discharge and step tests on the boreholes. The pumps were installed on the 17th November and connected by an electrician to a single-phase mains supply from one of the GAA pitch lighting towers. This supply was adequate, but it was found that the voltage dropped when all three pumps were in operation. As a result the smaller pumps were only able to operate at a rate of 1 l/s, whilst the larger pump could operate at just over 3 l/s. As the objective was to test the three holes as a combined source, at a rate of 72,000 gpd, or the equivalent of 3.78 l/s, this power supply arrangement was accepted as the best compromise available.

A short proving test was carried out from 17.35 hr on the 17th with No.3 pumping at 2.67l/s and Nos. 1 and 2 at 1 l/s. The test was stopped at 20.00 hr. The water level in the boreholes was monitored using Diver loggers. The water levels were allowed to recover overnight.

18th November
The recovery data was downloaded and analysed and static water levels measured as follows;

Borehole No.1 1.81 m below the top of the blue Boode PVC casing

Borehole No.2 1.75 m below the top of the blue Boode PVC casing

Borehole No.3 3.05 m below the top of the blue Boode PVC casing

The more powerful Grundfos pump was in Borehole No.3. It was decided to start by carrying out short step tests at increasing discharge rates on Borehole No.3 and monitor the impact in Boreholes 1 and 2. The tests would continue with Borehole No.3 pumping at the maximum rate and the pumps switched on in Boreholes No.s 1 and 2

Step tests on Borehole No.3 started at 12.00 hr

Step 1 pumping rate is 1.33 l/s
Step 2 pumping rate is 2.0 l/s
Step 3 pumping rate is 2.5 l/s
Step 4 pumping rate is 3.1 l/s
Step 4 continues as a long test on Borehole No.3 and boreholes 1 and 2 started at 14.20 hr and the pumps were left running until the late afternoon on the 22nd November.

The pump test data is shown as a series of graphs. The graphs do not have report figure numbers but are distinguished by their figure titles.

The step test data for borehole 3 is shown in the first graph. It shows a series of short steps with pumping at different rates. The graph shows that with each increase in pumping rate the water level falls (drawn down) rapidly for a short period of a few minutes and then the rate of decline slows. The sharp, but small, initial drawdown at the beginning of each step is a measure of the increase in head difference between the water level in the hole, and the water head (pressure) in the aquifer necessary to get the flow from the aquifer to increase to the new pumping rate. Thereafter the decline in water level is a measure of the response in the aquifer to the new pumping rate. As can be seen the rate of drawdown, after the initial drop, decreases with time, and after about 20 minutes, for example in steps 2 and 3, there is little change in water levels. The sudden drop at the start of each step plus the way that the water levels begin to level off is a measure of the efficiency of the borehole as a hydraulic structure. A small drop for each increase in pumping rate and a rapid levelling off of the drawdown curve indicates that the screened section of the borehole is able to let water through it from the aquifer efficiently at that pumping rate. Small drops in the water level such as 0.2 to 0.4 metres indicate that the flow through the screen, and through the natural gravel pack developed in the adjacent aquifer material, is relatively easy and there are low friction losses. In other words the borehole is an efficient and effective structure permitting the ingress of water from the adjacent thin, variable grain size aquifer material.

Having assessed the efficiency of Borehole No.3, the pump was left running at 3.1 l/s and the pumps in Borehole 1 and 2 were started each at 1 l/s.

The second graph shows the water level drawdown data for all three boreholes over the next 6,000 minutes. On the far left hand side of the graph the red data points show the four step tests on Borehole No.3 described above. It can be seen that there was an immediate but small response in the water levels in boreholes No.s 1 and 2. This data set and others during the testing of these three holes shows that the water levels measured in the boreholes are a measure of the water pressure in the aquifer. In other words the water in the gravel is under pressure because the overlying clays, silts, marl and peat form a low permeability confining layer. It is probably a 'leaky' confining layer, that stores water and permits a slow movement of water and release of pressure from the aquifer below. However a confining layer means that when a pump is turned on in one borehole there is an almost immediate small drop in pressure transmitted throughout the confined gravel aquifer. The fall in pressure or water levels in boreholes 1 and 2 during the step tests on 3 was only about 0.1 metre. The data on the left hand side of the second graph shows the drawdown in boreholes 1 and 2 when their pumps were turned on at 1l/s. The drawdown was about 0.6 to 0.7 metres in both holes in the first few minutes. The small rise and fall in water levels shown in borehole 3 is the effect of removing the logger, down loading the data and re-setting the logger position. It is an instrument effect and not the effect of the pumping in boreholes 1 and 2. Pumping 1 l/s from boreholes 1 and 2 had little measurable effect on water levels in borehole 3.

The drawdown in borehole 3 continued at a relatively steep gradient over the 1,600 minutes until there was a slight rise and fall before the water level reached the pump intake. From 2000 minutes until 3200 minutes the line of data points shown in the graph remains horizontal. Borehole No.3 cannot sustain a pumping rate of 3.1 litres per second whilst 2 litres per second is also withdrawn from boreholes 1 and 2.

Whilst the drawdown in borehole continued it is very noticeable that the water levels in boreholes 1 and 2 rose and fell in unison. This periodic oscillation is the impact of pumps turning off and on in the main well field next to the Community Centre. It shows that the new supplementary production boreholes are drawing water from the same confined aquifer as the earlier boreholes. The water level data from boreholes 1 and 2 are also shown separately in the third and fourth pumping test graphs

Heavy rainfall took place on the 20th November. The recharge appears to have rapidly percolated into the coarse, un confined, permeable materials in the core of the esker, and created an increase in water pressure in the confined aquifer at the margin. The pumping rate from borehole 3 probably increased again to 3.1 l/s until once again the water level was brought down to the pump intake at about 4,600 minutes. The pumping rate from borehole 3 at the end of the test was measured as 2.8 l/s. Boreholes 1 and 2 had continued to pump at 1 l/s throughout the test.

The combined, sustained pumping rate from all three holes was 4.8 litres per second (3,800 gph) or 91,240 gallons per day (414 m3/day). Therefore the three supplementary production boreholes in the wellfield can meet the design target rate of 72,000 gallons per day.

The pumps were turned off and the water levels recovered overnight. . The recovery is shown in the attached graph. The recovery was nearly complete within 1000 minutes.

On the 23rd November step tests were carried out alternately on boreholes 1 and 2 in order to determine the efficiency of these boreholes, and hence gain information on the optimum rate for production pumping from each hole.

The more powerful Grundfos pump was moved to each hole in turn. The other pumps were removed.

Short step tests on borehole No.1

Step 1 pumping rate is 1.87 l/s
Step 2 pumping rate is 2.66 l/s
Step 3 pumping rate is 2.88 l/s
Step 4 pumping rate is 3.29 l/s

Short step tests on borehole No.2

Step 1 pumping rate is 2.33 l/s
Step 2 pumping rate is 2.75 l/s
Step 3 pumping rate is 2.89 l/s
Step 4 pumping rate is 3.31 l/s

These data are shown on two separate graphs, which also show the impact of pumping on the other two boreholes. Borehole 3 registered a gradual smooth small decline in water levels of about 0.2 m during both tests. There was no reflection in water levels in borehole 3 of increases in pumping rate in the steps in the other holes. Boreholes 1 and 2 are closer and each responded to changes in pumping rate when the other was being tested.

It is evident that pumping in borehole 1 at approximately 3.3 l/s created a draw down in the pumping borehole of 3 metres, whereas pumping at the same rate from borehole 2 for the same length of time only created a drawdown of 1.8 metres. These data indicate, as expected that borehole 2 and 3 are more efficient and productive. The reason for this is clear in the well completion log for borehole 1. The saturated thickness of the aquifer is only 2 metres. Therefore even if the aquifer permeability is the same in all holes the transmissivity of the aquifer (its ability to transmit water) is less at borehole 1 because the aquifer cross section is less.

The results from the step tests on all three boreholes have been correlated on the final graph. This graph is a plot of drawdown in each hole at the same time interval for different pumping rates.

The graph shows that the drawdown in borehole 2 is less for each pumping rate than the other holes. Borehole 3 data show a straight line with a steeper gradient implying that borehole is equally efficient over the range of pumping rates. Borehole 1 shown in blue is different. It appears to be efficient at pumping rates up to 2.66 l/s but thereafter the drawdown increases for just a small increase in pumping rate.

As can be seen the step tests provide valuable information that can be used to recommend the optimum production pumping rate for each borehole. For example, if the design pumping rate from the three supplementary production boreholes together is set at 72,000 gpd or 3,000 gph, then the step test data would indicate that boreholes 2 and 3 should be pumped at a higher rate than borehole 1. The optimum individual rates could be as follows: -

Borehole No.1	1.0 l/s	-	19,000 gallons per day
Borehole No.2	1.5 l/s	-	28,000 gallons per day
Borehole No.3	1.5 l/s	-	28,000 gallons per day
Total	4.0 l/s	-	75,000 gallons per day

Reference to the graph shows that all three boreholes will be hydraulically efficient structures at these future production pumping rates.

However as the long pumping test data from Borehole No.3 has shown, it is not possible to pump one hole continuously at a much higher rate, whilst pumping at lower rates from the other holes.

Overall the pumping tests have shown that:-

The new boreholes are successful hydraulic structures that can be used to efficiently draw groundwater from the shallow confined gravel aquifer to the north of the GAA pitch.

The three boreholes should be considered as a single source; i.e. one source that consists of three adjacent access points into the same aquifer.

The pump intake in each borehole must always be above the base of the pump chamber casing.

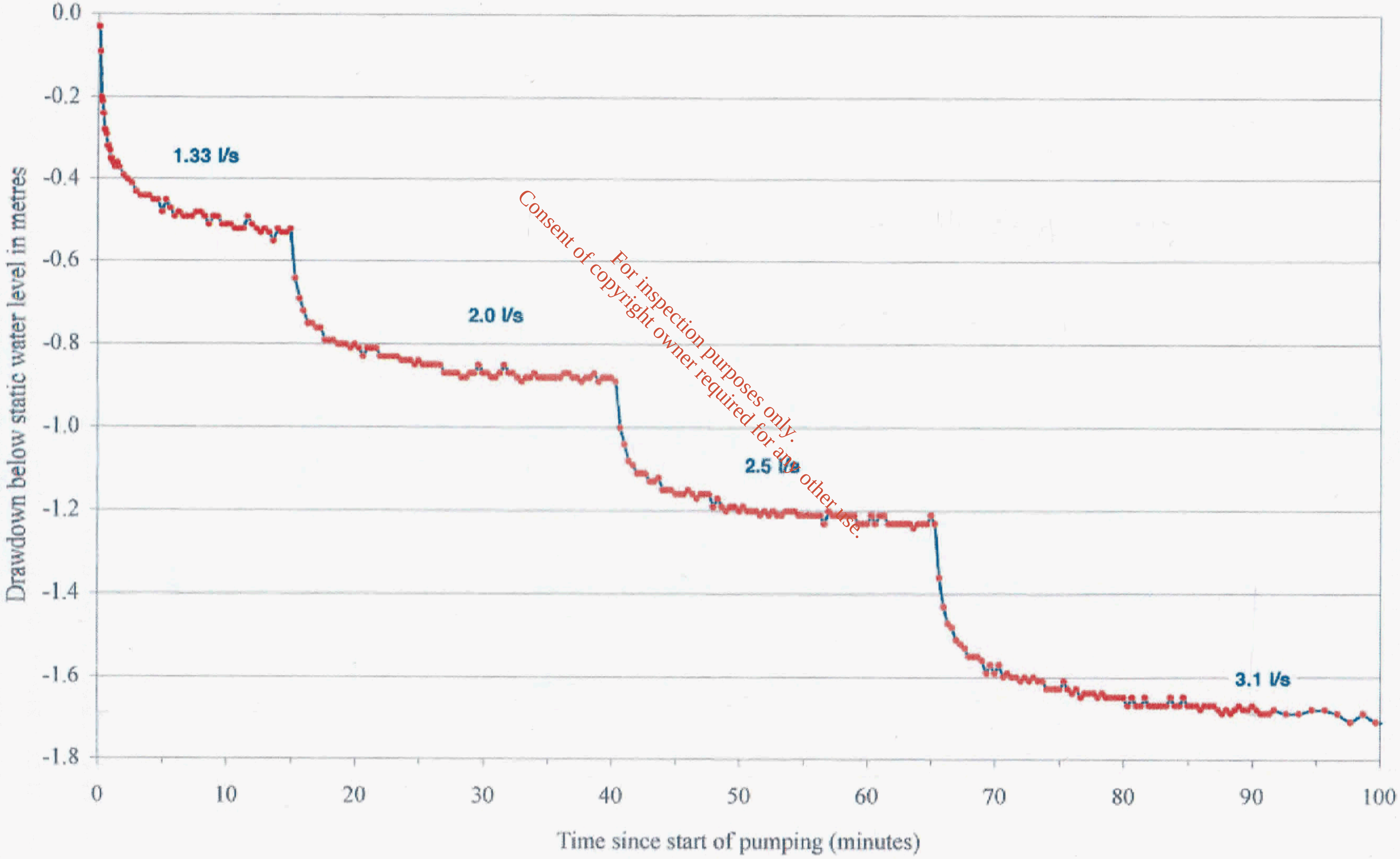
The boreholes can be pumped for short periods (minutes and hours, rather than days and weeks) at high rates of 2-3 l/s, but the aquifer cannot continuously sustain this rate of abstraction.

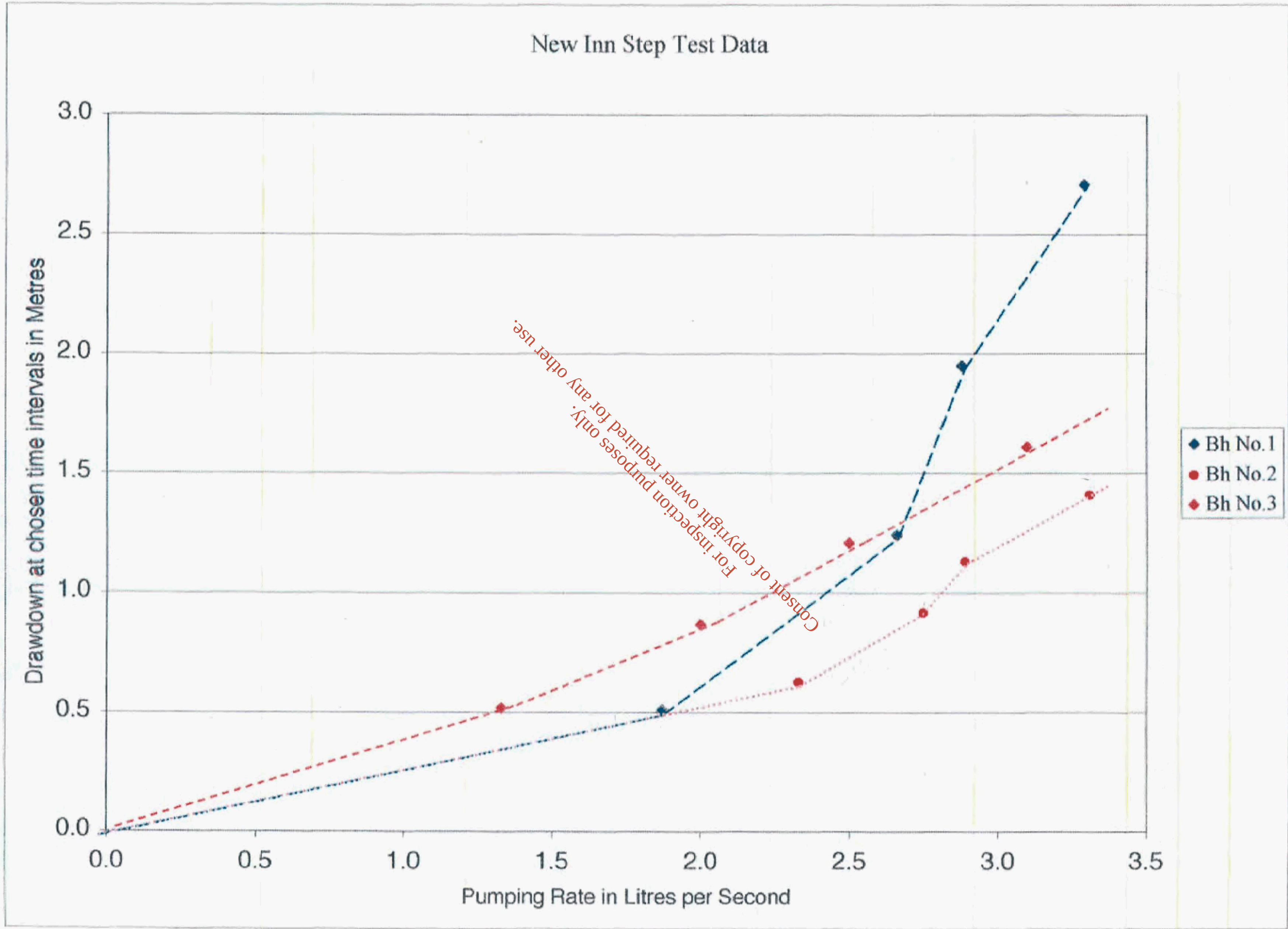
The optimum operating regime is for all the new boreholes to be pumped continuously at a gentle rate. The same operating principle would apply to the existing boreholes near the Community Centre.

The optimum continuous pumping rate for the new source will be 4 l/s or 75,000 gallons per day.

Pumping from the three boreholes in the new supplementary source will influence the piezometric pressure in the aquifer in the area of the existing production boreholes. Similarly pumping from the existing boreholes will reduce the piezometric pressure in the aquifer at the supplementary source.

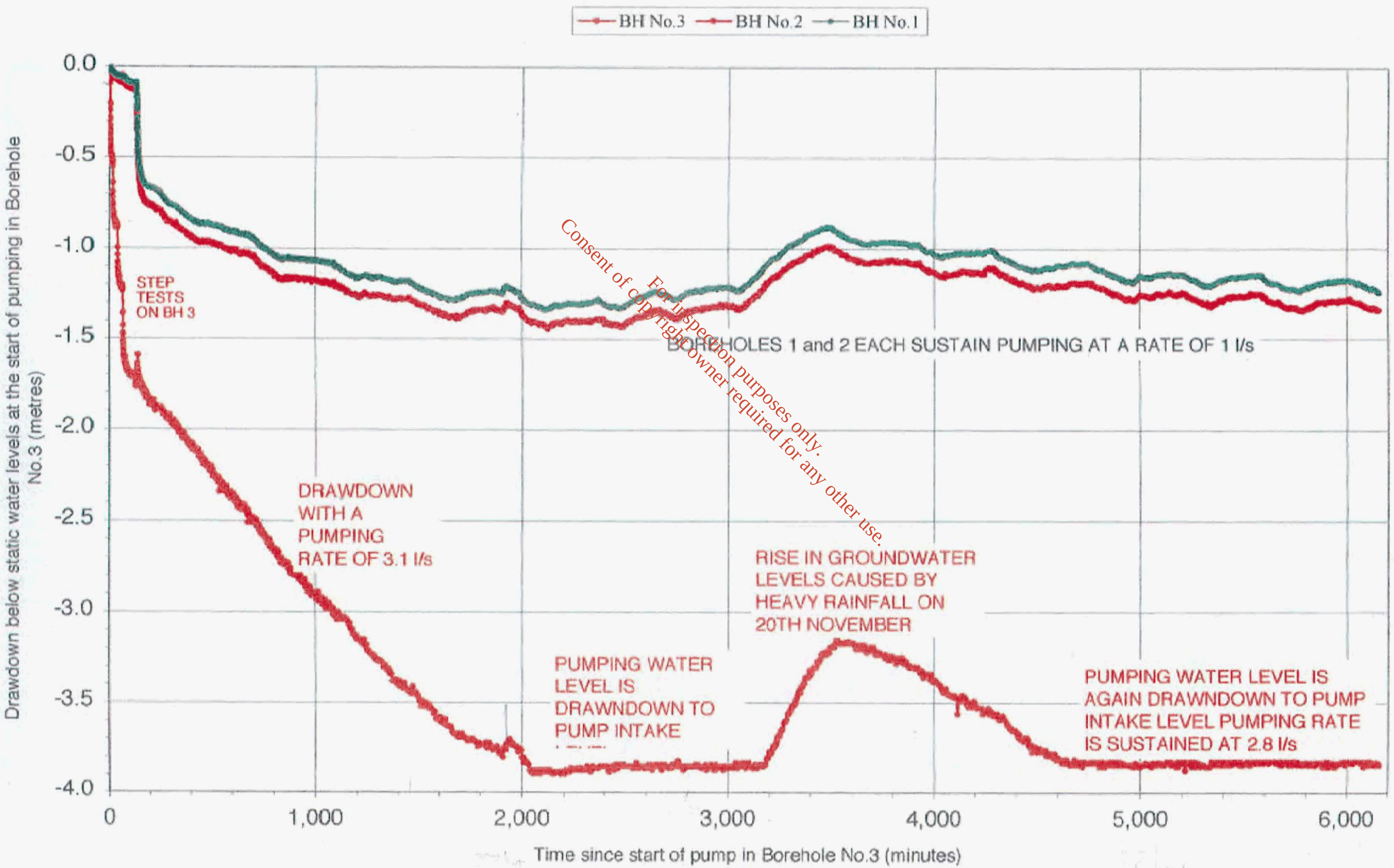
NEW INN PRODUCTION BOREHOLE NO.3 STEP TESTS
18th November 2004

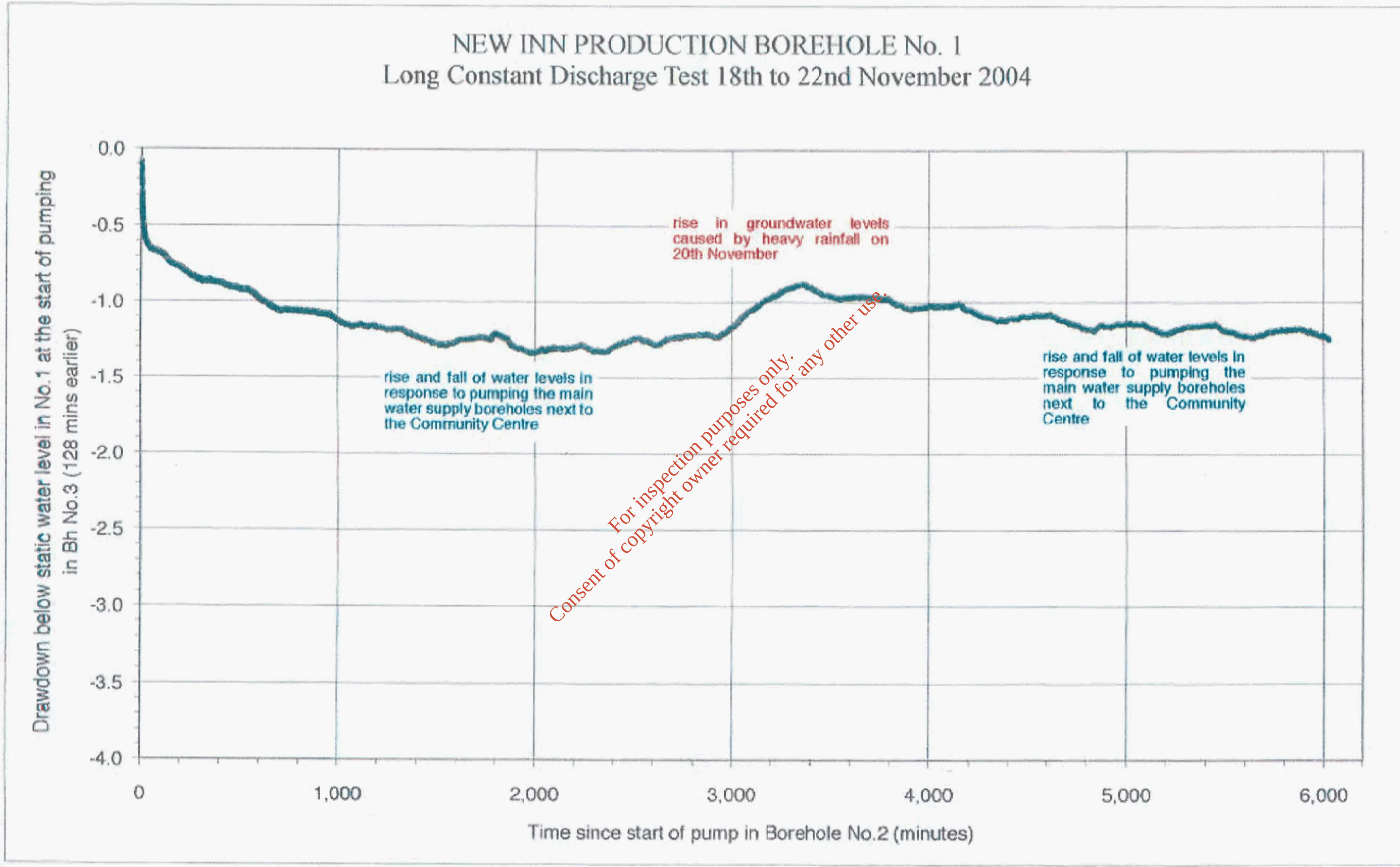


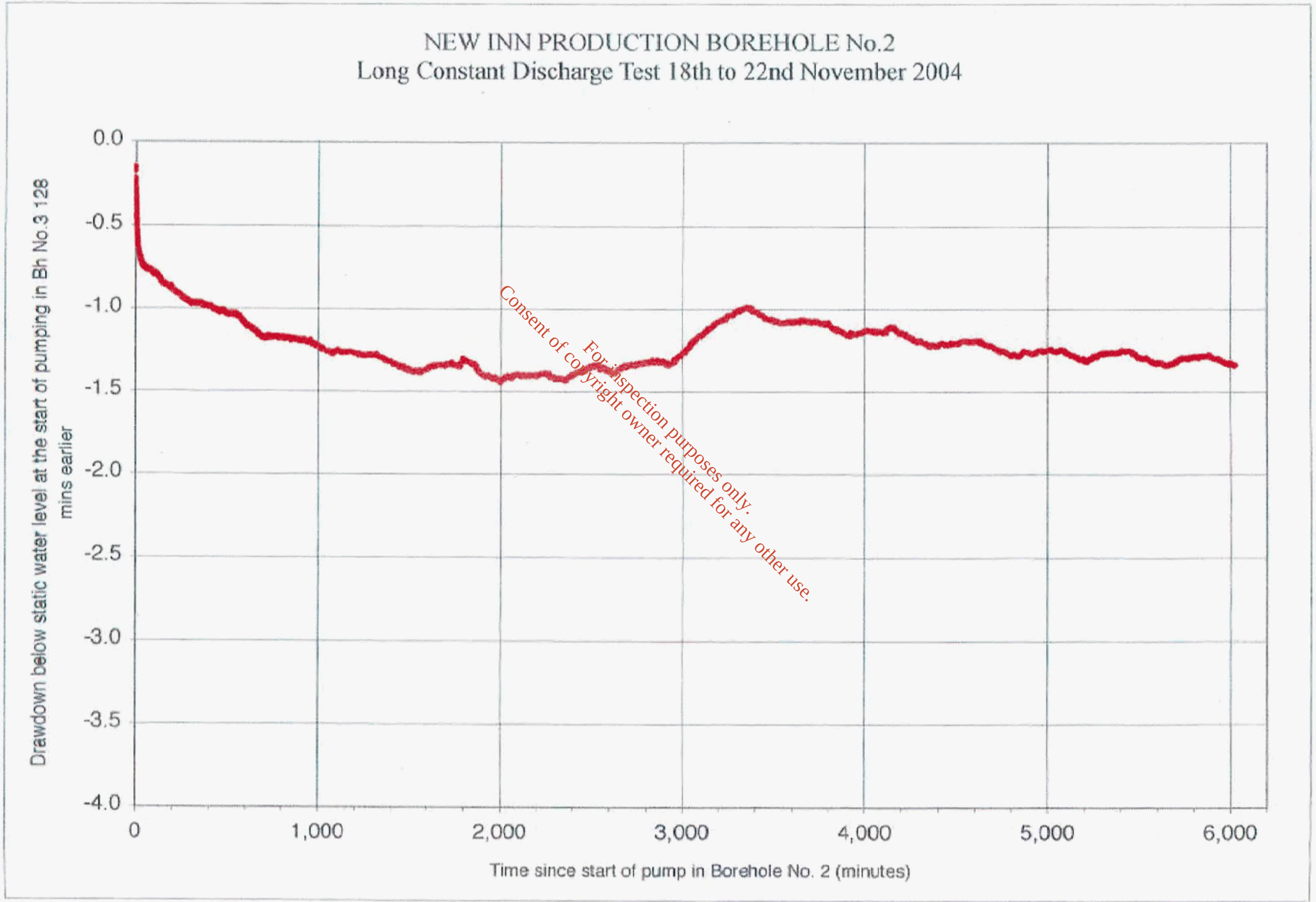

New Inn Step Test Data
Drawdown at chosen time intervals in Metres
3.0
2.5
2.0
1.5
1.0
0.5
0.0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Pumping Rate in Litres per Second
Bh No.1
Bh No.2
Bh No.3

NEW INN PRODUCTION BOREHOLES 1, 2, AND 3

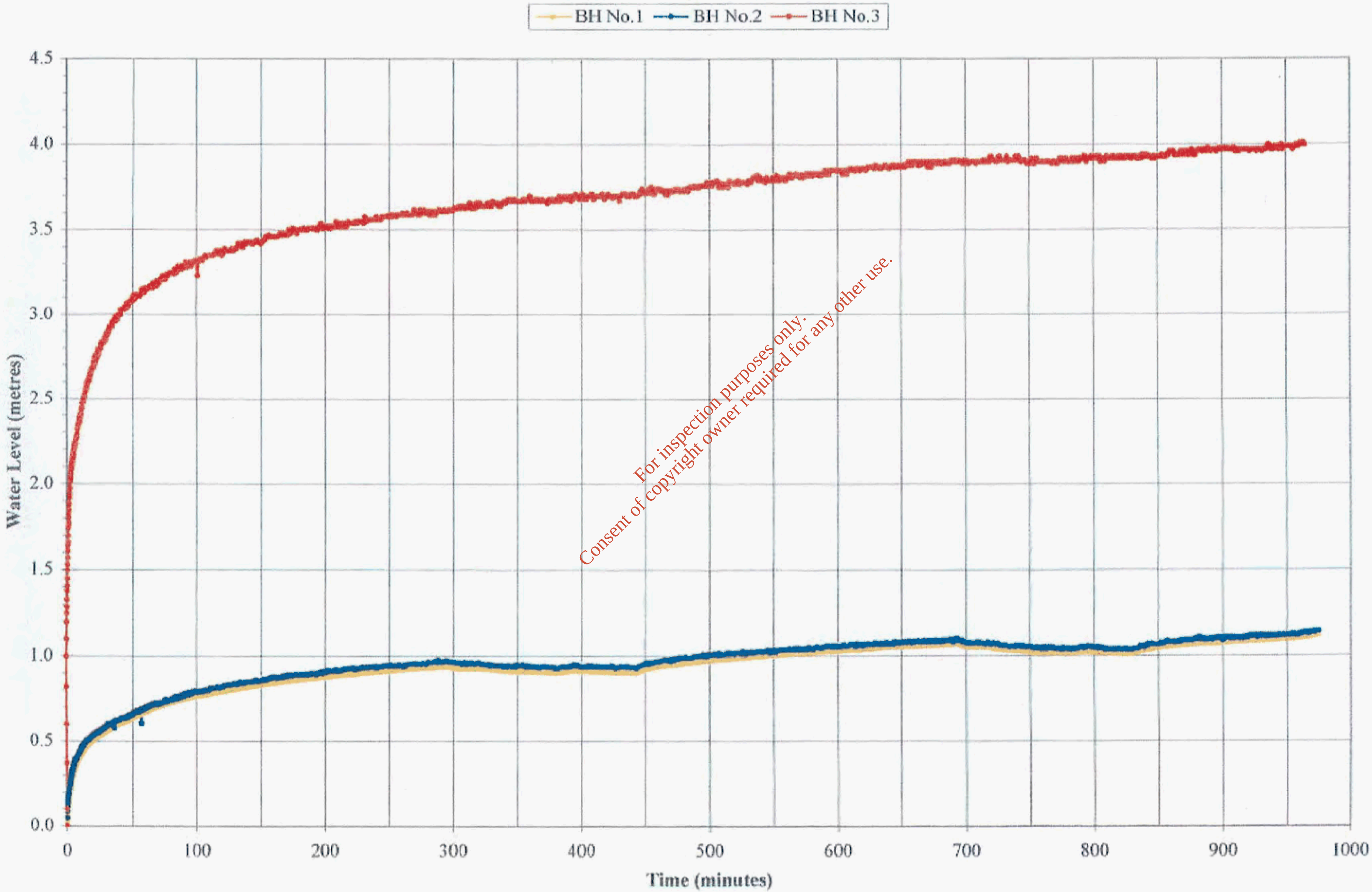
Drawdown during initial Step Tests on Borehole No.3, and subsequent Long 'Constant' Discharge Test pumping on all three boreholes
18th - 22nd November 04



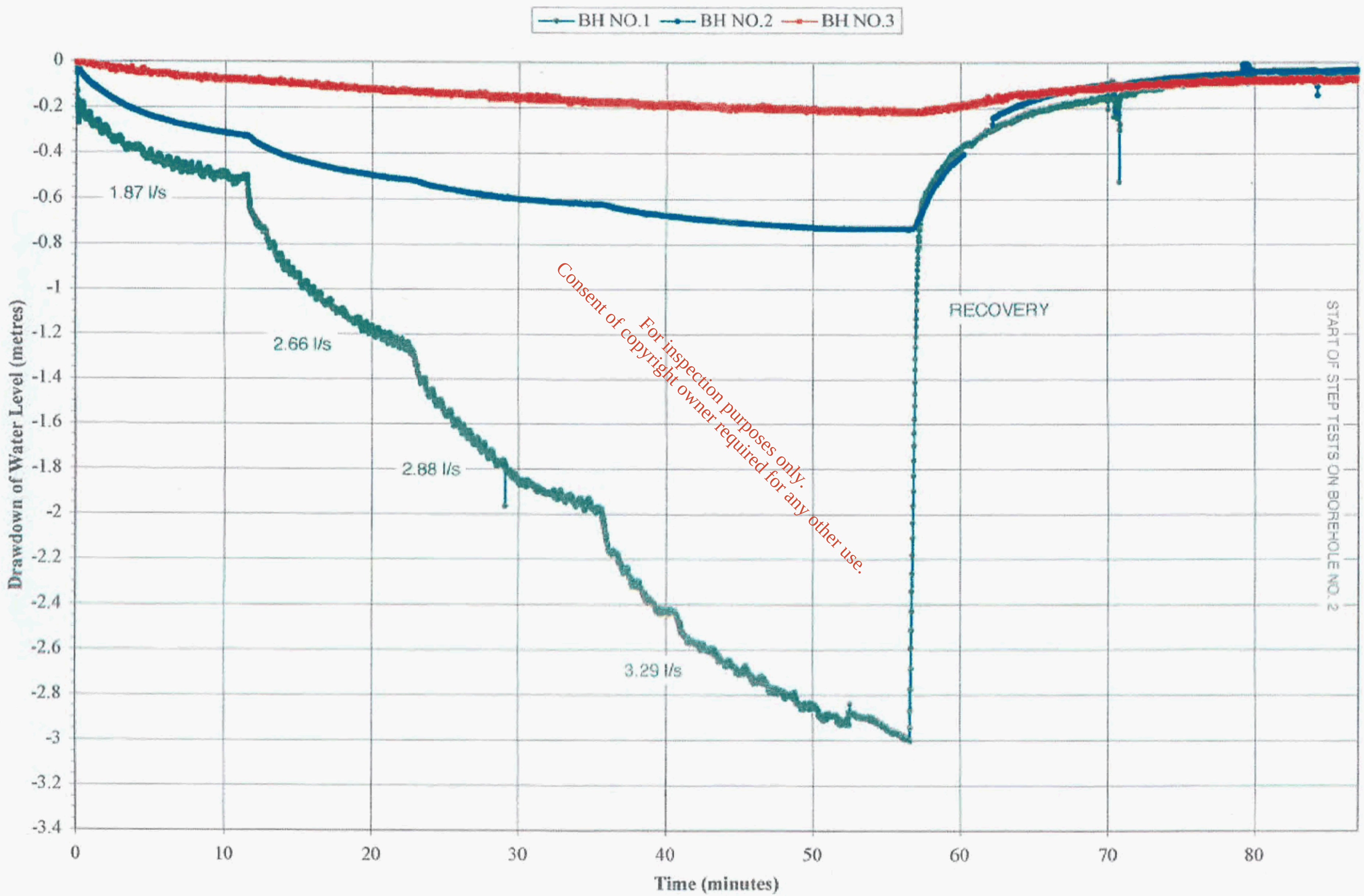

NEW INN PRODUCTION BOREHOLE No. 1
Long Constant Discharge Test 18th to 22nd November 2004
Drawdown below static water level in No.1 at the start of pumping in Bh No.3 (128 mins earlier)
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
0
1,000
2,000
3,000
4,000
5,000
6,000
Time since start of pump in Borehole No.2 (minutes)
rise in groundwater levels caused by heavy rainfall on 20th November
rise and fall of water levels in response to pumping the main water supply boreholes next to the Community Centre
rise and fall of water levels in response to pumping the main water supply boreholes next to the Community Centre

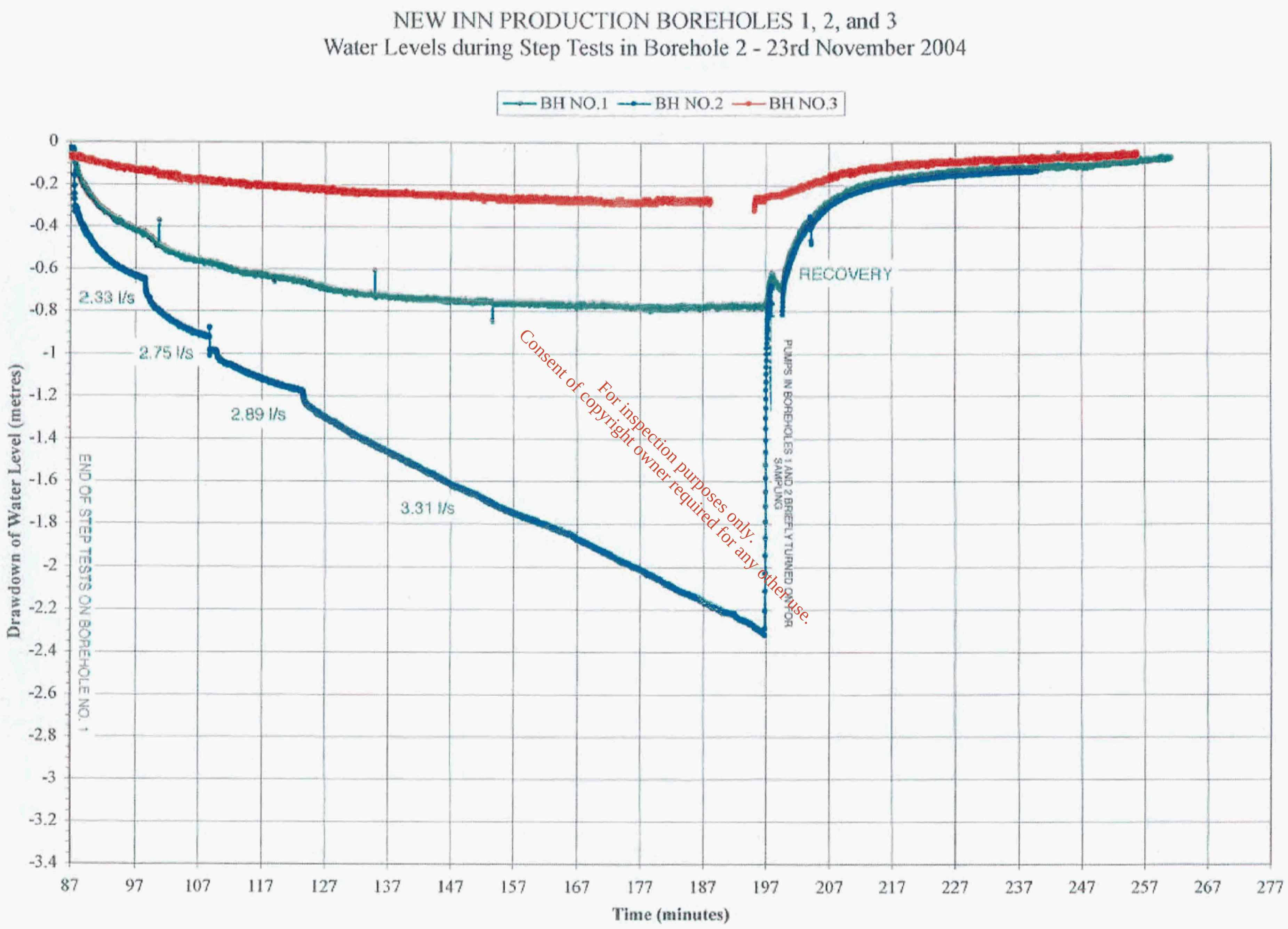

NEW INN PRODUCTION BOREHOLE No.2
Long Constant Discharge Test 18th to 22nd November 2004
Drawdown below static water level at the start of pumping in Bh No.3 128 mins earlier
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
-4.0
0
1,000
2,000
3,000
4,000
5,000
6,000
Time since start of pump in Borehole No. 2 (minutes)

New Inn - BH's 1-3. Recovery of Water Levels After Long Pumping Test.
22nd - 23rd November 04



NEW INN PRODUCTION BOREHOLES 1, 2, and 3
Water Levels during Step Tests in Borehole 1 - 23rd November 2004





NEW INN PRODUCTION BOREHOLES 1, 2, and 3
Water Levels during Step Tests in Borehole 2 - 23rd November 2004
BH NO.1
BH NO.2
BH NO.3
Drawdown of Water Level (metres)
Time (minutes)
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
-1.6
-1.8
-2
-2.2
-2.4
-2.6
-2.8
-3
-3.2
-3.4
87
97
107
117
127
137
147
157
167
177
187
197
207
217
227
237
247
257
267
277
2.33 l/s
2.75 l/s
2.89 l/s
3.31 l/s
END OF STEP TESTS ON BOREHOLE NO. 1
PUMPS IN BOREHOLES 1 AND 2 BRIEFLY TURNED ON FOR SAMPLING
RECOVERY

However, the reduction in the piezometric pressure in both areas will be less than 10 centimetres. These small pressure (or water level) changes in the production boreholes will not have a significant influence on the sustainable pumping rate from either group of boreholes.

4. Water Chemistry and Bacteriology

The principle focus of attention at New Inn has always been obtaining and sustaining an adequate quantity of water to meet the seasonal variation in water demand. Moves to chlorinate the raw water were resisted on taste grounds until relatively recent times. Routine bacteria sampling by the County Council apparently never indicated a problem with faecal contamination. I use the term 'apparently' because I have not seen the results of the sampling except for one occasion in July 1999.

I was sent the following preliminary bacteria results by fax when apparently 1 E. coli count had been reported for one borehole by the Council.

Source Borehole	TVC @ 22°C	Total Coliforms
Borehole 2	29	2
Borehole 3	300	26
Borehole 4	50	4

I also recall that water samples were taken subsequently which showed that the water, as expected, was hard and contained significant levels of chloride.

I took two water samples at the end of the pumping tests on the new supplementary production boreholes. The boreholes are adjacent and draw from the same aquifer. I therefore took one sample from Borehole No.1 for both major anion and cation analysis and bacteria analysis. I took a second sample from Borehole No.2 for just confirmatory bacteria analysis. The samples were analysed by City Analysts in Dublin

The results are tabulated below:

Borehole No.1

pH	6.9
Conductivity	1193 μS/cm @25°C
Ca	168 mg/l
Mg	5.0 mg/l
Na	12.0 mg/l
K	22.0 mg/l
HCO3	600 mg/l
SO4	44.0 mg/l
Cl	41.1 mg/l
NO3 as N	0.043 mg/l
NO2 as N	0.002 mg/l
NH3 as N	1.37 mg/l
F	0.32 mg/l
Fe	0.111 mg/l
Mn	0.066 mg/l

TVC @ 22°C	2890 cfu/ml
TVC @ 37°C	22 cfu/ml
E. Coli	<1 MPN/100ml

Borehole No.2

TVC @ 22°C	1500 cfu/ml
TVC @ 37°C	17 cfu/ml
E. Coli	1.0 MPN/100ml

These results indicate that the quality of groundwater in the aquifer is influenced by either septic tank or agricultural organic wastes. This opinion is based on the high conductivity level and the relatively high levels of chloride, potassium and ammonia. Potassium and chloride ions are good indicators of the break down of organic wastes at some point distant from the source.

The bacteria incubated at 22°C show that there are a large number of bacteria living in the aquifer. This often occurs when there is a plentiful supply of nutrients moving through the groundwater system. The TVC's at 37°C and the low or absent levels of E.Coli bacteria show that if faecal material is recharging the aquifer, the source is some distance away and the bacteria are being filtered out or decaying in the aquifer.

The results are not unexpected, given that houses and farms up gradient of the site have septic tanks and produce animal wastes. However the results show that these wastes are being broken down in the granular aquifer before they reach the new production boreholes.

On the basis of the above results, and as there is a hardware store, a school, an animal feed store, a filling station and a haulage company all sited along the road either to the east or to the north, I recommend that future samples of raw water are also analysed for pesticides, herbicides and hydrocarbons.

5. Conclusions and Recommendations

The drilling of three supplementary production boreholes at a site just to the north of the GAA pitch has provided the New Inn water scheme with an additional source of water. The pumping tests have shown that this source can provide a modest but useful additional volume of 72,000 gallons per day or 327 cubic metres per day.

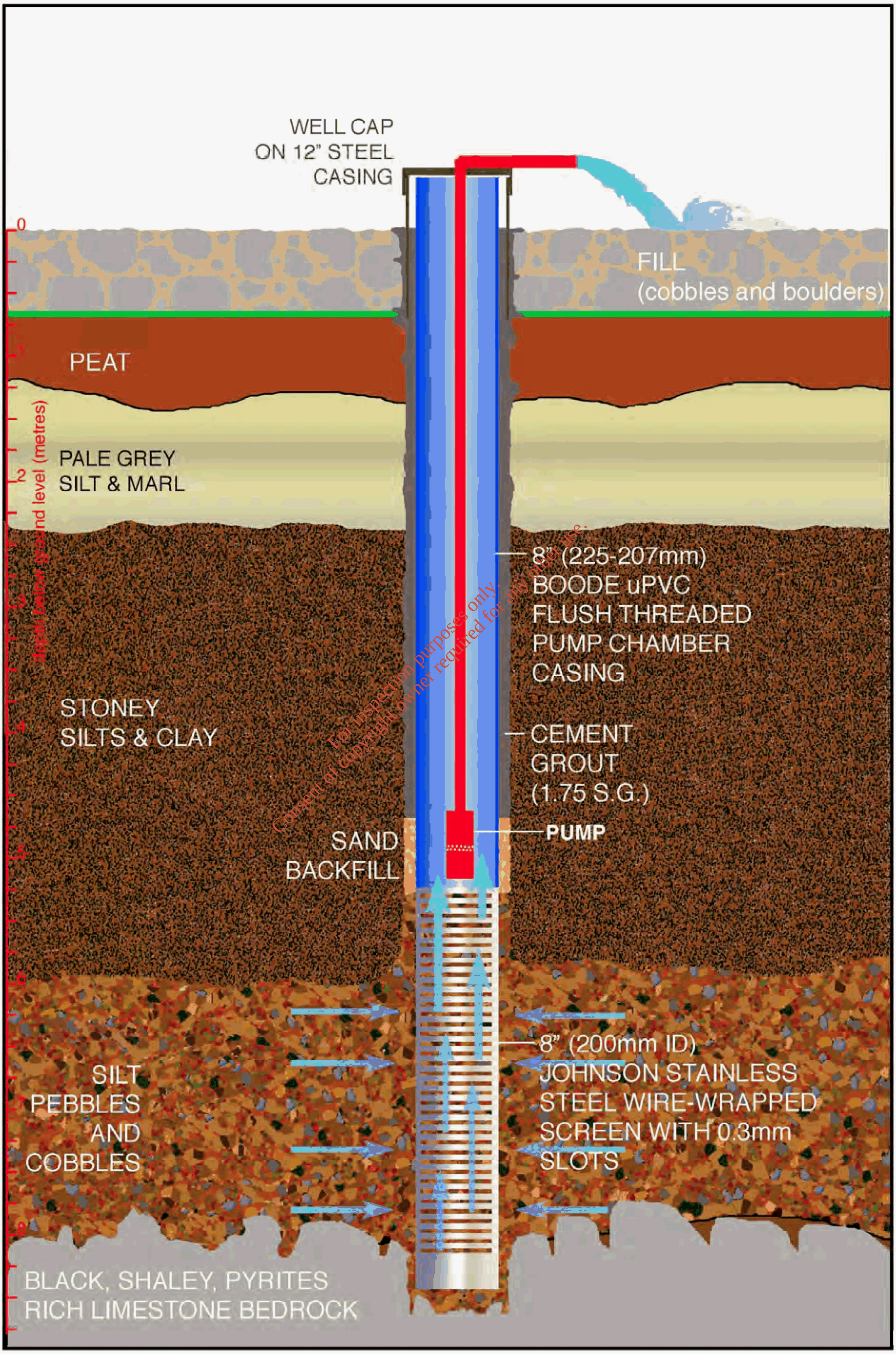
I recommend that the boreholes are pumped continuously and gently over a full 24 hours.

It is not appropriate to pump water intensively for short periods from the thin gravel aquifer at both the new source and the existing source. High pumping rates lead to a high drawdown in the pumped borehole, which in turn lead to temporary dewatering of the screen section, and high entrance velocities in the aquifer adjacent to the screen. This results in aquifer material being packed tight in pore spaces in the adjacent aquifer and into the screen slots. This reduces the ease with which water can flow into the borehole, and in effect reduces the efficiency and yield of the borehole. In other words if the boreholes are aggressively over-pumped for short periods to meet demand peaks, this will undermine the capacity of the boreholes, and the adjacent aquifer material, to provide the long term sustainable yield required.

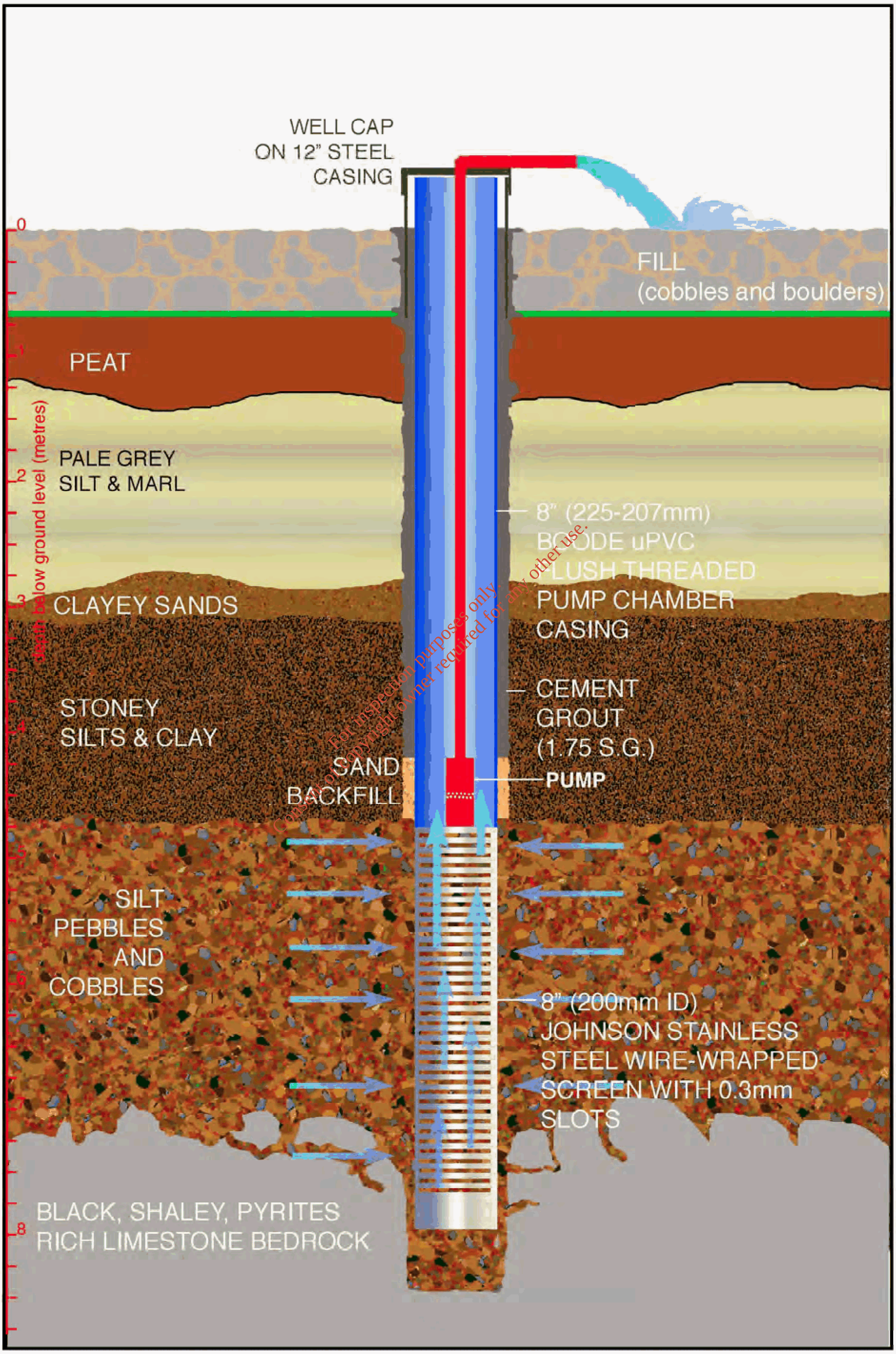
The optimum drawdown in the new boreholes and the existing boreholes is small and less than 5 metres below ground level. New Inn is at roughly 85 metres above sea level. As there are two clusters of boreholes it may be feasible, and prudent economically, to consider pumping each cluster of boreholes, or wellfield, with a single, surface-mounted, centrifugal pump, rather than a separate electric submersible pump in each hole. Two, low head, centrifugal pumps could pump into a small, low level storage, or balancing, chamber on the site. The water could be pumped from this chamber by a single, powerful, high head pump to the reservoir. If the net suction head to a surface mounted pump is too high during the summer, when water levels are low, the centrifugal pumps could be placed in a subsurface chamber. In other words it may be worthwhile considering just three surface mounted pumps for the scheme rather than eight submersible pumps.

The water chemistry and bacteriology of the new source, and probably, also, the main source is not ideal, but there appears to be no surface water or groundwater alternative that will offer better quality. The underlying black shaley limestone bedrock is a poor aquifer and the water contained in it, is noted for high iron and sulphide levels. The streams and drains in the area are fed by groundwater in summer and have small flows, and would be prone to contaminated surface water runoff from farms and fields in winter.

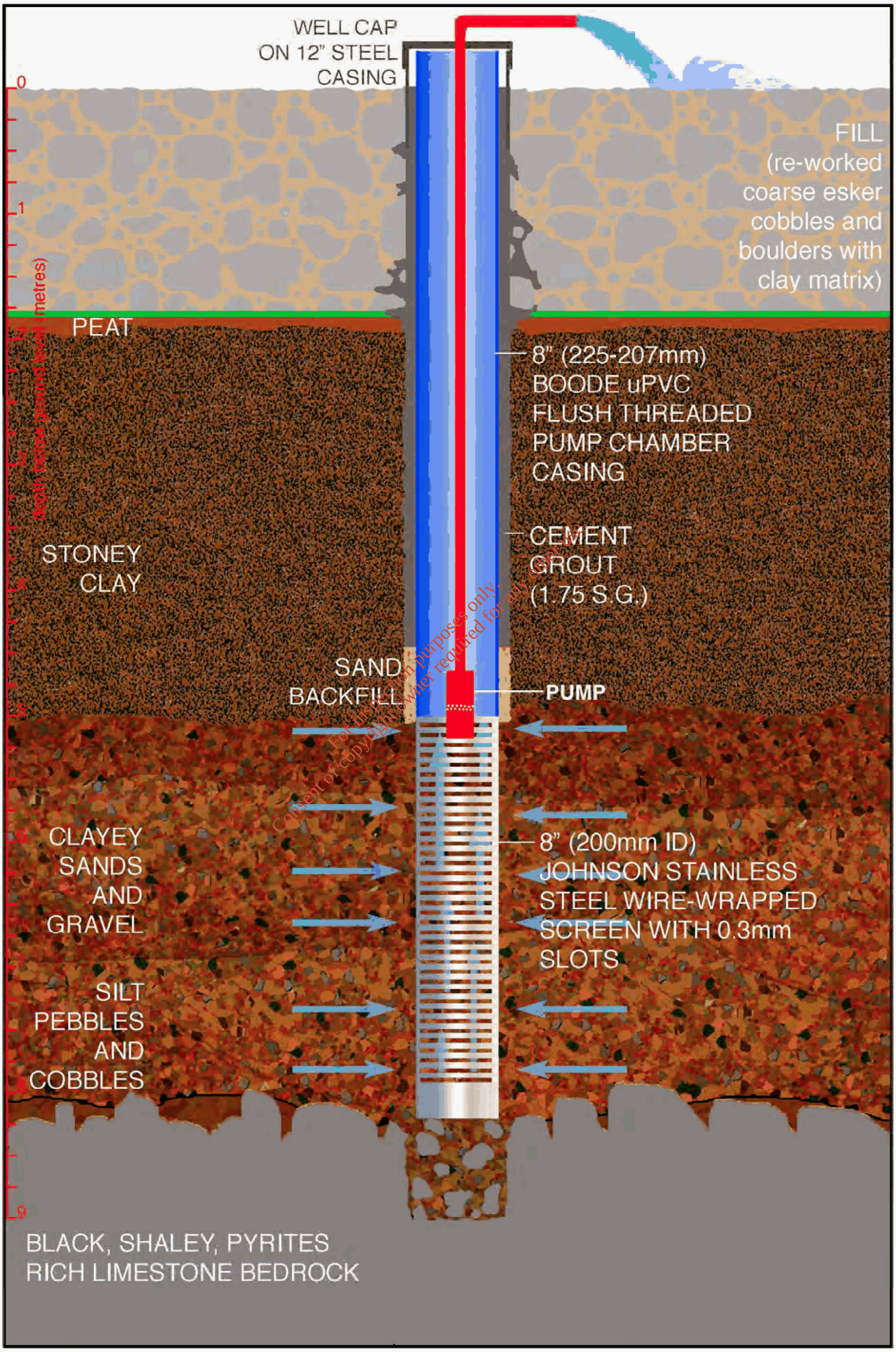
New Inn New Production Borehole No. 1



New Inn New Production Borehole No. 2



New Inn New Production Borehole No. 3



Appendix 6

Calculations

Transmissivity Calculations

Borehole	Q (m3/day)	Factor	b (m)	s (m)	Data source	T (1) m^2/day (T = 1.22Q/s Confined Logan)	T (2) m^2/day (T = 2.43 Qb/(s(2b-s)) Unconfined Logan, after Misstear, 1998 GW Newletter No. 34)	T (2) + Error +10%	T (2) + Error -10%
BH S3	190	1.22	5	1.64	Q, s: Ball, D. (2005) BH 3 Step Tests; b: D.B and TEnv w.l.s	141	166	183	148

Uniform Flow Eqn (confined) Downgradient Distance (Todd D.K., 1980 Groundwater Hydrology)

Distance = Q/2πKbi

Borehole	Q (m^3/d)	T (m^2/d)	i	DGD (m)
BH S3	307	150	0.0014	233

Uniform Flow Eqn (confined) Maximum Half Width calculation (Todd D.K., 1980 Groundwater Hydrology)

Distance = +/- Q/2Kbi Unconfined conditions met.

Borehole	Q (m^3/d)	T (m^2/d)	i	Max Half Width (m)
BH S3	307	150	0.0014	731

Groundwater gradient (i) estimated from BH6 and BH 2 static water levels to river tributary immediately south west of BHs

Transmissivity (T) confined value of 150 m^2/day, calculated from BH S3 above, used in calculations.