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## **1. INTRODUCTION**

Geotechnical and Environmental Services Ltd. were appointed by McCarthy Hyder Consultants (MHC), on behalf of Wicklow County Council (WCC), to provide hydrogeological expertise and produce a groundwater assessment report as part of a larger project to obtain a sustainable supply of water to supply the East Wicklow area. This report provides details pertaining to hydrogeological site investigations carried out under Contract 1A Trial Well Drilling & Testing.

A Preliminary Groundwater Assessment report, outlining the geological and hydrogeological setting of the area and the potential for future development of groundwater sources within the study area was submitted by GES Ltd. to MHC in October 2004. The preliminary assessment referred to the available information (mainly from the Geological Survey of Ireland) and noted that there are no Regionally Important Aquifers in Co. Wicklow. Using this information and additional information on well yields from existing groundwater supplies throughout the study area, it was concluded that the development of a single-site wellfield supply from groundwater, capable of supplying the entire study area will be unlikely. It was concluded that a number of strategically sited supplies would be required.

A number of areas within the larger study area were highlighted, based on their geological setting and aquifer classifications, as potential groundwater resource areas where trial well drilling should be concentrated. MHC, in conjunction with WCC identified a number of potential drilling sites, following the submission of the report in October 2004 and again in January 2006. Further sites were also identified in the Nun's Cross and Ballinahinch areas in 2007. Following a visual assessment of these sites by GES Ltd. and discussion with MHC, their potential for development was assessed based on aquifer classification, available information on yields from existing wells, potential contamination sources in the vicinity (groundwater vulnerability), accessibility for drilling rig, of the site to potential users and water supply infrastructure.

These sites were mainly concentrated in:

- (i) A gravel aquifer north west of Ashford village (Ref. AN1)
- (ii) A locally important bedrock aquifer west of Rathnew (Ref AN5)
- (iii) A locally important bedrock aquifer in the vicinity of Jack White's Cross and across to the coast at Brittas Bay (Ref. AN3)
- (iv) A bedrock aquifer between Glenealy and Ashford (close to the Cronroe Reservoir) (Ref. AN5)

The Wicklow Water Supply Scheme, Groundwater Resource Areas and sites drilled in Contract 1A are shown in Figure 1 overleaf.

Figure 1

MHC procured a drilling contractor by the Public Procurement Competitive Process. Following an open tender procedure, Aquadrill Services (Patrick Briody & Sons) was appointed to undertake all drilling and testing works. The trial well drilling programme commenced in August 2005 and was completed in September 2006. Additional trial wells were drilled between May 2007 (TW17) and September 2007 (TW19 and TW20).

## 2. GEOLOGY AND HYDROGEOLOGY

### 2.1 Bedrock Geology

The study area which has been investigated is mainly underlain by shales, siltstones, sandstones, greywackes, with minor quartzites and schists of Cambrian and Ordovician age.

The geological formations which underlie each of the sites at the Trial Wells are listed in the Table 2.1 below.

**Table 2.1: Bedrock Geology**

<b>Trial Wells</b>	<b>Geological Unit</b>	<b>Description</b>
TW2, TW2A, TW3, TW3A, TW3B, TW9, TW19 (close to boundary with Maulin Formation) and TW20. Also TW4B which is on or close to a boundary with Maulin Formation & TW2B which is on or close to a boundary with the Bray Head Formation	Devil's Glen Formation	greywackes and shales
TW6. Also TW2B which lies on or close to the boundary with the Devil's Glen Formation.	Bray Head Formation	greywacke, sandstones and siltstones interbedded with slates and quartzites
TW4, TW4A, TW4D, TW4E, TW5, TW14, TW15, TW16 and TW17. Also TW4B located on a boundary with Devil's Glen Formation	Maulin Formation	slates, commonly laminated with pale siltstones with some schists
TW7	Kilmacrea Formation	mudstones with pale sandstones

### 2.2 Subsoil Geology – Gravels

A number of different subsoil types are mapped within the area of the wells drilled. In terms of potential groundwater resources, the glacial sand and gravel deposits were considered prime targets to investigate, mainly the large gravel deposit (approximately 4.6 km<sup>2</sup>) located around the town of Ashford. Information available from the desk study, prior to drilling, indicated that this deposit reaches thicknesses of between 10m and 38m. Gravels deposited by melting glaciers normally comprise rounded clasts of gravel with sand. The finer fractions of silts and clays are normally washed out and as such the permeability can be sufficient to allow groundwater sources to be developed.

Trial wells TW2, TW2A, TW2B, TW3 and TW3A drilled in this area encountered sands and gravels with a high degree of fines (silts and clays) and the productivity of this glacial gravel is now considered limited. However, the trial wells drilled into the river gravels further south along

the Vartry River (trial wells TW4, TW4A, TW17 and TW4D) encountered coarser sands and gravels with little or no fines in a discrete horizon and as such, yields were significantly higher.

Other subsoil types in the area include tills (derived from the underlying sandstones, siltstones and granites in the area), alluvium (along some of the rivers, including the Vartry River north west of Ashford) along with some areas of peat and gravels.

## **2.3 Hydrogeology**

The GSI Groundwater Protection Scheme for County Wicklow indicates that there are no Regionally Important Aquifers in County Wicklow. In the study area, it appears that approximately 60% to 65% of the area is underlain by Locally Important Aquifers while between 35% and 40% is underlain by Poor Aquifers.

Sites for trial well drilling were chosen based on their location within the Locally Important Bedrock Aquifers and the Gravel Aquifer mapped north of Ashford.

The aquifers which underlie the trial well sites are listed in Table 2.2 below:

**Table 2.2: Aquifer Details**

<b>Trial Wells</b>	<b>Aquifer Type</b>	<b>Description</b>
TW2, TW2A, TW2B, TW3, TW3A, TW3B, TW9, TW19 and TW20	Locally Important Gravel Aquifer underlain by Poor Bedrock Aquifer	Gravels underlain by the Devil's Glen Formation
TW4, TW4A, TW4B, TW4D, TW4E and TW17	Locally Important Gravel Aquifer	Alluvial gravels (which were not previously classified as an aquifer) south of the glacial gravels which were classified.
TW5, TW7, TW14, TW15 and TW16.	Locally Important Bedrock Aquifer	Maulin and Kilmacrea Formations
TW6	Poor Bedrock Aquifer	Bray Head Formation

### 3. TRIAL WELL LOCATIONS

The boreholes drilled in Contract 1A between September 2005 and August 2006 and between May 2007 and September 2007 are shown on Figure 1 (page 2) and Drawings 812/02/101-103 as shown in Appendix 7 and detailed in Table 3.1 below:

**Table 3.1: Well Details**

Well No.	Site location/Landowner	(Grid Ref)	Expected Aquifer	Successful Wells
TW2	P.O.S., Tottenham, Killiskey Road, <u>Ashford</u>	25714 98828	Potential gravel aquifer	
TW2A	P.O.S., Tottenham, Killiskey Road, <u>Ashford</u>	25714 98816	Poor bedrock aquifer	✓
TW2B	P.O.S., Tottenham, Killiskey Road, <u>Ashford</u>	25756 99164	Poor bedrock aquifer	✓ (limited)
TW3	P.O.S., Tottenham, Killiskey Road, <u>Ashford</u>	25536 98396	Potential gravel aquifer underlain by poor bedrock aquifer	✓
TW3A	P.O.S., Tottenham, Killiskey Road, <u>Ashford</u>	25508 98114	Potential gravel aquifer underlain by poor bedrock aquifer	✓
TW3B	P.O.S., Tottenham, Killiskey Road, <u>Ashford</u>	25720 97909	Potential gravel aquifer underlain by poor bedrock aquifer	
TW4	C.O.S. at Ballinahinch, <u>Ashford</u>	26593 97578	Potential gravel aquifer	✓
TW4A	C.O.S. at Ballinahinch, <u>Ashford</u>	26455 97556	Potential gravel aquifer	✓
TW4B	P.O.S., McCarthy, at Ballinahinch, <u>Ashford</u>	26298 97482	Potential gravel aquifer	
TW4D	C.O.S. at Ballinahinch, <u>Ashford</u>	26628 97516	Potential gravel aquifer	✓ (limited)
TW4E	GAA-owned, Ashford village	26884 97437	Potential gravel aquifer	
TW5	C.O.S. on road re-alignment site, north west of <u>Rathnew</u>	28481 95875	Locally important bedrock aquifer	
TW6	C.O.S. at Conroe Reservoir, <u>Ashford</u>	26216 96562	Poor bedrock aquifer	
TW7	P.O.S. near <u>Jack White's Cross</u>	28157 82961	Locally important bedrock aquifer	
TW9	P.O.S., Tottenham Ballincurry Demesne, <u>Ashford</u>	26514 98537	Potential gravel aquifer underlain by poor bedrock aquifer	
TW14	P.O.S., Johnson, Milltown,	27046 95770	Locally important bedrock aquifer	✓ (limited)
TW15	P.O.S., White, Milltown	26881 95794	Locally important bedrock aquifer	✓
TW16	P.O.S., Mooney, Milltown	26512, 95849	Locally important bedrock aquifer	✓
TW17	C.O.S. at Ballinahinch, <u>Ashford</u>	26648, 97573	Potential gravel aquifer	✓
TW19	P.O.S., Hedigan, south Nun's Cross Bridge	25899, 97345	Potential gravel aquifer underlain by poor bedrock aquifer	
TW20	P.O.S., Hedigan, south Nun's Cross Bridge	25865, 97415	Potential gravel aquifer underlain by poor bedrock aquifer	

**Note:** P.O.S – Privately Owned Site, C.O.S. – Council Owned Site.

## **4. TRIAL WELL DRILLING**

The trial well drilling commenced with TW4 on 25th August 2005. Phase 1 of the drilling continued until the middle of September 2005. Phase 1 consisted of trial wells TW4, TW9, TW2, TW3, TW5, TW6 and TW7.

Phase 2 of the drilling commenced on the 13th December 2005. Boreholes were drilled at TW3B, TW3A and TW4B before Christmas. Drilling re-commenced on the 8th February 2006 at TW4A and continued until the 23rd February 2006, drilling wells at TW2A, TW14 and TW15.

Phase 3 of the trial well drilling programme commenced on the 23rd June 2006 and continued until the start of September 2006. Boreholes were drilled at TW4E, TW4D, TW2B and TW16.

Phase 4 of the trial well drilling was undertaken during May 2007. An additional well, TW17, was drilled in the County Council-owned site between the 30<sup>th</sup> April and 2<sup>nd</sup> May 2007, to replace the successful TW4 which will now not be used due to its position close to the proposed Council housing development. Another well, TW18, proposed for this site, closer to the road, was not drilled.

Phase 5 in the programme of trial well drilling was undertaken during September 2007. 2 no. additional wells were drilled in a private site, just south of Nun's Cross Bridge, in an area close to the confluence of the main Vartry River (coming from the north) and a smaller unnamed tributary stream (flowing from the west). Local information indicated that there may be significant water resources available on this site. Some alluvial gravels, associated with the Vartry River were mapped in the eastern part of this site with some more glacial gravels further west. Following a desk study, it was considered that the gravels may not have as much potential as on the Council-owned site to the east, but that perhaps the underlying poor aquifer may provide some further water resources. Wells TW19 and TW20 were drilled on this site between the 20<sup>th</sup> and 26<sup>th</sup> September 2007.

Borehole logs are included in Appendix 2 of this report.

### **4.1 Successful Boreholes**

#### **4.1.1 TW2A**

Borehole TW2A was drilled between the 15th and 21st February 2006. Drilling began at 400mm diameter (through the upper layers of gravel) and was reduced to 200mm into the rock. Initially a slightly gravelly CLAY was encountered which was underlain by SAND with some layers of gravelly CLAY to 24m. This was further underlain by coarse GRAVELS (where some water was encountered) with some gravelly SAND to 39m, where some weathered rock was encountered. The rock encountered is described as a green / grey fine-grained siltstone, with some quartzite veins or a brown weathering in certain lenses. Water was encountered in some



of these weathered and fractured veins and particularly at 42m, 45m and between 60m and 72m. 30m of 250mm steel casing was installed along with 90m of 165mm PVC liner. The driller estimated the yield at approximately 550 m<sup>3</sup>/d following development. The borehole was subsequently disinfected in preparation for the pumping test and sampling.

#### **4.1.2 TW2B**

Borehole **TW2B** was drilled between the 20<sup>th</sup> and 21<sup>st</sup> July 2006. Drilling began at 400mm diameter (as it was considered that the gravels may contain groundwater in this area). Initially a sandy slightly gravelly CLAY was encountered which was underlain by a clayey GRAVEL between 3m and 18m. This gravel contained some water but no significant volumes were encountered. At 18m a grey, weathered fine-grained siltstone (rock) was encountered. Drilling continued from 18m (below the gravels) at 250mm diameter (to 40m) and 200mm diameter (to 90m) and encountered a grey / brown weathered to very weathered siltstone rock with occasional clay-filled veins and quartzite at various levels. Water was encountered in some of these veins, particularly at 21m and 62m. 18m of 250mm steel casing was installed (to case out the gravels) along with 90m of 125mm of PVC liner. The driller estimated the yield at approximately 100 m<sup>3</sup>/d following development. The borehole was subsequently disinfected in preparation for the pumping test.

#### **4.1.3 TW3**

Borehole **TW3** was drilled between the 2<sup>nd</sup> and 6<sup>th</sup> September 2005. Drilling began at 400mm diameter (as it was considered that this may be a potential gravel aquifer). Initially, gravelly CLAY was encountered which was underlain by a gravelly SAND to 21m and further underlain by weathered rock and some gravels between 21m and 39m. However, drilling was reduced to 250mm as soon as it became clear that the overlying subsoils would not yield any substantial volumes of water and it would then be necessary to explore the underlying bedrock. The rock encountered is described as a grey / green fine-grained siltstone (with quartzite veins or a brown weathering at some levels). Water was encountered in some of these veins and particularly between 75m and 77m in a small cavity. 33m of 250mm steel casing was installed along with 90m of 165mm PVC liner. The main water bearing levels were noted at 47m, 57m and 75m and the driller estimated the yield at approximately 330 m<sup>3</sup>/d following development. The borehole was subsequently disinfected in preparation for the pumping test and sampling.

#### **4.1.4 TW3A**

Borehole **TW3A** was drilled between the 9th and 13th December 2005. Drilling began at 400mm diameter through the upper layers of sand and was dropped down to 250mm after 18m through compacted gravels until rock was encountered when the drilling diameter was dropped down again to 200mm. Initially, a light brown SAND was encountered to 6.0m which was

underlain by a gravelly CLAY with some horizons of a dense SAND and GRAVEL all between 6.0m and 15m. At this level, a dense very clayey GRAVEL was encountered, layers of which alternated with a gravelly SILT / CLAY to 30m. A very weathered rock, described as a coarse to medium siltstone, was encountered at 30m along with some water at 36m. This siltstone continued to the end of the borehole at 90m. The only significant inflow of water was at 36m and it was estimated by the driller, following development that the yield would be between 130 m<sup>3</sup>/d and 160 m<sup>3</sup>/d. 30m of 250mm steel casing was installed along with 90m of 125mm PVC liner. The borehole was subsequently disinfected in preparation for the pumping test and sampling.

#### **4.1.5 TW4**

Borehole **TW4** was drilled between the 23<sup>rd</sup> and 25<sup>th</sup> August 2005 in a field owned by the County Council. Drilling began at 400mm diameter into the gravel using a temporary supporting casing (250mm diameter) which was advanced as the drilling proceeded. The drilling initially encountered 12m of overburden comprising gravelly sand and rounded gravel cobbles. This was underlain by a horizon of coarse gravels (comprising rounded clasts of granite, quartzite, slates, limestones and schistose rock) which was encountered between 12m and 27m. Underlying this horizon, more coarse sands with some gravels were encountered to 36m. At this point, a green highly weathered siltstone rock was encountered to the end of the borehole at 40m. 40m of 165mm PVC liner was installed in the hole and the temporary steel casing was withdrawn back to 12m to case out the upper clay and sand layers. The main water-bearing levels were noted as between 12m and 24m. The borehole was developed for 5 hours and the driller estimated a yield of approximately 330 m<sup>3</sup>/d. The borehole was subsequently disinfected in preparation for the pumping test and sampling.

#### **4.1.6 TW4A**

Borehole **TW4A** was drilled between the 8<sup>th</sup> and 10<sup>th</sup> February 2006 in the same field as TW4, approximately 150m to the west and at a similar topographic level. Drilling began at 400mm diameter into the gravel using a temporary supporting casing (250mm diameter) which was advanced as the drilling proceeded. The drilling initially encountered 6m of overburden comprising (very) gravelly, (slightly) clayey coarse sand which was underlain by a horizon of coarse gravels (comprising rounded clasts of sandstone, quartzite, granite etc.) from 6m to 9m. This is similar to what was encountered in Borehole TW4, but no water was encountered in this horizon in TW4A. Underlying this horizon, more coarse sands with some gravels were encountered between 9m and 15m. Then, at 15m, a horizon of sand and coarse gravel (comprising cobbles of rounded to sub-angular clasts of sandstone, granite and some quartzite) was encountered to 18m. Large volumes of water were encountered in this horizon. This was underlain by a medium SAND to 24m which was further underlain by a green highly weathered siltstone rock. A more competent green siltstone was encountered from 30m to the end of the

borehole at 40m. 40m of 165mm PVC liner was installed in the hole and the temporary steel casing was withdrawn back to 12m to case out the upper sand layers. The borehole was developed and the driller estimated a yield of approximately 550 m<sup>3</sup>/d. The borehole was subsequently disinfected in preparation for the pumping test and sampling.

#### **4.1.7 TW4D**

Borehole **TW4D** was drilled between the 28<sup>th</sup> and 30<sup>th</sup> June 2006 in the same County Council owned field in which TW4 and TW4A are located. Drilling began at 400mm diameter into the gravels using a temporary supporting casing (250mm diameter) which was advanced as the drilling proceeded. The drilling initially encountered 3m of clayey sandy GRAVEL with cobbles which was underlain by a SAND and GRAVEL layer and then a medium to coarse GRAVEL to 18m. Between 15m and 18m, these gravels contained water. At 18m depth, the diameter of drilling was reduced to 250mm and a layer containing a lot of fine SAND as well as water was encountered between 18m and 26m. Below 26m, clayey GRAVELS were encountered to 33m when gravels and weathered rock was encountered. This weathered rock, described as a very weathered siltstone rock, was encountered between 33m and the end of the borehole at 40m. Initially the temporary steel casing (250mm diameter) was advanced to 21m. 200mm casing was installed to 30m and it was intended to withdraw the temporary steel casing back to expose the productive gravel layer above 18m. However, due to difficulties during development at this well, the 250mm casing remains down to 21m. 40m of 165mm manually slotted casing was installed following development of the well. The main water-bearing levels were noted between 15m and 18m (clean water) and between 18m and 26m (sandy water). The driller estimated a yield of approximately 220 m<sup>3</sup>/d and perhaps more, although there may be difficulties with the expected high level of sand ingress and ground instability. The borehole was subsequently disinfected in preparation for the pumping test and sampling.

#### **4.1.8 TW14**

Borehole **TW14** was drilled between the 13<sup>th</sup> and 15<sup>th</sup> February 2006 in a field, along a minor road at Milltown, south of Ashford. Drilling began at 250mm diameter and was then dropped down to 200mm below the overburden and weathered rock. The drilling initially encountered 3m of a silt / clay which was underlain by a coarse sand to 6m and more slightly gravelly silt / clay to 12m. Between 12m and 18m, a clayey sand with weathered rock was encountered which was underlain by a soft grey highly weathered clay-rich rock between 18m and 24m. At 24m, a grey fine-grained siltstone with some quartzite was encountered to 30m and was underlain by a medium-grained, finely laminated mudstone with abundant quartzite, especially between 36m and 39m where some water was encountered. Fine grained siltstones and mudstones with varying proportions of quartzite were encountered between 39m and the end of the borehole at 90m. Some more water was encountered between 66m and 69m, but the main significant inflow of water was mainly between 36m and 39m. 18m of 200mm steel casing was

installed along with 90m of 125mm PVC liner. The yield of this borehole was estimated by the driller, following development, as approximately 165 m<sup>3</sup>/d. The borehole was subsequently disinfected in preparation for the pumping test and sampling.

#### **4.1.9 TW15**

Borehole **TW15** was drilled between the 21<sup>st</sup> and 23<sup>rd</sup> February 2006, along a minor road at Milltown, south of Ashford, in a field just west of where TW14 was drilled. Drilling began at 250mm diameter and was then dropped down to 200mm below the overburden and weathered rock. The drilling initially encountered 6m of a loose clayey, medium to coarse gravel which was underlain by a very gravelly silt / clay to 9m and a soft silt / clay to 12m. Between 12m and 18m, a clay with soft weathered rock (siltstone) was encountered which was underlain by a grey weathered fine grained mudstone with some quartzite and water to 27m. At 27m, a more competent grey soft, fine-grained siltstone was encountered which was underlain by harder rock at 39m. Fine grained siltstones and mudstones (with quartzite in some horizons) were encountered between 39m and the end of the borehole at 90m. The main significant inflows of water were mainly between 18m and 30m. The yield of this borehole was estimated by the driller, following development, as approximately 450 m<sup>3</sup>/d. 12m of 250mm steel casing was installed along with 90m of 125mm PVC liner. The borehole was subsequently disinfected in preparation for the pumping test and sampling.

#### **4.1.10 TW16**

Borehole **TW16** was drilled between the 30<sup>th</sup> and 31<sup>st</sup> August 2006, further west along the minor road at Milltown, to the west of TW14 and TW15. Drilling began at 250mm diameter and was then dropped down to 200mm below the overburden and weathered rock. The drilling initially encountered 3m of a soft gravelly, sandy clay topsoil, which was underlain by a loose clayey, sandy fine gravel to 9m. Between 9m and 18m, a soft, very weathered rock, a dark grey fine-grained siltstone, was encountered. This was underlain by a dark grey to black slightly weathered fine-grained siltstone with some quartzite veining and water to 24m. At 24m, a more competent dark grey fine-grained siltstone with minor quartzite was encountered which was underlain by a more weathered layer of siltstone, with weathered quartzite veins and some more water between 27m and 30m. Between 30m and 42m a dark grey to black weathered fine-grained, laminated siltstone was encountered which was underlain by a highly weathered layer of siltstone with some quartzite and some more water, to 48m. Between 48m and the end of the borehole at 90m, a grey/green or grey fine grained siltstone (with quartzite in some horizons) was encountered. No water was encountered below 48m. The main inflows of water were mainly at 18m, 27m and 45m. The yield of this borehole was estimated by the driller, following development, as between 80 m<sup>3</sup>/d and 90 m<sup>3</sup>/d. 17.2m of 200mm steel casing was installed along with 90m of 125mm PVC liner. The borehole was subsequently disinfected in preparation for the pumping test and sampling.

#### **4.1.11 TW17**

Borehole **TW17** was drilled between the 30<sup>th</sup> April and 2<sup>nd</sup> May 2007 in the County Council-owned field North West of Ashford village, where TW4 and TW4A had previously been drilled. Drilling began at 400mm diameter into the gravel using a temporary supporting casing (250mm diameter) which was advanced as the drilling proceeded. The drilling initially encountered 12m of overburden comprising gravelly sand and rounded gravel cobbles, similar to the conditions encountered in TW4. This was underlain by a horizon of coarse gravels (comprising rounded clasts of granite, quartzite, slates, limestones and schistose rock) which was encountered between 12m and 21m. Coarse very gravelly sands were encountered between 21m and 24m which were further underlain by a layer of silty gravel to 27m and gravelly very coarse sand to 30m. At this point, a very weathered green siltstone rock was encountered, along with some gravel clasts to 33m. This was further underlain by less weathered rock to the end of the borehole at 40m. No competent rock was encountered. 40m of 165mm PVC liner was installed in the hole and the temporary steel casing was withdrawn back to 14m to case out the upper clay and sand layers. The main water-bearing levels were noted as between 15m and 21m. The borehole was developed for 5 hours and the driller estimated a yield of approximately 880 m<sup>3</sup>/d. The borehole was subsequently disinfected in preparation for the pumping test and sampling.

## **4.2 Unsuccessful Boreholes**

Boreholes were drilled at the locations given above for trial wells TW2, TW3B, TW4B, TW4E, TW5, TW6, TW7, TW9, TW19 and TW20. Little if any water was encountered during drilling at these locations and as such it was not considered necessary to retain them (either by installing casing or undertaking pumping tests to prove their lower yields).

The details of what was encountered in these boreholes are included in the borehole logs in the Appendix 2 of this report. It is not considered necessary to further describe in detail what was encountered at each.

During the assessment of the potential for groundwater sources in the southern part of the scheme area, around Brittas Bay, an existing well at Aghatruhan Bridge (named TW8 for this assessment) was identified. It was considered by local residents in the area that this well was artesian and very high yielding which could have potential to supply the scheme. This well was to be pump tested to determine its sustainable yield as part of the programme of works, however, when it was assessed (by Aquadrill Services Ltd. and Seamus Kelly & Sons Ltd.) the pipe covering the wellhead was found to be welded into position. The pipework was also found to be in a poor condition and access (to install a pump and monitoring equipment) would have been difficult. From speaking to local residents, it was also established that the well is currently

supplying 2 properties with water. As a result, it was decided that this well could not be tested. Sites for drilling in this area were difficult to identify and acquire. One well (TW7) was drilled at Jack White's Cross but this proved to be unsuccessful.

It is recommended that any unsuccessful trial wells, which are not required by the landowners for domestic use, or for monitoring during development and testing of the production wells, be fully decommissioned. This should be undertaken as part of a groundwater protection procedure to eliminate potential pathways for surface water or shallow potentially poor quality groundwater entering the wells and having a direct, uninhibited route to the aquifer from which a potable water supply is being abstracted.

Any of the unsuccessful (from the Wicklow WSS perspective) trial wells which are to be retained for use as domestic and / or farm wells (e.g. TW9, TW20) should be limited in abstraction rates to just 20m<sup>3</sup>/d so as not to affect any production wells to be located close to them. It is also recommended that the wellhead protection around these wells be improved so as to minimise the risk of contamination of the groundwater in the underlying aquifer. The annular space between casing and liner (or drilled hole and casing) should be grouted and a well chamber built around the well (above ground if possible) to eliminate the possibility of potentially contaminating surface runoff getting into the well. (as per *Guidelines for drilling wells for private water supplies*, March 2007, Institute of Geologists of Ireland)

Detailed method statements for the decommissioning of each of the wells to be re-instated will be forwarded to the drilling contractor. Each well will require a different method of decommissioning depending on the geological conditions encountered during drilling of the trial well.

If plastic liner / uPVC casing was installed into the trial well, an attempt will be made to remove it, gradually while backfilling the well (from bottom up to ground level) with various materials – a combination of gravel (in the gravel wells) and concrete (mainly in the bedrock wells, but also used in the upper parts of all wells).

The unsuccessful trial wells drilled and the recommended actions are listed in the table overleaf.

Table 4.1: List of unsuccessful trial wells and recommended actions.

Non-pumping Well Number	Location	Retain / Decommission
TW2 <sup>(1)</sup>	Adjacent to TW2A	Retain –to use as monitoring for PW1, PW2 & PW3 testing
TW2B <sup>(1)</sup>	North of TW2A	Retain –to use as monitoring for PW1, PW2 & PW3 testing
TW3B <sup>(1)</sup>	South of TW3A and beyond lake	Retain –to use as monitoring for PW1, PW2 & PW3 testing
TW4	Ashford wellfield, west of TW17	<b>Decommission</b> – successful well but will not be used due to proposed housing development (TW17 is the alternative location). Could retain for monitoring but not necessary due to other wells present and the housing and foul sewers etc. will pose a risk to water quality, so recommend to backfill and decommission
TW4B <sup>(1)</sup>	West of Ashford wellfield	Retain – no impact noted during pumping tests on TW4 and TW4A but should be retained to measure any impact during production well testing and after commissioning
TW4D <sup>(1)</sup>	South of TW17	Retain –for monitoring, especially during production well testing and river monitoring. Awkward location in relation to housing development but should retain if possible.
TW4E	At GAA field	<b>Decommission</b> –not required. Failed well and too far away for any monitoring
TW5	On old N11 outside Rathnew	<b>Has already been decommissioned</b> - not required. Failed well and too far away for any monitoring
TW6	At Cronroe reservoir site – within Council owned site	<b>Decommission</b> - not required. Failed well and too far away for any monitoring
TW7	In field at Jack White's cross	<b>Decommission</b> - not required. Failed well and too far away for any monitoring
TW9	In field to east of Nun's Cross wellfield, within Charles Tottenham's land	Retain - no response noted in this well during pumping tests but is within the catchment of the Ashford wellfield (to the south) so may need to retain for long-term monitoring. However, may be required by landowner for domestic / farm use. Pumping at this should be limited to 20 m <sup>3</sup> /d so as not to overpump - would have to agree this with all concerned
TW14 <sup>(1)</sup>	East of TW15 in Milltown	Retain – was a slight response in pumping test on TW15 so will be required for long term monitoring
TW19	In south east corner of Hedigan's field, to west of Ashford wellfield	<b>Decommission</b> – failed well and into bedrock – far enough away from and in different aquifer to gravel wells in Ashford wellfield so not required for monitoring
TW20	Along south eastern boundary of Hedigan's field – to west of Ashford wellfield	Retain – failed well and into bedrock – far enough away from, and in different aquifer to, gravel wells in Ashford wellfield to the east, so not required for monitoring. However, may be required by landowner for domestic / farm use. Pumping at this should be limited to 20 m <sup>3</sup> /d so as not to overpump. Also recommend water quality tests be undertaken before use as a drinking water supply.

Note 1: Review following drilling and pump testing of production wells.



## **5. PUMPING TESTS**

### **5.1 Individual Step and 72 Hour Tests**

Following the completion of Phase 1 of the drilling it was considered that just 2 of the boreholes were productive enough to warrant a pumping test to further assess their sustainable yields. These were TW4, a borehole drilled into gravels, and TW3, a borehole considered to be tapping a productive fissure in a bedrock aquifer.

Following the completion of Phase 2 of the drilling, a number of productive boreholes were drilled. These 5 boreholes, TW2A (bedrock) TW3A (bedrock), TW4A (gravels), TW14 (bedrock) and TW15 (bedrock), were tested to assess their sustainable yields.

Following the completion of Phase 3 of the drilling, it was considered that 3 of the boreholes TW2B (bedrock), TW4D (gravels) and TW16 (bedrock) should be tested to determine their sustainable yields.

Phase 3 pumping tests were to be undertaken as per the previous 72 hour tests, i.e. step tests followed by 72 hour constant rate tests on the individual wells. These tests would then be followed by multi-well 7-day tests to determine the combined yield of wells tested previously.

Arrangements were made with Seamus Kelly & Sons, Pumping Contractors, to undertake pump tests of 72 hours duration. It was considered that short step tests, comprising 3 steps, should be undertaken prior to each pumping test proper, to establish pumping conditions over a range of rates and to allow the optimum pumping rate to be chosen. Following this test, arrangements were then made for a 7 day multi well pump test.

After Phase 4 of the trial well drilling phase was complete, it was considered that TW17 should be tested, both on its own (step test and 72 hour test) and in conjunction with TW4A (tested previously) over a 7 day test, to determine the sustainable yield of this gravel aquifer.

### **5.2 TW2A**

#### **5.2.1 Step Test**

The step test on borehole TW2A commenced on the 13<sup>th</sup> March 2006. The static water level was established as 6.88m below datum. The step test was carried out in 3 steps, each of 100 minutes duration; the first step rate was set at 220 m<sup>3</sup>/day which held relatively well; the second step rate was increased to 440 m<sup>3</sup>/day which also held well and the third step rate was further increased to an average of 605 m<sup>3</sup>/day. The total drawdown at the end of the step test was 17.41m. Borehole TW2A is within 10m of borehole TW2 (which is 40m deep) which was used as an observation well during the step test. The step test on TW2A induced a drawdown of 5.88m at TW2.



Following the step test, the pump in TW2A was switched off and the water levels allowed to recover over the next 20 hours, by which time the water levels had recovered to within 0.25m of the initial water level.

A second step test was undertaken on the 15<sup>th</sup> March 2006 in order to stress the well further as the previous test indicated the well was capable of more than 605 m<sup>3</sup>/day. The static water level was established at 7.65m below datum and the second step test commenced. The step 1 rate was set at 765 m<sup>3</sup>/day which held relatively well. The second step rate was increased to 925 m<sup>3</sup>/day, which also held well. The step 3 rate was further increased to 1090 m<sup>3</sup>/day. The total drawdown at the end of the 300 minute step test was 49.27m. Water levels monitored at TW2 nearby dropped from 7.41m below datum to 18.1m, a drawdown of 10.69m.

Following the second step test, the pump in TW2A was switched off and the water levels allowed to recover over the next 16 hours, by which time the water levels had recovered to within 0.33m of the initial water level.

The plot of the data from the step tests is included in Appendix 3 of this report and indicates that this well is capable of pumping up to 800 m<sup>3</sup>/d while inducing moderate drawdown in the water levels.

### **5.2.2 72 Hour Test**

On the 27<sup>th</sup> March 2006, the 72 hour pumping test commenced at TW2A. The static water level at the start of this test was established at 7.6m below datum. The discharge rate for the pumping test was set at 785 m<sup>3</sup>/day. The pumping rate held relatively steady throughout the 72 hour test, dropping back slightly to 775 m<sup>3</sup>/d by the end of the test. The average pumping rate over the 72 hours of the test was 775 m<sup>3</sup>/d. The total drawdown at the end of the 72 hour pumping period was 32.35m. Equilibrium conditions had not been achieved by this stage and the drawdown was still increasing.

Once the 72 hour pumping test was complete, the pump was switched off and a recovery test undertaken. The recovery was slow such that the water level took 20 hours to recover back to within 0.52 m of its initial level. The water level in the observation well (TW2) was also monitored during the recovery period. The recovery at TW2 mirrored that at TW2A, such that it was slow and took 20 hour to recover back to within 0.66m of its initial level.

The results of the pumping test, the water levels measured and graphs of the response of the water levels to pumping are included in the Appendix 3.

### **5.3 TW2B**

#### **5.3.1 Step Test**

The step test on borehole TW2B commenced on the 10th August 2006. The static water level was established at 7.45m below datum. The step test was carried out in 3 steps, each of 100 minutes duration. The first step rate was set at 103 m<sup>3</sup>/day which held relatively well and induced a drawdown of 8m. The step 2 rate was increased to 170 m<sup>3</sup>/day which subsequently decreased to 145 m<sup>3</sup>/day during the test. A drawdown of 66.03m was induced during this step, which was significant, given the depth of the well. As such it was considered that the step test should not continue past 200 minutes. The step test on TW2B did not affect the water level at TW2A, which is located 300m to the south of the pumping well.

Following the 200 minute step test, the pump in TW2B was switched off and the water levels allowed to recover over the next 4 hours, by which time the water levels had recovered to within 0.25m of the initial water level. Recovery was relatively fast in this well.

The plot of the data from the step test on TW2B is included in Appendix 3 to this report, and indicates that this well is capable of pumping no more than 100 m<sup>3</sup>/d to maintain moderate levels of drawdown.

#### **5.3.2 72 Hour Test**

On the 14th August 2006, the 72 hour pumping test commenced at TW2B. The static water level at the start of this test was 7.79m below ground level. The discharge rate for the pumping test was set at 96 m<sup>3</sup>/d. The pumping rate fell back gradually during the 72 hour test, dropping back to 80 m<sup>3</sup>/d by the end of the test. The average pumping rate over the 72 hours of the test was 86.5 m<sup>3</sup>/d. The total drawdown at the end of the 72 hour pumping period was 33.43m. Equilibrium conditions had not been achieved by this stage and the drawdown was still increasing steadily.

Once the 72 hour pumping test was complete, the pump was switched off and a recovery test undertaken. The recovery was slow and such that the water level took 24 hours to recover back to within 1.12 m of its initial level. No further tests were undertaken on this well.

The results of the pumping test, the water levels measured and graphs of the response of the water levels to pumping are included in Appendix 3.

## **5.4 TW3**

### **5.4.1 Step Test**

The step test on borehole TW3 commenced on the 29<sup>th</sup> September 2005. The static water level was established at 19.18m below datum. The step test was carried out in 3 steps, each of 100 minutes duration. The first step rate was set at 218 m<sup>3</sup>/day which held well and induced a drawdown of 7.38m. The step 2 rate was increased to 327 m<sup>3</sup>/day which also held well and drew the water levels down to 12.84m. The Step 3 rate was further increased to 490 m<sup>3</sup>/d. The total drawdown at the end of the step test was 20.83m. The pump was then switched off and the water levels recovered relatively quickly, such that they were within 2.17m of the initial level after 3 hours.

### **5.4.2 72 Hour Test**

On the 3rd October 2005, the 72 hour pumping test commenced at TW3. The static water level at the start of this test was established at 19.25m below datum. The discharge rate for the pumping test was set at 490 m<sup>3</sup>/d. The pumping rate held relatively steady throughout the 72 hour test, dropping back slightly to 480 m<sup>3</sup>/d by the end of the test. The average pumping rate over the 72 hours of the test was 476 m<sup>3</sup>/d. The total drawdown at the end of the 72 hour pumping period was 30.36m. Equilibrium conditions had not been achieved by this stage and the drawdown was still increasing.

Once the 72 hour pumping test was complete, the pump was switched off and a recovery test undertaken. The recovery was slow such that the water level took 42 hours to recover back to within 4.86m of its initial level.

The results of the pumping test, the water levels measured and graphs of the response of the water levels to pumping are included in Appendix 3

## **5.5 TW3A**

### **5.5.1 Step Test**

The step test on borehole TW3A commenced on the 13<sup>th</sup> March 2006. The static water level was established as 22.42m below datum. The step test was carried out in 3 steps, each of 100 minutes duration. The first step rate was set at 100 m<sup>3</sup>/day, although this fell back slightly such that the average over this step was 93 m<sup>3</sup>/day. Step 1 induced a drawdown of 0.63m. The step 2 rate was increased to 230 m<sup>3</sup>/d, which held relatively well and drew the water levels down to 9.4m. The step 3 rate was further increased to 333 m<sup>3</sup>/d and held well during the next 100 minutes. However it appears that this pumping rate was too high as the water levels fell quickly to a total drawdown of 38.6m, which in a borehole of 90m depth is considered significant.

Borehole TW3A is within 250m of borehole TW3, which was used as an observation well during the step test. Pumping at TW3A induced a slight drawdown of 0.09m at TW3.

Following the step test, the pump in TW3A was switched off. Water levels had recovered to their initial levels within 4 hours.

The data from the step test indicates that the well has a relatively limited yield (when compared with TW2A) and would not be capable of sustainably pumping more than 250 m<sup>3</sup>/d.

### **5.5.2 72 Hour Test**

On the 20th March 2006, the 72 hour pumping test commenced at TW3A. The static water level at the start of this test was established at 22.4m below datum. The discharge rate was set at 250 m<sup>3</sup>/day. The pumping rate held relatively well during the 72 hour test, dropping back slightly to 235.8 m<sup>3</sup>/day by the end of the test. The average pumping rate over the 72 hours of the test was 242.5 m<sup>3</sup>/day. The total drawdown at the end of the 72 hour pumping period was 11.19m. The graph of the pumping test (included in Appendix 3) indicates that equilibrium conditions had started to become established as the water levels stabilised.

Once the 72 hour pumping test was complete, the pump was switched off and a recovery test undertaken. The recovery was slow such that the water level took 24 hours to recover back to within 0.14m of its initial level.

The results of the pumping test, the water levels measured and graphs of the response of the water levels to pumping are included in Appendix 3

## **5.6 TW4**

### **5.6.1 Step Test**

The step test on borehole TW4 commenced on the 30th September 2005. The static water level was established at 5.74m below datum. The step test was carried out in 5 steps with the first 3 steps and final steps of 100 minutes duration, while the fourth step was just 60 minutes duration. The first step rate was set at 218 m<sup>3</sup>/day which held well and induced a drawdown of just 0.11m. The Step 2 rate was increased to 436 m<sup>3</sup>/d and also held well, drawing the water levels down only slightly to 0.29m drawdown. The pumping rate was increased for Step 3 to 654 m<sup>3</sup>/d but again had little effect on the water levels. A series of additional steps were undertaken to further stress the borehole. The Step 4 rate was opened up to 880 m<sup>3</sup>/d for 60 minutes, drawing the water levels down to 0.79m of drawdown. The final step, Step 5, rate was set at 1130 m<sup>3</sup>/d which held well and drew the water levels down to a total of just 1.16m. This drawdown is considered minimal given the volumes of water that had been pumped during the step test.

The pump was then switched off and the water level recovered to its original level within 2 hours.

### **5.6.2 72 Hour Test**

On the 4<sup>th</sup> October 2005, the 72 hour pumping test commenced on TW4. The static water level at the start of this test was established at 5.74m below datum. The discharge rate for the pumping test was set at 1874.5 m<sup>3</sup>/d as it was considered necessary to stress the well and induce some drawdown of the water levels. The pumping rate held relatively steady and following a change in the size of the discharge pipe, increased to 2075 m<sup>3</sup>/d, which held throughout the remainder of the 72 hour test. The average pumping rate over the 72 hours of the test was 1945 m<sup>3</sup>/d. The total drawdown at the end of the 72 hour pumping period was just 1.94m. We are of the opinion that equilibrium conditions had been achieved by this stage.

Once the 72 hour pumping test was complete, the pump was switched off and a recovery test undertaken. The water level recovered back slowly and gradually to within 0.2m of its initial level within 24 hours of the pump being switched off.

The results of the pumping test, the water levels measured and graphs of the response of the water levels to pumping are included in the Appendix 3

## **5.7 TW4A**

### **5.7.1 Step Test**

The step test on borehole TW4A commenced on the 14<sup>th</sup> March 2006. The static water level was established at 2.78m below datum. This step test was carried out in 4 steps, each of 100 minutes duration. The first step rate was set at 440 m<sup>3</sup>/day which held relatively well and induced a drawdown of 1.61m. The step 2 rate was increased to 915 m<sup>3</sup>/day which also held well and drew the water levels down to 6.13m of drawdown. The step 3 rate was further increased to 1188 m<sup>3</sup>/day, inducing 10.21m of drawdown. A 4<sup>th</sup> step was undertaken at a rate of 1866 m<sup>3</sup>/day. However, the discharge rate fluctuated such that the average was closer to 1650 m<sup>3</sup>/day. The total drawdown at the end of the step test was 19.25m. Borehole TW4A is within 150m of borehole TW4 which was used as an observation well during the step test. The step test on TW4A induced a drawdown of 0.18m at TW4.

Following the step test, the pump in TW4A was switched off and the water levels allowed to recover over the next 2 hours, by which time the water levels had fully recovered to the original water level.

The data from the step test indicated that the well was pumping between 1300 m<sup>3</sup>/day and 1400 m<sup>3</sup>/day although the drawdown induced is larger than that in TW4 which appears to be the more productive of the 2 wells on this site.

### **5.7.2 72 Hour Test**

On the 20<sup>th</sup> March 2006, the 72 hour pumping test commenced at TW4A. The static water level was established at 2.78m below datum. The discharge rate was set at 1400 m<sup>3</sup>/day. The pumping rate held relatively well throughout the 72 hour test. It dropped back slightly a couple of times but a valve on the rising main was opened to try to maintain the pumping rate. By the end of the test the pumping rate had risen slightly to 1415 m<sup>3</sup>/day. The average pumping rate over the 72 hours of the test was 1405 m<sup>3</sup>/day. The total drawdown at the end of the 72 hour pumping period was 9.92m. Although the pumping rate was not held constant during this test, near-equilibrium conditions were reached by the end of the test and the drawdown had stabilised.

A small impact was noted at TW4 (150m from borehole TW4A) with 0.38m of drawdown.

Once the 72 hour pumping test was complete, the pump was switched off and a recovery test undertaken. The recovery was slow such that the water level took 24 hours to recover back to within 0.15m of its initial level.

The results of the pumping test, the water levels measured and graphs of the response of the water levels to pumping are included in Appendix 3

## **5.8 TW4D**

### **5.8.1 Step Test**

The step test on borehole TW4D commenced on the 21<sup>st</sup> August 2006. The static water level was established at 3.56m below datum. Due to ground stability problems encountered during the drilling and development stage, the step test was carried out under strict conditions to ensure the stability of the ground was maintained. The pumped water was also directed to a tank so settlement of the sand in the groundwater (noted during development of the well) could occur before discharge to the river.

It was considered that the step test would comprise a number of steps of varying duration so that equilibrium conditions could be established prior to any increase in the pumping rate. The first step rate was set at a relatively low rate (130 m<sup>3</sup>/day) to determine how silty the pumped water would be. However, by 3 minutes into the test the pump intake was becoming blocked and the pumping rate fell steadily during the first step, back to 65 m<sup>3</sup>/day after 10 minutes. The pumping rate was opened up to 216 m<sup>3</sup>/day after 10 minutes. The water was noted as

appearing very dirty and the pumping rate decreased over a short period of time such that after a further 10 minutes (20 minutes into the overall test) the rate was back to 173 m<sup>3</sup>/day. At this stage the valve was opened up to its maximum (pump capable of 500 m<sup>3</sup>/d) but it was noted that the in-take of the pump became blocked so it was not possible to increase the flow rate. The pump was switched off after a total of 26 minutes of pumping and at this point the inner casing of the borehole moved up while the ground surface subsided slightly. Following consultation with all parties, it was decided to abandon the test on this trial well given the practical difficulties. Reports from the pumping contractor stated that there are high volumes of water at this site but the high level of silt and sand at this particular location makes it too difficult to test. The total drawdown at the end of the 26 minute step test was 0.16m, although this represents a slight recovery following the maximum drawdown of 0.45m which was noted at 14 minutes into the test.

The results of this short step test / equipment test, the water levels measured and graphs of the response of the water levels to pumping are included in Appendix 3

## **5.9 TW14**

### **5.9.1 Step Test**

The step test on borehole TW14 commenced on the 24<sup>th</sup> March 2006. The static water level was established at 4.78 m below datum. The step test was carried out in 2 steps. The first step rate was set at 113 m<sup>3</sup>/day, although this fell back to about half of this within 5 minutes. The valve was opened up to try to maintain the chosen pumping rate but it continued to fall back such that the pumping rate at the end of the step was relatively steady at 60 m<sup>3</sup>/day. The average pumping rate over the course of Step 1 (140 minutes duration) is calculated 69.5 m<sup>3</sup>/day. The Step 2 rate was increased to 151 m<sup>3</sup>/d, but this also fell back (to 130 m<sup>3</sup>/day within 5 minutes, to 108 m<sup>3</sup>/day within 10 minutes and to 96 m<sup>3</sup>/day within 15 minutes). The valve was opened again a few more times during this higher step and by the end of the step (after 100 minutes) the pumping rate was at 96.75 m<sup>3</sup>/day. The average pumping rate over the course of Step 2 is calculated at 112 m<sup>3</sup>/d. The total drawdown at the end of the 240 minute step test was 46.88m, which in a borehole of 90m depth is considered quite significant. Borehole TW14 is within 200m of borehole TW15 which was used as an observation well during the step test. There was a slight effect on the water levels in TW15 such that the step test on TW14 induced a drawdown of 0.05m at TW15.

Following the 240 minute step test, the pump in TW14 was switched off and the water levels allowed to recover over the next 6 hours, by which time the water levels had recovered to within 3.65m of its initial water level.

The results of the step test, the water levels measured and graphs of the response of the water levels to pumping are included in the Appendix 3. An assessment of this data was undertaken and it is considered that TW14 is not as productive as the estimate from drilling had predicted. It is considered that the borehole is probably capable of safely supplying no more than 86 m<sup>3</sup>/day. There were also significant inflows of silt into the borehole (which may have been causing some of the problems with the reducing yields) and as such it is considered it would be difficult to predict if this borehole could be used on an ongoing basis given the treatment requirements.

It was therefore concluded that it would not be necessary to undertake a 72 hour pumping test on this well.

## **5.10 TW15**

### **5.10.1 Step Test**

The step test on borehole TW15 commenced on the 27<sup>th</sup> March 2006. The static water level was established at 0.95m below datum. The step test was carried out in 3 steps, each of 100 minutes duration. The first step rate was set at 321.5 m<sup>3</sup>/day which held well and induced a drawdown of 8.46m. The Step 2 rate was increased to 434.5 m<sup>3</sup>/day and held relatively well, drawing the water level down to 13.15m of drawdown. The Step 3 rate further increased to 565 m<sup>3</sup>/d. This pumping rate fell back slightly such that the average pumping rate was 550 m<sup>3</sup>/d. The total drawdown at the end of the step test was 17.45m. Borehole TW15 is within 200m of borehole TW14 which was used as an observation well during the step test. There was a slight effect on the water levels in TW14 such that the step test on TW15 induced a drawdown of 0.35m at TW14.

Following the step test, the pump in TW15 was switched off and the water levels allowed to recover over the next 16 hours, by which time the water levels had recovered to within 2.92m of its initial water level.

### **5.10.2 72 Hour Test**

On the 28<sup>th</sup> March 2006, the 72 hour pumping test commenced at TW15. The water levels had not fully recovered from the Step Test undertaken the previous day, but it was decided to start the 72 hour test due to time constraints later in the week. Therefore the “static” water level was established at 3.87m below datum (within 2.9m of the static water level of the previous day). The discharge rate was set at 575 m<sup>3</sup>/day. The pumping rate held relatively for the first 10 hours of the test, but as the water levels fell, so did the pumping rate, dropping back to 505 m<sup>3</sup>/day by the end of the test. The average pumping rate over the 72 hours of the test was 557 m<sup>3</sup>/day. The total drawdown at the end of the 72 hour pumping period was 23.63m.



Equilibrium conditions had not been achieved by this stage and the drawdown was still increasing.

Once the 72 hour pumping test was complete, the pump was switched off and a recovery test undertaken. The recovery was slow such that after 24 hours, the water levels had only recovered back to within 6.27m of its initial level at the start of the 72 hour test.

The results of the pumping test, the water levels measured and graphs of the response of the water levels to pumping are included in the Appendix 3

## **5.11 TW16**

### **5.11.1 Step Test**

The step test on borehole TW16 commenced on the 5th September 2006. The static water level was established at 5.83m below datum. The step test was carried out in 3 steps, each of 100 minutes duration. The first step rate was set at 58 m<sup>3</sup>/day which held well and induced a drawdown of 3.87m. The Step 2 rate was increased to 103 m<sup>3</sup>/day which also held relatively well and drew the water levels down to 7.46m of drawdown. The rate for Step 3 was set at 160 m<sup>3</sup>/d. This rate also held well and the total drawdown at the end of the first step test was 11.88m.

Following the first step test, the pump in TW16 was switched off and the water levels allowed to recover. Within 2 hours the water levels had recovered to within 1.7m of its initial water level.

A second step test was undertaken on the 6th September 2006 in order to stress the well further as the previous test had indicated that the well was capable of more than 150 m<sup>3</sup>/day. The static water level was established at 5.81m below datum and the second step test commenced with the pumping rate for the first step set at 235 m<sup>3</sup>/d. This held relatively well falling back slightly to 229 m<sup>3</sup>/day, and induced 16.35m of drawdown. The Step 2 rate was increased to 308 m<sup>3</sup>/day, which held relatively well although it fell back slightly to 294 m<sup>3</sup>/day and drew the water level down to 24.07m of drawdown. The rate for step 3 was increased to 410 m<sup>3</sup>/day, although it fell back slightly to 350 m<sup>3</sup>/day. The total drawdown at the end of the second step test was 44.93m.

Following the second step test, the pump in TW16 was switched off and the water levels allowed to recover over the next 14 hours, by which time the water levels had recovered to within 0.58m of the initial water level.

The plot of the data from the step tests is included in the Appendix 3

### **5.11.2 72 Hour Test**

On the 8th September 2006, the 72 hour pumping test commenced at TW16. The static water level was established at 6.06m below datum. The discharge rate for the pumping test was set at 300 m<sup>3</sup>/day. The pumping rate held relatively well throughout the test, although it did fall back to 268 m<sup>3</sup>/day by the end of the test. The average pumping rate over the 72 hours of the test was 280 m<sup>3</sup>/day. The total drawdown at the end of the 72 hour pumping period was 35.47m. Equilibrium conditions had not been achieved by this stage and the drawdown was still increasing.

A small drawdown impact was noted at TW15 (approximately 350m from TW16). At the end of the test on TW16, 0.15m of drawdown was noted at TW15.

Once the 72 hour pumping test was complete, the pump was switched off and a recovery test undertaken. The recovery was slow such that after 24 hours, the water levels had only recovered back to within 3.06m of its initial level at the start of the 72 hour test.

The results of the pumping test, the water levels measured and graphs of the response of the water levels to pumping are included in the Appendix 3

## **5.12 TW17**

### **5.12.1 Step Test**

The step test on borehole TW17 commenced on the 11<sup>th</sup> May 2007. The static water level was established at 3.95m below datum. The step test was carried out in 4 steps, each of 100 minutes duration. The first step rate was set at 645 m<sup>3</sup>/day which held well and induced a drawdown of just 0.52m. The Step 2 rate was increased to 868 m<sup>3</sup>/day which also held relatively well and drew the water levels down to 0.79m of drawdown. The rate for Step 3 was set at 1302 m<sup>3</sup>/d with the drawdown at the end of this step being 1.4m. The pumping rate was increased again for the 4<sup>th</sup> Step to 1854 m<sup>3</sup>/d. This rate also held well and the total drawdown at the end of the step test was 2.53m.

Following the first step test, the pump in TW17 was switched off and the water levels allowed to recover. Within 2 hours the water levels had recovered to within 0.1m of its initial water level. Following 12 hours of monitoring the recovery, the water levels had rebounded to within 0.07m of the initial static water level.

The plot of the data from the step test is included in the Appendix 3

### **5.12.2 72 Hour Test**

On the 14<sup>th</sup> May 2007, the 72 hour pumping test commenced at TW17. The static water level was established at 4.07m below datum. The discharge rate for the pumping test was set at 1830 m<sup>3</sup>/day. The pumping rate held relatively well throughout the test. The average pumping rate over the 72 hours of the test was 1820 m<sup>3</sup>/day. The total drawdown at the end of the 72 hour pumping period was 2.74m. Equilibrium conditions had not quite been achieved by this stage and the drawdown was still increasing slightly.

The other wells on this site (i.e. TW4D, TW4 and TW4A) were monitored during the test on TW17. Small drawdown impacts were noted at all 3 no. wells. A total of 0.84m drawdown was noted at TW4D, approximately 65m south of TW17. The response in TW4, approximately 55m to the west of TW17, was similar at 0.8m. The smallest response was felt, as expected in the furthest well monitored, TW4A which is located approximately 195m west of TW17. Just 0.46m of drawdown was noted in this well during pumping at TW17.

Once the 72 hour pumping test was complete on TW17, the 7 day multi-well test on TW17 and TW4A commenced – without any recovery test being undertaken on TW17. The pump in TW4A was switched on at a rate of 1270 m<sup>3</sup>/d. The multi-well test is described below in Section 5.12.

The results of the 72 hour pumping test, the water levels measured and graphs of the response of the water levels to pumping are included in the Appendix 3

A summary of the data from the individual step and 72 hour tests for each well tested is listed in Table 5.1 table overleaf:

Table 5.1: Summary of Step Test & 72 hour test data.

Well	Step Tests	Drawdown	72 Hour Test (Average Pumping Rate)	Drawdown
<b>TW2A</b>	1 – 9.1 m <sup>3</sup> /hr 2 – 18.2 m <sup>3</sup> /hr 3 – 25.0 m <sup>3</sup> /hr  1 – 32 m <sup>3</sup> /hr 2 – 38.5 m <sup>3</sup> /hr 3 – 45 m <sup>3</sup> /hr	5.02m 11.41m 17.41m  19.89m 30.78m 49.27m	775 m <sup>3</sup> /day	32.35m
<b>TW2B</b>	1- 3.5 m <sup>3</sup> /hr 2 – 6.0 m <sup>3</sup> /hr	8m 66.0m	86.5 m <sup>3</sup> /day	33.43m
<b>TW3</b>	1 – 9.1 m <sup>3</sup> /hr 2 – 13.6 m <sup>3</sup> /hr 3 – 20.4 m <sup>3</sup> /hr	7.38m 12.84m 20.83m	476 m <sup>3</sup> /day	30.36m
<b>TW3A</b>	1 – 3.8 m <sup>3</sup> /hr 2 – 9.5 m <sup>3</sup> /hr 3 – 13.9 m <sup>3</sup> /hr	0.63m 9.4m 38.6m	242.5 m <sup>3</sup> /day	11.19m
<b>TW4</b>	1 – 9.1 m <sup>3</sup> /hr 2 – 18.1 m <sup>3</sup> /hr 3 – 27.25 m <sup>3</sup> /hr 4 – 36.75 m <sup>3</sup> /hr 5 – 47 m <sup>3</sup> /hr	0.11m 0.29m 0.52m 1.14m 1.16m	1945 m <sup>3</sup> /day	1.94m
<b>TW4A</b>	1 – 18.3 m <sup>3</sup> /hr 2 – 38 m <sup>3</sup> /hr 3 – 49.5 m <sup>3</sup> /hr 4 – 68.75 m <sup>3</sup> /hr	1.61m 6.13m 10.21m 19.25m	1405 m <sup>3</sup> /day	9.92m
<b>TW14</b>	1 – 2.9 m <sup>3</sup> /hr 2 – 4.7 m <sup>3</sup> /hr	20.48m 46.88m	-	-
<b>TW15</b>	1 – 13.5 m <sup>3</sup> /hr 2 – 18.1 m <sup>3</sup> /hr 3 – 23 m <sup>3</sup> /hr	8.46m 13.15m 17.45m	557 m <sup>3</sup> /day	23.63m
<b>TW16</b>	1 – 2.4 m <sup>3</sup> /hr 2 – 4.3 m <sup>3</sup> /hr 3 – 6.6 m <sup>3</sup> /hr  1- 9.8 m <sup>3</sup> /hr 2 – 12.8 m <sup>3</sup> /hr 3 – 17 m <sup>3</sup> /hr	3.87m 7.46m 11.88m  16.35m 24.07m 44.93m	280 m <sup>3</sup> /day	35.47m
<b>TW17</b>	1 – 26.8 m <sup>3</sup> /hr 2 – 36 m <sup>3</sup> /hr 3 – 54.25 m <sup>3</sup> /hr 4 – 77.25 m <sup>3</sup> /hr	0.52m 0.79m 1.4m 2.53m	1820 m <sup>3</sup> /day	2.74m

### **5.13 Multi-Well 7-Day Pumping Tests**

Following the completion of all individual well tests further testing was undertaken to determine the sustainable yields of the more productive wells over a longer period of 7 days.

It was also considered that the wells located in groups should be tested simultaneously to determine if there are interference effects which may lower the overall yield of each group (compared with the individual well yields).

The productive wells in the siltstones to the north of Ashford, TW2A, TW3 and TW3A, were tested together over 7 days based on the yields proven in previous tests. The productive wells in the gravels to the west of Ashford, TW4 and TW4A, were also tested together, and it was expected that there would be strong interference effects, given the results of previous tests. When TW17 was drilled later on, TW4A and TW17 were also tested together over 11 days. Similarly the Milltown wells, TW15 and TW16 were also tested together given their proximity to each other.

#### **5.13.1 Wells North of Ashford in Bedrock – TW2A, TW3 and TW3A (Nuns Cross Wellfield)**

The data from the 72 hour pumping tests undertaken in October 2005 (on TW3) and March 2006 (on TW2A and TW3A) indicated that little interaction was expected between the wells during the 7 day pumping tests, given the distance between them and the results of the previous pumping tests. As such the combined pumping rate for the multi-well test was expected to be equal to the sum of the individual pumping rates for each well separately.

On the 17<sup>th</sup> August 2006, the multi-well, 7 day pumping test commenced at TW2A, TW3 and TW3A. The rest water levels at each of the wells was recorded prior to pumping such that their levels were at the start of the test, were 7.21m in TW2A, 19.83m in TW3 and 22.69m in TW3A. The pumping rates set at the start of each test (770 m<sup>3</sup>/d, 450 m<sup>3</sup>/d and 260 m<sup>3</sup>/d) held relatively well throughout the 7 day test. At borehole TW2A the rate dropped back to 673 m<sup>3</sup>/d. At TW3, it dropped back to 393 m<sup>3</sup>/d, while at TW3A it dropped back slightly to 245 m<sup>3</sup>/d. The average pumping rates over the 7 day test were 694 m<sup>3</sup>/d at TW2A, 415 m<sup>3</sup>/d at TW3 and 252 m<sup>3</sup>/d at TW3A. Drawdown at the end of the 7 day pumping period was 27.98m at TW2A, 29.99m at TW3 and 18.39m at TW3A. The drawdown in TW2A had started to level out by the end of the test and we are of the opinion that equilibrium conditions were being approached. However, the water levels in TW3 were still falling steadily at the end of its 7 day test and steady state conditions had not been achieved by the end of the test. TW3A behaved similarly to TW2A, in that water levels were still falling slightly by the end of the test, but had started to level out and it is considered that equilibrium conditions were being approached.

During the 7 day multi-well tests on wells TW2A, TW3 and TW3A, the effect on the water levels in TW2 (very close to TW2A) and TW2B were also monitored.

The water level in TW2 was measured before the start of the test at 8.1m below datum. It fell gradually throughout the test to 22.41m by the end of the test (i.e. a drawdown of 14.31m), which is significant but it is considered to be related to the proximity of well TW2 to well TW2A and that they are potentially tapping the same fracture system within the siltstones.

The water level in TW2B was also monitored. The static water level was recorded at approximately 8m below datum and the water level appears to have fluctuated before being drawn down to 8.61m by the end of the test (i.e. a drawdown of 0.61m) which is not considered significant.

The shallow spring (located in private lands to the east of well TW2A) was also monitored (by the landowner) during the test. No change in the water level or flow in the spring was noted.

Once the 7 day multi-well pumping test was complete, the pumps were switched off and the recovery tests undertaken. The recovery in well TW2A was relatively fast until a residual drawdown of 11.7m was reached (i.e. when the water level was at 18.88m below datum). After this point (approximately 25 minutes into the recovery test) the recovery was relatively slow such that the water level took until 24 hours to recover back to within 3.2m of its initial level.

The recovery in well TW3 occurred at a more steady pace than in TW2A. The recovery was initially fast until a residual drawdown of 16.29m was reached (i.e. when the water level was at 36.12m below datum). After this point (approximately 45 minutes into the recovery test) the recovery was slow such that the water level took 24 hours to recover back to within 10.01m of its initial level with a longer recovery period expected (possibly up to 36 hours) before the static water level was achieved.

The recovery in well TW3A was initially very fast for the first 5 minutes when a residual drawdown of 1.8m was reached (i.e. when the water level was at 24.49m below datum). After this point (approximately 5 minutes into the recovery test) the recovery was slow such that the water level took 24 hours to recover back to within 0.55m of its initial level.

The results of the pumping tests, the water levels measured and graphs of the response of the water levels to pumping are included in the Appendix 3. The sustainable yields of each of the wells in Nun's Cross and their impact on each other is discussed in Section 6.2.

### **5.13.2 Wells West of Ashford in Gravel – TW4, TW4A / TW4A, TW17 (Ashford Wellfield)**

The data from the 72 hour pumping tests undertaken in September / October 2005 (on TW4) and March 2006 (on TW4A) indicated that these wells, located in the alluvial gravels were very

productive (although TW4 is a more productive well than TW4A). It was expected that there would be interaction between the wells during the pumping tests, given the results of the previous pumping tests and their relative proximity, and as such the combined pumping rate could be less than the sum of the individual pumping rates for each well separately.

On the 29<sup>th</sup> August 2006, the 7 day multi-well pumping test commenced at TW4 and TW4A. The rest water levels at each of the wells was recorded prior to pumping such that their levels, at the start of the test, were 5.5m in TW4 and 3.62m in TW4A. The pumping rate for TW4 was initially set at 1880 m<sup>3</sup>/d although this was increased slightly (to 1970 m<sup>3</sup>/d) at 90 minutes into the test. This higher rate held relatively well throughout the 7 day test, dropping back only slightly to 1962 m<sup>3</sup>/d by the end of the test. At borehole TW4A, the rate was initially set at 1200 m<sup>3</sup>/d which held well throughout the test, dropping back only slightly to 1195 m<sup>3</sup>/d by the end of the test. The average pumping rates over the 7 day test were 1940 m<sup>3</sup>/d at TW4 and 1195 m<sup>3</sup>/d at TW4A. Drawdown at the end of the 72 hour pumping period was 3.5m at TW4 and 6.38m at TW4A. The drawdown in TW4 is considered to be relatively low given the overall depth of the well and the pumping rates which were achieved during the test. The water levels had started to stabilise by the end of the test and it is considered that equilibrium conditions were being approached. Similarly at TW4A, the water levels were coming towards equilibrium conditions by the end of the test.

During the 7 day tests on wells TW4 and TW4A, the effect on the water levels in TW4D, in the south east corner of the field, closer to the river, was monitored. The water level in TW4D was measured before the start of the test at 2.95m below datum. It fell gradually throughout the test to 4.31m by the end of the test (i.e. a drawdown of 1.36m) which over the course of a 7 day test is not considered excessive.

Once the 7 day, multi-well pumping test was complete, the pumps were switched off and the recovery tests undertaken. The recovery in well TW4 was fast until a residual drawdown of 1.2m was reached (i.e. when the water level was at 6.7m below datum). After this point (approximately 20 minutes into the recovery test) the recovery was relatively slow such that the water level took until 22 hours to recover back to 0.83m of its initial level.

The recovery in well TW4A occurred more steadily than at TW4. The recovery at TW4A was initially fast until a residual drawdown of 1.45m was reached (i.e. when the water level was at 5.07m below datum). After this point (approximately 10 minutes into the recovery test) the recovery was slow such that the water level took 22 hours to recover back to within 0.77m of its initial level.

The results of the pumping tests, the water levels measured and graphs of the response of the water levels to pumping are included in the Appendix 3. The sustainable yields of each of the wells in the Ashford Gravel and their impact on each other are discussed in Section 6.3.

Following discussions between Wicklow County Council Housing Section and Water Services Section, it was considered that TW4 was not in a suitable position, given the proposed housing development. Trial Well TW17 was drilled further east on the site, along the eastern boundary and tested by means of a 72 hour test between the 14<sup>th</sup> and 17<sup>th</sup> May 2007. Given the well was successful with a similar yield to TW4, it was considered this new trial well, TW17, should be tested in tandem with TW4A for at least 7 days to replicate the test undertaken on TW4 and TW4A in September 2006.

Immediately following the 72 hour test on TW17, the pump in TW4A was switched on, starting the multi-well pumping test on the 17<sup>th</sup> May 2007. The rest water levels at each of the wells was recorded (although the water levels in both wells had been affected by pumping during the 72 hour test on TW17); 6.81m at TW17 and 3.4m at TW4A. The pumping rate at TW17 continued (following the 72 hour test) at approximately 1835 m<sup>3</sup>/d, until 166 hours (almost 7 days) into the test. At this point, the pumping rate was pulled back to 1427 m<sup>3</sup>/d and remained around 1420 m<sup>3</sup>/d until the end of the test (11 days / 264 hours). At borehole TW4A, the pumping rate was initially set at 1270 m<sup>3</sup>/d which dropped back slightly to 1250 m<sup>3</sup>/d by 94 hours (almost 4 days) into the test. At this stage the pumping rate was pulled back to 1082 m<sup>3</sup>/d. The rate remained relatively steady until approximately 142 hours (almost 6 days into the test) when the pumping rates dropped back to 962 m<sup>3</sup>/d and eventually back to an average of 955 m<sup>3</sup>/d until the end of the 11 day test. The calculation of average pumping rates for either well over the full 11 day test are not possible due to the adjustments made in the rates throughout the test. The graphs shown in Appendix 3 indicate the average for each phase of the pumping rates used. Drawdown at the end of the 14 day (72 hour and 11 day) pumping period was 2.81m at TW17 (although the maximum drawdown of 3.49m was reached at almost 10 days into the test prior to the pumping rate being pulled back). At TW4A the final drawdown was noted as 4.6m, although the maximum drawdown of 5.92m was recorded after 90 hours of pumping at this well prior to the pumping rate being pulled back from 1250 m<sup>3</sup>/d to 1080 m<sup>3</sup>/d. The drawdowns, especially those recorded in TW17, are considered to be relatively low given the overall depth of the wells and the pumping rates which were achieved during the test. Equilibrium conditions were not reached during the test due to the adjustment in the pumping rates undertaken.

During the 72 hour and 11 day tests on wells TW17 and TW4A, the effect on the water levels in TW4 between the 2 pumping wells and in TW4D, in the south east corner of the field, closer to the river, was monitored.

The static water level in TW4 was measured prior to the start of the 72 hour test on TW17 (at 4.8m) and before the start of the 11 day test, at 5.6m below datum. The 72 hour test had therefore induced 0.8m of drawdown in this well. The water levels fell further throughout the 11 day multi-well test on TW17 and TW4A, so that by the end of the test, the water level in TW4 was 6.36m (i.e. a total drawdown of 1.56m).



The static water level in TW4D was also measured prior to the start of the 72 hour test on TW17 at 2.61m and again prior to the start of the 11 day multi-well test on TW17 and TW4A, at 3.45m. There was an initial drawdown, over the 72 hours, of 0.84m. Further drawdown in the water levels at TW4D was noted during and after the 11 day multi-well test, such that the final water level in TW4D was 4.13m (a total drawdown of 1.52m).

Given that either one or both of TW17 and TW4A had been pumping continuously for 14 days, the drawdowns recorded in the monitoring wells are not considered excessive.

Once the 11 day, multi-well test on TW17 and TW4A was complete, the pumps were switched off and the recovery tests undertaken. The recovery in well TW17 was initially fast such that it recovered back to within 1m of its initial level in just 10 hours. However, the recovery slowed down for the latter part of the recovery test and by 48 hours into the test, the water level was only back within 0.7m of its initial level.

The recovery in well TW4A initially occurred faster than in TW17. Within 4 hours, the water levels had recovered by 3.8m to a residual drawdown of 0.8m. However, the recovery happened slower such that the water level took 48 hours to recover back to within 0.36m of its initial level.

The results of the pumping tests, the water levels measured and graphs of the response of the water levels to pumping are included in the Appendix 3. The sustainable yields of each of the wells in the Ashford Gravel and their impact on each other is discussed in Section 6.3.

### **5.13.3 Wells in Milltown, South of Ashford in Bedrock – TW15 and TW16**

The data from the 72 hour pumping test undertaken on TW15 in March 2006 indicated that this well, located in the Maulin Formation (slates, siltstones and schists) was relatively productive with a yield of up to 500 m<sup>3</sup>/d. Trial well TW16, drilled in August 2006 and tested (by means of a 72 hour pumping test) in September 2006 is also considered relatively productive with a possible sustainable yield of 250 m<sup>3</sup>/d.

It was considered that there could be some limited interaction between the wells (TW15 and TW16) during the pumping tests, given that a slight response (0.15m drawdown) was noted in TW15 during the 72 hour test of TW16.

On the 12th September 2006, the 7 day, multi-well pumping test commenced at TW15 and TW16. The static water levels at each of the wells were recorded prior to pumping such that their levels at the start of the test, were 1.71m in TW15 and 9.12m in TW16. The pumping rate for TW15 was initially set at 600 m<sup>3</sup>/d. This higher rate held relatively well throughout the 7 day test, dropping back only slightly to 509 m<sup>3</sup>/d by the end of the test. At borehole TW16, the rate was initially set at 264 m<sup>3</sup>/d which held well throughout the test, dropping back slightly to 233

m<sup>3</sup>/d by the end of the test. The average pumping rates over the 7 day test were 523 m<sup>3</sup>/d at TW15 and 240 m<sup>3</sup>/d at TW16. Drawdown at the end of the 72 hour pumping period was 37.94m at TW15 and 31.76 m at TW16. The drawdown in TW15 were still falling steadily at the end of its 7 day test and steady state conditions had not been achieved by the end of the test. The water levels at TW16 were also still falling, although less markedly than at TW15, by the end of the test. It is considered that equilibrium conditions had not been reached by the end of this test.

Once the 7 day, multi-well pumping test was complete, the pumps were switched off and the recovery tests undertaken. The recovery in well TW15 was initially relatively fast until a residual drawdown of 27.91m was reached (i.e. when the water level was at 29.62m below datum). After this point (approximately 60 minutes into the recovery test) the recovery slowed such that the water level had only recovered back to within 15.85m of its initial level at the end of the 24 hour recovery period.

The recovery in well TW16 also occurred relatively rapidly initially such that the water level recovered back to 19.52m (from 40.88m) within 2 hours. However, after this point (120 minutes into the recovery test) the recovery slows (as it does in TW15) such that the water level took 24 hours to recover back to within 3.98m of its initial level.

The results of the pumping tests, the water levels measured and graphs of the response of the water levels to pumping are Milltown and their impact on each other is discussed in Section 6.4.

A summary of the data from the 7 day pumping tests for each well tested is listed in Table 5.2 overleaf.

Table 5.2: Summary of 7 day / 11 day multi-well test data

	Well	Average Pumping Rate	Drawdown	Recovery
7 day multi-well test Nun's Cross wellfield	<b>TW2A</b>	694 m <sup>3</sup> /day	27.98m	24 hours to recover back to within 3.2m of static water level
	<b>TW3</b>	415 m <sup>3</sup> /day	29.99m	24 hours to recover back to within 10.01m of static water level
	<b>TW3A</b>	252 m <sup>3</sup> /day	18.39m	24 hours to recover back to within 0.55m of static water level
7 day multi-well test	<b>TW4</b>	1940 m <sup>3</sup> /day	3.5m	22 hours to recover back to within 0.83m of static water level
Ashford wellfield	<b>TW4A</b>	1195 m <sup>3</sup> /day	6.38m	22 hours to recover back to within 0.77m of static water level
7 day multi-well test	<b>TW15</b>	523 m <sup>3</sup> /day	37.94m	24 hours to recover back to within 15.85m of static water level
Milltown wellfield	<b>TW16</b>	240 m <sup>3</sup> /day	31.76m	24 hours to recover back to within 3.98m of static water level
11 day multi-well test Ashford wellfield (May 2007)	<b>TW4A</b>	1255 m <sup>3</sup> /d for first phase Dropped back to 1077 m <sup>3</sup> /d for second phase Cut back again to 955 m <sup>3</sup> /d for end of test	5.92m (max) 5.12m (end of 2nd phase) 4.6m (end of test)	48 hours to recover back to within 0.36m of static water level
	<b>TW17</b>	1830 m <sup>3</sup> /d for first phase Dropped back to 1420 m <sup>3</sup> /d for second phase	3.49m (max) 2.81m (end of test)	48 hours to recover back to within 0.7m of static water level

## **6. INTERPRETATION OF SUSTAINABLE YIELDS**

### **6.1 Methodology**

The pumping tests (72 hour, 7 day and 11 day duration) were undertaken to stress the trial wells to provide an indication of the maximum yields. However, an estimate of the sustainable yield of each well, over a longer term and based on the available resource in the various aquifers to be exploited, was also required to provide long term projections of the operational pumping rates for the proposed water supply.

Estimates of aquifer transmissivities and well specific capacities were obtained from the 7 day pumping test data. The data gathered was analysed using a variety of numerical methods, to determine aquifer characteristics. For each set of data, the “Logan Approximation” was used to estimate an approximate transmissivity (T) value for the relevant aquifer, using the formula

$$T = Q/s$$

where Q = average pumping rate

and s = maximum drawdown recorded during the 7 day test.

Further analysis of the time versus drawdown (semi-log) plots (included in Appendix 4) was used to determine further estimates of aquifer transmissivities (for the middle and later parts of the test), using the formula

$$T = (2.3*Q) / (4\pi*\Delta s)$$

where Q = average pumping rate

and  $\Delta s$  is the drawdown per log cycle

The range of aquifer transmissivity values estimated using the various analytical methods was assessed and a representative value chosen based on available data on aquifer characteristics from the GSI Groundwater Protection Scheme for Co. Wicklow.

The specific capacity of each borehole, which indicates how productive the well is as opposed to the overall aquifer characteristics, was calculated using the formula

$$\text{Specific Capacity} = Q/s$$

where Q = average pumping rate

and s is total drawdown

The aquifer and well values for each trial well are shown on the data calculation sheets in Appendix 4.

However, in most cases the water levels were still falling by the end of the 7 day tests and it is considered that in some cases the aquifers had not reached equilibrium conditions. It is

considered that these wells were pumped at rates higher than what they are capable of over a longer term. A method to determine the sustainable long term discharge from each well was required. Ideally, long term operational data on pumping rates (from a supply which has been in use) are used to estimate reliable long term sustainable yields from groundwater supplies. In shallow, unconfined, fissure flow-aquifers, such as encountered in the bedrock wells (TW2A, TW3, TW3A, TW15 and TW16) the actual well performance may vary considerably from that predicted based on theoretical considerations (Misstear & Beeson, 2000). If water levels have been recorded over time, drought levels of water in the aquifer may be available which will allow reliable yields to be estimated.

No information on drought conditions in these aquifers in the vicinity of the proposed water supply wells is available. Rainfall events during the pumping tests, undertaken between September 2005 and September 2006 were not recorded. Information available from Met Eireann indicates that most of the 7 day pumping tests undertaken in 2006 were undertaken in relatively wet months (August to September 2006) although they followed a couple of dry months (June and July 2006). The extended (72 hour and 11 day) tests undertaken on TW17 and TW4A in May 2007 were undertaken following a very dry April (just 5.4mm at Casement) and average May (39mm). However, this data does not provide any correlation with the water levels in the aquifers. It is considered that although the gravel aquifer (TW4, TW4A and TW17) may respond rapidly to rainfall events, it is unlikely that fluctuations in the water levels in the bedrock aquifers would be noticeable over the course of the pumping tests.

Where there is no operational information available, an analytical approach to reliable yield estimation is required. A methodology is outlined in Misstear & Beeson (2000) and requires a number of elements based on the data from the Step Tests, where the wells were pumped at various pumping rates. These elements are (1) calculation of short term pumping water levels from step-test data and (2) extrapolation of longer-term pumping water levels based on the Cooper-Jacob equation (see below).

The short term, step test drawdown levels for the trial wells tested as part of this assessment have already been calculated (summarised Table 6.1). Longer term drawdown values are estimated by extrapolating the short-term values using the following formulae (i) and (ii), based on the Cooper-Jacob equation

$$\text{Formula (i) } \Delta s = (2.3 \cdot Q) / (4\pi \cdot T)$$

where  $\Delta s$  is the drawdown per log cycle of time,

$Q$  = pumping rate for the step being assessed

and  $T$  is the transmissivity value for the aquifer (calculated previously using the 7 day test data)

$$\text{Formula (ii) } s^a = L \cdot \Delta s$$

where  $s^a$  = the additional long-term drawdown (to be added to the short-term drawdown)

and  $L$  = number of log cycles of time between the end of the step (step duration = 100 minutes) and the time for which the yield estimate is to be made (in this case 200 days) (i.e. 3.46).

The total drawdown (sum of the short-term and extrapolated long term drawdowns) is added to the static water level to obtain a long term pumping water level. This is plotted against the discharge rate for that step and an extrapolated step test curve is produced (included in Appendix 4).

The potential / reliable yield is taken from the intersection of this extrapolated curve and the Deepest Advisable Pumping Water Level (DAPWL). Where there are no records on the lowest recorded water levels in the aquifer, it is considered prudent to choose a DAPWL, which may be defined as, for example, the level below which undesirable effects, such as dewatering and/or sand pumping may occur. The borehole logs for each of the trial wells were assessed and the main water entry levels were noted. The DAPWL for the wells is taken as the level of the main water bearing fissure.

This methodology is summarised in Appendix 4. The characteristics of the individual wells and the cluster groups which form 3 different well-fields are discussed below.

## **6.2 Nun's Cross Well Field (TW2A, TW3 and TW3A)**

Using the methodology outlined above the maximum potential yield for Well TW2A, which would draw the water levels down to the DAPWL is considered to be 740 m<sup>3</sup>/d. However, given the poor aquifer classification for the aquifer from which this borehole is abstracting, it seems unlikely that this yield is sustainable. In this case, a figure of 500 m<sup>3</sup>/d is considered to be more conservative and realistic estimate of the sustainable yield.

The methodology was also applied to the step test data for TW3. The yield at which the water level reaches the first of the fissures in TW3 is considered to be 330 m<sup>3</sup>/d. It is considered that this yield is sustainable in the long term for this well as there are a number of fissures below the first which will also support the planned abstraction.

The step test data for TW3A was also assessed using the methodology described above. This well is less productive than the other two in this well field as its sustainable yield is considered to be 180 m<sup>3</sup>/d.

These wells are abstracting from the Devil's Glen Formation which is classified as a Poor Aquifer. The water supplying these wells is coming from individual fracture / fissure zones at depth and it is considered that there will be little if any interconnectivity between the fissure zones supplying each individual well. The static water levels in TW3 and TW3A are at different levels even though they are located relatively close to each other (within 250m) and at a similar elevation. Flow paths in low permeability rock types such as these greywackes and shales, will be short (in the order of a few hundred metres) and as such it is considered unlikely that there

will be any interference effects between the wells in the Nun's Cross Well field as each well will have its own separate sub-catchment.

Therefore the total sustainable yield for this well field together is considered to be equal to the sum of the individual well yields, i.e. 1010 m<sup>3</sup>/d.

### **6.3 Ashford Well Field (TW4, TW4A and TW17)**

Using the methodology outlined above the potential yield for well TW4, which would draw the water levels down to the DAPWL is considered to be up to 2500 m<sup>3</sup>/d. The methodology was also applied to the step test data for TW4A. This well appears to be less productive, with a potential yield between 1000 m<sup>3</sup>/d and 1200 m<sup>3</sup>/d. The methodology was also applied to the step test data for TW17 and DAPWL is considered to be up to 2800 m<sup>3</sup>/d.

However, as the alluvial gravel deposit is limited in aerial extent to less than 1km<sup>2</sup>, the sustainable yields need to be examined in further detail to see if they can be supported by the available recharge. The high yields achieved in the pumping tests may have been largely supported by storage in the aquifer. Storage in an unconfined coarse gravel aquifer such as this can range between 20% and 30% and it is possible that the water pumped during the pumping tests came mainly from storage. Using conservative figures of 0.5 km<sup>2</sup> aerial extent of gravel (1km<sup>2</sup> is mapped), 10m thickness of the coarse gravels (thicknesses of between 12m and 15m encountered in boreholes), a storage value of 20% and assuming that the wells may only capture one-fifth of the cross-sectional width of the aquifer, it is estimated, that there may be up to 200,000 m<sup>3</sup> available from storage.

The main sustainable resource of the aquifer is considered to be from the recharge it receives, both directly from effective rainfall onto the outcrop of the alluvial gravels and indirectly from the outcrop of the glacial gravels to the north which may act as further storage.

The recharge directly onto the alluvial gravel aquifer from which the TW4, TW4A and TW17 wells are abstracting is calculated using meteorological data and estimates of runoff, as follows.

Rainfall data for the area (from Met Éireann) indicates that average annual rainfall, measured at their recorder stations at Glenealy (Kilmacurragh) and Roundwood (Filter Beds) (for the period 1961-1990) was 1119mm and 1192mm respectively. Interpolation of this data indicates the site at the trial wells receives approximately 1150mm of rainfall (R) per year.

Potential Evapotranspiration (P.E.) data is also available from Met Éireann for their station in Casemount (the closest synoptic station) and is 504mm/yr. Actual Evapotranspiration (A.E.) is then calculated by taking 95% of the potential figure, to allow for soil moisture deficits. A.E. is therefore estimated as 478.5 mm/yr. Using these figures, the Effective Rainfall (E.R.) is taken to be approximately 671.5 mm/yr. This is equivalent to the Potential Available Recharge.

This potential recharge is subjected to losses from runoff. The area is considered to be covered by permeable gravels in a flat topographical setting with a gentle gradient towards the Devil's Glen River. In this case the runoff is taken to be approximately 10% based on the permeability of the soils and subsoils. A figure for actual recharge is therefore taken to be approximately 604 mm/yr as outlined below.

Average Annual Rainfall (R)	1150 mm
Potential Evapotranspiration (P.E.)	504 mm
Estimated <i>Actual</i> Evapotranspiration (A.E.)	478.5 mm
Potential Recharge (R – A.E.)	671.5 mm
Runoff Losses (10% of Potential Recharge)	67.15 mm
Estimated <i>Actual</i> Recharge	604 mm

This recharge will filter directly into the underlying sands and gravels. 604mm per year is equivalent to  $1.65 \times 10^{-3}$  m/day.

The alluvial gravels are mapped as having an aerial extent of  $1\text{km}^2$ . If a conservative approach is taken, it is considered that perhaps only half of this area is thick enough to be considered as an aquifer and as such the aerial extent for calculations of recharge is taken as  $0.5\text{ km}^2$  ( $500,00\text{m}^2$ ). Using the recharge rate calculated above and the recharge area, a recharge volume of  $825\text{ m}^3/\text{d}$  can be considered to be available for abstraction directly from the alluvial gravels.

It is considered that there is additional recharge available from the glacial gravels to the north, north of Nun's Cross. These gravels were explored as part of the trial well drilling programme in this area. Although the gravels contained much less water than was originally expected (due to its classification as a Locally Important Gravel Aquifer by the Geological Survey of Ireland) and could not be exploited as a groundwater source for this scheme, it is considered that the gravels hold water in storage for the underlying bedrock aquifer and that some of this water also flows within the gravels to the south, discharging into the alluvial gravels before discharging into the river. As such, it is considered that further recharge to the alluvial gravels is available from the glacial gravels to the north.

The recharge calculations for the glacial gravels are slightly different as it is considered that there will be more slightly more runoff based on the topographical setting. The gravels themselves have a lower permeability (when compared with the alluvial gravels) due to the higher percentage of fines (silts and clays) within them. This would also lead to a higher degree of runoff. That said, the drainage density is relatively low over the outcrop of the glacial gravels. It is considered that the runoff percentage can be increased to approximately 30%. Using the rainfall, evapotranspiration figures listed above and a runoff of 30%, it is considered that the



effective rainfall (recharge rate) for the glacial gravels is closer to 470mm/yr, equivalent to  $1.28 \times 10^{-3}$  m/day.

The glacial gravels (upgradient of wells TW4, TW4A and TW17) are mapped covering an area of approximately 3.65 km<sup>2</sup>. Using the recharge rate calculated above and the recharge area, a recharge volume of 4,670 m<sup>3</sup>/d can be considered to be available in the glacial gravels. A proportion of this will filter directly through to the underlying bedrock. However as the underlying bedrock is described as a low permeability poor aquifer, it is considered that a significant proportion of the recharge will flow south to recharge the alluvial gravels. This proportion cannot be accurately quantified but is considered to be at least 50%. As such, it is possible that up to 2,335 m<sup>3</sup>/d is available from the glacial gravels.

A simple water budget shown below, indicates that the alluvial gravel aquifer has significant water available from both storage (available in the short term but not sustainable in the longer term) and also from recharge (sustainable in the longer term) both directly from the alluvial gravels and indirectly from the glacial gravels to the north and possible from the river at certain times of the year.

**Table 6.1: Water budget of gravel aquifer**

	<b>Inputs</b>	<b>Outputs</b>
Water Available from Storage	200,000 m <sup>3</sup> /	
Recharge Directly onto alluvial gravels	825 m <sup>3</sup> /d	
Recharge indirectly from glacial gravels	2,335 m <sup>3</sup> /d	
Recharge indirectly from river at certain times of the year	<i>Unknown</i>	
Recommended maximum abstraction volume from the wells		3000 m <sup>3</sup> /d
<b>TOTAL</b>	<b>3,160 m<sup>3</sup>/day</b>	<b>3,000 m<sup>3</sup>/day</b>

These wells are abstracting from a band of alluvial gravels associated with the Devil's Glen River. They are not mapped as an aquifer resource by the Geological Survey of Ireland but are considered by GES Ltd. to represent a Locally Important Gravel Aquifer in this area, following investigation of its resources as part of this hydrogeological assessment.

The gravels are assumed to have very high permeabilities (Transmissivity values of between 300 and 600 m<sup>2</sup>/d were determined using the 7 day / 11 day pumping test data) and as such it is assumed that there will be a high degree of interaction between the wells (TW4A and TW17)

which are abstracting from the same alluvial gravel deposit. This was seen by the effect pumping at any of the wells in this gravel aquifer had on water levels in the other nearby wells in the same gravels.

Flow paths in gravels such as these will be relatively short (in the order of 500m) but there will be interference effects between the wells in the Ashford well field. The sum of the individual wells is considered to be around 3000 m<sup>3</sup>/d. However, it is considered that the interference effects may lower the overall combined yield by approximately 30%, thus reducing the overall yield for this well field to 2200 m<sup>3</sup>/d.

However, it is also considered that it may be possible to exploit more from this resource in the winter when more recharge is available so allowance should be made for abstraction rates up to 3000 m<sup>3</sup>/d.

#### **6.4 Milltown Well Field (TW15 and TW16)**

Using the methodology outlined for the Nuns Cross Wellfield the sustainable yield for Well TW15, which would draw the water levels down to the first fissure is considered to be 220 m<sup>3</sup>/d, although more water may be available as there is another deeper fissure.

The methodology was also applied to the step test data for TW16. The yield at which the water level reaches the main productive fissure in TW16 is considered to be 180 m<sup>3</sup>/d.

These wells are abstracting from the Maulin Formation which is classified as a Locally Important Aquifer. The water supplying these wells is coming from individual fracture / fissure zones at depth. In a Locally Important Aquifer there may be some interconnectivity between the fissure zones supplying each individual well, as could be seen by the slight effect pumping at TW16 had on the water levels in TW15. It is noted that this effect was observed at a higher pumping rate than is actually planned on an operational basis at these sources so the effect will be smaller in an operational situation. Flow paths in moderate permeability rock types such as these slates, siltstones and schists will be relatively short (in the order of 500m) and as such it is considered that there will be minimal interference effects between the wells in the Milltown well field.

Therefore the total sustainable yield for this well field together is considered to be equal to the sum of the individual well yields, i.e. 400 m<sup>3</sup>/d.

It may be possible to drill another well in the vicinity of TW15 and TW16 to make it a more viable scheme. The Poor Aquifer and the Locally Important Aquifer are both located in this area and further investigation of sites close to the boundary of the aquifers may reveal a higher degree of fracturing and perhaps higher yields.

## 7. CHEMICAL AND BACTERIOLOGICAL ANALYSES

Water samples were taken towards the end of the pumping tests on boreholes TW2A, TW3, TW3A, TW4, TW4A, TW4D, TW14, TW15, TW16 and TW17. The water sampled from all boreholes was noted as clear and colourless with no obvious odours or other visual signs of contamination. Samples were also taken in sterile containers for bacteriological analysis.

The water samples were transported to T.E. Laboratories in Carlow for analysis. The samples taken from TW3 and TW4 in October 2005 were analysed for the full SI 439 range of parameters, while the samples taken from TW2A, TW3A, TW4A and TW15 in March 2006 were analysed for a broad range of indicator parameters (but not the full SI 439 suite). This provided information on a broad range of physical, chemical and bacteriological parameters to assess the baseline quality of the groundwater sampled at each of the sites.

Following the multi-well, 7 day tests undertaken in August and September 2006, further groundwater samples were taken from all wells tested. The samples taken from TW2A, TW3A, TW4, TW4A, TW4D, TW15 and TW16 were analysed for the full SI 439 range of parameters, while the sample taken from TW3 was analysed for a broad range of indicator parameters (but not the full SI 439 suite as this had been done previously in October 2005). These analyses provided information on a broad range of physical, chemical and bacteriological parameters to assess the quality of the groundwater following a prolonged period of pumping.

A sample was also taken from TW17, the replacement well for TW4, after the initial 72 hour test on the 17<sup>th</sup> May 2007. The sample was analysed for the full SI439 range of parameters, so a comparison could be made with the water quality from TW4 and to provide a full background water quality suite for this well.

The results of the analyses are included in Appendix 5 to this report. The results indicate good quality water from most of the trial wells (although in some cases some bacteriological contamination is indicated).

The **pH** concentrations range from **6.5 at TW4A to 7.9 at TW3**. These concentrations are within the range required by the Drinking Water Standards i.e. between 6.5 and 9.5.

The **Electrical Conductivity** concentrations in the samples range between **214 µS/cm at TW4A and 419 µS/cm at TW3A** below the EU MAC for Drinking Water, of 2,500 µS/cm.

The **ammonia** concentrations in the samples were all **<0.1 mg/l NH<sub>4</sub>** (below the limit of detection of the analytical method used) and below the EU MAC of 0.3 mg/l NH<sub>4</sub>.

The **nitrate** concentrations at most of the boreholes sampled are considered relatively low ranging between **<0.5 mg/l NO<sub>3</sub> at TW15 to 24 mg/l NO<sub>3</sub> at TW2A**, all below the Guide Level of

25 mg/l NO<sub>3</sub> and below the EU MAC of 50 mg/l NO<sub>3</sub>. However, the nitrate concentration at **TW2A** is considered slightly elevated at **24 mg/l NO<sub>3</sub>**, just below the guide level, although still below the MAC concentration. The water quality at this borehole may be influenced by the intensive tillage lands in the immediate vicinity.

The **nitrite** concentrations are considered low at **all boreholes** at **<0.2 mg/l NO<sub>2</sub>**, below the limit of detection of the analytical method used and below the EU MAC of 0.5 mg/l NO<sub>2</sub>.

The **chloride** concentrations are considered normal for an area within 5km of the sea, ranging from **16 mg/l Cl at TW4A** to **31 mg/l Cl at TW15**, all below the EU MAC of 250 mg/l Cl.

The **iron** concentrations in the water from all but 2 of the boreholes are considered low at **<0.05 mg/l Fe**, below the limit of detection and below the EU MAC of 0.2 mg/l Fe. However, the iron concentrations in the samples from **TW15** and **TW16** are considered elevated. The concentrations in the samples from **TW15** were **0.7 mg/l Fe** (March 2006), and **0.59 mg/l Fe** (September 2006), while the concentration in the sample from **TW16** taken in September 2006 was **0.52 mg/l Fe**, all above the EU MAC concentration. It is considered that these iron concentrations are as a result of the natural geochemistry of the clay-rich mudstones and siltstone which these boreholes encountered.

The **manganese** concentrations in the water from all but 2 of the boreholes are considered low at **<0.03 mg/l Mn**, below the limit of detection and below EU MAC of 0.05 mg/l Mn. However, the manganese concentrations in the samples from **TW15** and **TW16** are considered elevated. The concentrations in the samples from **TW15** were **0.2 mg/l Mn** (March 2006) and **0.16 mg/l Fe** (September 2006), while the concentration in the sample from **TW16** taken in September 2006 was **0.97 mg/l Mn**, all above the EU MAC concentration. It is considered that this is due to the natural geochemistry of the clay-rich mudstones and siltstones from which TW15 is abstracting.

Samples were also taken from the boreholes for **bacteriological** analysis. It is considered the bacteriological quality of the groundwater from most of the boreholes is good to fair. Initially, following disinfection of the boreholes (after drilling and prior to the pumping tests) the bacteriological quality was good in TW2A, TW3, TW3A, TW4A and TW17 with no total or faecal Coliforms detected. Low concentrations of both Total and Faecal Coliforms (at a concentration of 1 CFU per 100ml) were detected in initial samples taken from TW4 and TW15. Following a period of between 5 and 11 months, additional samples were taken from the wells between August and September 2006. During this sampling round, bacteriological contamination was detected in more of the wells, namely TW2A (>100 CFU per 100ml Total Coliforms along with an elevated colony count of 13 CFU per 100ml), TW3 (3 CFU per 100ml Total Coliforms), TW3A (Colony count of 46 CFU per 100ml, although no Total or Faecal Coliforms were detected), TW4 (5 CFU per 100ml for both Total and Faecal Coliforms), TW15 (2 CFU per 100ml Total

Coliforms and 7 CFU per 100ml Colony Count) and TW16 (10 CFU per 100ml Total Coliforms and 85 CFU per 100ml Colony Count). No bacteriological contamination was detected in the water from TW4A or TW17.

A summary spreadsheet, which illustrates the results of the main water quality parameters, is provided in the Appendix 5 to this report.

Various forms of treatment will be required on the majority of the well sources, results of the groundwater chemistry analysis are given in Appendix 5 and Figure 2 (Drawing No. 812/02/105).

The elevated iron and manganese concentrations noted in the samples from **TW15** and **TW16** in the Milltown well field are considered to be related to the natural geochemistry of the clay-rich mudstones and siltstones. It is possible that the concentrations would decrease following further pumping. However, as the concentrations are quite high (ranging from 0.52 mg/l Fe to 0.7 mg/l Fe for Iron and from 0.16 mg/l Mn to 0.97 mg/l Mn for manganese), it is recommended that iron and manganese removal treatment systems may be required for these two well sources.

Bacteriological parameters above the Drinking Water Limits were detected (albeit in relatively low concentrations) in samples from all but one of the well sources. As such it is recommended that the wells are treated to protect the bacteriological quality of the proposed drinking water source.

It is also considered that a number of the wells will require treatment for turbidity. Samples from **TW3**, **TW3A**, **TW4** and **TW4A** had levels of turbidity above the limit of 5 FTU units. It is possible that the design of the production wells and proposed pumping regime may limit the amount of sandy / turbid water from being pumped and as such turbidity levels may drop. However, if this level of turbidity is noted in samples from the production wells treatment (possibly periodically in the case of the wells in the gravels) will be required.

The turbidity levels in the trial wells at Milltown (**TW15** and **TW16**) are significantly higher (than in the wells in Ashford and Nun's Cross) and would definitely require treatment if this situation persisted in the production wells.

## **8. IMPACT ON, AND MONITORING OF, THE VARTRY RIVER**

The Ashford Wellfield is the most productive of the 3 no. wellfields to be developed as part of this scheme. It is proposed to abstract up to 2,200 m<sup>3</sup>/d from TW4A (PW4) and TW17 (PW5). These wells are supplied by the alluvial gravels associated with the Vartry River. Further investigation is required due to the proximity of the river to the wellfield, the level of interaction between the river and the alluvial gravels associated with it and the potential impacts that this level of groundwater abstraction may have on the river flow and its supported ecosystems.

It is considered that the groundwater abstractions in the Nun's Cross Wellfield, i.e. TW2A (PW1), TW3 (PW2) and TW3A (PW3) will not have any impact on flow in the Vartry River. The wells will be abstracting from bedrock aquifers and are not considered to have a direct connection with the River Vartry. The static groundwater levels in these wells are approximately 10m lower than the levels in the river, as can be seen from the cross sections shown in Appendix 6. The cross section is drawn from north to south and shows the levels (both topographic and water levels) at wells TW2A, TW3, TW3A, TW3B and the Vartry River. The river in this part of its catchment, to the west of the Nun's Cross wellfield, is in a steep sided valley (the lower part of the Devil's Glen) and is considered to have "flashy" characteristics (i.e. flow is dependent on rainfall and runoff from the surrounding land) and is unlikely to be dependent on the underlying groundwater system for recharge or flow. There is also likely to be little interaction between the river and the groundwater in this low permeability aquifer. The pumping water levels in the wells are also shown on the cross section and indicate that although there was significant drawdown in the water levels in some of the wells (between 22m and 50m), the Vartry River was not affected due to the river and groundwater being quite separate environments in this area.

The Ashford Wellfield, however, will be abstracting from alluvial gravels which are associated with the Vartry River and the wells are located in a different, flatter, part of the river catchment where flow may be supported to some degree by groundwater flow. Flow in the gravel aquifer is of an intergranular nature (rather than through fractures and fissures which would be the main flow mechanism in a rock aquifer). Information from the trial well drilling programme, geophysical survey and data from the pumping tests has indicated that the productive, coarse gravel layers lie between 12m and 24m depth. The conceptual model of recharge discussed in Section 6.3 above, indicates that these gravels are recharged directly from rainfall and indirectly from the glacial gravels mapped to the north of the wellfield.

The static water levels in the Ashford Wellfield trial wells are relatively high and above the water level in the Vartry River, although they can be within 3m of the river level – as can be seen on the cross sections for this wellfield, included in Appendix 6. Two cross sections were drawn, from north to south, for this wellfield, and show the levels (both topographic and water levels) at wells TW4A, TW4, TW17, TW4D and the Vartry River. The cross section indicates that the

static water levels in the alluvial gravel aquifer are close to but still above the Vartry River level. In this lower part of the river catchment, the river flows along a flatter gradient and it is considered that there is likely to be some interaction between the river bed and the alluvial gravels which are closely associated with it – given that they were probably deposited by the river at various stages (during its lifetime and during various flood events). The cross section shows that the gravels possibly extend beneath the river and out to the other side of it as they are mapped on both sides. The maximum pumping water levels recorded during the pumping tests (undertaken in 2006 and 2007) are also shown on the cross section. These indicate that there was very little drawdown, for example in TW17, and in this case, the pumping water levels were still above the level of the Vartry River. It is unlikely that this pumping scenario reversed that natural groundwater gradient and pulled water back from the river towards the wells. However, on the cross section showing TW4A, it appears that the pumping water level was drawn down to a level below the Vartry River. It is not known if river water was being pumped at this point. It is considered further monitoring is required before a more definitive assessment of the interaction between the river and the alluvial gravels can be made.

The river may receive baseflow from the gravels and as such it is considered important to determine the dry weather flows (DWF) in the river and pump test the production wells at this time to see how pumping will affect the DWF. Pumping tests undertaken on the trial wells in summer 2006 (a dry summer up to August / early September) did not note any recharge effects from the river to the gravel aquifer, although no direct monitoring of the river levels was undertaken at that time.

Once the production wells are drilled, it is recommended that long term pumping tests are undertaken in conjunction with river monitoring. This river monitoring will be undertaken prior to and during the production well testing to establish the level of interaction between the river and the gravels.

### **Proposed Vartry River Monitoring Programme**

A programme of monitoring is required prior to and during the production well testing phase, to determine the level of interaction between the river and the gravel aquifer and any potential impacts the proposed groundwater abstractions may have on the river.

Firstly, river gauges should be installed at suitable sites located upstream, in the vicinity and downstream of the abstraction point in the gravel aquifer (Ashford wellfield) to measure river flow. The suitable sites will be initially surveyed (for ease of access, measurement, proximity to wellfield and gravels etc.) and staff gauges installed. Topographical surveys of the river channel (cross sections) will be undertaken at the gauging sites and flow measurements will be taken along with levels on the staff gauges, to develop a “stage / discharge relationship” for each site. It is recommended that flow measurements are taken prior to any well testing to



determine background data and to see if there are additions to the flow along the channel which may indicate the river may be partially groundwater fed.

The flow in the river will be defined during the monitoring period (prior to production well testing) and flow durations curves will be developed for upstream and downstream of the wellfield locations.

Some dye-tracing could also be undertaken, initially under natural conditions and then under abstraction conditions, between the wells and the river to establish if there is a link and the nature of the connection between the two systems.

Production wells PW4 and PW5 are drilled in close proximity to the trial wells (TW4A and TW17 respectively). These are currently being initially tested for a 24 to 48 hour period to determine if yields are similar to the trial wells. It is proposed that extended tests (possibly up to 28 days duration) will be undertaken in late summer (Dry Weather Flow conditions) and the sustainable yields of the production wells will be reviewed to give a more accurate estimate of their long term yield.

Water samples from the pumped wells and the river will be taken prior to and during the well tests and, if possible, in-line monitoring of the groundwater being pumped could be undertaken which may give information on the changing signature of the water chemistry (particularly with regard to Conductivity, pH, Dissolved Oxygen etc.) if the river water is influencing the pumped groundwater.

During the long term production well testing programme (multi-well test), the flow response of the river to the groundwater abstraction will be measured under the expected dry weather flow conditions. Large changes in the pumping rates would be made during the latter stages of the tests to see if any response is noted in the river flow. This would help derive flow accretion profiles and quantify how pumping from the boreholes at various rates impacts on these profiles.

In addition to the groundwater abstraction and river flow data, supporting data will be required to quantify other inputs to the flow in the river, namely rainfall and the controlled overspill from the Vartry Reservoir in the headwaters of this river. It would be useful to acquire local rainfall data for the site (or very close to it) to correlate with flows in the river. Data will also be required from Dublin City Council, who operate the reservoir at Vartry, on the operation / timing schedule of overflow from the reservoir system.

Once the pumping tests and river monitoring have been undertaken, the data will be assessed to quantify the level of interaction between the river and the gravels and to determine the impact, if any, long term pumping from the wells will have on the flow in the river.



Once the relationship between the groundwater levels in the gravels and the flows in the Vartry River have been established, an assessment of the potential impacts of any reduced water levels and flows in the Vartry River may have on the fish populations and other protected species will be examined and a separate report will be prepared if necessary.

When the production wells are commissioned, it is proposed that discharge meters and data loggers are installed on the boreholes to record operational data. Regular sampling of the groundwater and surface waters would provide more information on the level of interaction between the two water systems. A long term monitoring programme of at least one year duration will be implemented in order to establish a baseline across all seasons.

## **9. CONCLUSIONS**

Following the assessment of the investigation as discussed in this report the conclusions are as follows:

- The total available sustainable yield from the 7 no. wells tested (**TW2A**, **TW3**, **TW3A**, **TW4A**, **TW15**, **TW16** and **TW17**) is over **3,500 m<sup>3</sup>/d**. These are conservative values of sustainable yield and it is considered that more water may be available, specifically from the gravels of the Ashford Wellfield, in the winter months. This cannot be quantified until monitoring is undertaken on the production wells, following their commissioning, for a full 12 months (over all seasons) to determine if there is any impact from pumping on the river or surrounding wells.
- Low concentrations of Coliforms were detected in samples at most of the wells with the exception of **TW2A**.
- Iron and Manganese concentrations at the Milltown wells (**TW15** and **TW16**) are considered elevated and related to the natural geochemistry of the aquifer from which these wells are abstracting.
- Turbidity levels in the water from most of the wells are above the desirable levels for the Milltown wells (**TW15** and **TW16**), Nuns Cross Wells (**TW3** and **TW3A**) and the Ashford gravel wells (**TW4A**).

The findings are summarised in Table 8.1 and on Figure 2 (Drawing 812/02/105) overleaf.

Table 9.1: Summary of Groundwater Chemistry Results

Well Number	Sustainable Yield	Water Quality	Comment
TW2A (Bedrock)	500 m <sup>3</sup> /d	Good, although slightly elevated Nitrate and Total Coliforms	Little or no effect noted at TW3 or TW3A when pumping
TW3 (Bedrock)	330 m <sup>3</sup> /d	Good but with some Total Coliforms	Little or no effect noted when TW2A or TW3A pumping
TW3A (Bedrock)	180 m <sup>3</sup> /d	Good	Little or no effect when TW3 and TW2A is pumping
Sub total Nun's Cross wellfield	<b>1,010 m<sup>3</sup>/d</b>		
TW4A (Gravel)	770 m <sup>3</sup> /d	Good but with slightly low pH	Slightly affected by pumping at TW4
TW17 (Gravel)	1400 m <sup>3</sup> /d	Generally good	Slightly affected by pumping at TW4A
Sub total Ashford wellfield	<b>2,200 m<sup>3</sup>/d</b>		
TW15 (Bedrock)	220 m <sup>3</sup> /d	Generally good but elevated iron and manganese and traces of Total and Faecal Coliforms	Very slightly affected by pumping at TW16
TW16 (Bedrock)	180 m <sup>3</sup> /d	Generally Good but elevated iron and manganese and traces of Total Coliforms	
Sub total Milltown wellfield	<b>400 m<sup>3</sup>/d</b>		
<b>TOTAL</b>	<b>3,580 m<sup>3</sup>/d</b>		

FIGURE 2

## **10. RECOMMENDATIONS**

1. **TW2A, TW3, TW3A, TW4A, TW15, TW16 and TW17** are suitable for future development into production wells.
2. Any of the unsuccessful (from the Wicklow WSS perspective) trial wells which are to be retained for use as domestic and / or farm wells (e.g. TW9, TW20) should be limited in abstraction rates to just 20m<sup>3</sup>/d so as not to affect any production wells to be located close to them. It is also recommended that the wellhead protection around these wells be improved so as to minimise the risk of contamination of the groundwater in the underlying aquifer. If possible the annular space between casing and liner (or drilled hole and casing) should be grouted and a well chamber built around the well (above ground if possible) to eliminate the possibility of potentially contaminating surface runoff getting into the well. (as per *Guidelines for drilling wells for private water supplies*, March 2007, Institute of Geologists of Ireland)
3. We recommend that any of the unsuccessful trial well which are not retained for private use should be fully decommissioned to eliminate potential pathways for surface water to contaminate groundwater.
4. We recommended that proposed sustainable yields for the successful wells, as detailed in this report, are revised if necessary following the installation of the production wells to give a more accurate estimate of their sustainable long term yield. We recommend that the Ashford production wells should be tested for a period of 28 days, and the Nuns Cross and Milltown production wells should be tested for a period of 10 days.
5. Further investigation of the groundwater resource around Milltown is recommended as currently only 400 m<sup>3</sup>/d has been proven in this area which is approximately 2km from the higher yielding wells in Ashford.
6. Conjunctive use of the Ashford wells should be considered to cater for seasonal abstraction rates.
7. It is recommended that monitoring of the Vartry River is undertaken prior to and during any extended tests on the Production Wells to be installed in the Ashford wellfield. This monitoring programme, explained above in Section 8, will allow an assessment of the potential impacts the proposed groundwater abstractions may have on the Vartry River and its surrounding surface waters. Water level monitors will be installed in the wells and staff gauges installed along the river (upstream and downstream of the abstraction area). The data collected will be used to determine the level of interaction between the groundwater in the alluvial gravels and the river flow. A tracer test is also possible to

identify the link between the two systems. If required, further monitoring can also be undertaken up to commissioning of the water supply from these wells.

8. Following construction of the production wells at Ashford, we also recommended that regular sampling of the groundwater and surface water would provide more information on the level of interaction between the two water systems. If the unsuccessful trial well at TW4B is to be retained, this could also be instrumented to monitor the response of water levels further west from the pumping wells.
9. We recommend treatment for bacteriological parameters to protect the water supply from bacteriological contamination.
10. We recommend treatment for iron, manganese and turbidity to comply with the SI 439 of 2000 EU Drinking Water Directive.
11. We recommend that a Source Protection Plan be prepared prior to commencing negotiations with private landowners. There was no impact noted on adjacent landowner wells.

## **APPENDIX 1**

### **GLOSSARY OF TERMS**

## GLOSSARY OF TERMS

MHC	McCarthy Hyder Consultants
WCC	Wicklow County Council
GES	Geotechnical and Environmental Services Ltd
AN	Aquifer Number
TW	Trial Well
GSI	Geological Society of Ireland
SI	Statutory Instrument
MAC	Maximum Allowable Concentration
S	Maximum draw down recorded during the 7 day period
$\Delta\Sigma$	Draw down per log cycle of time.
L	Number of log cycles of time between the end of the step and the time for which the yield estimate is to be made
Q	Flow rate.
T	Transmissivity
DAPWL	Deepest Advisable Pumping Water Level
PE	Potential Evapotranspiration
AE	Actual Evapotranspiration
ER	Effective Rainfall
R	Annual Rainfall
CFU	Colony Forming Unit
FTU	Equivalent Turbidity Unit



**APPENDIX 2**

**BOREHOLE LOGS**

**APPENDIX 3**

**PUMP TEST DATA**

**APPENDIX 4**

**CALCULATIONS**

## **APPENDIX 5**

### **GROUNDWATER CHEMISTRY RESULTS**

## **APPENDIX 6**

### **CROSS SECTIONS ACROSS RIVER**

## **APPENDIX 7**

### **DRAWINGS**