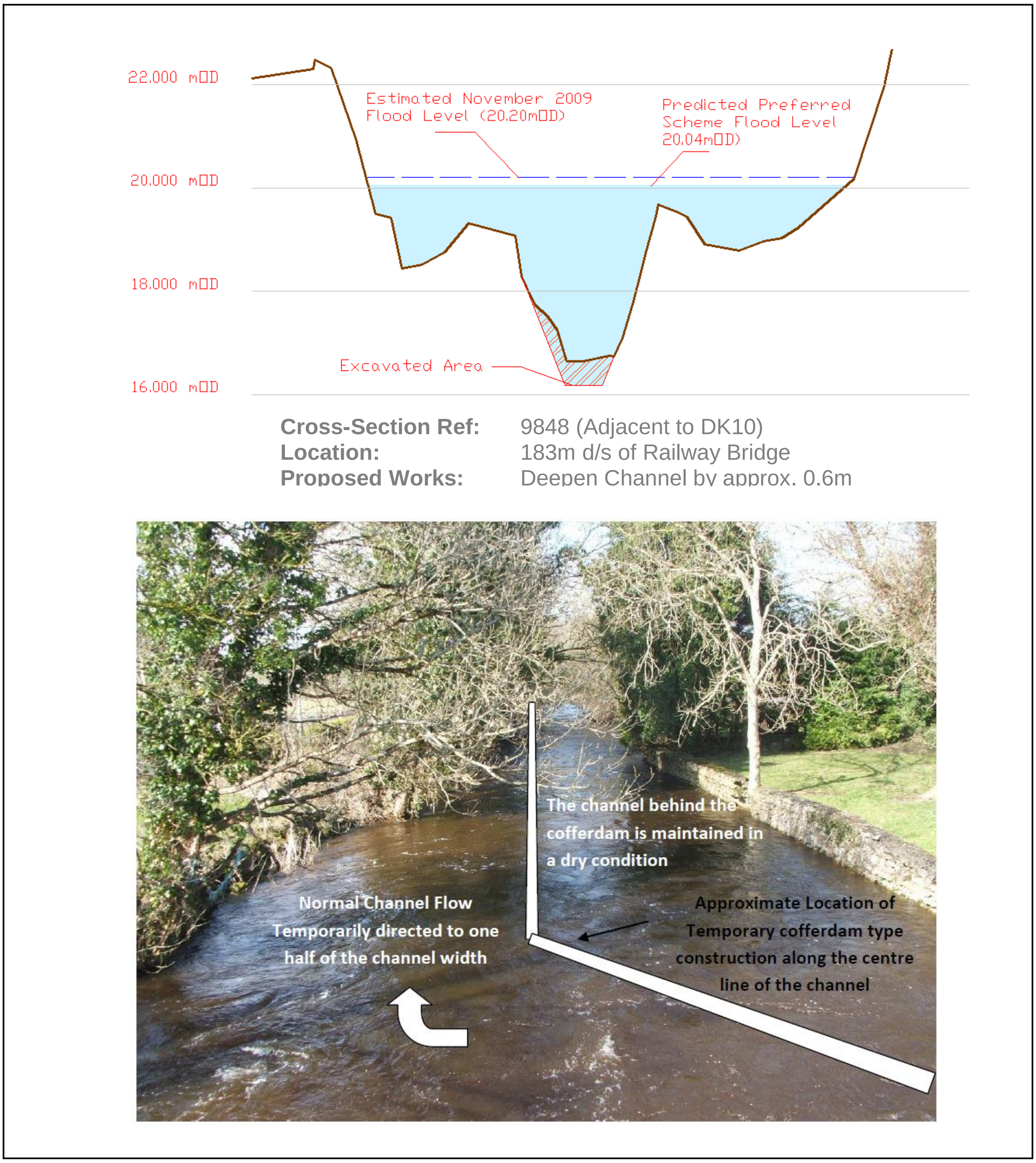


Figure 3-8 – Proposed Works Channel Works in the vicinity of Craughwell Village and sketch of cofferdam location

It is envisaged that excavation of the channel in this location will be dependent on the phasing of works along the bypass channel, low flow conditions in the river and the extent to which flow in the river can be diverted or restricted to one half of the existing channel. In addition it is also proposed to retain existing bankside trees (if healthy and suitable for retention) provided that their retention does not pose a concern with regard to the safe construction of the works, safe recreational use of the channel and safe maintenance of the channel. It is expected that a qualified arborist will be retained at the detailed design stage to examine and determine the most appropriate trees that can be retained or if necessary make recommendations with regard to the replacement of trees that require removal.

Works associated with channel deepening in the vicinity of the old stone bridge and the bridge crossings of the R446 can be undertaken in dry conditions whereby the bypass channel can be utilised a diversion route once the proposed channel works and underpinning on the bypass channel are complete.

The remaining channel works downstream of the proposed confluence of the bypass channel and the Dunkellin River will be undertaken along the length of the channel in segmented sections using cofferdam type temporary works construction.

It is envisaged that temporary cofferdam type construction or temporary sheet pile walls (with a length of 50 to 100m depending on the depth of water and ground conditions) will be used in the location described in Figure 3-8. This process allows river water to be directed to one half of the channel width allowing the civil engineering works to be undertaken, in relatively dry conditions, on the other side of the channel. Once this half of the proposed channel works is excavated, within the confines of the cofferdam, it is expected that river water will be directed to the new section allowing the adjacent excavations to be completed. This sequence of construction is expected to commence at the lower downstream point of the works and continue upstream in this "*leap-frog*" type construction method. This method of construction reduces the risk of construction debris and silt entering the river.

It is also proposed to store excavated material, such as the natural gravels, boulders and cobbles found on the existing river bed, so that such material can be reused in the development of the river enhancement works. The design of the river enhancement works together with the associated construction works method statements will be the subject of detailed design between Galway County Council, the OPW and Inland Fisheries Ireland upon conclusion of the planning process.

Such river enhancement works along this stretch of the river will aim to restore the natural morphological form (C type) of this channel at the new river bed level and develop a series of riffle, glide and pool structures. This process involves the reintroduction of some excavated material to create weirs or paired deflectors, excavation of pools and the introduction of salmonid spawning beds.

It is also proposed that the river enhancement works will be undertaken in tandem with the main excavations works within each cofferdam enclosure so that the short term impact on ecology is minimised.

3.4.2 Works Item No. 5, 3, and 2 – Works at the Railway Bridge, old multi-arched stone pedestrian bridge and main R446 Bridge in Craughwell

As noted in Section 3.3.1 it is proposed to regrade the main channel in Craughwell from a location downstream of the railway bridge to a location just upstream of the village. The regrading works will include a reduction in bed level in the range of 1.0 to 1.5m over an approximate length of 947m.

This regrading also requires the deepening of the bed level at the three main bridges in Craughwell, namely; the Railway Bridge, the old stone multi-arched pedestrian bridge and the bridge crossing on the R446. This proposed work is shown in Figure 3-9 to Figure 3-11 inclusive. The required depth of underpinning will be as follows:

1) Up to 0.50m of underpinning or scour protection required at the Railway Bridge
2) Up to 0.70m of underpinning at the old stone multi-arched pedestrian bridge and
3) Up to 0.60m of underpinning at the bridge crossing on the R446.

Underpinning or scour protection involves one of two main techniques whereby :

a) material is excavated from beneath the foundations of the existing bridge and replaced with mass concrete. The sequence of work is such that that the stability of the existing structure is not compromised. The work tends to be labour intensive and is normally undertaken in partial but sequential excavations under the bridge abutment.
b) a secant or contiguous piled wall is constructed along the foundation of the existing bridge to allow the deepening or regrading to take place.

It is envisaged that the foundations of the existing R446 road bridge and the stone arched pedestrian bridge will be supported through the use of direct underpinning i.e., item (a) above, where all of the work can be undertaken in the dry when the existing bypass channel is deepened and temporarily used as the main river channel for the duration of the underpinning and channel deepening. The underpinning of these structures will be labour intensive as the works will be undertaken by hand because headroom beneath each bridge soffit is minimal and access for heavy plant is limited.

It is envisaged that the foundations of the existing railway bridge will require scour protection through the use of a secant or contiguous piled wall along each side of the bridge piers or abutments i.e., item (b) above. However, this work will require the use of either a floating barge or construction of a temporary cofferdam to facilitate access to the bridge piers. The use of temporary cofferdams allows the works to be undertaken in two phases, whereby flow can be restricted to one half of the channel width allowing the civil engineering works to be undertaken in the dry conditions which exist within the other half of the channel.

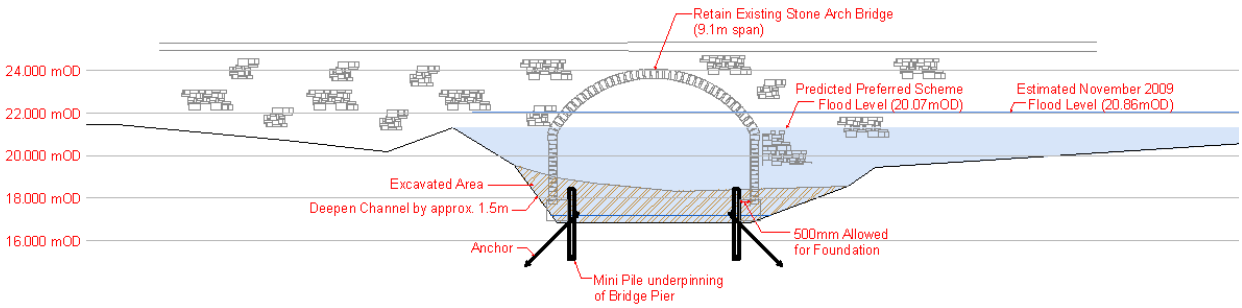


Figure 3-9 – Proposed Works at the Railway Bridge in Craughwell

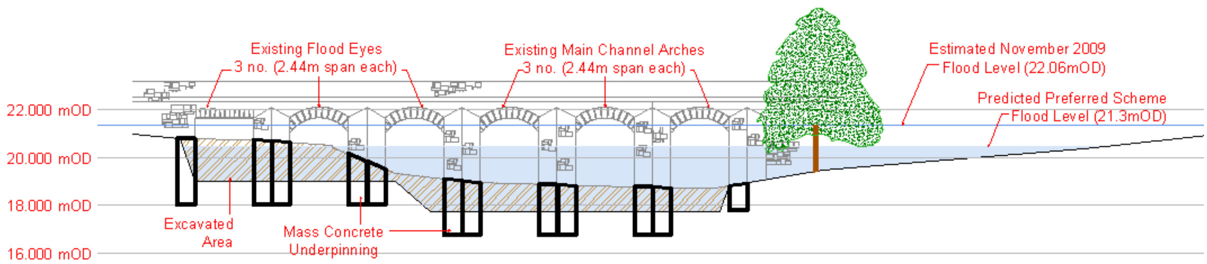


Figure 3-10 – Proposed Works at the Old Pedestrian Bridge in Craughwell

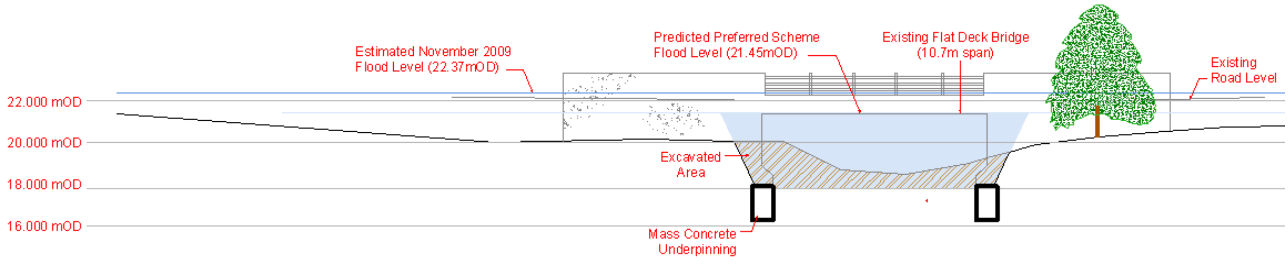


Figure 3-11 – Proposed Works at the R446 Road Bridge in Craughwell

3.4.3 Works Item No. 4 – Works along the By-Pass Channel

It is proposed to regrade the entire length of the bypass channel in Craughwell, from 18.5mOD upstream to 18.0mOD downstream. The regrading works will include a reduction in bed level of approximately 1.5m at the bypass bridge on the R446 road. This deepening will require underpinning of the existing bridge and it is envisaged that this will involve the excavation of material from beneath the foundations of the existing bridge and replacing this with mass concrete. The sequence of work is such that that the stability of the existing structure is not compromised. The work tends to be labour intensive and is normally undertaken in sequential excavations under the bridge abutment.

It is envisaged that this underpinning work can be undertaken in the dry as the bypass channel is normally only utilised when the main channel is in flood. The underpinning of this structure will again be labour intensive as the works will be undertaken by hand because headroom beneath the bridge soffit is minimal and access for heavy plant will be extremely limited.

Figure 3-12 provides an illustration of the works to be undertaken along this section of the bypass channel.

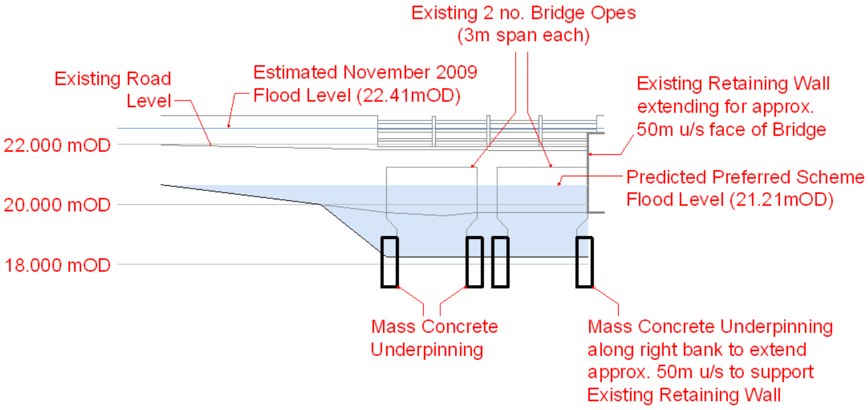


Figure 3-12 – Proposed Works at the By-Pass Channel Bridge in Craughwell

3.5 PROPOSED MAINTENANCE WORKS ALONG THE AGGARD STREAM

The proposed works along the Aggard Stream will consist of culvert replacement works whereby existing blocked and undersized piped crossings will be replaced with larger diameter piped culverts. The proposed works will involve minor localised excavations within the existing stream. The overall proposal for works along the Aggard Stream is to replace blocked culverts (circa 14 No. culverts) with 1500mm diameter precast concrete open jointed pipes.

Photographs No. 24 & 25 provide an illustration of typical culverts which require replacement along the Aggard Stream.

Photograph 24 – Typical Culvert along the Aggard Stream which requires replacement

Photograph 25 – Typical Culvert along the Aggard Stream which requires replacement

The works proposed for the Aggard Stream are minor in nature and consist of maintenance works aimed at the removal of encroachment of vegetation, removal of fallen trees and other obstacles (i.e. gates, minor obstructions, fences in the river poor culvert conveyance etc..), excessive silt deposits and that excavations not include for significant dredging and no channelization/arterial drainage works. Vegetation along the river banks would be managed (i.e. trimming back) rather than being removed, where at all possible.

3.6 ALTERNATIVES CONSIDERED AND OTHER PLANS OR PROJECTS IN THE AREA

3.6.1 Alternatives considered

As noted in Section 3.1 four main strategic schemes were considered during the preliminary design stage of the project. Whilst the fourth scheme includes the preferred scheme flood relief measures, a series of alternative options were considered throughout the study area. These alternatives considered included :

Zone 1 Craughwell Village

a. Pumping of the excess flood river flows was considered at the early stages of the study. Whilst this proved to be an effective technical option the pumps were of a size that did not merit consideration. In addition, the pipework required was also significant in size and the flow velocities had the potential to create a risk of significance ground disturbance at their point of discharge.
b. Whilst demolition of the existing multi-arched stone pedestrian bridge was considered in the initial study, early consultation with statutory bodies indicated that even though the structure was not protected, the bridge was considered to be of archaeological significance and may also be used as a bat roost and as such demolition was not considered to be a viable option.
c. Channel widening of the existing river, within the village of Craughwell, was also considered at an early stage of the study. However, the main hydraulic restriction along this channel reach was the railway bridge. Channel widening would require the construction of a large flood culvert under the railway line. This alternative was not considered to be viable as installation of a large structure would require, for safety & health reasons, closure of the railway line for a significant period of time, a restriction not considered to be possible.
d. The provision of bypass culverts were also considered on each side of the R446 road bridges. However, due to localised access and land acquisition restrictions, the presence of existing utilities such as water mains, gas mains, broadband (fibre optic) facilities, underground power cables and Eircom cabling and the need for road closures on the R446 this option was not considered to be a viable solution.

Zone 2 Rahasane Turlough

a. Channel widening of the existing channel between the mouth of Rahasane Turlough to Rinn Bridge was also considered. Figure 3-13 shows the affect this widening has compared to the preferred scheme, most notably at levels over 15.7m. This alternative scheme is not considered to be viable as it has the potential to reduce the water profile in the Rahasane Turlough cSAC, to levels which would significantly impact on the normal flood regime and therefore impact on the local flora and fauna. This was not considered to be viable as the turlough is a protected habitat and heritage site.

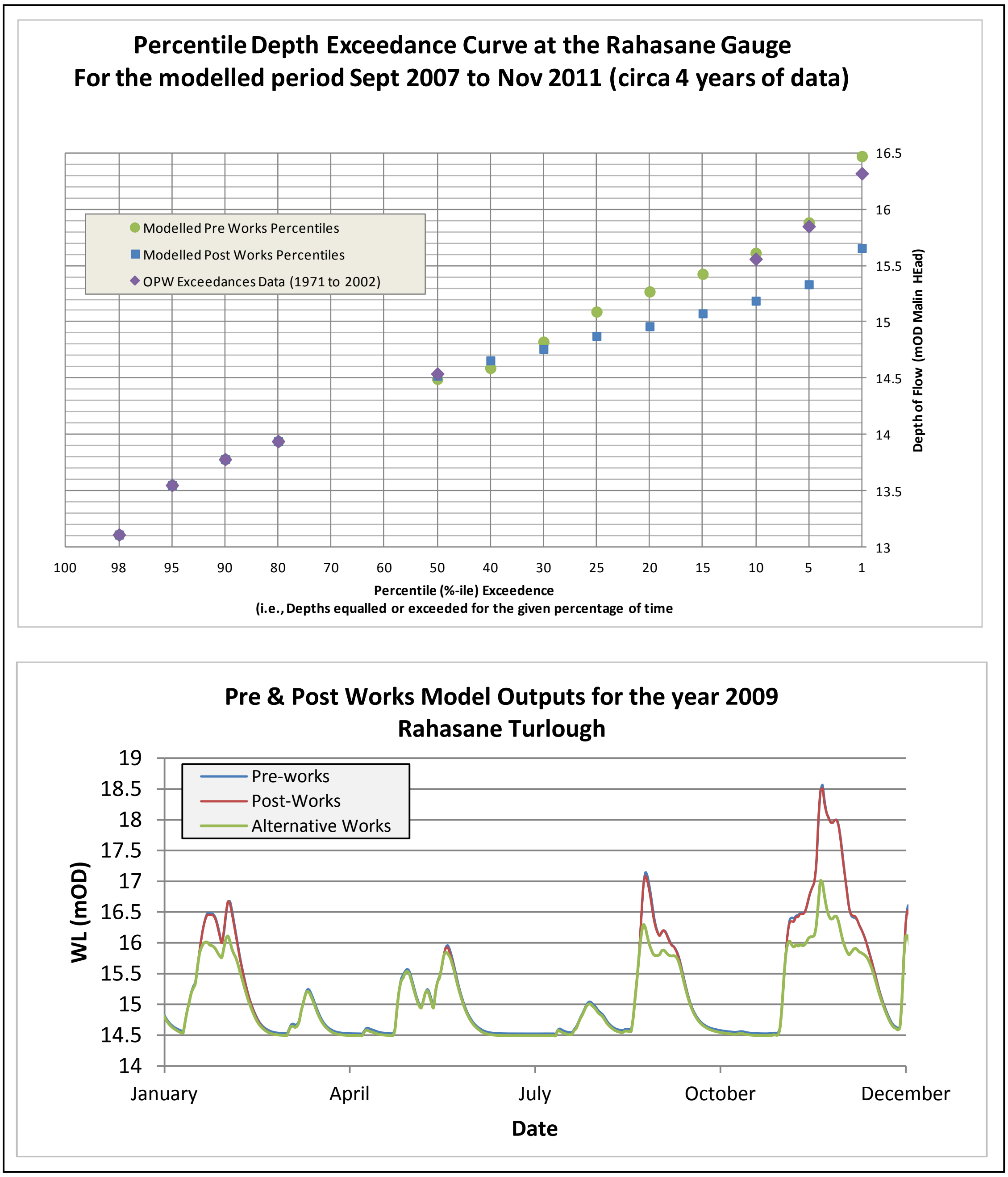


Figure 3-13 – Impact of Alternative Works on the depth ranges in the Rahasane Turlough

Zone 3 Downstream of the Rahasane Turlough to the N18 at Kilcolgan Bridge

a. Channel deepening of the existing river, downstream of the Rahasane Turlough cSAC, was also considered at an early stage of the study. However, the main hydraulic restriction along this channel reach was the water level in the turlough. Channel deepening would result in significant reductions in bed levels throughout this reach of the river. This alternative was not considered to be viable as it has the potential to reduce the water profile in the Rahasane Turlough cSAC, to levels which would significantly impact on the normal flood regime and therefore impact on the local flora and fauna. This was not considered to be viable as the turlough is a protected habitat and heritage site.

3.6.2 Other Plans or Projects in the Area

Work on the construction of new motorway between Gort and Tuam in Co Galway is expected to begin in late 2014/early 2015. The new 57km motorway will consist of a four lane carriageway from Gort in the south to Tuam in the north, and a major junction with the M6 Galway-Dublin route to the east of Galway City. The road will bypass Tuam, Ardrahan, Claregalway, Kilcolgan, Clarinbridge and Gort and the first traffic along the route is expected in 2018. The location of the proposed motorway is detailed on Drawing No's 6408-2201 and 6408-2204.

In preparing the EIS (dated August 2006), for the proposed motorway, a number of studies were undertaken to assess what impacts this road scheme would have on the surface water hydrology of the region. The proposed road crosses two rivers, the Clarinbridge River and the Dunkellin River.

With regard to the proposed Dunkellin and Aggard Flood Relief Scheme the proposed motorway will cross the Dunkellin River at a point approximately 600m upstream of the Dunkellin Bridge and 400m upstream of where the proposed flood relief scheme will commence.

The EIS for the motorway noted that:

In Section 8.2.1.2 under the heading of Effects of Proposed Development

"The proposed crossing point for the new N18 is located approximately 2.5km upstream of the existing N18, between Dunkellin Bridge and Rinn Bridge. The proposed crossing will consist of a three span bridge spanning the main river channel and a portion of the floodplain on either side. The preliminary span sizes used in this study are 35m for the central span, and 25m for side spans on either side. The river channel at the proposed crossing point has a width of approximately 20m. The bridge will therefore span approximately 65m of floodplain beside the river channel. It is possible that the span widths may be adjusted during detailed design. The road approaching the bridge will pass over the Dunkellin flood plain on embankments for approximately 300m."

In Section 8.4.2 of the EIS, under the heading of Hydrology

"Surface water will be attenuated through treatment ponds before entering the watercourse. This will reduce the volume of water entering the river to a peak flow equal to the green field runoff rate. This is not expected to have any significant or measurable impact on the river flows."

In Section 8.4.2.2 of the EIS, under the heading of Hydrology and referring specifically to the Dunkellin Turlough just upstream of the Dunkellin Bridge,

"The proposed crossing of the Dunkellin River requires approximately 300m of embankment to be constructed in the Dunkellin River flood plain. This causes a constriction in the flow at the proposed crossing point, and depending on the degree of constriction, bridge construction can cause considerable afflux, or backwater, upstream of the crossing. The crossing was modelled to estimate the extent of afflux which would be caused"

"The modelling showed that the overall water levels in the Dunkellin floodplain are controlled by the restriction imposed on flow in the river by the existing Dunkellin Bridge, and by a high bed level immediately downstream of the bridge…………..The model predicts a maximum difference in pre and post development water levels of 11mm just upstream of the bridge, reducing gradually to no difference approximately 450m upstream. There is no predicted difference in the downstream water levels from the bridge."

"The construction of the proposed new dual carriageway crossing is therefore expected to have a slight negative impact on the hydrology of the Dunkellin River. This impact will, however, be imperceptible due to the negligible amount of additional land flooded during extreme flood events due to the 11mm rise in water levels."

The proposed motorway has been considered in the overall context of plans and projects in the vicinity of the proposed flood relief works, and because:

a. the proposed Dunkellin and Aggard Flood Relief Scheme commences at a location approximately 400m downstream of the M18 bridge crossing, and
b. the proposed M18 bridge crossing at Dunkellin is not expected to have an impact on water levels downstream of the new motorway bridge,

it is expected, that there will be no additional impact, from the M18, on water levels associated with the proposed Dunkellin and Aggard Flood Relief Scheme.

3.7 ENVIRONMENTAL RIVER ENHANCEMENT PROGRAMME

Inland Fisheries Ireland (IFI) define the Environmental River Enhancement Programme as :

"an Office of Public Works (OPW) funded project that is being co-ordinated and managed by Inland Fisheries Ireland. The programme focuses on the enhancement of drained salmonid rivers in Ireland. These drained rivers are a result of a number of large and small scale arterial drainage schemes which were carried out, across the country, by the OPW since the 1940's. While such works substantially reduced flooding in many areas and brought much benefit to agriculture there were unfortunately some negative impacts on fisheries, angling and on the river corridor habitat."

"Monitoring of the enhancement works by IFI consists of carrying out pre and post works habitat assessments on representative river stretches….. In parallel, pre and post works biodiversity assessments at representative river stretches scheduled for development are also carried out. These include surveys of aquatic insects; river corridor vegetation and other dependent river corridor animals and birds as appropriate"

Galway County Council, in consultation with the OPW, have undertaken to implement, in conjunction with the proposed channel works, a programme of River Enhancement Works along the Dunkellin River.

Two reaches of the Dunkellin River have been identified as areas with high enhancement potential. These are highlighted in Figure 3-14 and are :

1. the channel stretching from the N18 at Kilcolgan to the Rahasane Turlough, and
2. the channel reach stretching from the Rahasane Turlough to the Railway Bridge and upstream to the R446 road bridge in Craughwell Village.

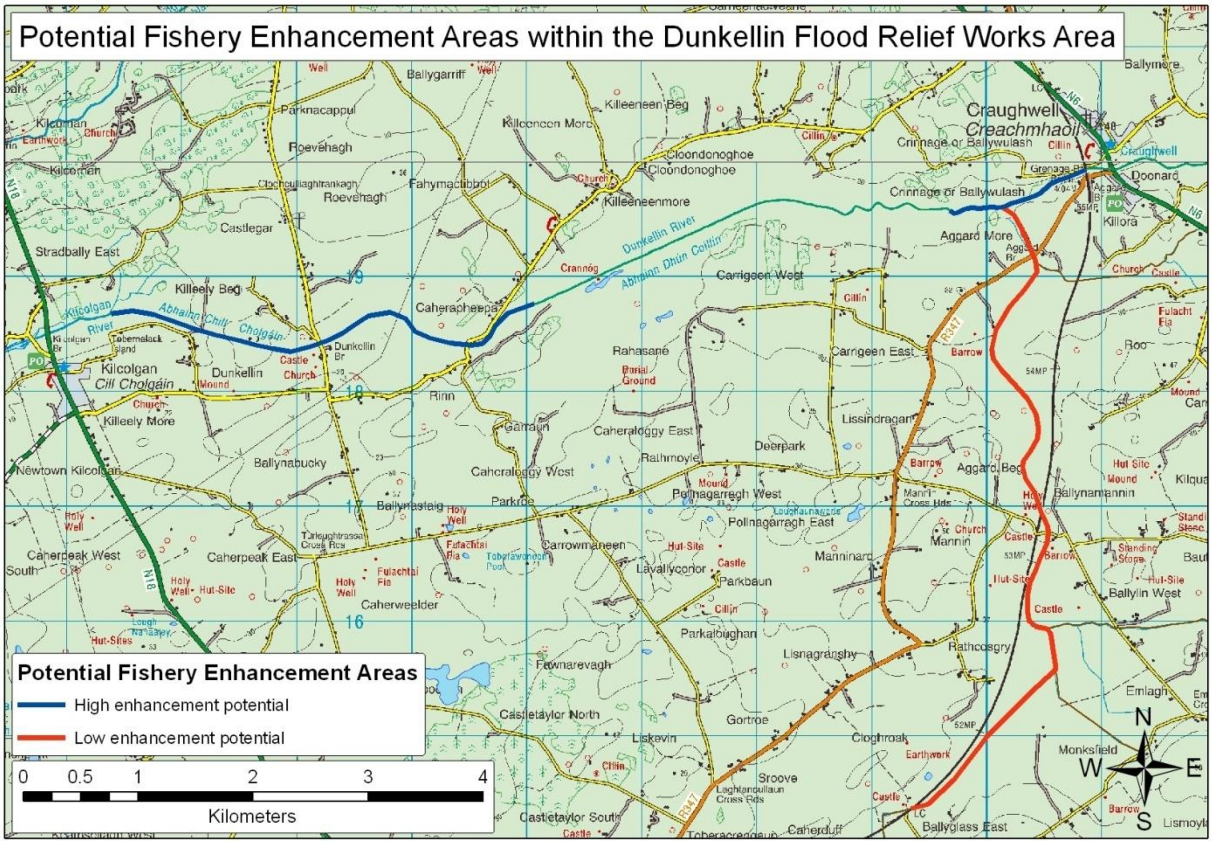


Figure 3-14 – Proposed Locations of River Enhancement Works

The aims of the programme, as defined by the IFI and OPW are to :

1. *"assist in achieving Good Ecological Status of drained rivers, and*
2. *improve biodiversity on drained salmonid rivers in Ireland while also maintaining their drainage function."*

In the case of the Dunkellin River it is proposed to utilise a number of enhancement details, including the :

1. provision of Centre Channel Pools.
2. provision of Lateral Scour Pools.
3. selected placement of gravel beds.
4. provision of Spawning Gravel at particular locations.
5. provision of rubble mats.
6. provision of paired stone deflectors.
7. Supply of alternating stone deflectors.
8. Vortex Stone Weirs.

With particular regard to the proposed channel deepening at Craughwell Village it is proposed that particular regard will be given to the gradient of the bed and the resultant impact on channel velocities. Following consultation with Inland Fisheries Ireland, the following site specific river enhancement methods will be undertaken between the confluence of the Aggard Stream/Craughwell River and Craughwell Village.

1. It is proposed to retain and store, on-site in designated areas, suitable excavated material such as the natural gravels, boulders, cobbles and sands for the purposes of habitat reinstatement. An area of land for the stockpiled

material and subsequent spreading of surplus material is detailed on Drawing No. 6408-2208.

2. A depth range or additional dredge depth of 500mm below the proposed design hydraulic bed level (water conveyance level) has been designated for the purposes of creating shallower bed levels and riffle/glide/pool sequences along the new channel. This depth range is detailed on Drawing No. 6408-2208.

Further details of the typical enhancements are contained in Appendix 3 of this section of the EIS.

4 HYDRAULIC IMPACT OF THE PROPOSED SCHEME

Following the development of the Preferred Scheme, as outlined in Table 3.1, an examination of the capacity of the proposed channel was undertaken to establish its performance to accommodate a range of flows.

For the purpose of this examination a series of extreme flows up to and including the November 2009 flow, were applied to the *"Preferred Scheme"* hydraulic model. The magnitudes of these flows are shown in Table 4-1.

These flows were provided by the OPW for the hydrometric stations at the R446 Bridge in Craughwell and the Aggard Bridge.

Table 4-1 – Magnitudes of Flow Scenarios Applied to the Hydraulic Model to Evaluate the Performance of the Preferred Scheme

	Hydrometric Station	
Flow Scenario	Craughwell Station No. 29007 (m^3/s)	Aggard Bridge Station No. 29010 (m^3/s)
Mean Annual Flow	4.205	0.857
10 percentile	12.2	1.9
5 percentile	16.2	2.48
Peak November 2009 Flow	84.8	21.46

4.1 EFFECT OF THE PROPOSED TWO-STAGE CHANNEL WORKS (CHANNEL WIDENING) ON WATER LEVELS IN THE CHANNEL DOWNSTREAM OF THE RAHASANE TURLOUGH CSAC.

Figures 4.1 to 4.3, inclusive, show a series of cross sectional views at a number of locations along the proposed channel downstream of the Rahasane Turlough cSAC. The predicted water surface profile, <u>post works</u>, for the various flow scenarios, as detailed in Table 4-1, are also shown.

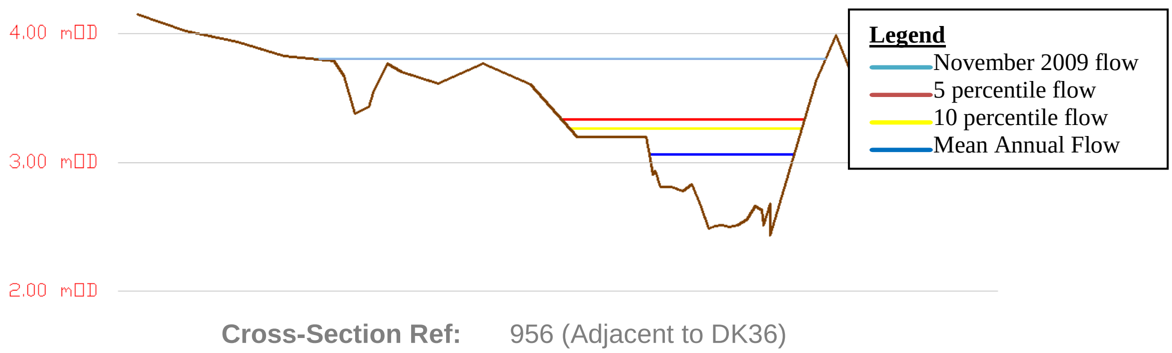


Figure 4-1 – Proposed channel downstream of Killeely Beg Bridge

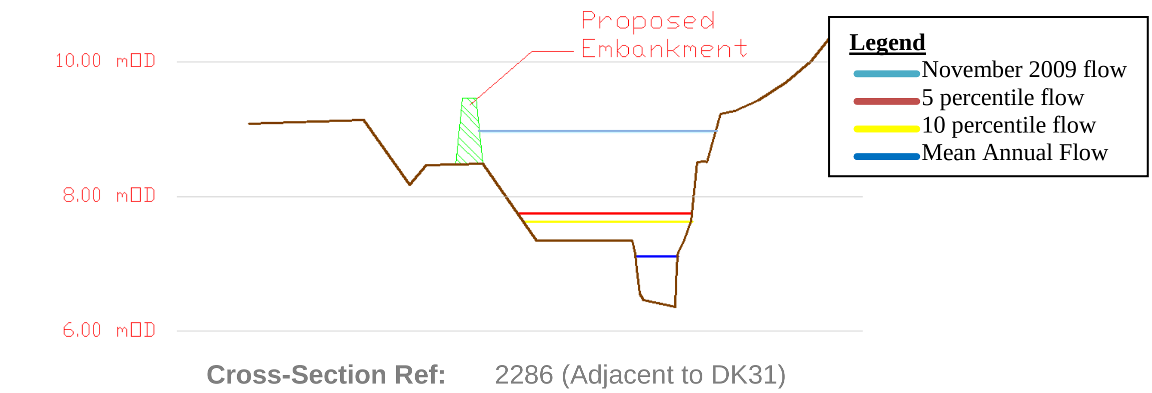


Figure 4-2 – Proposed channel downstream of Dunkellin Bridge

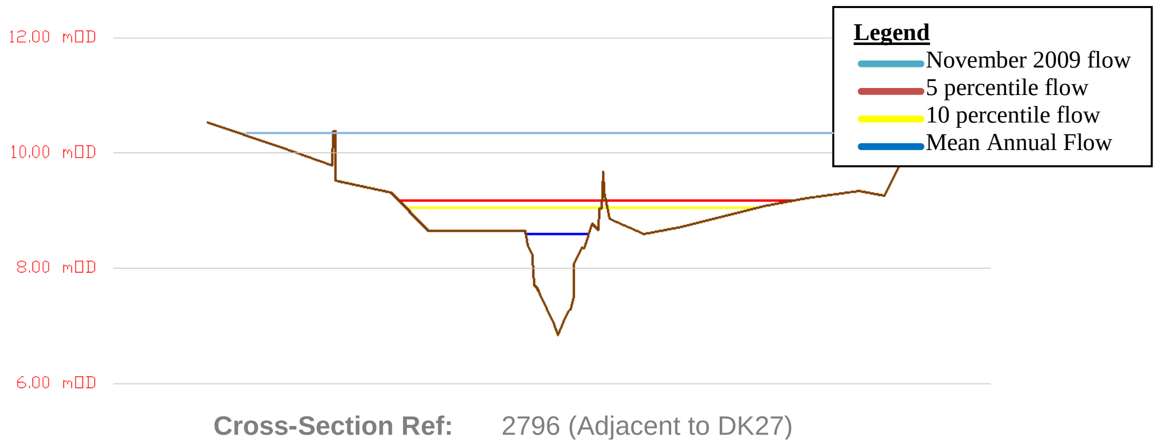


Figure 4-3 – Proposed channel downstream of Rinn Bridge

These sample cross sections demonstrate that the post works water surface profile associated with Mean Annual Flow is in most cases contained within the main channel downstream of the Rinn Bridge. Attempting to fully contain the higher 5 and 10 percentile flows within banks would lead to impractical widening and riparian disruption.

4.2 CHANGES TO SURFACE WATER PROFILE WITHIN THE RAHASANE TURLOUGH CSAC FOR A DEFINED RANGE OF FLOWS

The proposed alterations to the Dunkellin River and its bridges have the potential to alter the flow regime of the Rahasane Turlough cSAC. The impact, of the proposed works, across the range of flows detailed in Table 4-1 and the predicted surface water profile for each flow scenario were also examined as part of this stage of the project, albeit with reduced confidence due to the high flow that was used to calibrate the model.

Figure 4-4 shows the predicted surface water profile along the length of the Rahasane Turlough cSAC when the November 2009 flood event (which has been estimated to be a 1 in

122 year return event). Figure 4-5 shows the Rahasane Turlough when a 2 year return flood event is applied to the model of the preferred scheme.

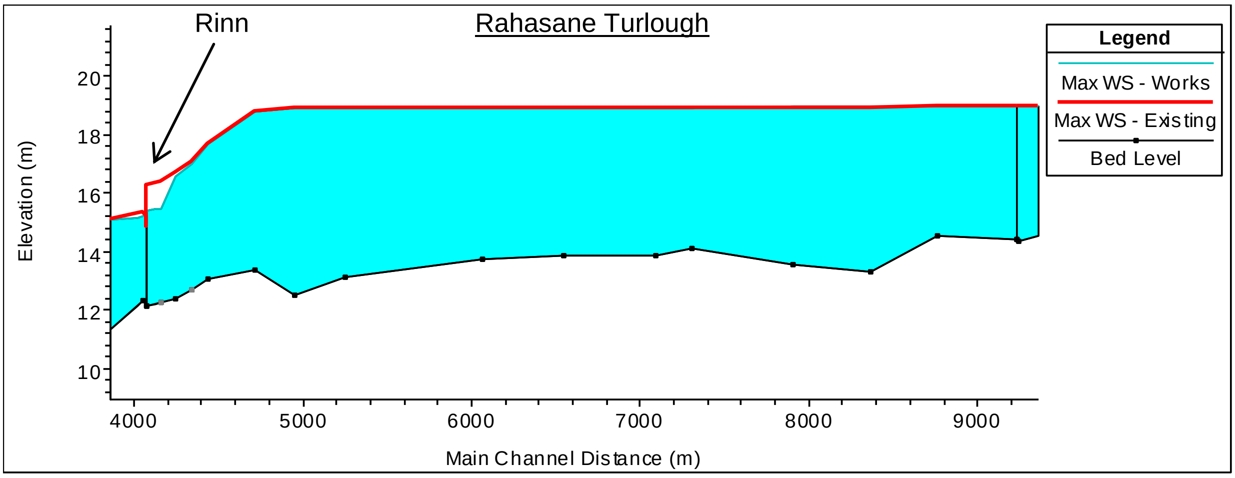


Figure 4-4 – Water Levels in Rahasane Turlough based on November 2009 Flood Flows

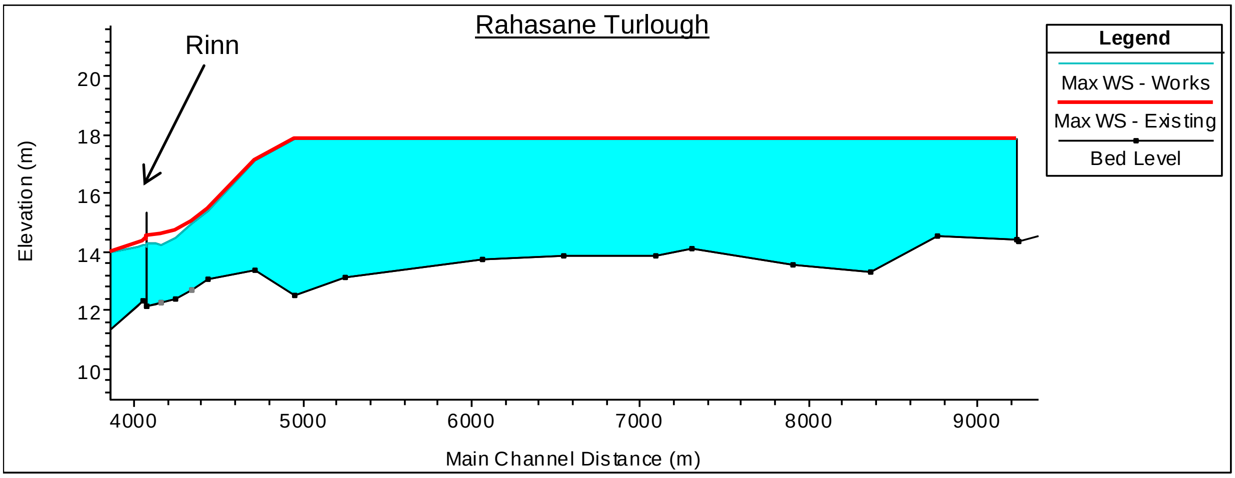


Figure 4-5 – Water Levels in Rahasane Turlough based on a 2-Year Return Period Event

From the diagrams it is clear that there are no changes expected in the water surface profile through the Rahasane Turlough for any magnitude of flood.

Figure 4-6 shows the predicted surface water profile at a cross sectional location within the Rahasane Turlough cSAC when the November 2009 Flood event, the 5%ile and the 10%ile flow events are applied to the model. It is again clear from these figures that there an almost undetectable change in the water levels in the turlough for these events.

In summary, it is predicted that, both average wet weather flows and very high flood flows will give rise to similar water levels on the turlough.

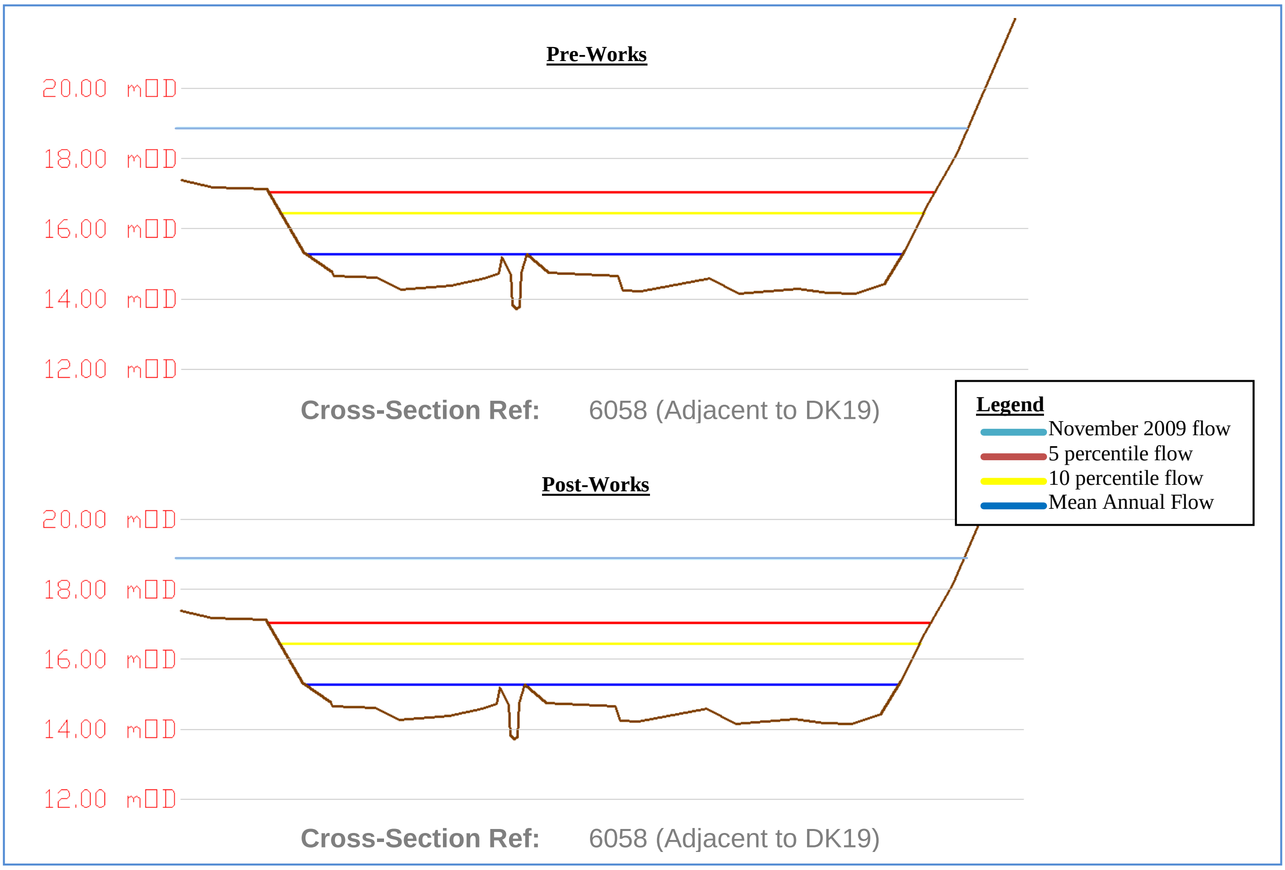


Figure 4-6 – Cross Section through Rahasane Turlough with estimated pre and post works water levels based on various flows

Figure 4-7 shows the estimated outline (in red) of the November 2009 flood event before the proposed works are implemented and also shows the predicted flood outline (in blue) when the same peak discharge 106.2m^3/sec (84.8 + 21.4 m^3/sec) is applied to the preferred scheme (i.e. after flood alleviation works are implemented).

There are no predicted changes in peak water levels, resulting from flood events similar to the November 2009 occurrence.

There is no estimated reduction in plan area for the November 2009 event.

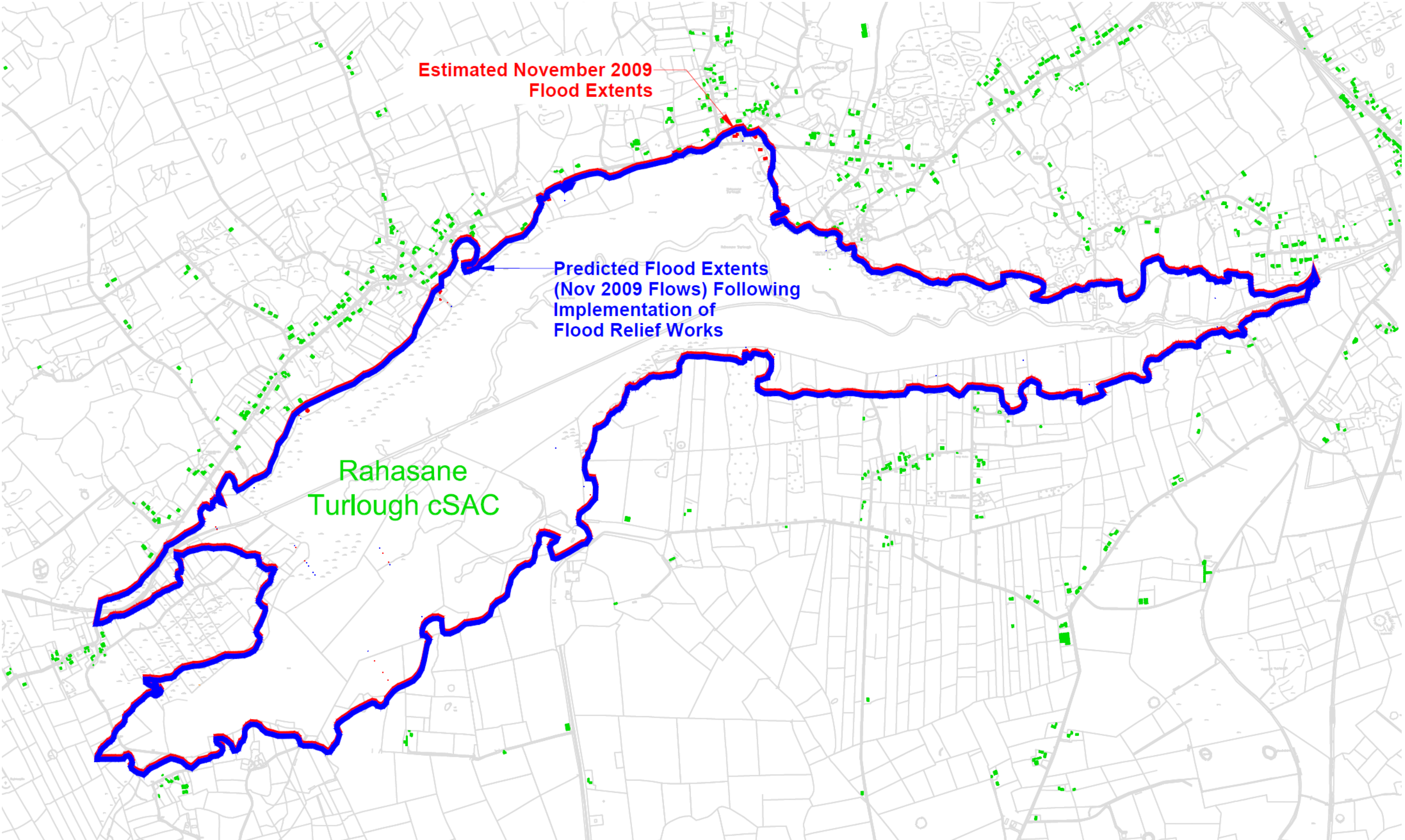


Figure 4-7 – Estimated extent of the flood plain within the Rahasane Turlough as generated by November 2009 Flows (pre and post flood alleviation works)

Figure 4-8 shows the effect of the proposed scheme on the Rahasane Turlough over 4 years of modelled flow between 2008 and 2011. This is further illustrated in Appendix No. 2. Based on this it is predicted that the Turlough will continue to behave as it does naturally at present.

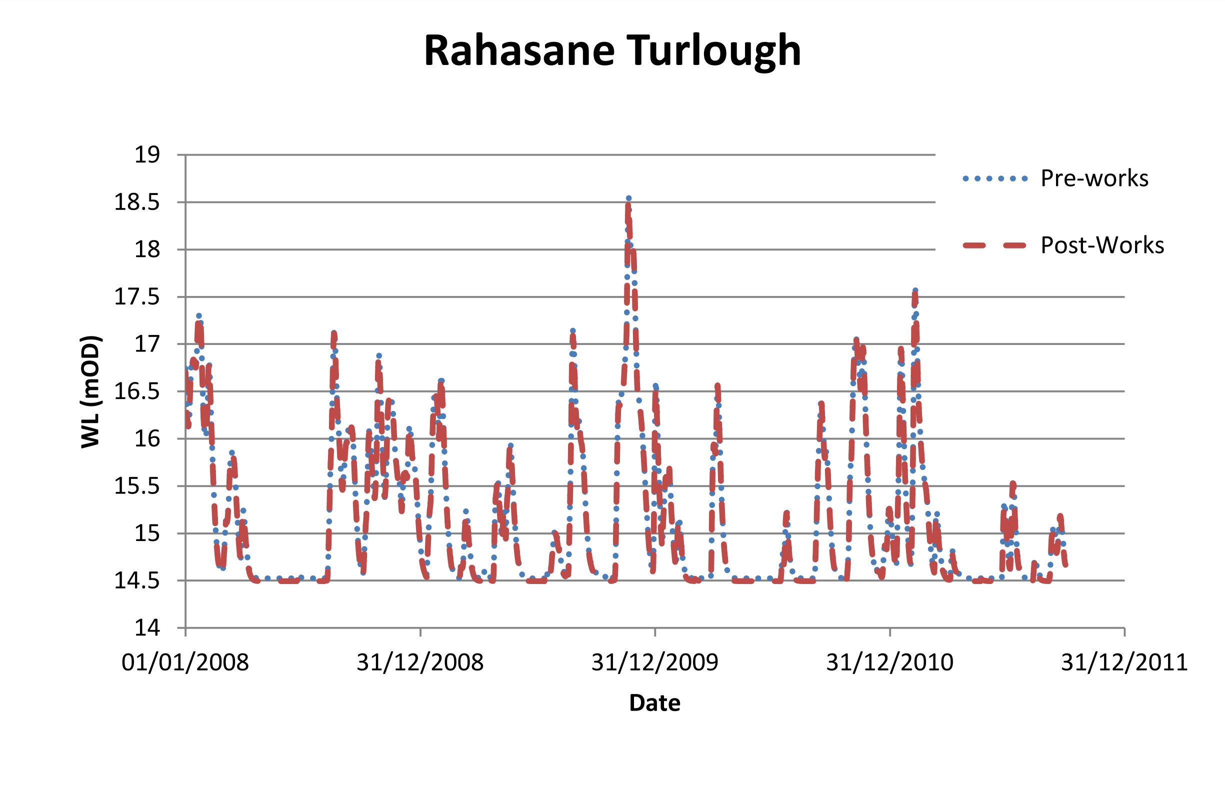


Figure 4-8 – Pre & Post Works Model Output (Depth of Flow at Rahasane)

4.3 IMPACT ON FLOW VELOCITIES

The scouring action of flood waters has the potential to impact on the water quality of the Dunkellin River and Rahasane Turlough cSAC and Galway Bay cSAC. Channel velocities play a significant part in the volume of sediment carried in suspension. During this current planning stage, the changes in flow velocities for the existing channel and proposed channel as modelled for the November 2009 flows were examined. It was found that flow velocities associated with the "Preferred Scheme", were predicted to be slightly higher than those estimated for the November 2009 event.

Open channel velocities during the November 2009 design flood (122 year flood) are in most cases predicted to have increased slightly in the new channel when compared with the existing channel. Table 4-2 summarises the estimated flow velocities at a number of locations along the Dunkellin River, when the November 2009 event is applied to the existing channel and the proposed channel.

Table 4-2 – Peak Velocities along the Dunkellin River for the November 2009 Event as predicted for the Existing Channel and Preferred Scheme

Location	Estimated Channel Velocities (m/s)					
	2009 Event		5 Year		2 Year	
	Pre-Works	Post-Works	Pre-Works	Post-Works	Pre-Works	Post-Works
Between R446 Bridge and Masonry Arch Pedestrian Bridge	1.07	1.08	0.86	1.07	0.95	1.13
Between Masonry Arch Pedestrian Bridge and Railway Bridge	1.05	1.3	0.98	1.78	1.03	1.75
d/s of Railway Bridge	1.67	1.87	1.08	1.13	1.21	1.26
Upper Rahasane Turlough	0.08	0.08	0.03	0.03	0.04	0.04
At Rinn Bridge	2.02	2.06	1.86	1.96	1.98	2.17
d/s of Rinn Bridge	1.72	1.16	1.57	0.83	1.55	0.9
d/s of Dunkellin Bridge	1.54	1.74	1.65	1.17	1.73	1.29
d/s of Killeely Beg Bridge	2.13	2.46	2.08	1.5	2.02	1.72

Examination of the channel velocities in the mathematical model (HEC-RAS) for the existing channel and Preferred Scheme scenario shows that expected changes in flow velocities is minimal.

4.4 IMPACT ON FLOW VOLUMES

The proposed alterations to the Dunkellin River and its bridges have the potential to alter the flow regime of the river system. The impact, of the proposed works, on the November 2009 flood event and the predicted hydrographs were also examined at this stage of the proposed scheme.

For the purpose of this study we have reviewed the peak discharge, hydrograph duration and cumulative volume of water discharged to Galway Bay during the November 2009 event. This examination was limited to a period of 206 hours starting approximately 95 hours before the peak of the November 2009 event.

The time to peak (T_p) is estimated to be reduced from 95 hours to 93 hours.

It is expected that implementation of the Preferred Scheme will result in a marginal increase (less than 1%) in the rate at which water is discharged to Galway Bay during a similar November 2009 flood event and on balance the volume of flood water passing Killeely Beg Bridge will not change significantly.

5 PROGRAMME AND PHASING OF THE WORKS

There are a number of constraints on the phasing and methods of construction works. The most significant constraint is that in general in-river work is only permitted between May and September each year.

This is a requirement resulting from the recommendations of a number of statutory bodies which were consulted during the early scoping stage of the planning stage. These include the Inland Fisheries Ireland, the NPWS and the timing restrictions are required to ensure that fish migration is not impeded during spawning seasons and that works do not impact on the crayfish populations who seek refuge within river banks during the winter months.

This programme is summarised in Figure 5-1 and it must be noted that this is an outline programme of works and may be subject to alterations subject to the timing of planning approvals, the final detailed design stage programme and following the appointment of a Works Contractor.

	No. of Employees	Jan-15	Feb-15	Mar-15	Apr-15	May-15	Jun-15	Jul-15	Aug-15	Sep-15	Oct-15	Nov-15	Dec-15	Jan-16	Feb-16	Mar-16	Apr-16	May-16	Jun-16	Jul-16	Aug-16	Sep-16
Advanced Works																						
Vegetation Clearance		Vegetation Clearance			No Vegetation Clearance Permitted March to Sept						Vegetation Clearance Permitted Sept to February					No Vegetation Clearance Permitted March to Sept						
Out Of River Works downstream of the Rahasane Turlough																						
River Works Crew No. 1 – Out of River Works or Channel Widening of the Dunkellin River from Kilcolgan Bridge to Killeely Beg Bridge.	6																					
Channel Widening of the Dunkellin River from Killeely Beg Bridge to Dunkellin Bridge.	6																					
River Works Crew No. 1 – Out of River Works or Channel Widening of the Dunkellin River from Dunkellin Bridge to Rinn Bridge.	6																					
River Works Crew No.2 - Out of River Works or Channel Widening of the Dunkellin River from Rinn	6																					
Bridge Works Crew A – Bridge Works at Killeely Beg Bridge.	8																					
Bridge Works Crew B – Out of River Bridge (Left Bank Works) /Culvert Works at Dunkellin Bridge.	8																					
Bridge Works Crew C – Out of River Bridge (Left Bank Works) /Culvert Works at Rinn Bridge.	8																					
In River Works upstream of the Rahasane Turlough																						
Bridge Works Crew D– In River Works or Channel Deepening downstream of the Railway Bridge (Rock Removal).	4																					
Bridge Works Crew E– In River Works or Channel Deepening in Craughwell.	4																					
Bridge Works Crew F – In River Works or Underpinning at the Railway Bridge in Craughwell.	4																					
Out Of River Works on the Bypass Channel followed by works on main R446 bridge & Multi-Arched Bridge																						
Works Crew No. 1 – Out of River Works or Channel deepening and underpinning along the bypass channel and retaining walls	4																					
Works Crew No. 2 – Out of River Works or Underpinning of the Old Stone Multi-arched bridge (Extended Programme to cater for variability in river flows)	4											Restrictions Apply to Works within this Time Period										
Works Crew No. 3 – Out of River Works or Underpinning of the main R446 bridge in Craughwell (Extended Programme to cater for variability in river flows).	4																					
Landscaping																						
Completion/Snagging and Handover																						

Estimated Max Number of Employees on Site	**44**

Figure 5-1 – Outline Construction Programme

6 EXCAVATIONS AND EXCAVATED MATERIALS

All river regrading and widening will be undertaken using tracked vehicles travelling along the temporary works area along the bank of the Dunkellin River.

It is anticipated that approximately 70,000m³ of overburden, rock and riverbed will be removed from the river and its surroundings as a result of channel deepening and widening.

This is broken down in Table 6-1.

It is envisaged that different techniques will be adopted with regard to the reuse or disposal of excavated material. However, the overall intention will be to reuse the excavated material as side slope protection, creation of flood embankments, creation of bankside spoil embankments and the creation of extended spoil heaps where initial treatment will require removal of topsoil, spreading of excavated material and reinstatement of the topsoil, undertaken with a view to minimising the transport of material off-site.

It is proposed that the use of bank side spoil heaps will be of the order of the dimensions detailed in Figure 6-1 where the estimated cross sectional area of the spoil heap (outside areas where flood embankments are used) is not expected to exceed 6m^2.

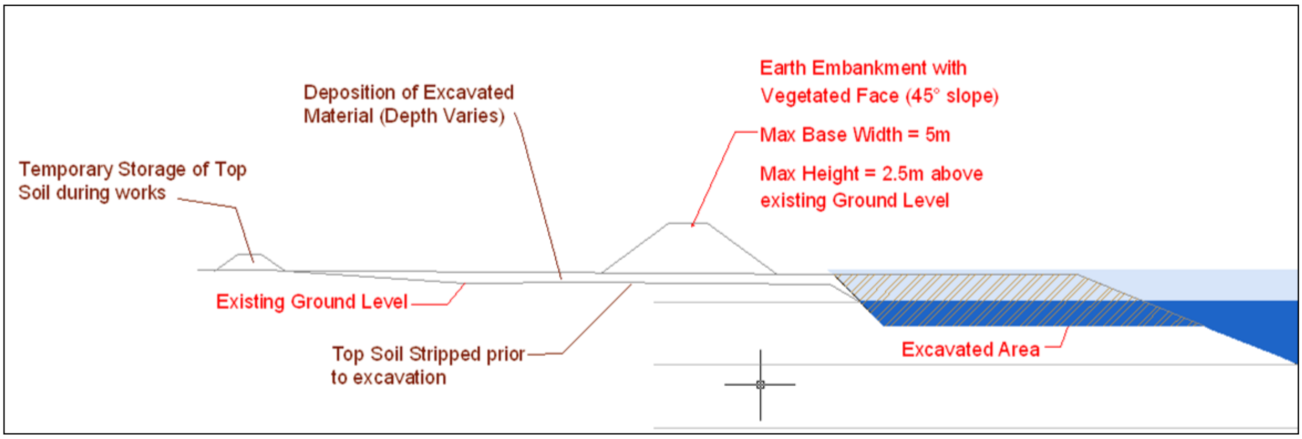


Figure 6-1 – Typical Detail of the Proposed Bank Side Spoil Heaps

Table 6-1 – Estimated Volumes of Excavated Materials

Area	Location	u/s Reference	d/s Reference	Distance (m)	Average X-Sectional Area to be excavated (m^2)	Typical Two-Stage Channel Width (m)	Typical Depth (m)	Volume (m^3)	Sub-Total (m^3)	Area Available for Spreading Spoil (m^2)	Approx. Depth of Land Spread (m)
Upstream of Rahasane Turlough	Craughwell Main Channel	10306	10285 (R446 Bridge)	36.00	12.69	-	1.50	457	5,233	45,002	0.12
		10285 (R446 Bridge)	10253 (Old Masonry Arch bridge)	31.97	13.94	-	1.00	446			
		10253 (Old Masonry Arch bridge)	10120	134.66	6.66	-	1.25	897			
		10120	10040 (Railway Bridge)	126.50	7.05	-	0.75	892			
		10040 (Railway Bridge)	9231	612.80	4.15	-	0.75	2,542			
	Bypass Channel	PYP 345	PYP 145 (R446 Bridge)	190.00	42.13	-	2.25	8,006	11,698		
		PYP 145 (R446 Bridge)	PYP 0	161.66	22.84	-	2.25	3,693			
									<u>16,932</u>		
Downstream of Rahasane Turlough	Rinn Bridge	4144	4119	25.00	19.99	10.00	2.00	500	5,318	21,906	0.24
		4119	4068 (Rinn Bridge)	50.00	39.98	20.00	2.00	1,999			
		4068 (Rinn Bridge)	4013	58.00	39.98	20.00	2.00	2,319			
		4013	3988	25.00	19.99	10.00	2.00	500			
	Upstream of Dunkellin Bridge	3045	2716	328.93	13.74	20.00	0.75	4,518	7,040	59,967	0.12
		2716	2666	50.00	23.65	25.00	1.00	1,182			
		2666	2626 (Dunkellin Bridge)	39.91	33.56	30.00	1.25	1,339			
	Dunkellin Bridge to Killeely Beg Bridge	2626 (Dunkellin Bridge)	2569	58.00	33.56	30.00	1.25	1,946	31,888	81,743	0.39
		2569	2519	50.00	32.52	25.00	1.50	1,626			
		2519	1709	810.00	31.49	20.00	1.75	25,507			
		1709	1659	50.00	29.22	17.00	1.75	1,461			
		1609	1559 (Killeely Beg Bridge)	50.00	26.96	14.00	2.00	1,348			
	Downstream of Killeely Beg Bridge	1559 (Killeely Beg Bridge)	1509	56.00	26.96	14.00	2.00	1,510	8,612	198,648	0.04
		1509	1459	50.00	17.17	17.00	1.25	858			
		1459	1059	400.00	7.37	20.00	0.50	2,949			
		1059	165	894.00	3.69	10.00	0.50	3,295			
									<u>52,858</u>		

Total Volume for Excavation = <u>69,790</u> m^3

The techniques are summarised items a) to f) over the following paragraphs.

a. Within the village of Craughwell, upstream of the railway bridge, it is expected that channel deepening along the Dunkellin and the bypass channel, will require the excavation of approximately 5,200m^3 of sandy/silty gravel with cobbles and boulders. It is expected that c. 3,500m^3 of this material can be reused in creating a flood defence embankment along the right bank of the Dunkellin River upstream of Craughwell as indicated in Figure 6-2. The remaining material will require disposal, at a licensed facility, in accordance with the Waste Management Act 1996.

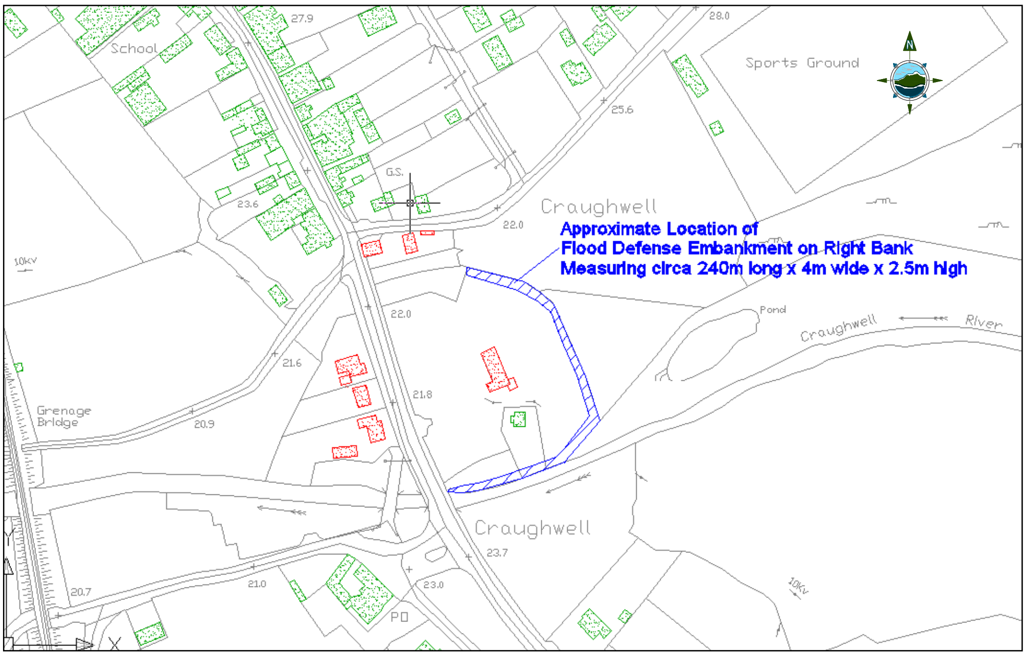


Figure 6-2 – Approximate Location of Flood Defence Embankment upstream of Craughwell

b. Downstream of Craughwell and the railway bridge, it is expected that channel deepening along the Dunkellin, will require the excavation of approximately 11,600m^3 of gravel with cobbles and boulders and a significant amount of rock. It is expected that c. 5,000m^3 of rock will be excavated and that this can be reused in creating side slope protection along the proposed channel deepening. It is expected that the remaining material which will consist of sandy gravels can be reused along the left & right banks. This technique will involve removal of tree growth on the banks, topsoil stripping (and storage) on the banks in advance of channel works, spreading of the excavated material across the works area and final reinstatement of the banks with the stored topsoil and final landscaping (tree planting) with native species. Alternatively, an embankment, constructed from excavated material may be created along the banks to minimise the need for transport of the excavated material away from the works area.

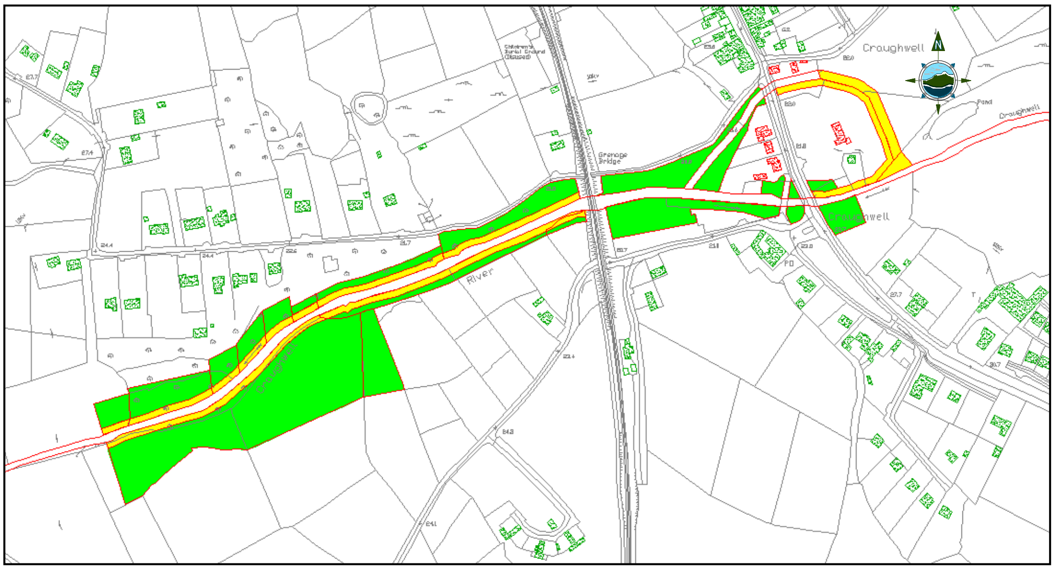


Figure 6-3 – Approximate Location of Lands required for temporary storage (River Enhancement Works) and deposition of excavated material (green) downstream of Craughwell Village (yellow indicates spoil heaps/embankments)

Photograph No. 26 – Approximate Location of Lands required for reuse of excavated material downstream of Craughwell Village

c. Downstream of the Rahasane Turlough cSAC but upstream of Rinn Bridge, it is expected that channel widening along the Dunkellin, will require the excavation of approximately 5,000m^3 of gravels and an amount of rock. It is expected that at least 3,500m^3 of rock will be excavated and that over 50% of this material can be reused in creating side slope protection along the lower reaches of the Dunkellin River, downstream of the Dunkellin Bridge. This will require significant traffic movement in the area to cater for this reuse of material. It is expected that the remaining material (circa 1,500m^3) which will consist of overburden or sandy gravels can be reused along the left bank. This technique will again involve topsoil stripping (and storage) on the left bank in advance of channel works, spreading of the excavated material across the stripped works area and reinstatement of the left bank with the stored topsoil. Alternatively, an embankment, constructed from excavated material may be created along the left bank to minimise the need for transport of the excavated material away from the works area.

Figure 6-4 – Approximate Location of Lands required for deposition of excavated material (green) upstream of Rinn Bridge (Yellow Areas indicate extent of channel excavations)

Photograph No. 27 – Location of Channel Works upstream of Rinn Bridge

d. Downstream of the Rinn Bridge but upstream of the Dunkellin Bridge, it is expected that channel widening along the Dunkellin, will require the excavation of approximately 7,000m^3 of gravels and rock. It is expected that circa. 5,500m^3 of rock will be excavated and that over 50% of this material can be reused in creating side slope protection along the lower reaches of the Dunkellin River, downstream of the Dunkellin Bridge. This will require significant traffic movement in the area to cater for this reuse of material. It is expected that the remaining material (circa 1,500m^3) which will consist of overburden or sandy gravels can be reused along the left bank to create an embankment along the outer extremes of the proposed channel widening. This technique will again involve topsoil stripping (and storage) on the left bank in advance of channel works, spreading and shaping of the excavated material across the stripped works area and reinstatement of the embankment left bank with the stored topsoil.

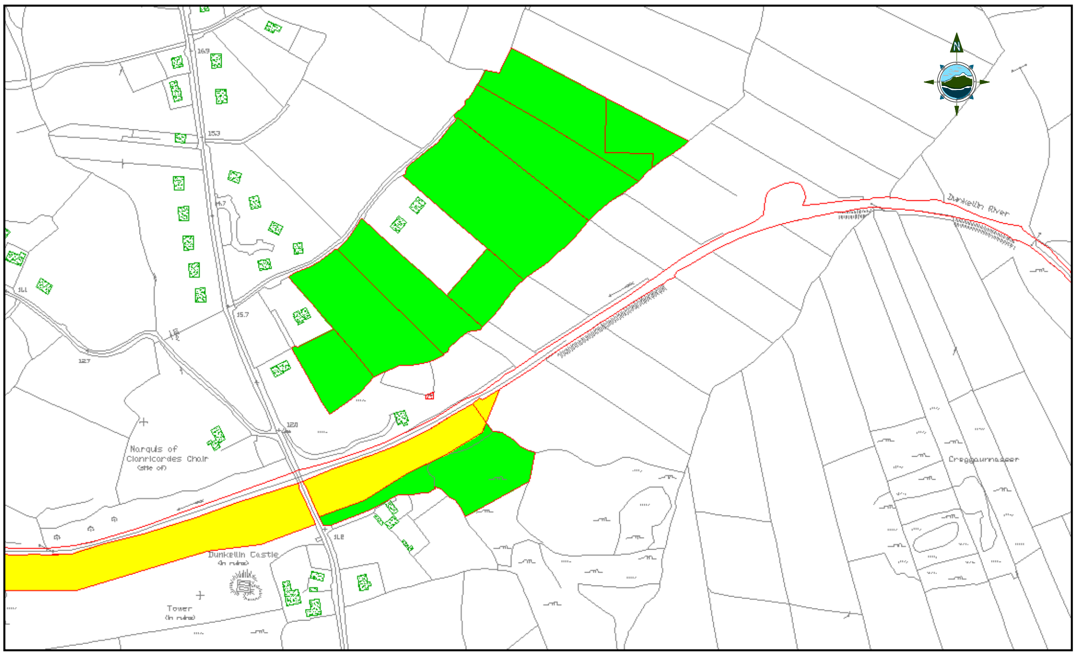
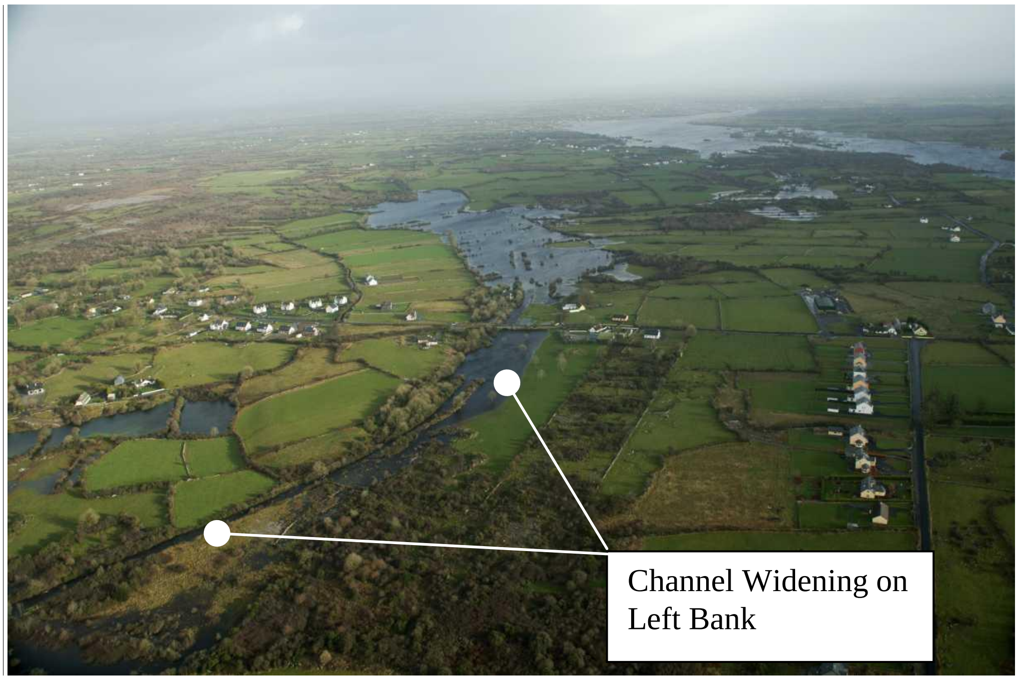


Figure 6-5 – Approximate Location of Lands required for deposition of excavated material (green) upstream of the Dunkellin Bridge (yellow areas indicate extent of channel works)

e. Downstream of the Dunkellin Bridge but upstream of the Killeely Beg Bridge, it is expected that channel widening along the Dunkellin River, will require the excavation of approximately 32,000m^3 of gravels and a significant amount of rock. It is expected that at least 20,000m^3 of gravels and rock will be excavated and that majority of this material can be reused in creating a left bank spoil embankment. This technique will again involve topsoil stripping (and storage) on the left bank in advance of channel works, spreading and or mounding of the excavated material across the stripped works area and reinstatement of the left bank with the stored topsoil. This technique will minimise the need for transport of the excavated material away from the works area.

Figure 6-6 – Approximate Location of Lands required for reuse of excavated material (green) upstream of Killeely Beg Bridge (yellow areas indicate extent of channel widening)



Photograph No. 28 – Location of Channel Works upstream of Killeely Beg Bridge

f. Downstream of the Killeely Beg Bridge but upstream of the N18, it is expected that channel widening along the Dunkellin River, will require the excavation of approximately 8,600m^3 of overburden, gravels and a portion of rock. It is expected that at least 6,000m^3 of gravels and rock will be excavated and that majority of this material can be reused in creating a left bank spoil embankment. This technique will again involve topsoil stripping (and storage) on the left bank in advance of channel works, spreading and or mounding of the excavated material across the stripped works area and reinstatement of the left bank with the stored topsoil. This technique will minimise the need for transport of the excavated material away from the works area.

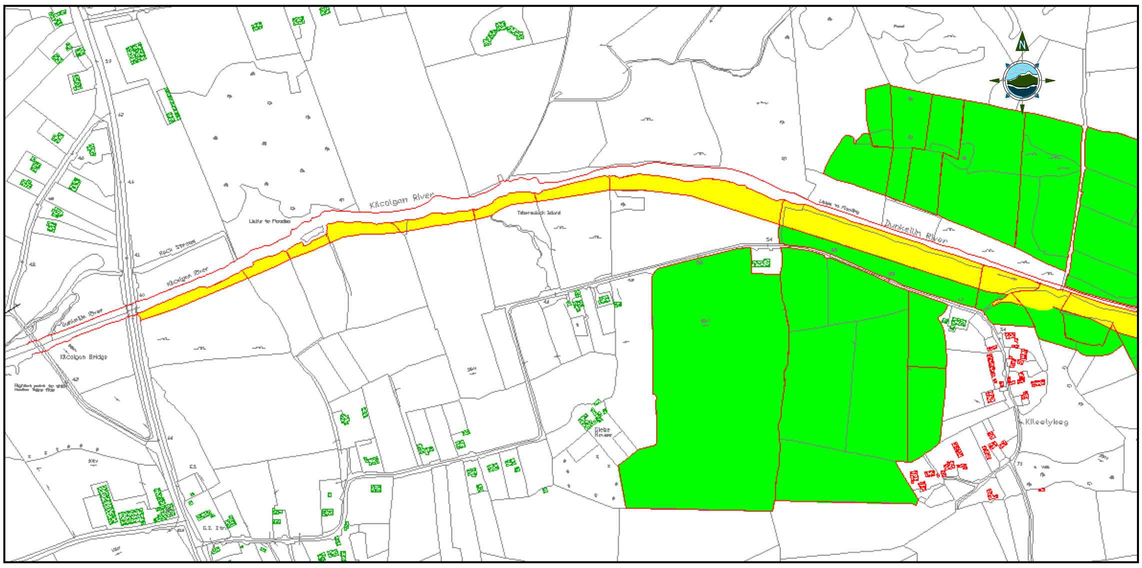
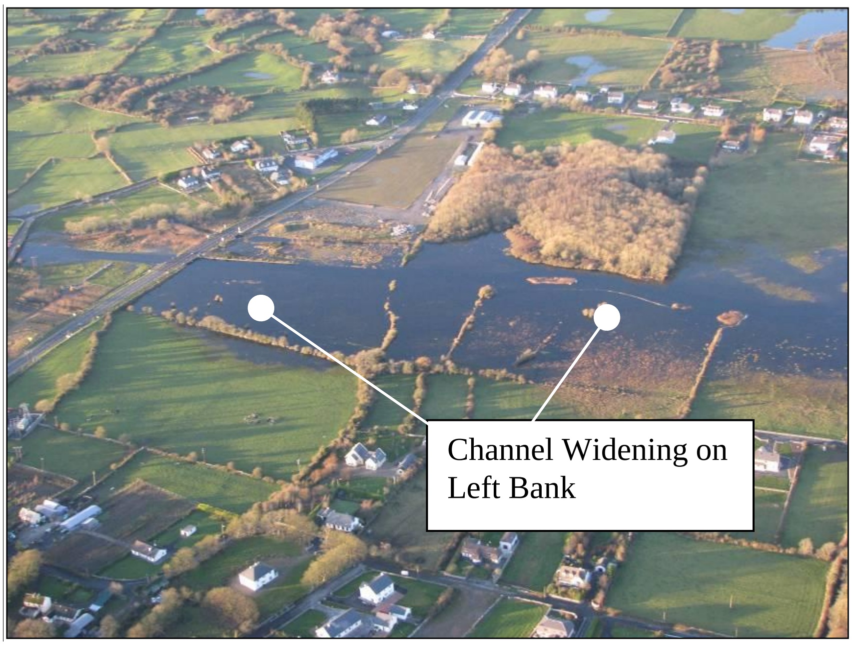


Figure 6-7 – Approximate Location of Lands required for deposition of excavated material (green) downstream of Killeely Beg Bridge (yellow areas indicate extent of channel works



Photograph No. 29 – Location of Channel Works downstream of Killeely Beg Bridge

7 ANCILLARY WORKS ITEMS & SITE ACCESS

7.1 WORKS ACCESS

It is envisaged that the construction of the proposed flood relief works will require the following ancillary works:-

i) Site compound at Killeely Beg Bridge.
ii) Site compound at Dunkellin Bridge.
iii) Site compound at Rinn Bridge.
iv) Provision of an access point into the Dunkellin River at Killeely Beg Bridge.
v) Provision of access point into the Dunkellin River at the Dunkellin Bridge.
vi) Provision of an access point into the Dunkellin River at Rinn Bridge
vii) Temporary access road to Killeely Beg Bridge to facilitate the movement of large precast bridge beams.
viii) Site compound at Craughwell Village.

As noted above it is envisaged that there will be four main site compounds which include short term staff welfare facilities and plant & materials storage for the proposed works.

An access point to the proposed river works will required at the three main locations detailed above. It is envisaged that these will consist of a temporary surface which will be provided along the river bank to allow vehicles to enter and travel to the proposed excavation sites.

It is envisaged that this track will be formed from stone excavated from the proposed works and will be constructed ahead of the excavation plant as work progresses.

7.2 DEALING WITH WATER WITHIN EXCAVATED WORKS

A number of the proposed works will require the use of dewatering pumps in order to maintain dry conditions within the excavations. It is envisaged that the construction of the proposed flood relief works will require the use of up to two (2) *"6 Inch"* dewatering pumps.

Such dewatering pumps have a capacity of up to 90l/sec and with two pumps in operation the maximum expected rate of trench/excavation dewatering could be of the order 180l/sec.

The use of such dewatering pumps will require the use of temporary constructed silt ponds for the disposal of excavated water.

8 EMERGENCY PROCEDURE DURING FLOOD EVENTS DURING CONSTRUCTION

With flooding events having occurred in January 2005 and November 2009 the likelihood of a flood event occurring during construction could be considered to be relatively high.

Although the proposed channel works are designed to provide flood relief, their construction may cause a temporary flow restriction along the channel particularly where bridge underpinning works are proposed. The contractor must therefore ensure that the risk of flooding is not increased as a result of the proposed works. Whilst rainfall in the catchment can result in significant flows, in the Dunkellin River, advance warning of such flood events is possible and the contractor will be required to monitor both long and short term weather forecasts so that machinery and personnel can be prevented from entering the channel during periods of peak flow. Monitoring of the flow in the upstream catchment may be used as an aid to predict high flow events.

Works in Craughwell and reduction of flooding risk can be facilitated by phasing of the proposed works as detailed in the Programme.

No machinery shall be left in the river overnight or outside of normal working hours.

9 OPERATION OF THE PROPOSED FLOOD RELIEF SCHEME

When fully implemented, the proposed flood relief scheme will provide a defence against the 1 in 100 year flood event with allowance made for climate change. This will accommodate November 2009 flood flows.

However, the Dunkellin River channel will require regular maintenance to prevent vegetation becoming overgrown thus increasing the risk of future flooding. This will be managed by Galway County Council as part of their overall maintenance responsibilities for the Dunkellin Drainage District

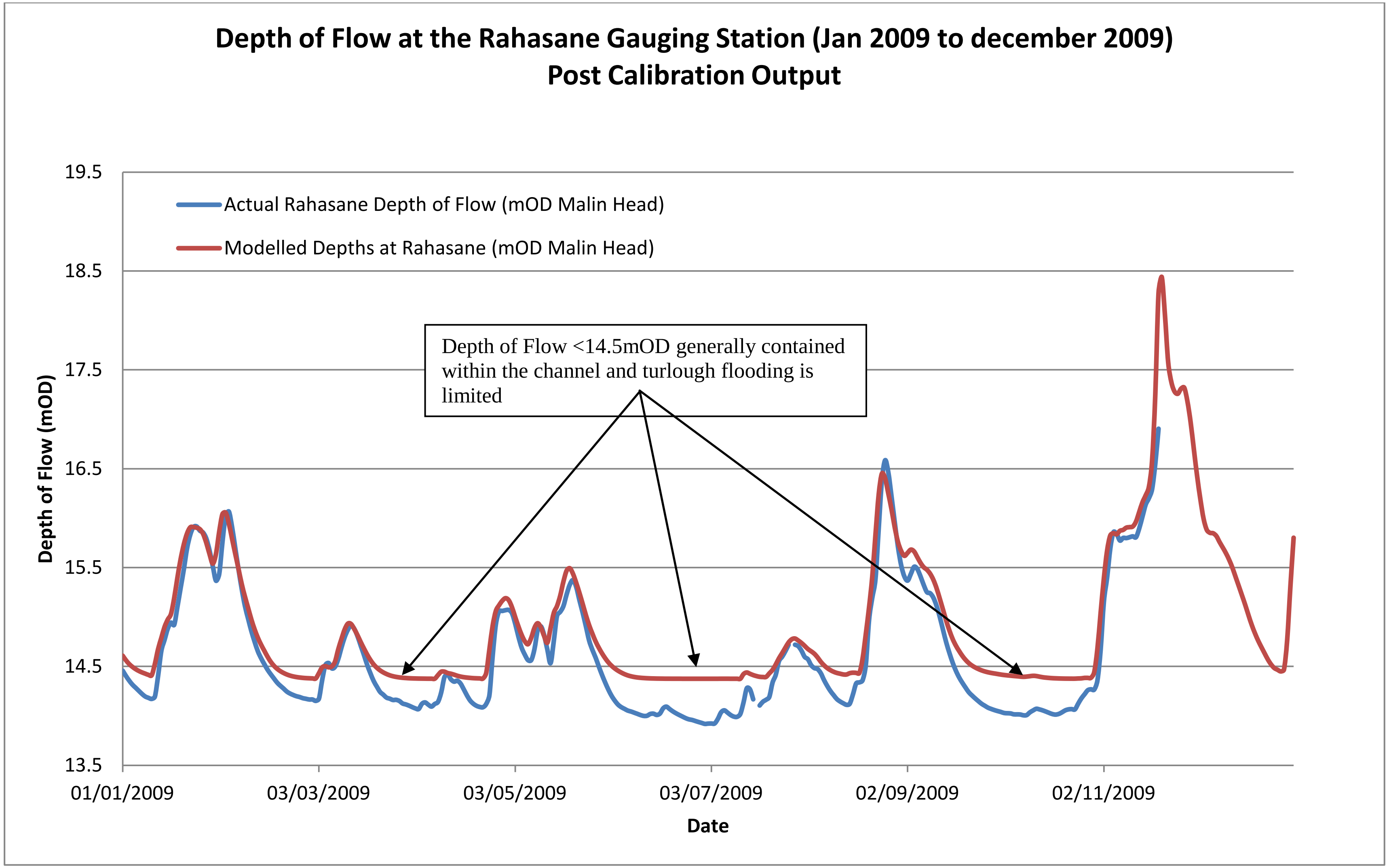
Galway County Council propose to undertake maintenance over a 5 year maintenance programme with activities being carried out as follows:

On a 5 year basis

- Light trimming of vegetation
- Non invasive cleaning of the river to remove excess silt or debris which may have gathered in the river.

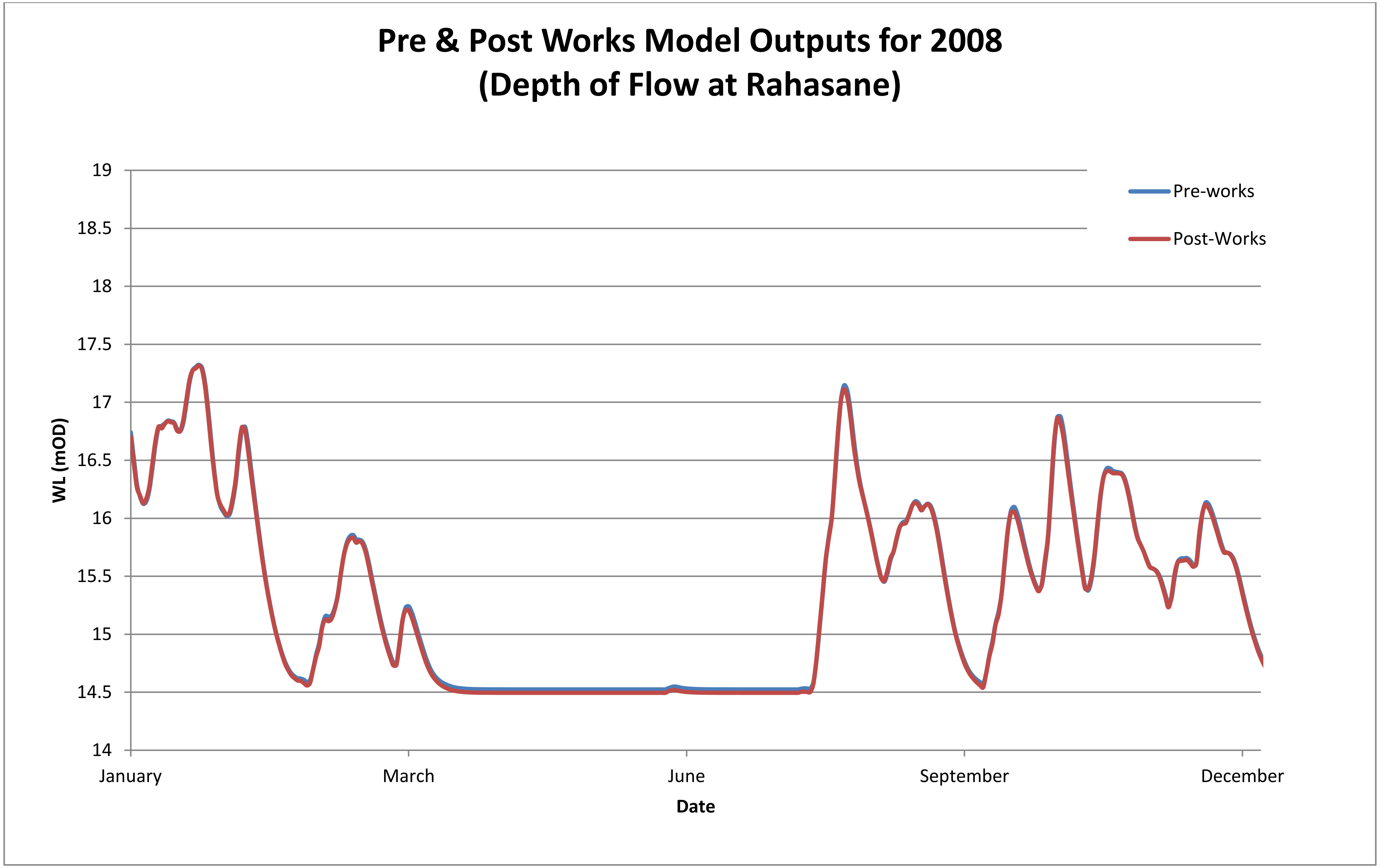
Appendix No. 1

Calibrated Output from the Mathematical Model

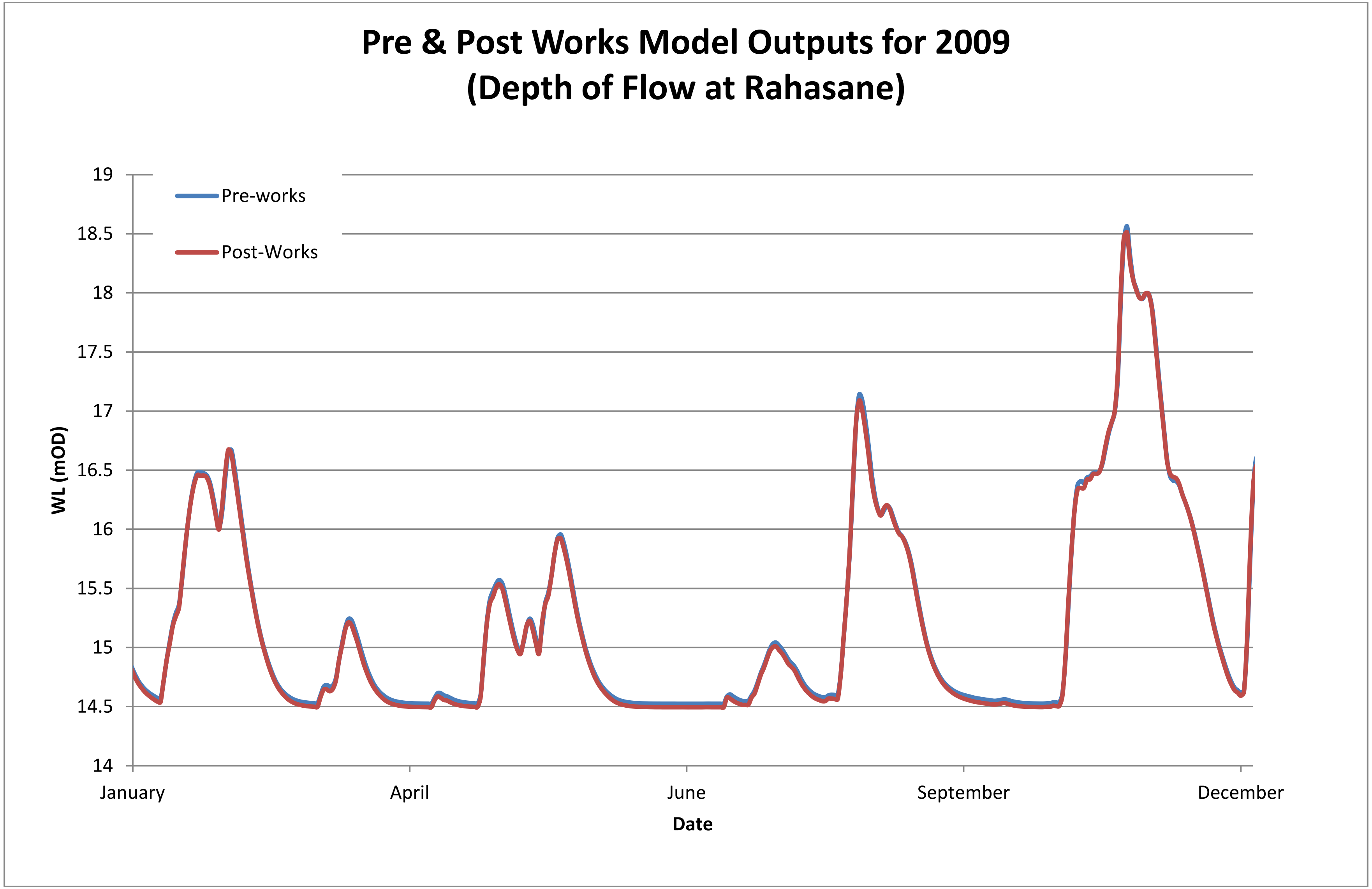

Depth of Flow at the Rahasane Gauging Station (Jan 2009 to december 2009)
Post Calibration Output
Actual Rahasane Depth of Flow (mOD Malin Head)
Modelled Depths at Rahasane (mOD Malin Head)
Depth of Flow <14.5mOD generally contained within the channel and turlough flooding is limited
Depth of Flow (mOD)
19.5
18.5
17.5
16.5
15.5
14.5
13.5
01/01/2009
03/03/2009
03/05/2009
03/07/2009
02/09/2009
02/11/2009
Date

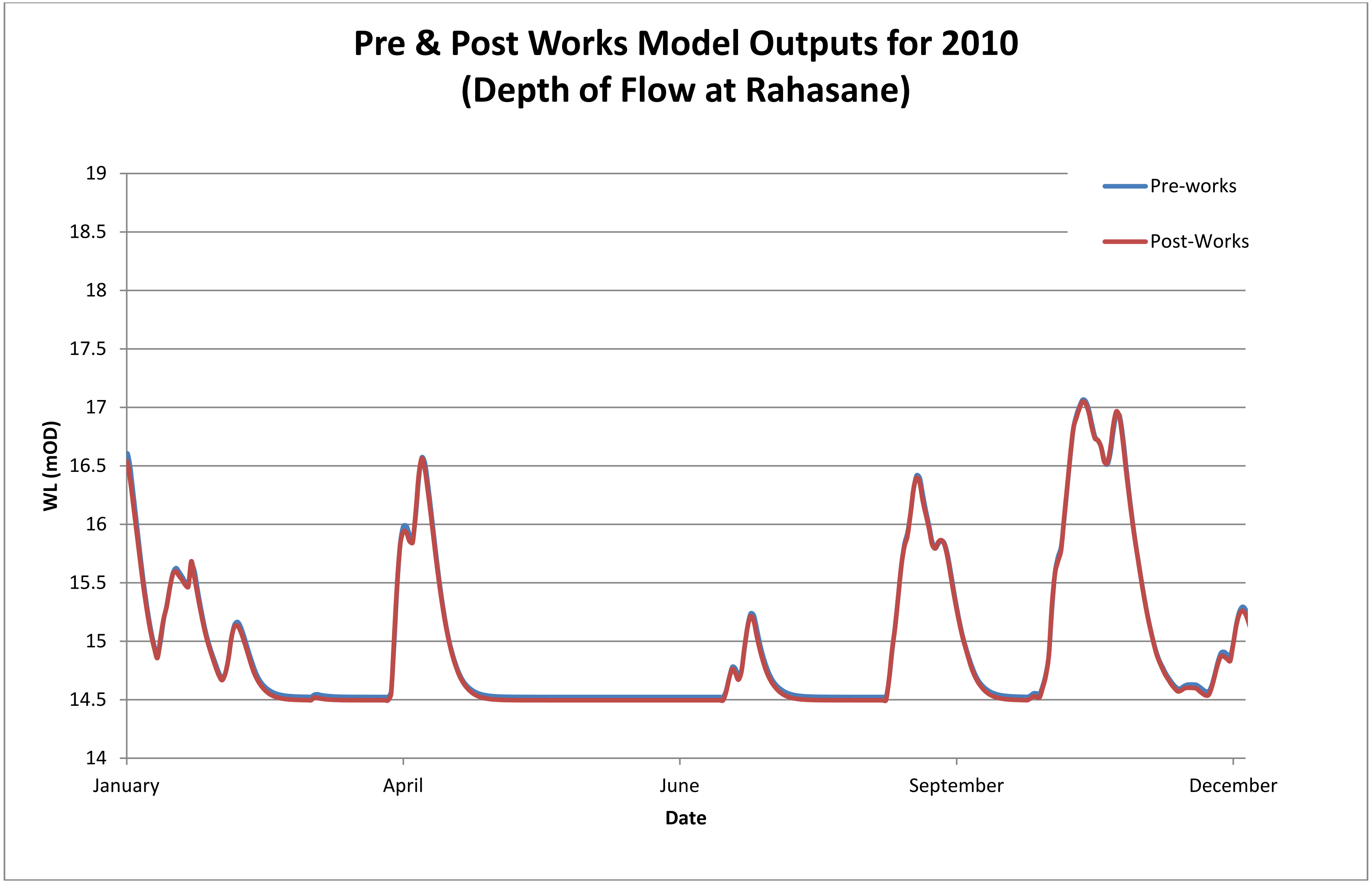
Appendix No. 2

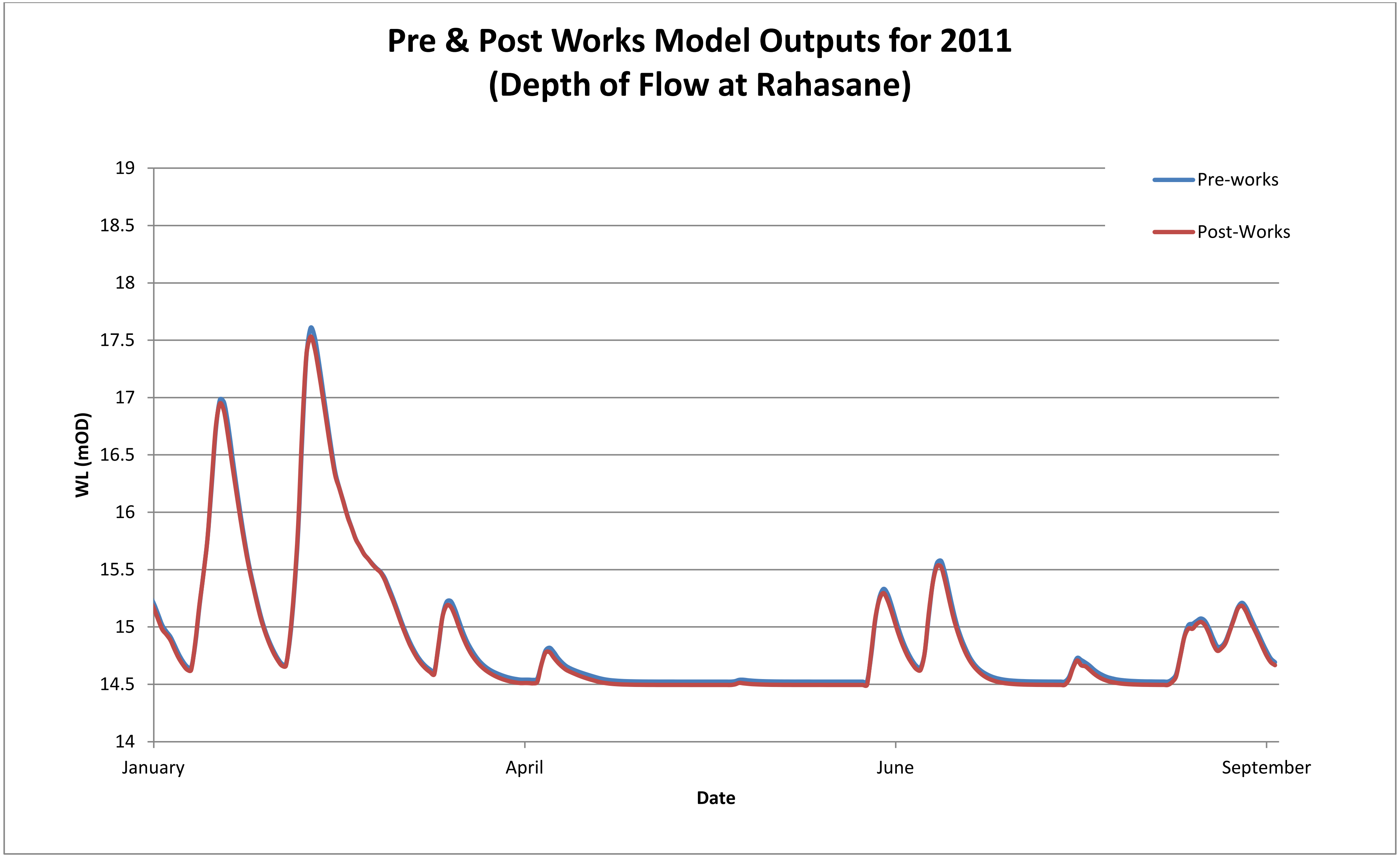
Predicted Pre and Post Works Depth of Flow Output from the HEC-RAS Model



Pre & Post Works Model Outputs for 2008
(Depth of Flow at Rahasane)
19
18.5
18
17.5
17
16.5
16
15.5
15
14.5
14
WL (mOD)
January
March
June
September
December
Date
Pre-works
Post-Works


Pre & Post Works Model Outputs for 2009
(Depth of Flow at Rahasane)
Pre-works
Post-Works
WL (mOD)
19
18.5
18
17.5
17
16.5
16
15.5
15
14.5
14
January
April
June
September
December
Date


Pre & Post Works Model Outputs for 2010
(Depth of Flow at Rahasane)
19
18.5
18
17.5
17
16.5
16
15.5
15
14.5
14
WL (mOD)
January
April
June
September
December
Date
Pre-works
Post-Works

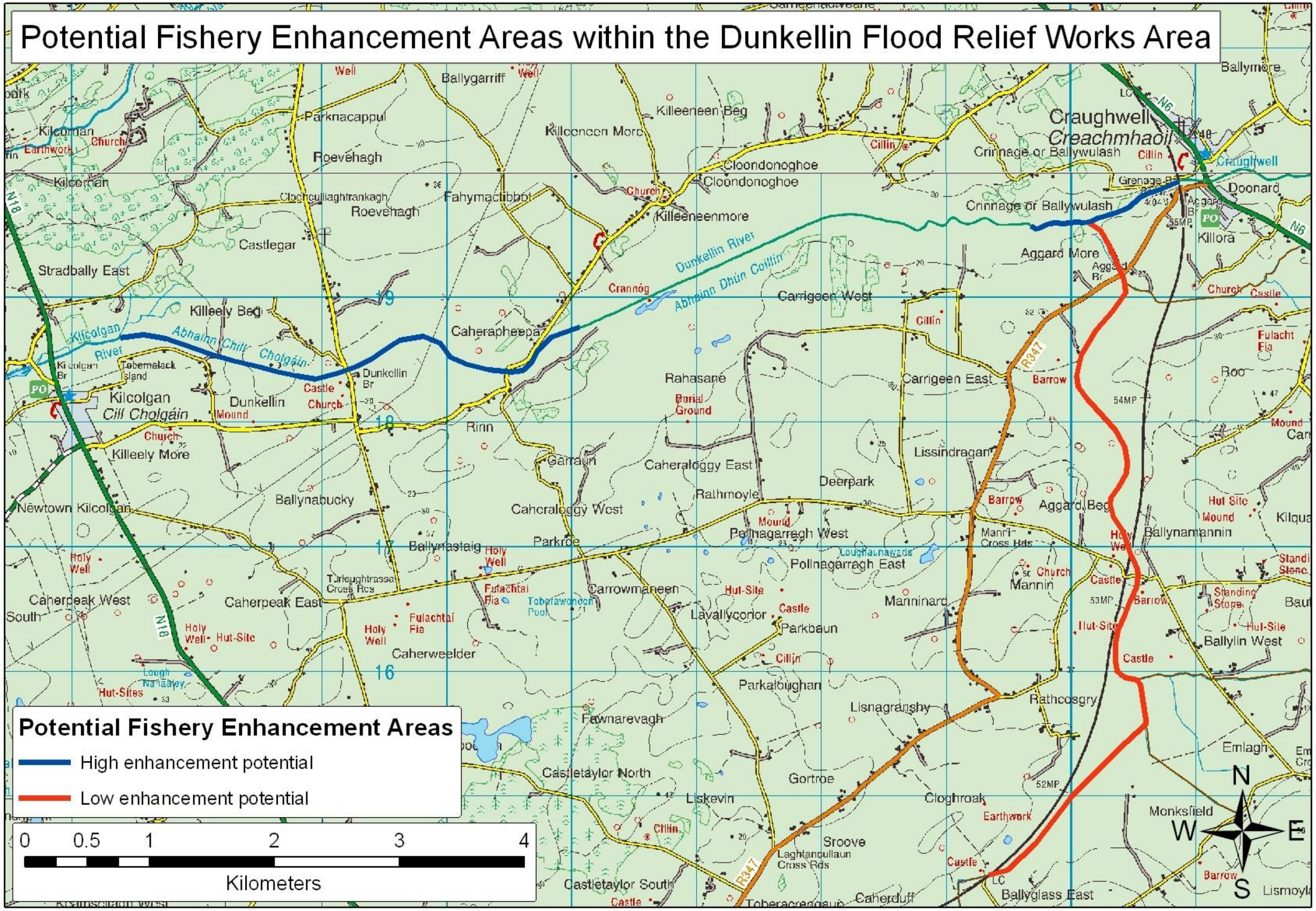


Pre & Post Works Model Outputs for 2011
(Depth of Flow at Rahasane)
Pre-works
Post-Works
WL (mOD)
19
18.5
18
17.5
17
16.5
16
15.5
15
14.5
14
January
April
June
September
Date

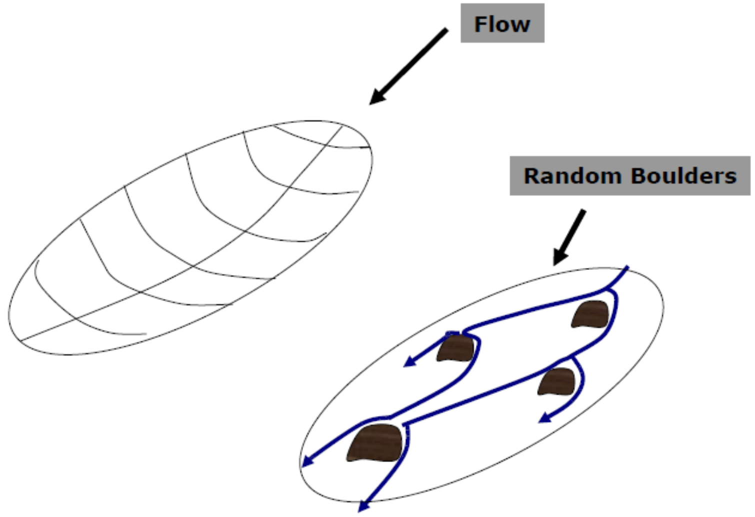
Appendix No. 3

Outline Typical Details of Proposed River Enhancement Works along the Dunkellin River as provided by Inland Fisheries Ireland

(Final Design & Location to be confirmed at Detailed Design Stage)


Potential Fishery Enhancement Areas within the Dunkellin Flood Relief Works Area
Potential Fishery Enhancement Areas
High enhancement potential
Low enhancement potential
0 0.5 1 2 3 4
Kilometers
N
S
E
W
Craughwell
Creachmhaoil
Kilcolgan
Cill Cholgáin
Dunkellin River
Abhainn Dhún Coillín
Kilcolgan River
Abhainn Chill Cholgáin
Killeeneenmore
Killeeneen Beg
Cloondonoghoe
Roevehagh
Parknacappul
Castlegar
Stradbally East
Killeely Beg
Killeely More
Caherapheepa
Dunkellin
Rinn
Garraun
Rahasane
Carrigeen West
Carrigeen East
Caheraloggy East
Caheraloggy West
Rathmoyle
Deerpark
Lissindragan
Aggard More
Aggard Beg
Killora
Doonard
Ballymore
Ballynabucky
Ballynastaig
Parkroe
Newtown Kilcolgan
Caherpeak West
Caherpeak East
Caherweelder
Carrowmaneen
Lavallyconor
Parkbaun
Parkaloughan
Pollnagarragh West
Pollnagarragh East
Manninard
Mannin
Ballynamannin
Ballylin West
Rathcosgry
Lisnagranshy
Fawnarevagh
Castletaylor North
Castletaylor South
Gortroe
Cloghroak
Sroove
Monksfield
Emlagh
Ballyglass East
Lismoyle
Liskevin
Ballygarriff
Fahymactibbot
N18
N6
R347

Detail 1. Centre Channel Pool



Key Features

Pool should be egg-shaped.

Pool Length 1.5 times channel width.

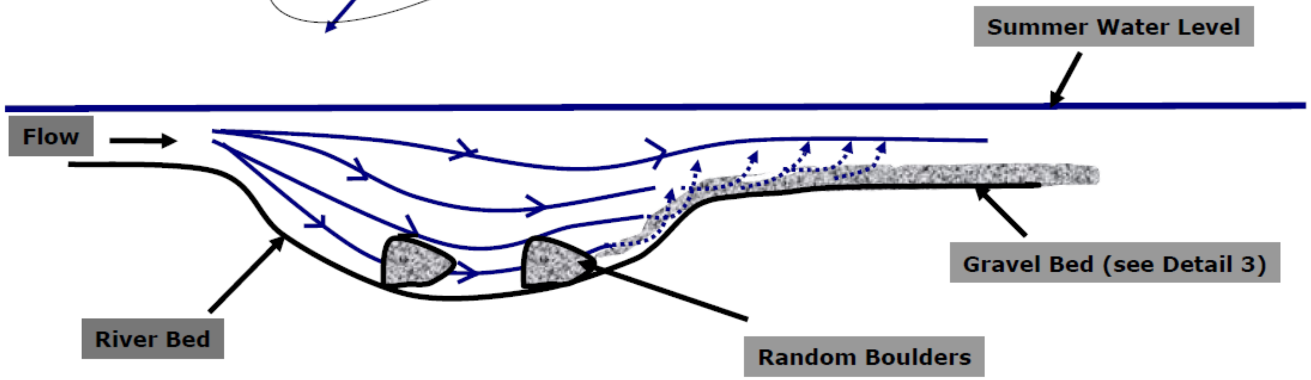
Gradually slope down to the deepest point (1.5m) in the centre and taper back up towards the tail.

Should also taper down from either side towards the centre.

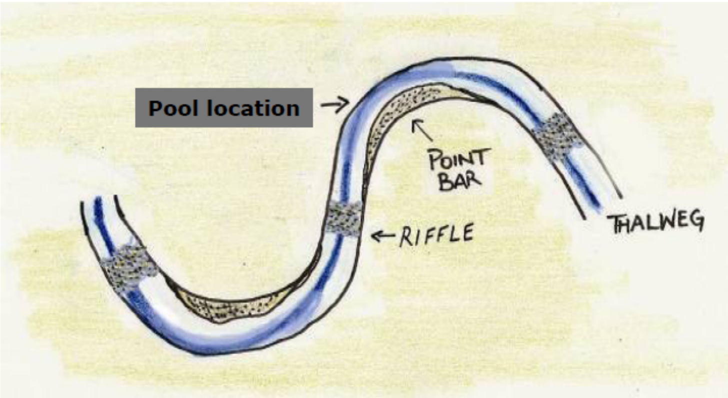
Should occupy the central 2/3 area of the channel cross section.

Place a number of boulders in the pool.
Boulders should be placed in a triangular or diamond shaped pattern

Pool should be placed on average 5-7 channels widths in distance apart



Detail 2. Lateral Scour Pool



Key Features

Pool should be placed on the **eroding side of bends** in a meadering channel.

Pool should be banana-shaped.

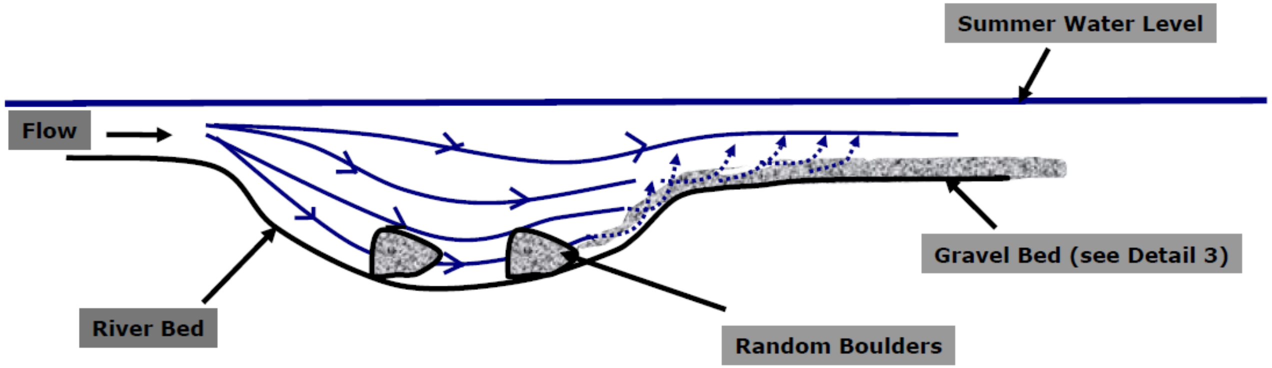
Pool length 1.5 times channel basewidth.

Pool width approximately 1/3 of the channel basewidth placed on eroding side of channel.

Gradually slope down to the deepest point (1.5m) in the centre of the pool and taper back up towards the tail.

Should also taper down from either side width deepest point leaning towards the eroding bank.

Place a number of boulders in the along the pool.



OPW The Office of Public Works

Iascach Intíre Éireann Inland Fisheries Ireland

Detail 3. Gravel Placement

Key Features

Pool and gravel bed should be approx same length (1.5 times channel width).

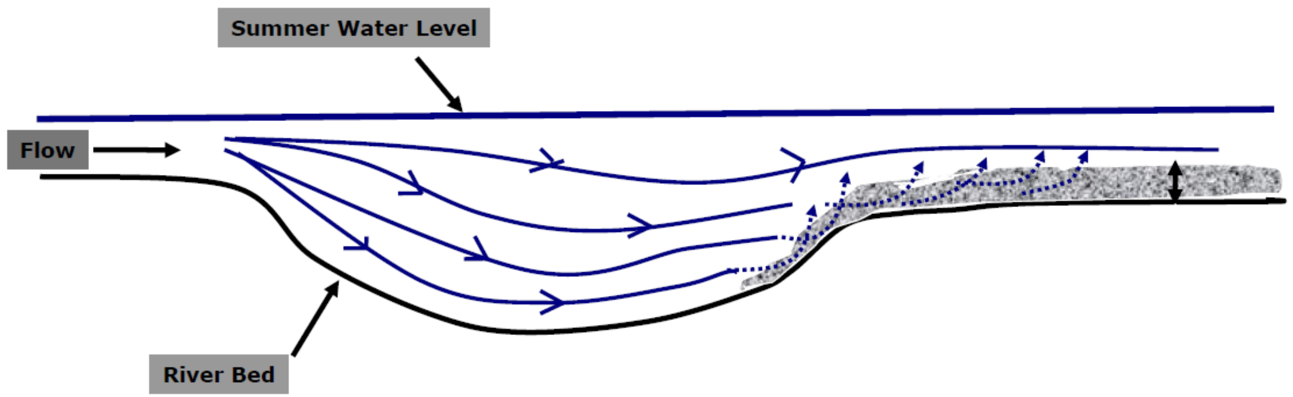
Should occupy the central 2/3 area of the channel cross section.

Start to place gravel at tail of pool (downstream end).

Gravel bed should be 35 to 40cm deep.

Gravel Size (see Detail 4 spawning gravels).

Up-welling of water through the gravels is essential.



OPW The Office of Public Works Oifig na nOibreacha Poiblí

Iascach Intíre Éireann Inland Fisheries Ireland

Detail 4. Spawning Gravel

Table 4.1

Type	Grade	% Composition
Cobble	64 - 190mm	10%
Very coarse gravel	32 - 64mm	35%
Coarse gravel***	16 – 32mm	25%
Medium gravel***	8 - 16mm	20%
Fine gravel***	4 – 8mm	10%

Table 4.2

Type	Grade	% Composition
Cobble	64 - 190mm	0%
Very coarse gravel	32 - 64mm	15%
Coarse gravel***	16 – 32mm	35%
Medium gravel***	8 - 16mm	30%
Fine gravel***	4 – 8mm	15%

Key Features

Wide variation in particle size.

Washed, rounded stones.

See table 4.1 below for range and % composition of stones required for **Irish salmon** and **sea trout** spawning gravels.

See table 4.2 below for range and % composition of stones required for **brown trout** spawning gravels.

***Least critical component of this mix as they will settle naturally once the cobble and very coarse gravel is placed.

Ratio of cobble to very coarse gravel to be placed - 50:50 .

For placement of gravel see Detail 3.

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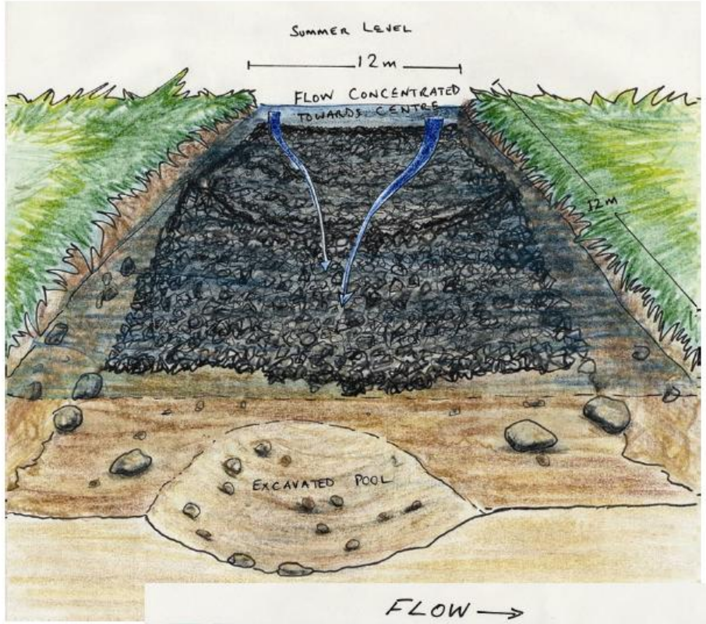
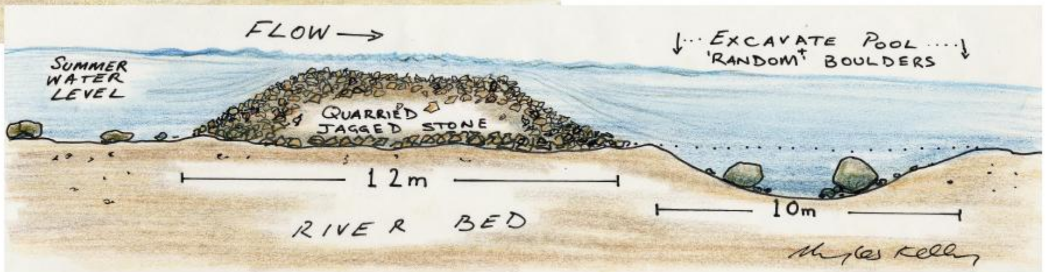
Detail 5. Rubble Mat





Key Features

Broken quarried stone (150 - 250mm).

Rubble mat Length equal to one channel width.

Stone placed below summer low water level from bank to bank.

Gulley should be made through the rubble mat concentrating flow towards centre of channel.

Excavate pool downstream of rubble mat (Detail 1)

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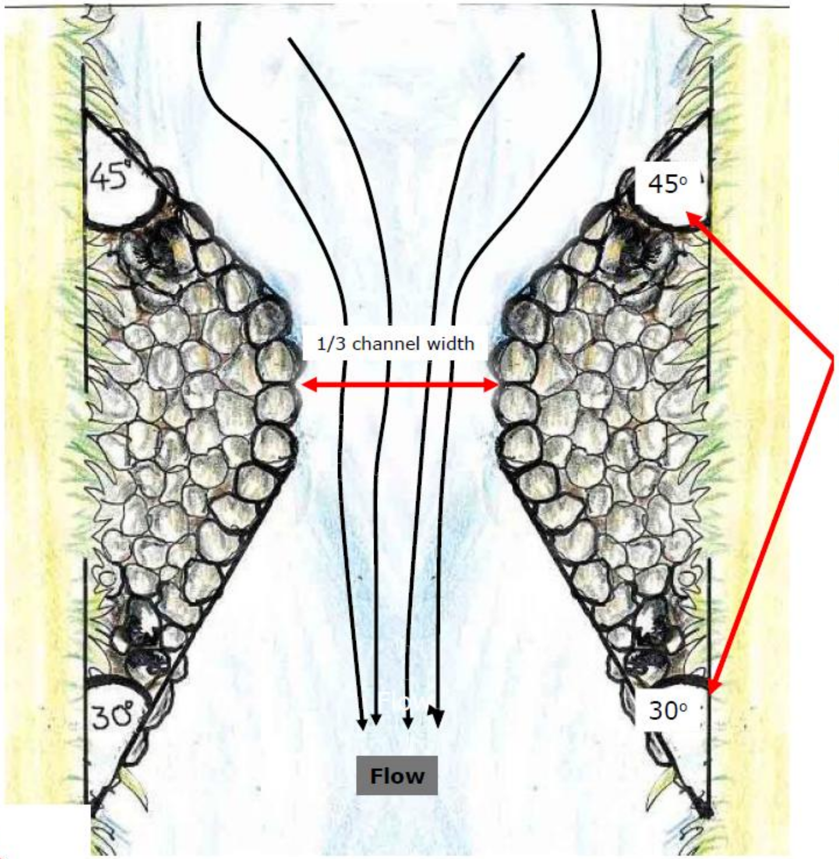
Detail 6. Paired Stone Deflectors



Key Features

The largest heaviest stones available should be used at the outer tip of each deflector where the maximum erosive pressure will be generated by river flows.

Outer stones should be buried a little more than the others as the structure must slope out and down from the bank, ie. the stones at the outer tip of the deflector need to be at the lowest point of the structure.

The outer tip of each deflector should be no higher than summer water level.

45° angle on upstream slope and 30° angle on downstream slope (as detailed in drawing) required to generate appropriate flow regime.

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Detail 7. Alternating Stone Deflectors

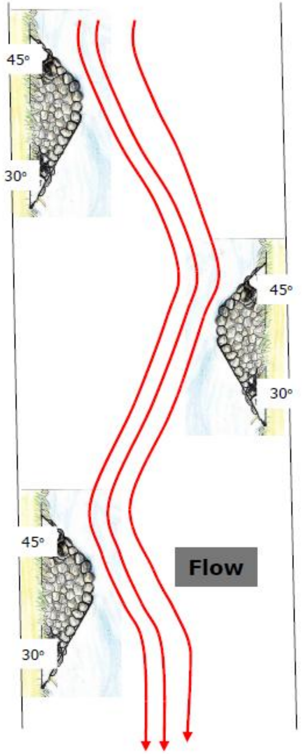


Figure 7.1

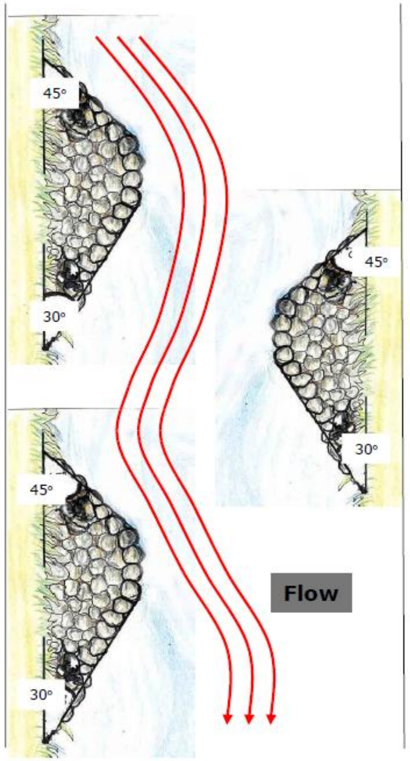


Figure 7.2

Key Features

The largest heaviest stones available should be used at the outer tip of each deflector where the maximum erosive pressure will be generated by river flows.

Outer stones should be buried a little more than the others as the structure must slope out and down from the bank, ie. the stones at the outer tip of the deflector need to be at the lowest point of the structure.

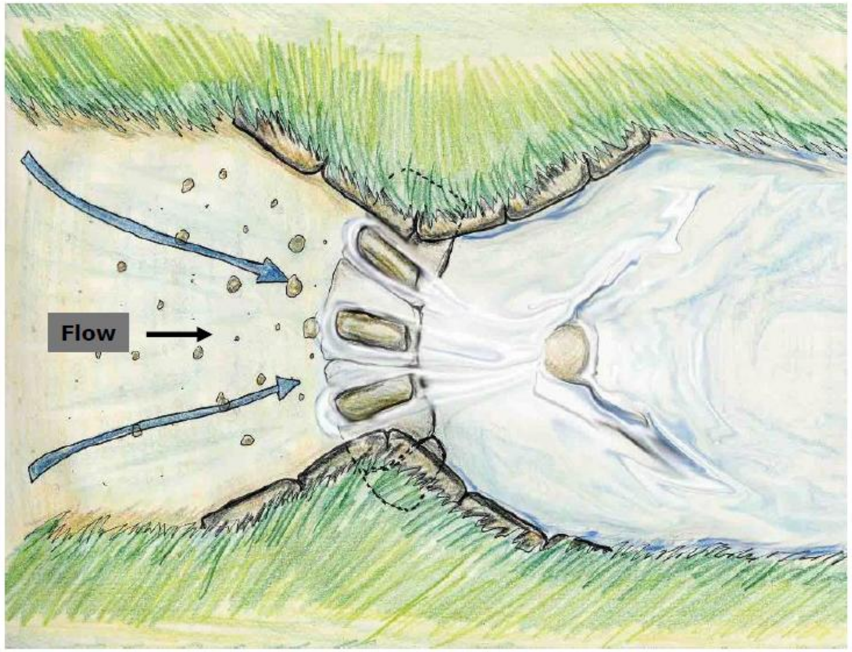
The outer tip of each deflector should be no higher than summer water level.

45° angle on upstream slope and 30° angle on downstream slope required to generate appropriate flow regime.

In fast-flowing channels, deflectors do not overlap (figure 7.1).

In slow-flowing, wide channels, deflectors may overlap (figure 7.2)

Detail 8. Vortex Stone Weir



Key Features

A series of rocks are built into both backs to direct flow towards centre of channel.

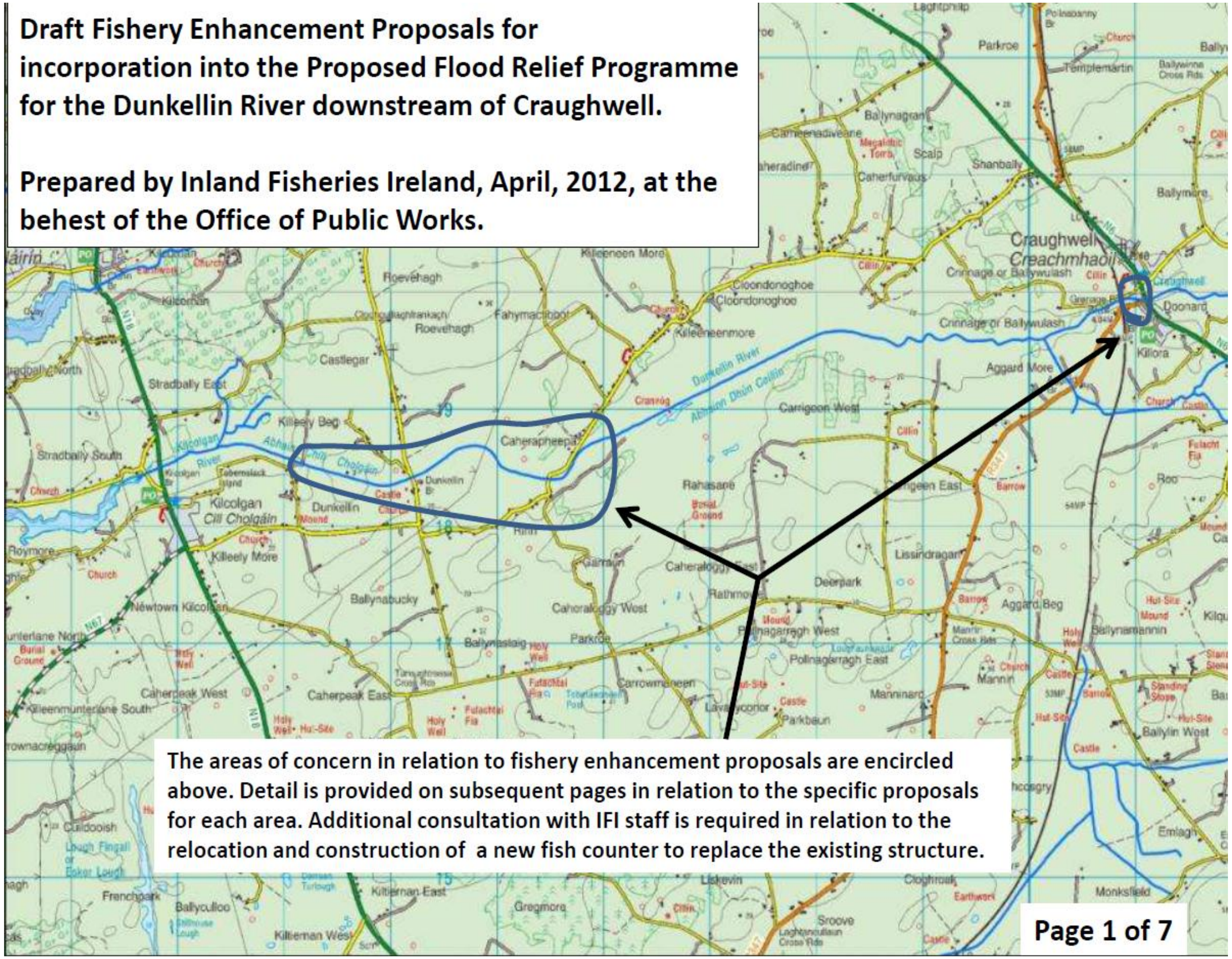
A line of footer stones, arched upstream are buried across the central channel area. The surface of these stones should be flush with the bed of the stream.

Three rocks are placed on top of the footer stones. The top of these rock are exposed by a few centimetres in summer low flow and are fully sumberged in high flows.

Excavate a pool dowmstream of the weir (see Detail 1 Centre Channel Pool)

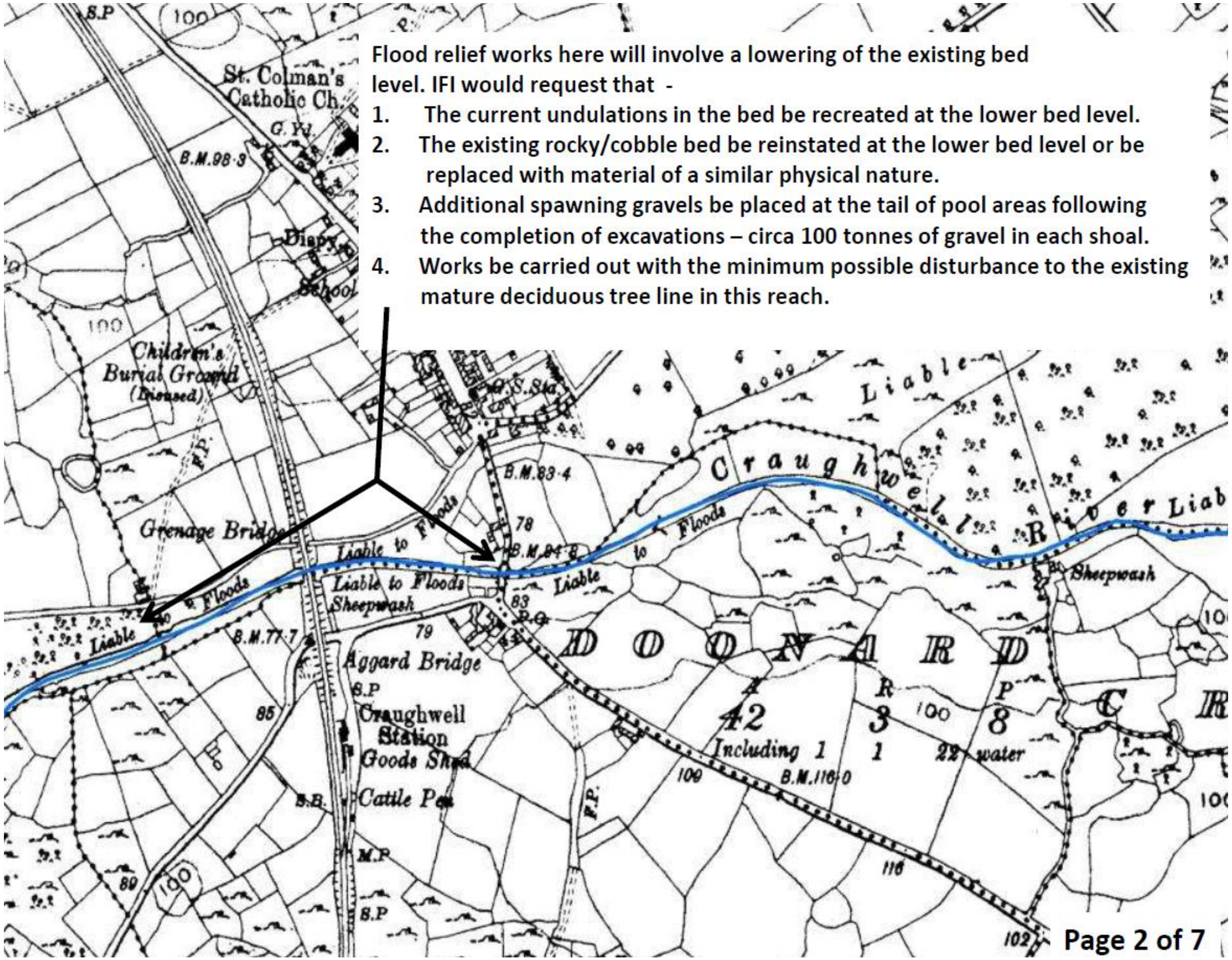
Draft Fishery Enhancement Proposals for incorporation into the Proposed Flood Relief Programme for the Dunkellin River downstream of Craughwell.

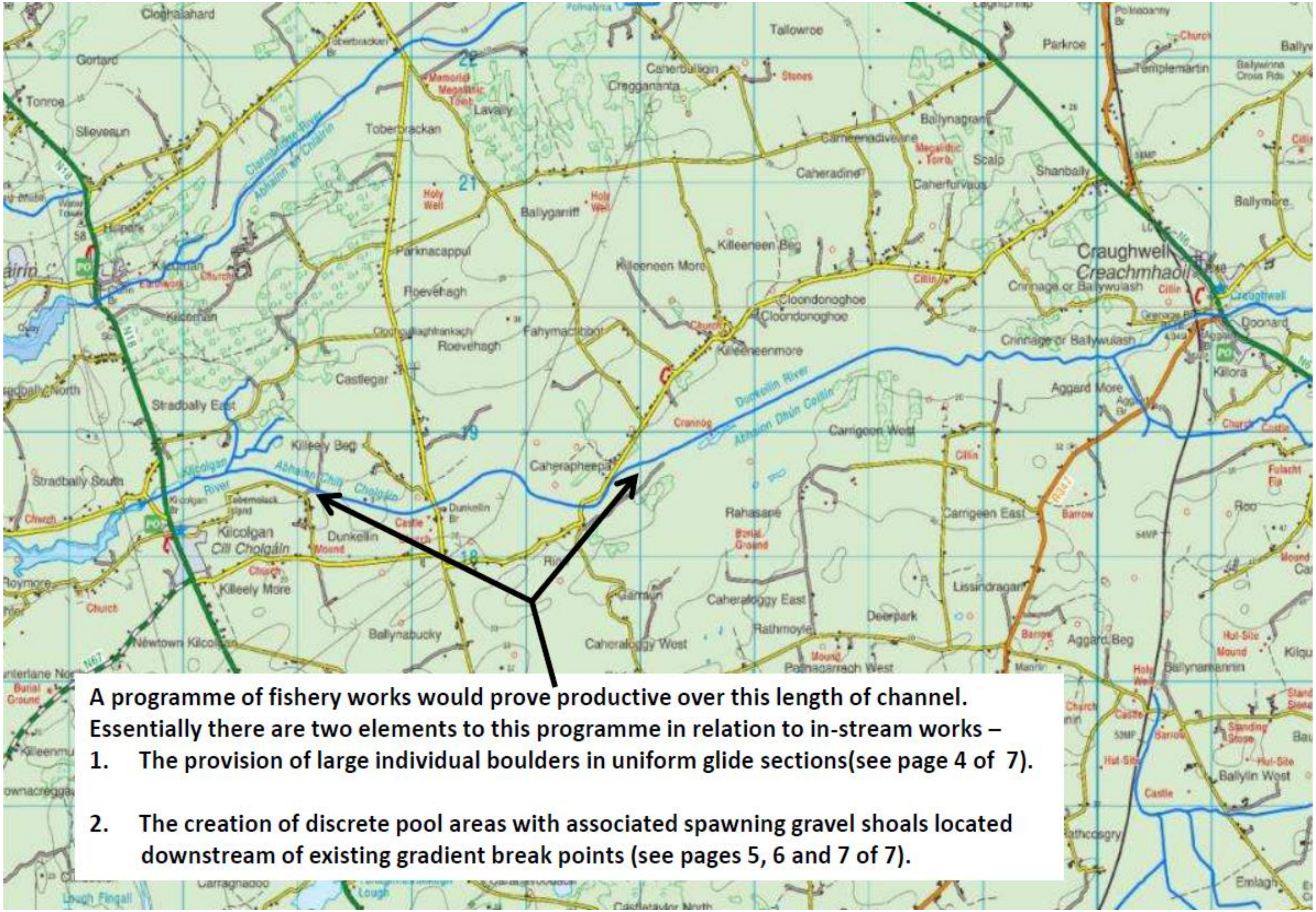
Prepared by Inland Fisheries Ireland, April, 2012, at the behest of the Office of Public Works.



The areas of concern in relation to fishery enhancement proposals are encircled above. Detail is provided on subsequent pages in relation to the specific proposals for each area. Additional consultation with IFI staff is required in relation to the relocation and construction of a new fish counter to replace the existing structure.

Page 1 of 7

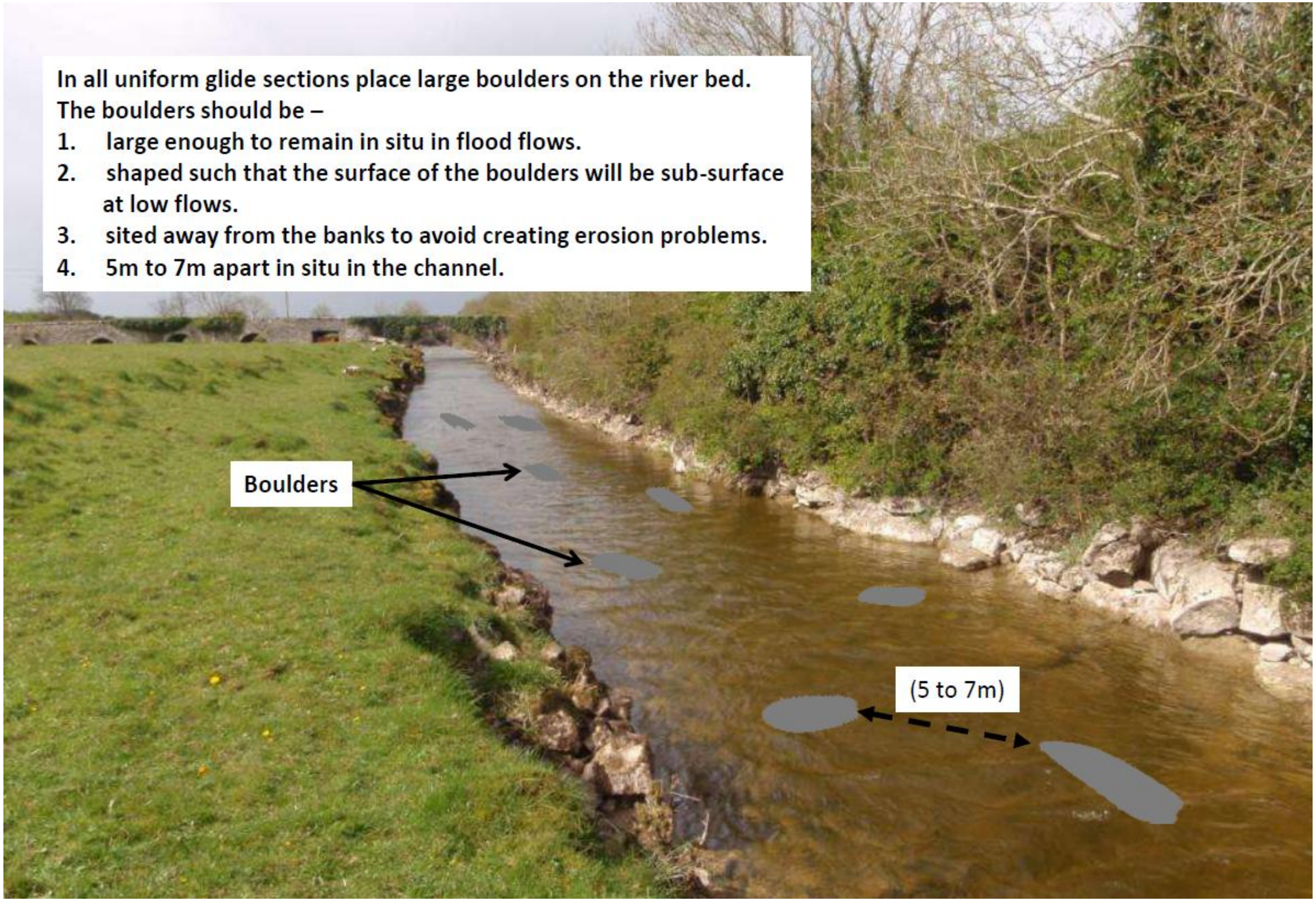

Flood relief works here will involve a lowering of the existing bed level. IFI would request that -
1. The current undulations in the bed be recreated at the lower bed level.
2. The existing rocky/cobble bed be reinstated at the lower bed level or be replaced with material of a similar physical nature.
3. Additional spawning gravels be placed at the tail of pool areas following the completion of excavations – circa 100 tonnes of gravel in each shoal.
4. Works be carried out with the minimum possible disturbance to the existing mature deciduous tree line in this reach.
St. Colman's Catholic Ch.
Children's Burial Ground (Disused)
Grenage Bridge
Liable to Floods
Sheepwash
Aggard Bridge
Craughwell Station
Goods Shed
Cattle Pen
Craughwell River
DOONARD
Including 1
water
Page 2 of 7

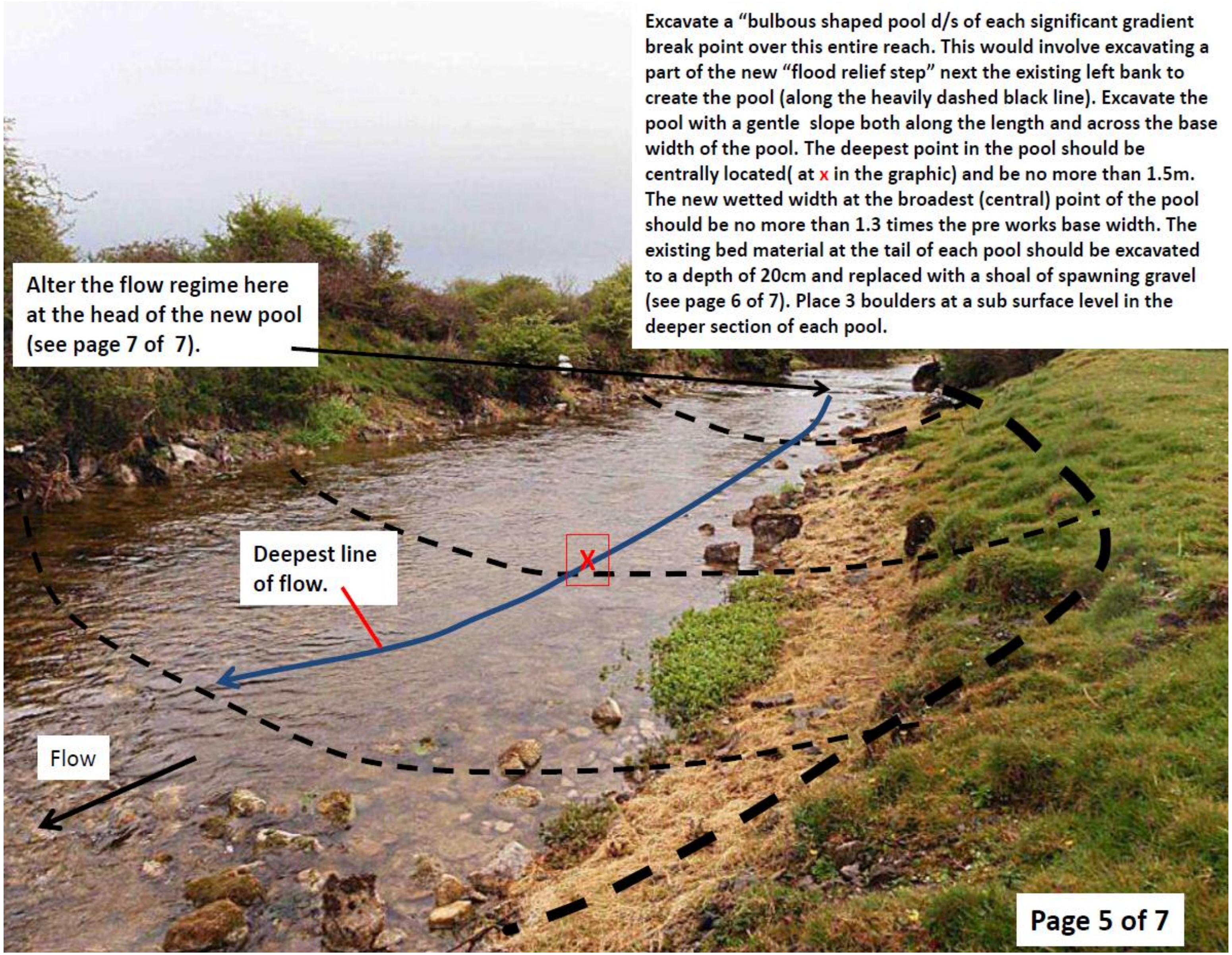


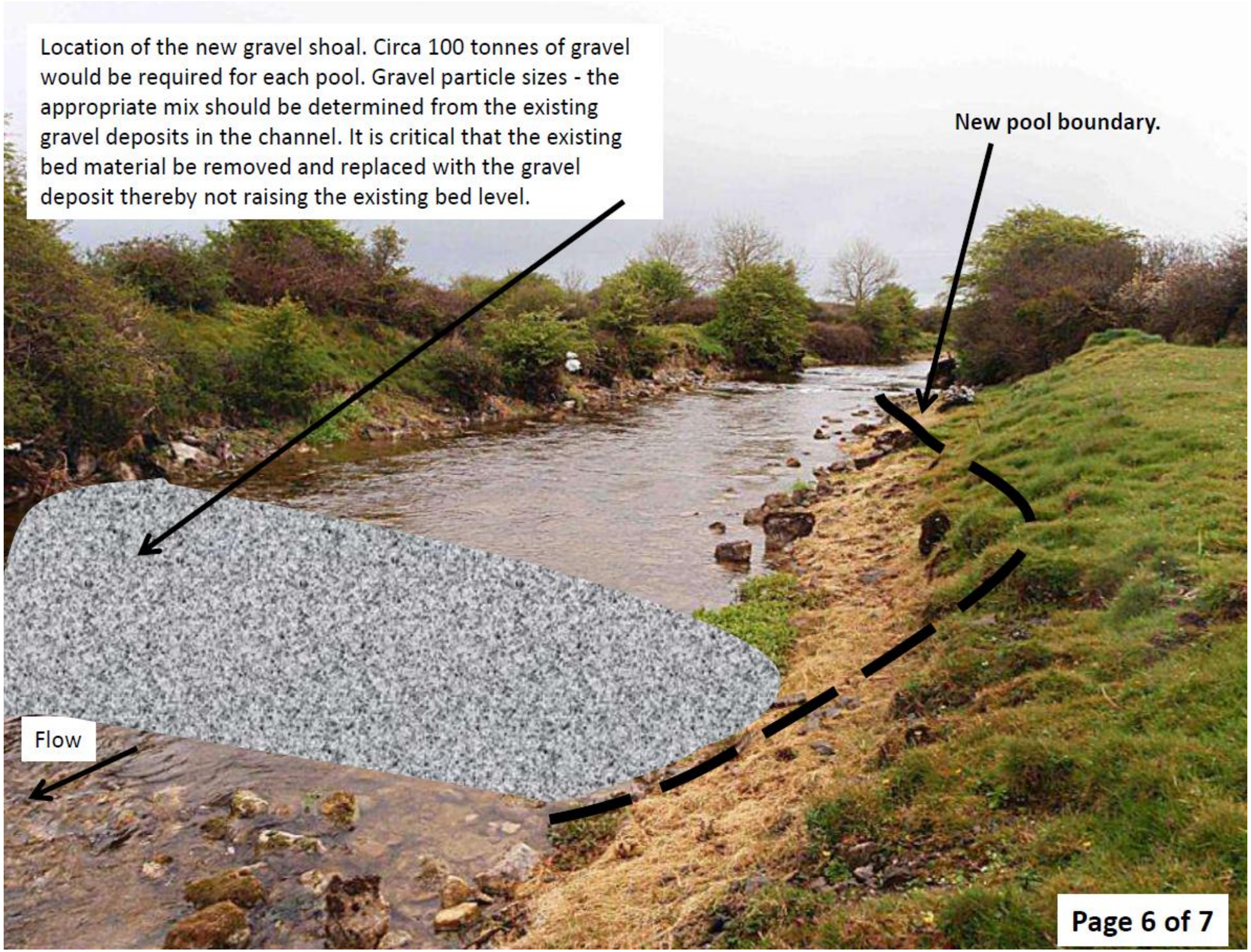
A programme of fishery works would prove productive over this length of channel. Essentially there are two elements to this programme in relation to in-stream works –

1. The provision of large individual boulders in uniform glide sections(see page 4 of 7).

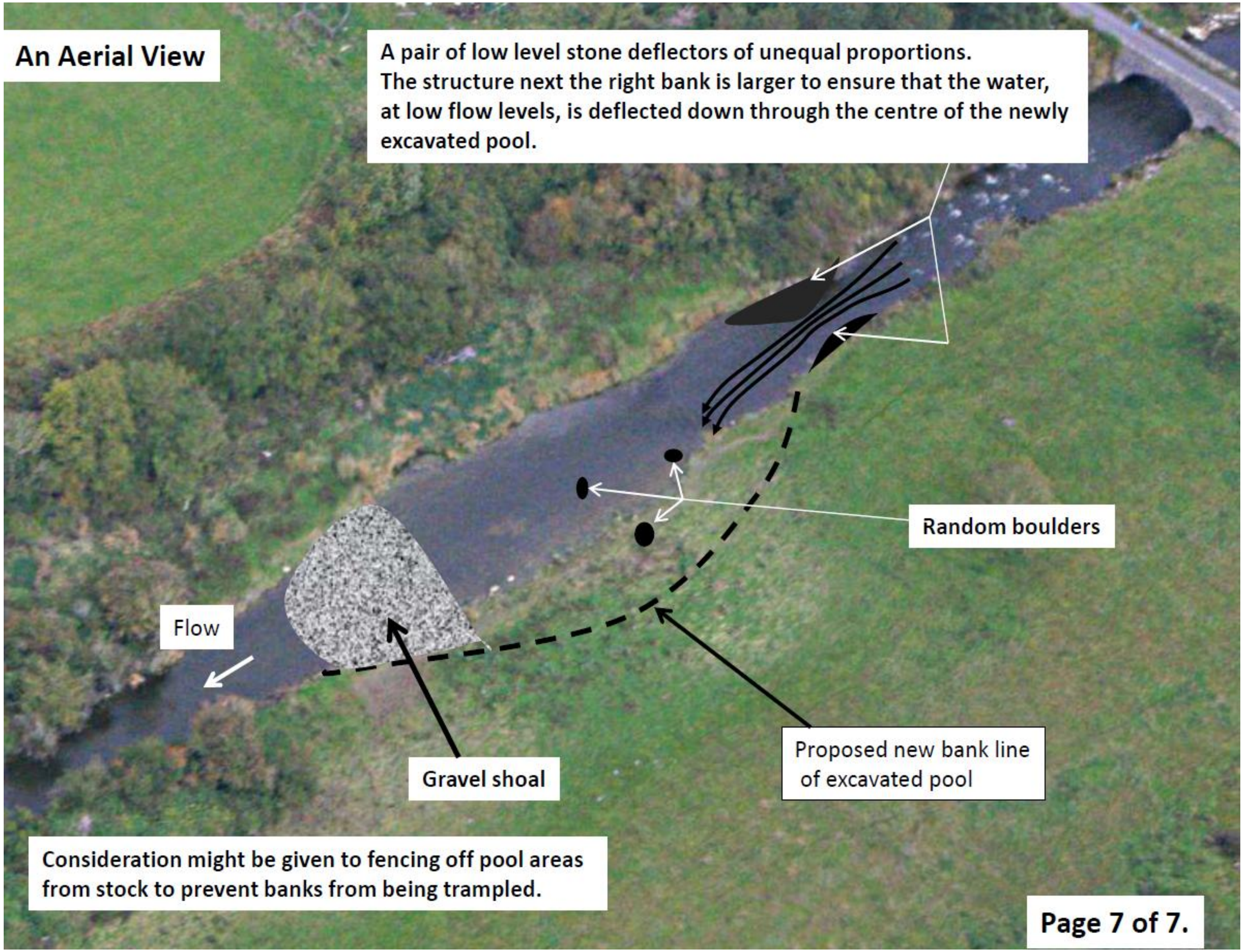
2. The creation of discrete pool areas with associated spawning gravel shoals located downstream of existing gradient break points (see pages 5, 6 and 7 of 7).


In all uniform glide sections place large boulders on the river bed.
The boulders should be –
1. large enough to remain in situ in flood flows.
2. shaped such that the surface of the boulders will be sub-surface at low flows.
3. sited away from the banks to avoid creating erosion problems.
4. 5m to 7m apart in situ in the channel.
Boulders
(5 to 7m)


Excavate a "bulbous shaped pool d/s of each significant gradient break point over this entire reach. This would involve excavating a part of the new "flood relief step" next the existing left bank to create the pool (along the heavily dashed black line). Excavate the pool with a gentle slope both along the length and across the base width of the pool. The deepest point in the pool should be centrally located(at x in the graphic) and be no more than 1.5m. The new wetted width at the broadest (central) point of the pool should be no more than 1.3 times the pre works base width. The existing bed material at the tail of each pool should be excavated to a depth of 20cm and replaced with a shoal of spawning gravel (see page 6 of 7). Place 3 boulders at a sub surface level in the deeper section of each pool.
Alter the flow regime here at the head of the new pool (see page 7 of 7).
Deepest line of flow.
X
Flow
Page 5 of 7



Location of the new gravel shoal. Circa 100 tonnes of gravel would be required for each pool. Gravel particle sizes - the appropriate mix should be determined from the existing gravel deposits in the channel. It is critical that the existing bed material be removed and replaced with the gravel deposit thereby not raising the existing bed level.
New pool boundary.
Flow
Page 6 of 7


An Aerial View
A pair of low level stone deflectors of unequal proportions.
The structure next the right bank is larger to ensure that the water, at low flow levels, is deflected down through the centre of the newly excavated pool.
Random boulders
Flow
Gravel shoal
Proposed new bank line of excavated pool
Consideration might be given to fencing off pool areas from stock to prevent banks from being trampled.
Page 7 of 7.

FURTHER DETAIL OF RIVER ENHANCEMENT WORKS AT CRAUGHWELL (IFI Proposals)

An Ecological Evaluation of the likely impacts of a proposed flood relief scheme on a reach of the Craughwell River at Craughwell, Co. Galway.

1.The Flood Relief Proposal

Details of this flood relief proposal are provided in Figure 1.Proposed works involve a continuous deepening of the existing channel from a point 160 metres upstream of Craughwell Village downstream to a point 912 metres below the village. No widening of any channel section within this reach is proposed. The proposal will incorporate a fishery enhancement "layer" designed to protect fish stocks and also improve general ecological diversity in the river corridor. To accommodate these objectives the design incorporates a deepening of dredging operations by 0.5m below the flood relief design bed level to allow one to provide morphological diversity (riffle/glide/pool sequences) in the channel post-dredging where possible.

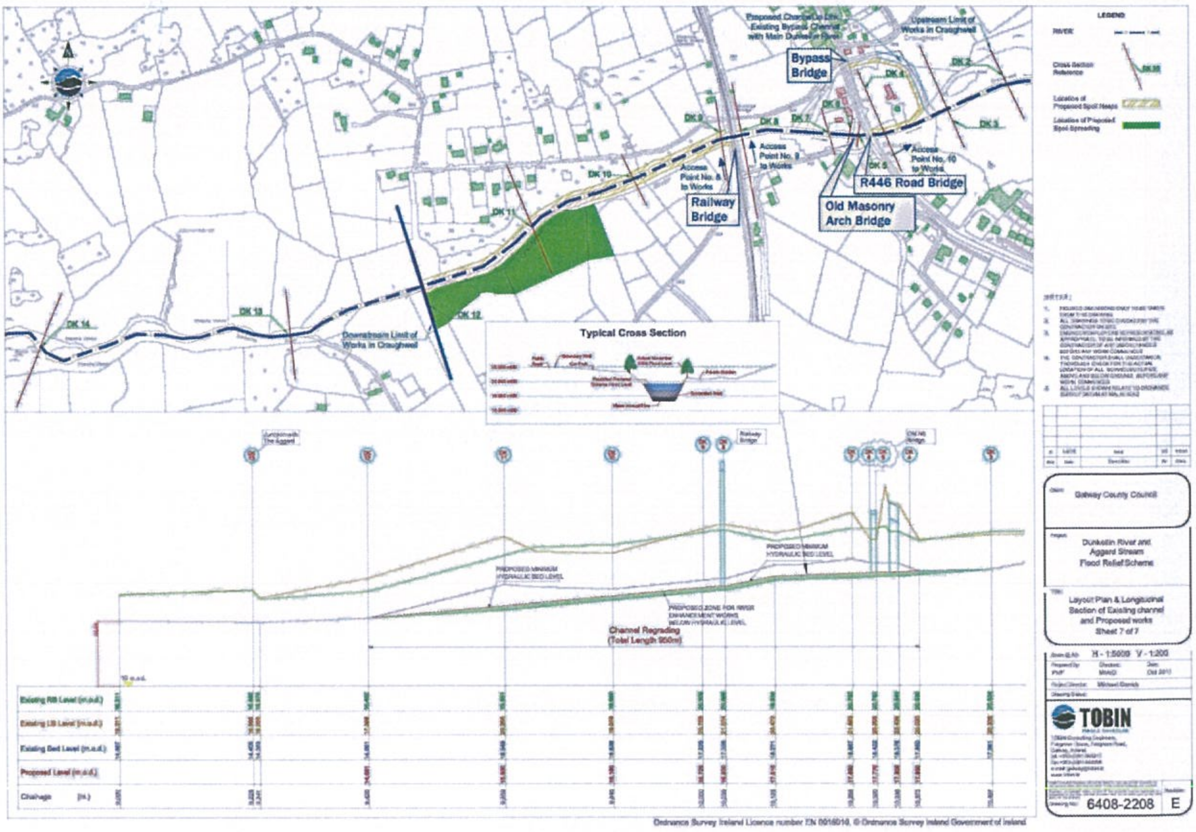


Figure 1. Detail in relation to the flood relief proposal.

2.The Current Status of this Channel Reach from a fluvial geomorphological and ecological perspective.

In fluvial geomorphological terms the Craughwell River would be classified as a "C Type" channel (after Rosgen, 1996). An undisturbed "C Type" channel would have well defined pool areas, on average, at intervals of 7 channel widths in distance apart with associated gravelled riffle areas adjacent to each pool. One would expect to find shallow glide areas between the pools. The current physical form of the Craughwell River reach in question does not fit this description. Clearly at some time in the past this river reach was dredged and partially canalised. Currently most reaches are either deep flats or uniform shallow glides. There is only one significant gravelled riffle throughout the entire reach (see Fishery Enhancement Plan, page 3).

In summary the existing channel can be described as;-

- having very little salmonid and lamprey spawning habitat.
- a dearth of well-defined pool areas which means that;-
  a – adult trout habitat is very limited.
  b – resting places for adult salmon and sea trout returning to spawn are restricted.
  c – significant fine silt deposits which would normally be found along the margins of well defined pool areas are not present which means that this reach currently cannot accommodate a significant juvenile lamprey population.
- the dearth of gravelled riffles will also limit the diversity of both the aquatic flora and macroinvertebrate fauna.
- the overall biological productivity of this river zone, downstream of the village, is limited because of excessive shading – currently significant river bed areas are devoid of algal, moss and macrophytic plant colonies because of excessive shade.

3.Likely Impacts of the Flood Relief Scheme once the Fishery Enhancement Proposals are Implemented as part of this Programme.

The incorporation of the fishery enhancement proposals (attached), as part of this flood relief scheme, will address some of the current morphological and ecological imbalances in this channel reach as outlined in Section 2.

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- a total of 13 new pool areas with associated gravelled riffles will be in place – currently there is only one gravelled riffle and one well defined pool area in this entire zone.
- the fish carrying capacity of deeper glide areas will be enhanced by the proposed addition of random boulders.
- the proposed partial and targeted reduction in bankside vegetation will significantly improve the biological diversity and overall productivity of this channel reach for the aquatic flora, macroinvertebrate fauna and fish stocks.

The author has been involved in designing and monitoring the effectiveness of river enhancement programmes, like this proposal, for over 30 years. To-day there is a significant body of evidence to show that the projected long-term positive impacts of this programme, as outlined above, are the most likely outcome once the proposed fishery enhancement scheme is adopted as part of the programme (some of the authors relevant scientific publications in this area are appended).

Professor Martin O'Grady, B.Sc., M.Sc., Ph.D., F.Z.S.I.

Senior Research Officer,

Inland Fisheries Ireland.

July 15th, 2014.

Some of the author's scientific publications of relevance to this document.

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O'GRADY, M.F. (1994) The enhancement of salmonid runs in Ireland. I.W.E.M. Conference, London Zoo.

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O'GRADY, M.F. (2002) Salmonid Riverine Enhancement in Ireland, Past, Present and Future. Went Memorial Lecture. Annual Papers in Irish Science and Technology, No. 26, Royal Dublin Society.

O'GRADY, M.F. (2006) Channels and Challenges. Enhancing Salmonid Rivers. Irish Freshwater Fisheries Ecology and Management Services : Number 4, Central Fisheries Board, Dublin, Ireland. ISSN: 1649-265X.

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O'GRADY, M.F., KING, J.J. and CORBETT, K. (1993) The ecological impact of drainage scheme design on salmonid stocks in the River Bonet with particular reference to newly created shallow areas .Water of Life. *Royal Dublin Society Seminar Proceedings, Number 5 p.163-166.*

O'GRADY, M.F., O'NEILL, J. and MOLLOY, S. (1997) Optimising Natural Production. Atlantic Salmon Trust / Atlantic Salmon Foundation Conference – Managing Wild Atlantic Salmon : New Challenges, New Techniques – Galway, September, 1997.

O'GRADY, M.F., KELLY, M. and O'REILLY, S. (2008) Brown Trout in Ireland. Irish Freshwater Fisheries Ecology and Management Series : No. 6. Central Fisheries Board, Dublin, Ireland. ISSN: 1649-265X.

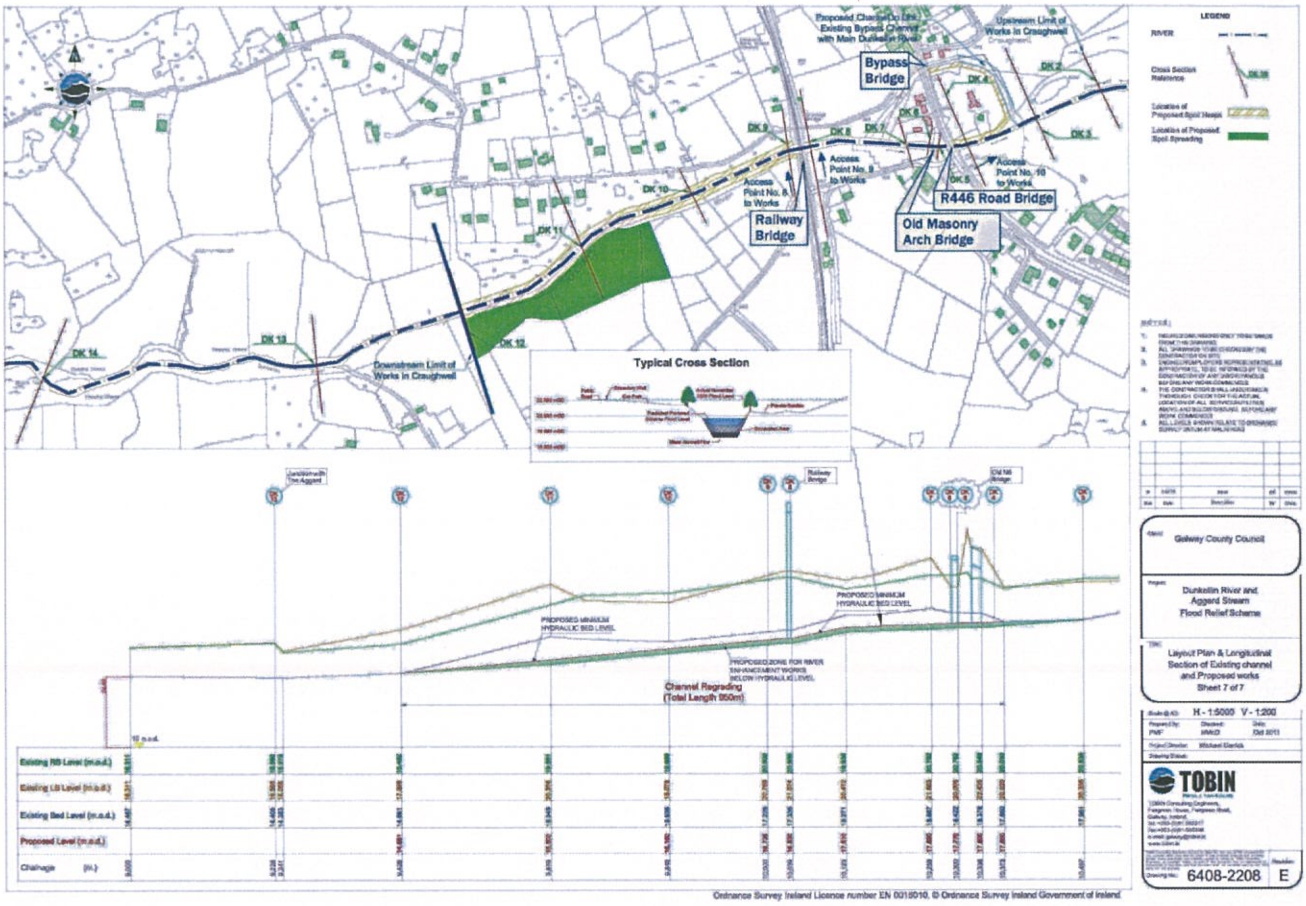
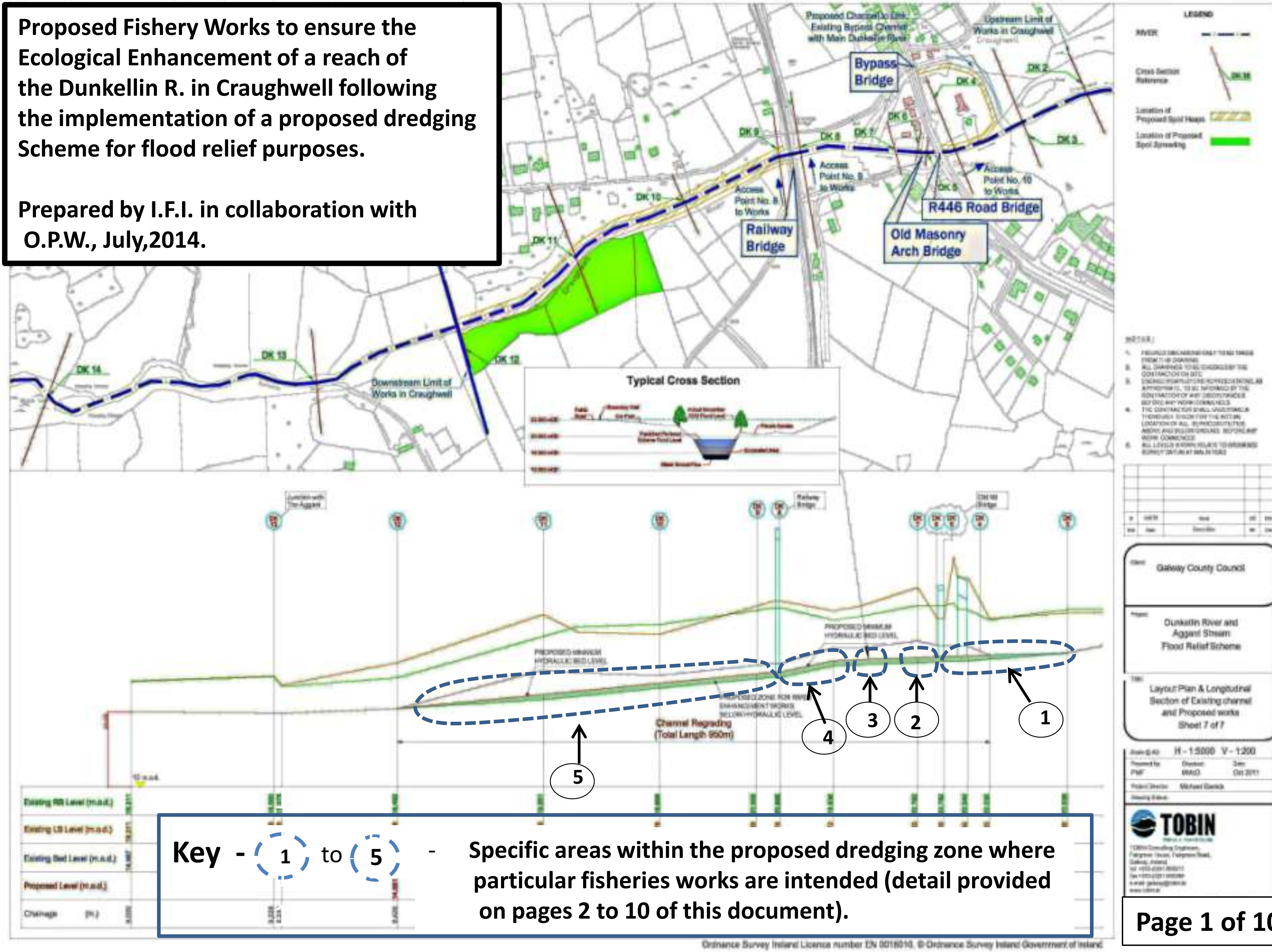


Figure 1. The location, nature and extent of the proposed flood relief scheme on the Craughwell River.

Proposed Fishery Works to ensure the Ecological Enhancement of a reach of the Dunkellin R. in Craughwell following the implementation of a proposed dredging Scheme for flood relief purposes.

Prepared by I.F.I. in collaboration with O.P.W., July,2014.



Key - 1 to 5 - Specific areas within the proposed dredging zone where particular fisheries works are intended (detail provided on pages 2 to 10 of this document).

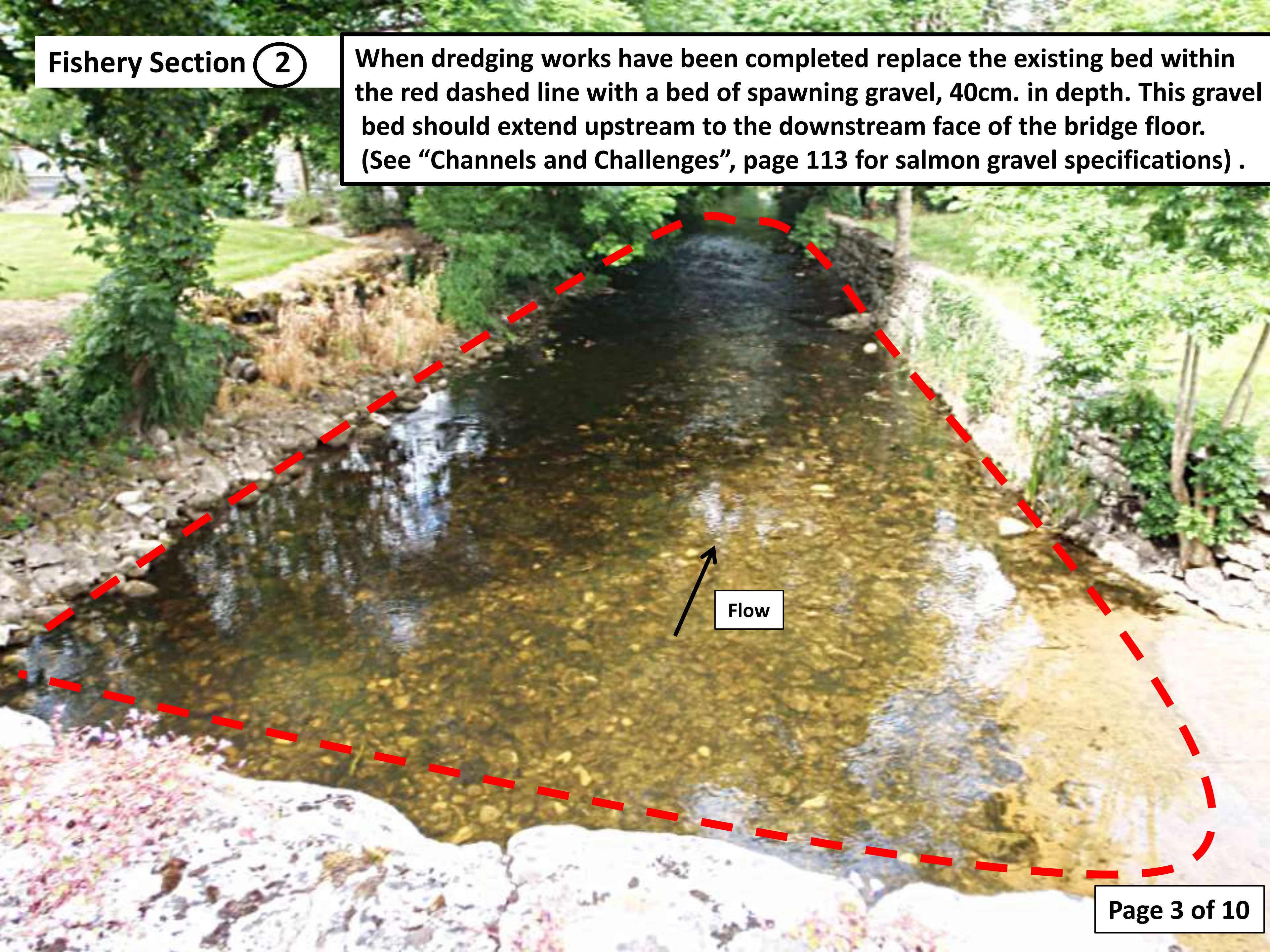
Fishery Section (1)

- When dredging is complete in Zone 1. place the existing heavy cobble material currently on the bed back in situ or, replace it with similar material .
- Keep any disturbance to the riparian zone to a minimum.

Looking u/s from the R446 Bridge.

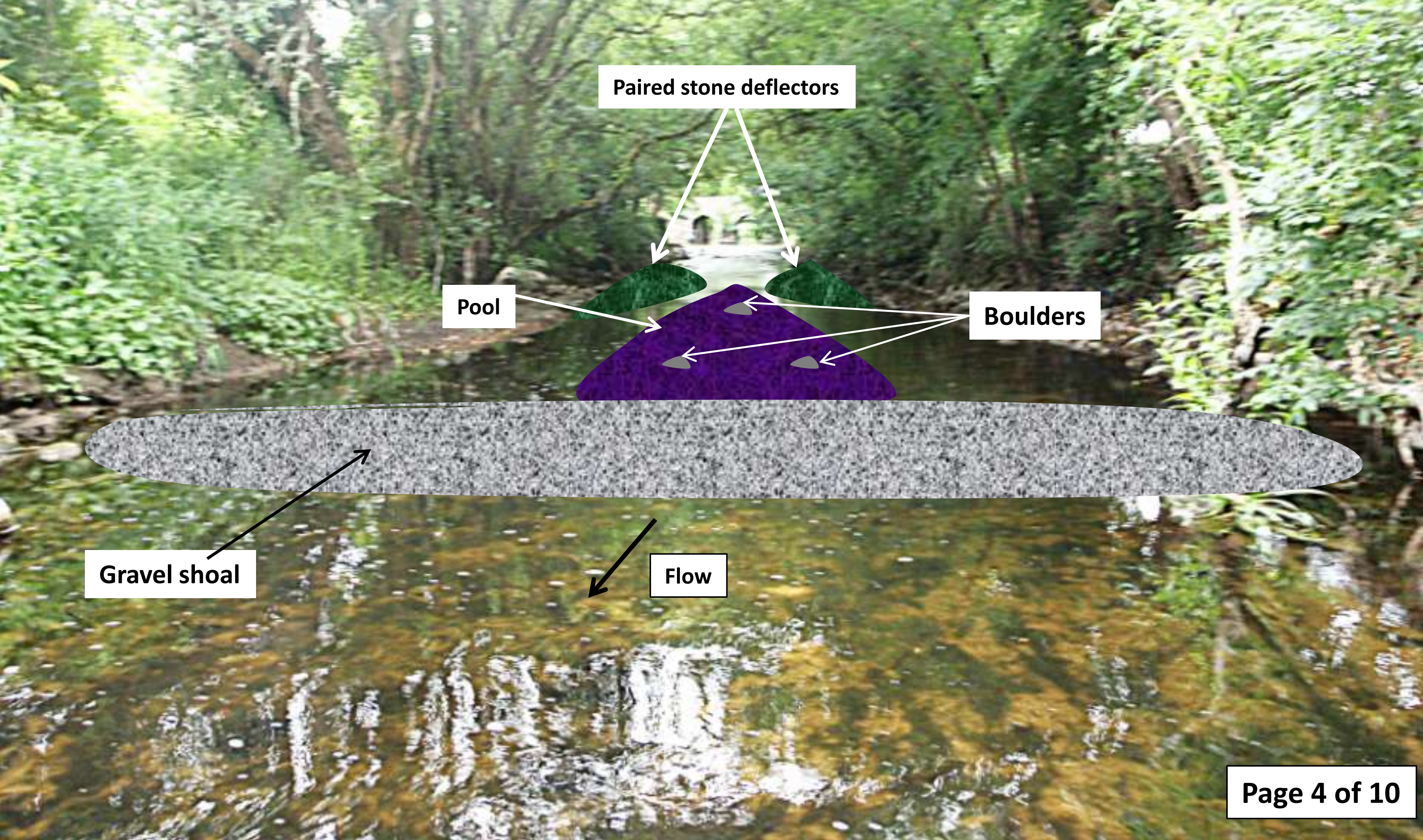
Fishery Section (2)

When dredging works have been completed replace the existing bed within the red dashed line with a bed of spawning gravel, 40cm. in depth. This gravel bed should extend upstream to the downstream face of the bridge floor. (See “Channels and Challenges”, page 113 for salmon gravel specifications) .



Fishery Section 3

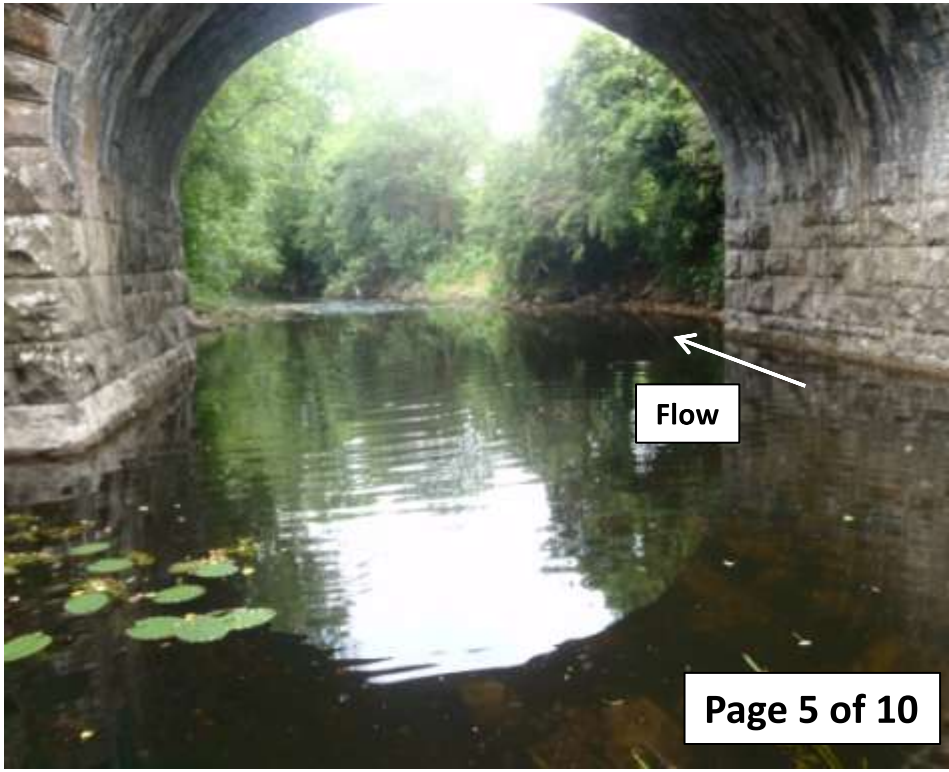
Construct a paired stone deflector with associated pool and gravel spawning shoal at this location. (See appendix for details). The specifications for all proposed paired deflectors, associated pools , boulders and gravel shoals throughout this scheme are the same.



Fishery Section (4)

Sequential views looking d/s through Fishery Section 4 from it's upper reaches to the end of this zone at the Railway Bridge.

Following dredging cover the bed of this channel reach with the type of heavy cobble presently in situ and place large boulders (1.5 to 2.0 tonnes) in the channel at 10m. centres.



Fishery Section 5

Currently the morphology of Fishery Section 5 is relatively uniform in nature with a cobbled bed throughout. There is only one high point on the bed in the middle of this reach (illustrated in this photo). Following the proposed flood relief dredging operation there will be a moderate gradient through a uniform glide over the entire length of Fishery Section 5 (circa 540m.). This will allow one to construct 12 paired stone deflectors with associated pools and gravel shoals, equidistant from one another, over this entire reach. The river bed sections, in between these structures, should be covered with a single layer of large cobbles like those evident along the margins in this photo.

Tunnelling Problems

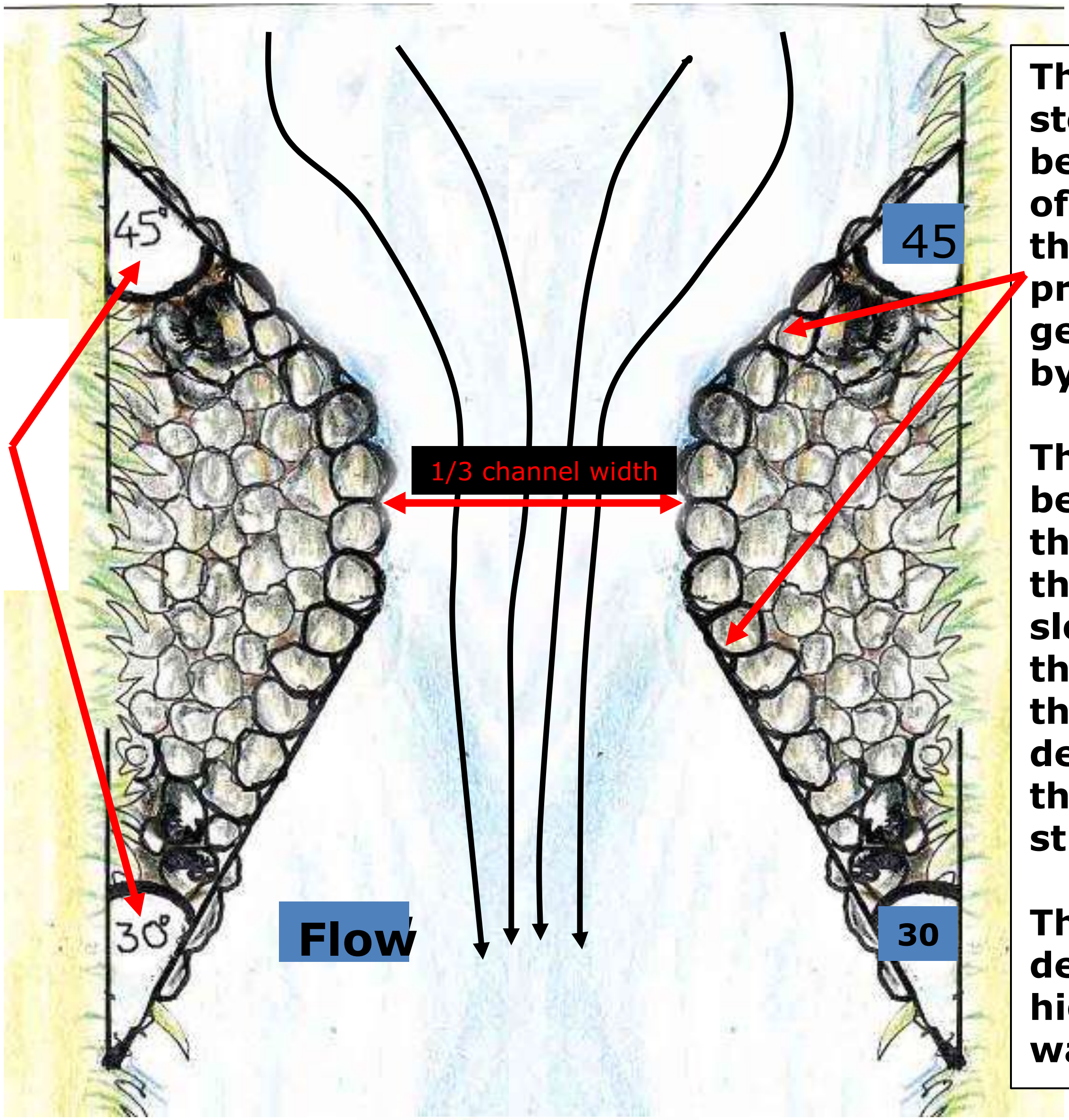
Long sections of this channel reach are heavily tunnelled from the "old masonry bridge" downstream to the end of the proposed dredging reach – note the paucity of ---The overall ecological diversity of flora and fauna in the channel would benefit from a pruning programme carried out along the right bank. Selected areas for pruning should increase the incident light levels on the newly established riffle areas following the proposed physical enhancement of the channel.

Appendix

Key construction features of paired stone deflectors With associated pools and gravel shoals.

A Paired Deflector – Key Features Irrespective of Channel Size

These angles are important to generate the proper flow regime.



The largest heaviest stones available should be used at the outer tip of each deflector where the maximum erosive pressure will be generated by river flows.

These stones will have to be buried a little more than the others because the structure needs to slope out and down from the bank ie. the stones at the outer tip of the deflector need to be at the lowest point of the structure.

The outer tip of each deflector should be no higher than summer water level.

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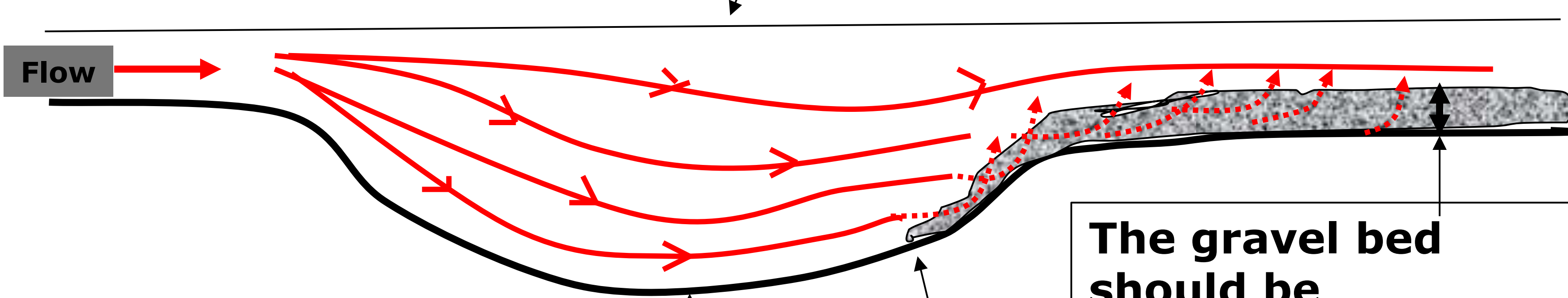
Key Features of Gravel Placement.

Summer Water level

Upwelling of water through the gravels is essential.



The gravel bed should be 35 to 40 cm. deep. See "Channels and Challenges" for dimensions

River Bed

The pool and gravel bed should be about the same length – about 1.5 times the channel width.

Start to place gravel in the "tail" of the pool.

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