AN ASSESSMENT OF THE QUALITY OF PUBLIC AND GROUP SCHEME GROUNDWATER SUPPLIES IN COUNTY OFFALY

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1 Introduction

This report contains a brief assessment of the readily available groundwater quality data for public and group scheme supply sources and of limited information on private supplies. It gives a number of recommendations for consideration by Offaly County Council.

2 Sources of Information

Data on hydrochemistry and water quality were obtained from the following sources:

- Chemical analyses supplied by Offaly County Council for public supplies in Offaly.
- Report on "Groundwater quality in Offaly", carried out by the GSI (Daly & Ryan, 1994).
- Water Quality Assessment of the Mountbolus public supply, carried out by the GSI (Cronin & Daly, 1997).
- Report on "Nitrates in Groundwater in County Offaly" carried out by the Environmental Protection Agency (1997).
- Nitrate data for all public supply and group scheme wells, compiled by Des Page, Offaly County Council (1999).
- Source reports carried out for Mountlucas and Toberdaly (Hudson, 1996) and for Tully and Hollimshill (Daly & Flynn, 1994).
- Comments on water quality in County Offaly (Daly, 1989).

All the data are not reproduced in this report; summaries of some of the data are given in Tables 1 and 2.

Hydrochemical analyses carried out by Offaly County Council generally record parameters such as hardness, nitrates, chloride, ammonia, iron and general appearance. Most analyses do not record major ion concentrations. The majority of public supply sampling points are pre-chlorinated and as a result bacterial analyses have largely been carried out for treated water samples only.

The groundwater quality report carried out by the GSI contains microbiological data and major ion analyses as well as measurements of parameters such as temperature, conductivity and pH for a number of the public supply and group scheme wells.

The study of groundwater quality in Offaly is hampered by the lack of microbiolgical analyses of untreated water.

3 Hydrochemistry

The groundwater in County Offaly can generally be classed as a calcium bicarbonate water type, reflecting the predominance of limestone bedrock and, in areas not underlain by limestone, of overlying limestone tills. As a consequence, it is generally hard (251-350 mg/l) to very hard (>350 mg/l).

At two sources – Gallen, Ferbane and Cloghan – there are indications of ion exchange. At Gallen, sodium (Na) concentrations of >30 mg/l are much higher than the general levels of 5-15 mg/l. At Cloghan, alkalinity generally exceeds total hardness, thus suggesting ion exchange.

4 Background Factors in Assessing Groundwater Quality

As human activities have had some impact on a high proportion of groundwater in Ireland, there are few areas where the groundwater is in pristine condition. Consequently most groundwater is contaminated to some degree although it is not necessarily polluted. In assessing groundwater quality, there is often a tendency to focus only on the EU maximum admissible concentrations (MAC). In the view of the GSI, there is a need for assessment of the degree of contamination of groundwater as well as showing whether the water is polluted or not. This type of assessment can indicate where appreciable impacts are occurring. Consequently, thresholds for certain parameters can be used to help

indicate situations where significant contamination but not pollution is occurring. The thresholds for assessing water quality in County Offaly are given below.

Parameter	**Threshold** mg/l	**EU MAC** mg/l
Nitrate	25	50
Potassium	4	12
Chloride	25	250
Ammonia	0.15	0.3
K/Na ratio	0.4	
Faecal bacteria	0	0

Other parameters can also be useful indicators of contamination; these include conductivity, iron, manganese, sulphate and nitrite. Further information on the use of these parameters in assessing groundwater quality can be obtained from the GSI.

Groundwater quality problems can be due either to the impact of human activities or to natural conditions. Nitrate (NO_3) and faecal bacteria are the main contaminants from human activities in Co. Offaly. The main quality problems caused by the natural chemistry of groundwater are the presence of iron (Fe) and hydrogen sulphide (H_2S).

5 Faecal Bacteria & Viruses

E. coli is the parameter tested as an indicator of the presence of faecal bacteria and perhaps viruses; constituents which pose a significant risk to human health. The most common health problem arising from the presence of faecal bacteria in groundwater is diarrhoea, but typhoid fever, infectious hepatitis and gastrointestinal infections can also occur. Although E. coli bacteria are an excellent indicator of pollution, they can come from different sources - septic tank effluent, farmyard waste, landfill sites, birds.

There are isolated occurrences of faecal bacteria in the treated water of a number of public supply wells e.g. Banagher, Clonbulloge, Mountbolus, Rahan, Rhode, Shinrone**,** Walsh Island and in the majority of group schemes (see Table 1 and 2). It is likely that more sources would have shown faecal bacterial contamination if more bacteriological analyses of raw water were available.

In different investigations 99.9% elimination of E. coli occurred after 10-15 days and 99.9% elimination of various viruses occurred after 16-120 days, with a mean of 35 days for Polio-, Hepatitis-, and Enteroviruses. Pathogenic bacteria can survive for more than 10 days under adverse conditions and up to 100 days under favourable conditions; entertoviruses can survive from about 25 days up to 170 days in soils.

As viruses are smaller than bacteria, they are not readily filtered out as effluent moves through the ground. The main means of attenuation is by adsorption on clay particles. Viruses can travel considerable distances underground; depths as great as 67 m and horizontal migrations as far as 400 m have been reported. The possible presence of viruses in groundwater as a result of pollution by septic tank systems is a matter of concern because of their mobility and the fact that indicator bacteria such as faecal coliforms have been found not to correlate with the presence of viruses in groundwater samples.

The natural environment, in particular the soils and subsoils, can be effective in removing bacteria and viruses by predation, filtration and absorption. There are two high risk situations: (i) where permeable sands and gravels with a shallow water table are present; and (ii) where fractured rock, particularly limestone, is present close to the ground surface. The presence of clayey gravels, tills, and peat will, in many instances, hinder the vertical migration of microbes, although preferential flow paths, such as cracks in clayey materials, can allow rapid movement and bypassing of the subsoil.

6 Cryptosporidium

Cryptosporidium has emerged since the 1980's as a common cause of gastro-enteritis in otherwise healthy people. It is lethal to those who are immuno-compromised - children, elderly people, people convalescing, people taking immunosupressant drugs. Cryptosporidium is a parasite that grows only within an appropriate host animal; it has a complex life cycle but survives as a hardy oocyst that is excreted in faeces. There s a very high level of cryptosporidia in the excreta of young lambs and calves. The precise number of cryptosporidium oocysts needed to cause infection in healthy adults is not known but is thought to be small, probably < 10 oocysts. These oocysts are resistant to disinfectants such as chlorine at current levels in treated water supplies. Therefore a chlorine treatment may remove E. coli and other bacterial indicators of pollution but the cryptosporidium oocysts remain viable and unaffected. Most waterborne outbreaks of cryptosporidium in the U.K. are related to sewage sources such as effluents discharging into water supply rivers. Where groundwater is thought to be contaminated by faeces; special consideration should be given to the risk posed by cryptosporidium (Ball, 1997).

7 Iron

The source of iron can be iron minerals in the rocks or soils, pollution by organic wastes or occasionally the corrosion of iron fittings in the water system. Groundwater from certain rock types such as dark muddy limestones, shales and sandstones and from boggy areas may contain high iron concentrations. The breakdown of high BOD organic wastes from farmyards and other sources can cause the formation of carbon dioxide and oxygen deficient conditions and can bring the iron into solution in the groundwater. Manganese is frequently associated with iron although it is less prevalent.

In Offaly high iron concentrations have been reported in private wells in the Calp Limestone in the Ballycommon and Portarlington areas and are likely at times in all the muddy limestones – Lower Limestone Shale, Ferbane Mudstones, Ballysteen Limestone and Calp Limestone. High concentrations are also likely in places in the Slieve Bloom area – in Silurian slates and mudstones, Old Red Sandstone and Cadamstown Sandstone. Occasional high levels are also reported in the Gormagh (Ardan) and Ferbane public supplies.

8 Hydrogen Sulphide

Hydrogen sulphide is a gas that is recognisable by its 'rotten egg' smell. It is present only in deoxygenated water, from rocks such as black clayey limestones or shales that contain pyrite, or from evaporite beds. It is often associated with iron problems and is common.

In Offaly hydrogen sulphide has been reported in private wells in the Calp Limestone in the Ballycommon and Portarlington areas.

9 Nitrate in Groundwater in Co. Offaly

9.1 General

Nitrate is one of the most common contaminants identified in groundwater. The nitrate ion is not adsorbed on clay or organic matter. It is highly mobile and under wet conditions is easily leached out of the rooting zone and through soil and permeable subsoil. It poses a potential health hazard to babies.

9.2 Sources of Nitrate

Elevated levels of nitrate can be derived from the following sources: septic tank effluent; slurry and soiled water in farmyards; spreading of organic wastes and fertilizers; and spreading of inorganic fertilizer.

Septic tank effluent contains nitrogen concentrations in the range 30-45 mg/l. As this nitrogen is usually converted to nitrate, it poses a risk to groundwater and can significantly raise nitrate levels in the vicinity of the septic tank system.

While farmyards contain large volumes of organic wastes, most are landspread and do not cause significant problems. However, infiltration of soiled or dirty water into the ground beneath and in the vicinity of farmyards can increase nitrate levels (and pollution by faecal bacteria). Also the disposal of soiled water by rain guns can raise nitrate levels in underlying groundwater if they are not moved regularly. Many farm wells in Ireland have been contaminated by soiled water.

Land spreading of slurry from cattle and dairy farms would not usually pose a significant risk to groundwater as the nutrients are recycled without entering groundwater. In contrast, organic wastes from piggeries and hatcheries pose a significant risk unless the rates and timing of spreading match crop needs. Also, other organic wastes such as sludges could become an important source of elevated nitrate levels in the future.

Inorganic fertilizers are a hazard, particularly in tillage areas (leaching of nitrates from tillage crops is generally greater than from grassland) and intensive dairying areas.

Drawing conclusions on the source on elevated nitrate levels in any particular well depends not only on assessing the nitrate data, but also the other parameters, in particular faecal bacteria, ammonia, potassium, chloride and the potassium/sodium ratio. It also requires some knowledge of the zone of contribution (ZOC) of the well, the vulnerability and potential hazards in the ZOC.

The nitrate data for sources with large abstractions give the best indication of general nitrate concentrations in groundwater because they draw water from large catchment areas where the impact of nearby point sources is less likely to make the concentrations unrepresentative. In contrast, while nitrate levels in small sources might reflect the overall situation in an area, more frequently they are likely to be reflecting the impact of nearby farmyards and septic tank systems.

9.3 Appraisal of Nitrate Data

Some statistical analyses of the nitrate data are given in Tables 1 and 2.

As part of a review of draft county reports on nitrate for the EPA, the GSI have subdivided groundwater sources into four broad categories:

- **Category A**: Nitrate levels regularly exceed 50 mg/l
- **Category B**: Average nitrate levels exceed 25 mg/l and peaks regularly approach or exceed 50 mg/l
- **Category C**: Average nitrate levels exceed 25 mg/l, peaks rarely approach 50 mg/l but give cause for concern
- **Category D**: Average nitrate levels <25 mg/l and peaks do not give cause for concern.

The GSI recommends the following responses for each category:

- **Category A**: Urgent action e.g. removal of the source of contamination or provision of an alternative source of water.
- **Category B**: Fairly urgent study: e.g. review of the most recent data; increased monitoring of untreated water; monitoring and assessment of other parameters; surveys of potential contamination sources, similar to the farm surveys carried out in the late 1980's; consideration of whether nitrate vulnerable zones need to be

delineated under the requirements of the EU Nitrate Directive; assessment of the likely source/s of nitrate; where the maps are available, using vulnerability zones and groundwater protection zones in the assessment process.

- **Category C**: Regular review of data, in particular maintaining, for instance, a graph of nitrate variations with time.
- **Category D**: No action other than the continuation of present monitoring is required.

The public supply and group scheme sources in County Offaly are assigned to the above categories as follows:

- **Category A**: Ballaghassan (now disused), Clerhane and Guilfoyles.
- **Category B**: Corndaragh, Cloneygowan, Daingean, Mount Bolus, Rath and Walsh Island.
- **Category C**: Aghancon, Ballyboy, Ballybruder, Ballyfore, Bloomhill, Coolderry, Geashill (including Ballinagar GWS), Dunkerrin, Durrow, Rahan, Island - Clara, Meelaghans, Killeigh, Sillogue, Shinrone, Tober, Wood of O.
- **Category D**: All remaining sources.

Larger sources in Offaly include: Edenderry, Gallen, Geashill, Guilfoyles, Kilcormac, Kinnity, Lisduff, Rahan, Rhode, Shannonbridge, Sillogue and Tullamore. Most of these larger sources lie within Categories C or D.

Nitrate levels for the Rhode source (Fig. 1) are relatively low – less than 16 mg/l – and have shown no increase in recent years. Since 1990, nitrate levels at Sillogue (Fig. 2) and Geashill (Fig. 3) tend to range from 20 to 30 mg/l. Nitrate levels at the Guilfoyles source (Fig. 4) are very high; this is a spring source and so is extremely vulnerable to contamination. However, recent nitrate levels have fallen in Guilfoyles.

While Mountbolus (Fig. 5) and Walsh Island (Fig. 6) are in Category B, nitrate levels have also dropped at these supplies in recent times. Nitrate levels in Geashill, Daingean (Fig. 7) and Shinrone (Fig. 8) have steadily increased in recent years.

In 1998, average nitrate levels for larger sources ranged from 19 mg/l to 24 mg/l. Concentrations in this range are likely to be representative of present general nitrate contamination by both diffuse (spreading of inorganic fertilizer and slurry) and point sources (septic tank systems and farmyards) in Offaly. In particular, the concentrations should not be over-influenced by the impact of nearby point sources and are likely to be largely due to the diffuse sources.

The relatively high nitrate concentrations in the Walsh Island, Mountbolus, Geashill, Daingean and Shinrone supplies are likely to be due largely to point sources. However, landspreading of organic and inorganic fertilizers is likely to have raised the background nitrate levels in the groundwater around the Mountbolus, Geashill and Shinrone wells.

10 Assessment of Quality of Selected Sources in County Offaly

10.1 Ferbane

The groundwater at the Gallen source comes from sandstone which is overlain by low permeability limestones. Consequently groundwater quality is good overall, although there are some iron problems. Nitrate levels at both the Gallen and Moyclare sources are below the guidelevel.

10.2 Geashill

Since 1991, nitrate levels have been slightly above or close to the EU guide level (25 mg/l). Chloride and K/Na levels are close the GSI threshold level. Ammonia was above the GSI threshold level (0.15 mg/l) on one occasion. It is probable that organic wastes are causing the contamination.

The sewage works at Geashill is likely to be in the ZOC of the spring, consequently careful management of the effluent is necessary.

10.3 Rahan

The Tully, Agall and Hollimshill sources collectively supply the Rahan Scheme and provide a good representation of general water quality in the main limestone aquifer. There has been a gradual increase in nitrate levels (see Fig. 9) for all three sources. Nitrate levels at Agall are generally less than the guidelevel of 25 mg/l. At Tully, nitrate levels lie close to the guidelevel. The Hollimshill source has the highest nitrates; the average for 1998 was 30.1 mg/l. The reason for this is unclear at present.

10.4 Toberdaly (Rhode)

This is the largest source in Offaly and so has a relatively large catchment area. Nitrate and chloride levels are generally low and overall groundwater quality in this area is good. However the vulnerability of the groundwater is ‘extreme’ and ‘high’ in different parts of the zone of contribution (Hudson, 1996).

10.5 Walsh Island

Nitrates regularly exceed the EU MAC at Ballaghassan and the K:Na ratio often exceed the GSI threshold value. The Ballaghassan source (now disused) is a spring which is extremely vulnerable to pollution. It is probable that pig farming in the vicinity has caused the pollution. The nitrate levels at Walsh Island (Coolgarry) exceeded the E.U. MAC 1994/1995. Since then there has been a steady drop in nitrate levels to approximately 30 mg/l. Nearby septic tank systems may be contributing to the high nitrates.

10.6 Mountbolus

Biannual sampling carried out at since 1993 has consistently shown nitrate values to be in excess of the threshold value and occasionally greater than the EU MAC. The chloride values are also approaching threshold levels. There are occasional occurrences of faecal bacteria in the drinking water.

The exceptionally high nitrates are likely to be due largely to point sources of contamination (septic tank systems and farmyards) for the following reasons (Cronin & Daly, 1997):

- background nitrate levels are likely to have been raised by diffuse sources (landspreading of organic and inorganic fertilisers), however it is unlikely that they are causing the high levels found in the well as farming does not appear to be any more intensive in the area than in the vicinity of the Rahan sources;
- the evidence suggests that the previous well at Mountbolus was contaminated by point sources;
- the presence of faecal bacteria and relatively high chloride levels suggests point organic sources;
- there are sufficient septic tank systems and farmyards in the ZOC of the well to cause the nitrate concentrations.
- the groundwater is either ‘highly’ or ‘extremely’ vulnerable in the area.

10.7 Group Scheme Sources

The quality of the group scheme sources is less satisfactory than the public supply sources particularly at Clerhane, Corndaragh, Cloneygowan and Rath. Both nitrate and chloride levels are, in general, somewhat higher. Faecal bacteria are present in most of the group scheme sources; this is of concern in view of the risk to health and the inadequate disinfection of most group scheme water.

11 Overall Assessment and Conclusions

- The groundwater in County Offaly is hard and can be classed as a calcium bicarbonate ($Ca(HCO_3)_2$) water type.

- The main groundwater quality problems due to the natural conditions in the ground and the natural chemistry of groundwater are caused by iron (Fe) and hydrogen sulphide (H_2S). Iron may be present in areas underlain by muddy limestone, particularly if peat is present overlying the limestone, and where the bedrock is sandstone. Hydrogen sulphide is found in muddy limestones. High iron concentrations have been reported in the Ferbane and Gormagh (Arden) public supply wells and in private wells in the Ballycommon and Portarlington areas. Hydrogen sulphide has been reported in private wells in the Ballycommon and Portarlington areas.

- The main water quality problems caused by the impact of human activities are due to faecal bacteria and nitrate (NO_3).

- In 1998, average nitrate levels in 18 of the 24 public supplies were less than the E.U. guidelevel.

- Based on the nitrate levels in both the public and group schemes, eight sources are considered to require 'urgent action' or 'urgent study' (see Section 9.3). Eighteen sources require 'regular review of data'.

- The data for the larger sources give a good indication of the general groundwater quality in Offaly. These data show that the quality is generally good.

- Groundwater quality of the smaller, shallower sources tends to be poorer than the larger, deeper sources.

- Groundwater quality in the group scheme sources is poorer than in the public supplies. In particular, the presence of faecal bacteria in most of these sources is of concern. The location of many group scheme wells close to septic tank systems and farmyards is likely to be the main reason for the relatively poor quality.

- The group scheme and smaller sources are more likely to be affected by point source contamination than by diffuse sources.

- In general, groundwater pollution is not extensive in County Offaly. However, some groundwater sources are polluted by faecal bacteria and there is evidence of chemical contamination. It is probable that the pollution and most of the significant contamination is caused by point sources, in particular farmyards and septic tank systems, and by poor sanitary protection of the sources.

12 Recommendations

- The data on which this report is based has meant that the assessment and the conclusions are tentative. Consequently, it is recommended that:
    - analyses of raw water rather than treated water should be carried out;
    - full analyses (including all major ions) should be carried out on a proportion of the samples;
    - where there is evidence of contamination, the sampling frequency should be increased.

- Nitrate data should not be considered in isolation as the likely sources of nitrate cannot be considered and evaluated.

- The actions suggested in Section 9.3, based on the nitrate levels, are recommended.

- Group scheme water should be disinfected adequately.

- A programme of undertaking groundwater protection zone delineation around public and group scheme supplies over the next few years is recommended.

- A programme of checking the sanitary protection at each well and spring site (i.e. on Co. Co. property in the immediate vicinity of the source) would help to ensure that shallow groundwater and surface water is not entering the source and that accidental spillages would not contaminate the source.

13 References

Ball, D. (1997). *Cryptosporidium and E. Coli 0157*. GSI Groundwater Newsletter, No. 32. November 1997.

Cronin, C. and Daly, D. (1997). *A water quality assessment of the Mountbolus public supply*. GSI report to Offaly County Council.

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Daly, D. and Ryan, T. (1994) *An assessment of the quality of public and group scheme groundwater sources in County Offaly*. GSI report to Offaly County Council.

EPA. (1997). *Nitrates in groundwater in County Offaly (Draft).* Environmental Protection Agency.

Hudson, M. (1996). *Groundwater source protection zones for Mountlucas group water scheme*. Geological Survey of Ireland.

Table 1 Summary data for Offaly County Council Groundwater Sources

Public Supply Source	Nitrates		N	Chlorides		Conductivity	Hardness	N	Faecal Bacteria	N	K:Na
	Mean	Range		Mean	Range	Mean	Mean				
	mg/l	mg/l		mg/l	mg/l	µS/cm	mg/l		**		
Agall	21.9	15.6 - 21.5	6	nd	nd	nd	nd	nd	nd	nd	nd
Banagher	9.8	4.4 - 19.2	9	21.2	19 - 24	525	304	9	1	31	0.10
Cloghan	6.9	4.2 - 8.3	3	21.0	20 - 22	557	289	3	0	1	0.18
Clonbulloge	10.9	9 - 14.8	24	16.1	15 - 17	580	302	7	2	33	0.17
Daingean	**32.1**	17.8 - **46.4**	37	24.1	20 - 27	664	404	7	0	29	0.28
Dunkerrin	15.5	6.4 - **25.5**	17	24.0	20 - 26	617	354	8	0	45	nd
Edenderry	7.7	6.2 - 10.4	13	13.3	8 - 15	503	354	8	0	32	0.16
Ferbane (Gallen)	0.37	0.1 - 0.6	3	19.2	17 - 20	513	215	10	0	34	nd
Geashill	**26.7**	19.5 - **41.4**	37	24.8	23 - 27	658	387	8	0	46	0.31
Guillfoyles	***50.6***	23.8 - ***64***	30	nd	nd	nd	nd	nd	nd	nd	nd
Hollimshill	**26.7**	17 - **42.2**	13	nd	nd	nd	nd	nd	nd	nd	nd
Kilcormac	24.3	20.3 - 24.7	15	22.0	19 - 24	625	359	8	0	46	0.12
Kinnitty	9.7	3.3 - 10	5	13.9	12 - 18	295	157	7	0	63	nd
Moneygall	17.0	9.6 - **29.2**	9	23.8	20 - 28	618	352	9	2	45	0.29
Mountbolus	**38.6**	2.8 - ***53.3***	12	24.0	16 - 28	634	369	8	0	56	0.38
Rahan	18.7	16.4 - 21.2	12	19.1	22 - 25	581	334	10	4	43	nd
Rhode (Toberdaly)	12.5	8.91 - 16	17	15.2	14 - 17	518	292	9	2	29	0.27
Shannonbridge	18.5	8.4 - **29.3**	12	21.9	18 - 31	586	332	7	0	35	nd
Shinrone	18.4	4.2 - **38.7**	27	24.0	22 - 28	586	324	9	1	60	nd
Tullamore	6.74	5.4 - 9	11	nd	nd	nd	nd	nd	nd	nd	md
Tully	22.4	19.7 - **27.9**	12	nd	nd	nd	nd	nd	nd	nd	nd
W. Island (Coolgarry)	**39.6**	14.6 - ***79.4***	53	nd	nd	nd	nd	nd	nd	nd	nd
W. Island (Ballaghassan)	***71***	**38 - *116***	57	nd	nd	nd	nd	nd	nd	nd	nd

Bold: Exceeds the GSI threshold value

Bold italics: Exceeds the E.U. MAC

nd: no data

NB K:Na data were obtained from Water Quality Report (Daly & Ryan, 1994) and are based on the results of one sample. All other data were obtained from Offaly County Council; the nitrate data are for the period 1990 to 1999; the Chloride data are for the period 1993 - 1996.

Table 2 Summary data for Group Schemes in Co. Offaly

Group Scheme	Nitrates		N	Chlorides		N	Faecal Bacteria **	N	K:Na
	Mean mg/l	Range mg/l		Mean mg/l	Range mg/l				
Aughancon	21.7	16.8 - 30.2	8	19.0	13 - 22	8	11	37	nd
Ballyboy	**33.1**	29 - 38.9	11	**27.8**	23 - 30	8	21	43	0.43
Ballybruder	**21.5**	nd	1	16.0	nd	1	1	2	nd
Corndaragh	**46.5**	nd	1	19.0	nd	1	0	3	nd
Ballyfore/Ballykillen	21.0	15.9 - 24.2	9	18.8	17 - 21	8	6	17	nd
Boher	15.3	12.3 - 22.3	8	20.5	18 - 25	8	10	19	nd
Bracknagh	19.3	15.4 - 24.4	8	20.3	18 -20	8	23	49	nd
Brosna	14.4	11 - 17.8	2	**27.1**	23 - 32	8	7	51	nd
Clareen	11.5	9.79 - 12.5	7	16.3	11 - 20	8	2	23	nd
Clerhane	37.1	32.8 - 44.3	4	**31.2**	29 - 33	5	0	5	nd
Cloneygowan	9.8	2.5 - 12.3	2	**28.5**	27 - 30	2	2	16	nd
Clondelara	4.5	nd	1	21.0	nd	1	0	1	nd
Clonfanlough	0.2	nd	1	22.0	nd	1	0	1	nd
Wood of O	23.9	nd	1	16.0	nd	1	2	0	nd
Durrow	21.1	7.7 - 27	8	24.3	23 - 26	4	8	18	nd
Killeigh	24.2	12.2 - 30.6	12	23.6	19 - 28	9	12	61	0.31
Leamore/Leabeg	10.9	6.3 - 14.1	3	19.8	18 - 21	6	8	22	nd
Meelaghans	24.3	19.1 - 30.8	10	23.7	22 - 27	7	3	40	0.34
Mountlucas	12.9	11.4 - 16.3	8	21.5	18 - 25	8	7	17	0.30
Tober	17.6	14.3 - 21.4	4	20.6	18 - 24	5	4	8	nd

Bold: Exceeds the GSI threshold value

N: Number of Samples

nd: No data available

**** Denotes the number of times faecal bacteria was detected.

K:Na data were obtained from Water Quality Report (Daly & Ryan, 1994) and are based on the results of one sample. All other data were obtained from Offaly County Council and the EPA Nitrate Report (1997) and are for the period 1993 to 1996.

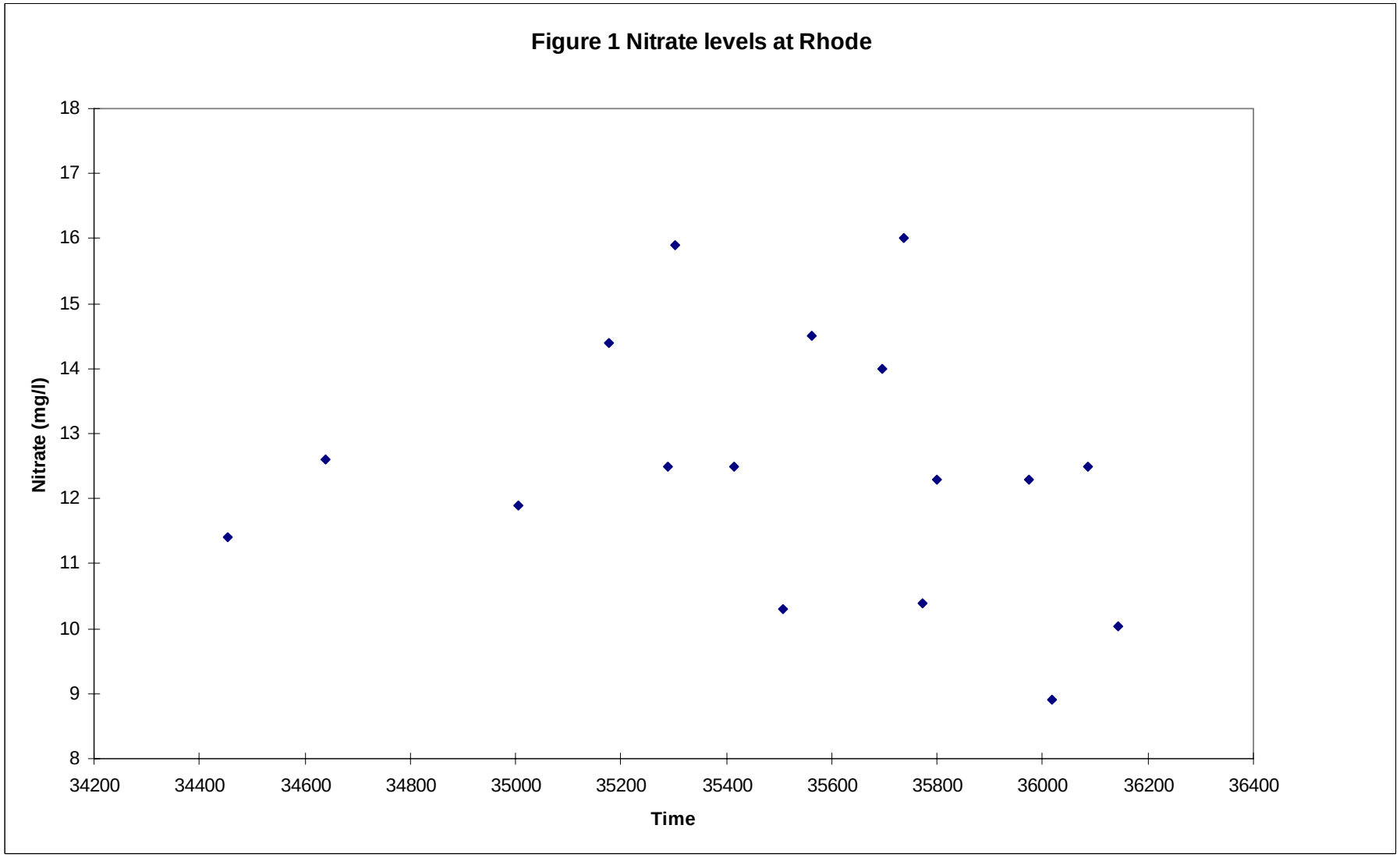
Figure 1 Nitrate levels at Rhode
Nitrate (mg/l)
18
17
16
15
14
13
12
11
10
9
8
34200
34400
34600
34800
35000
35200
35400
35600
35800
36000
36200
36400
Time

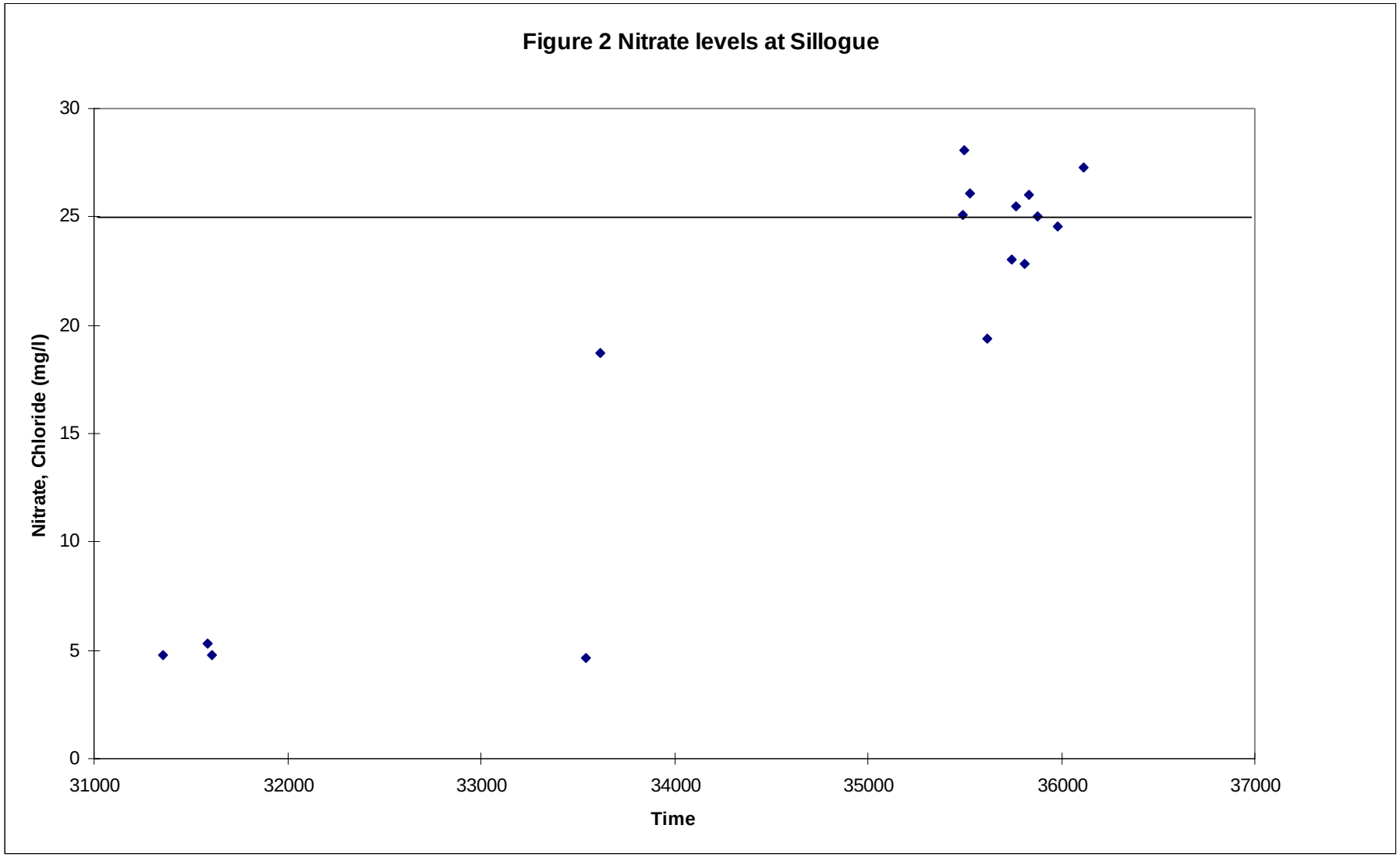
Figure 2 Nitrate levels at Sillogue
Nitrate, Chloride (mg/l)
30
25
20
15
10
5
0
31000
32000
33000
34000
35000
36000
37000
Time

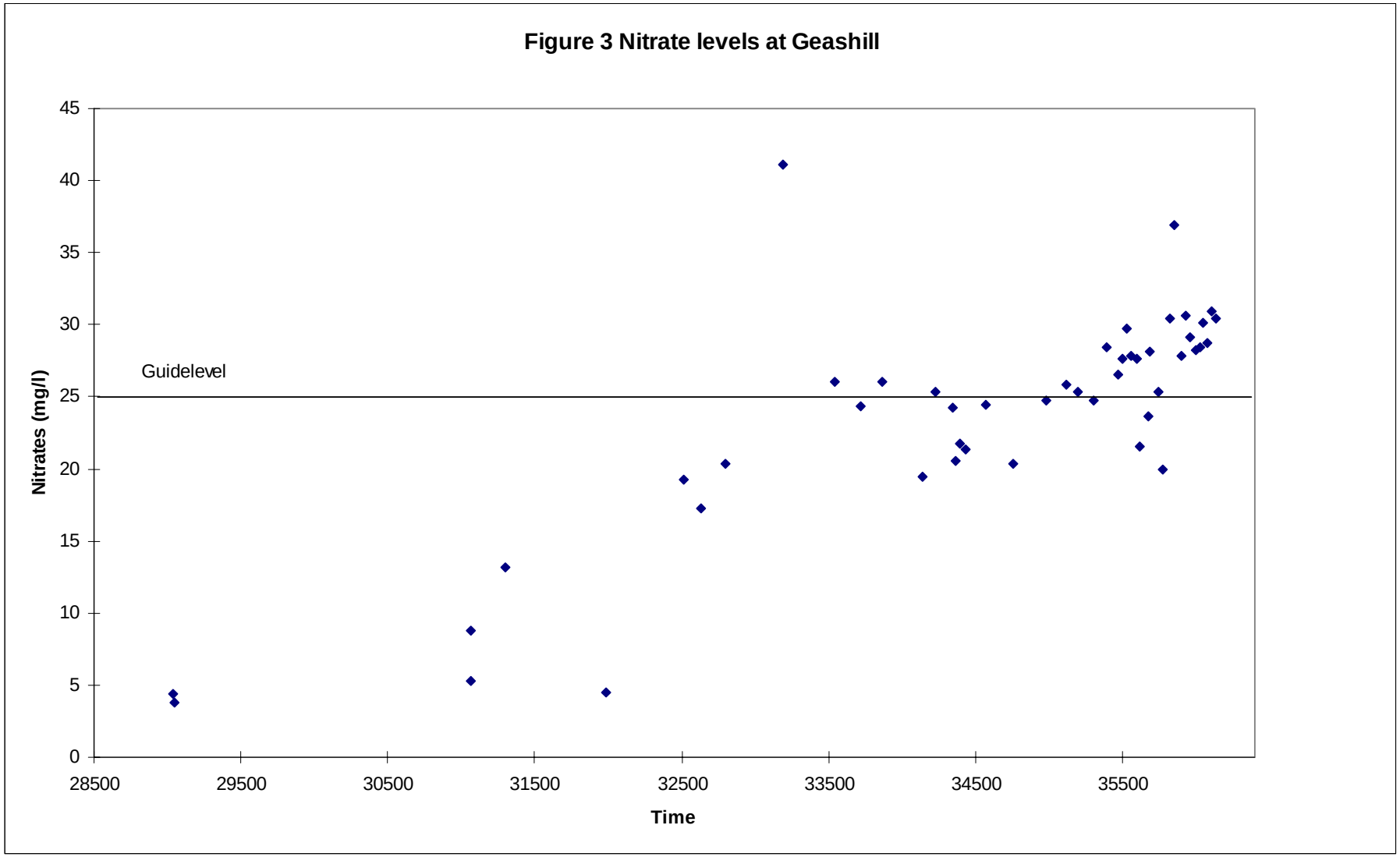
Figure 3 Nitrate levels at Geashill
Nitrates (mg/l)
45
40
35
30
25
20
15
10
5
0
Guidelevel
28500
29500
30500
31500
32500
33500
34500
35500
Time

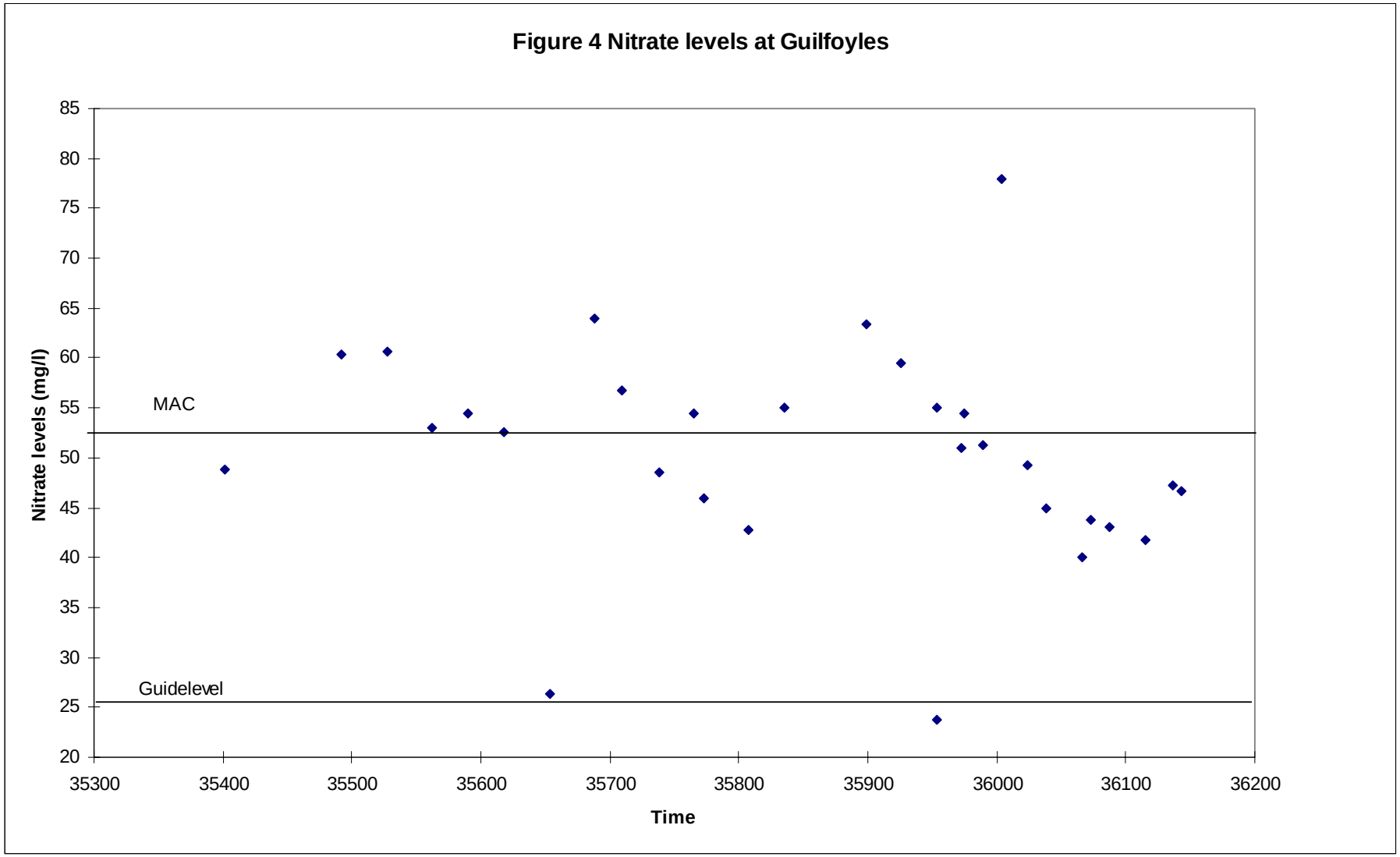
Figure 4 Nitrate levels at Guilfoyles
Nitrate levels (mg/l)
85
80
75
70
65
60
55
50
45
40
35
30
25
20
MAC
Guidelevel
35300
35400
35500
35600
35700
35800
35900
36000
36100
36200
Time

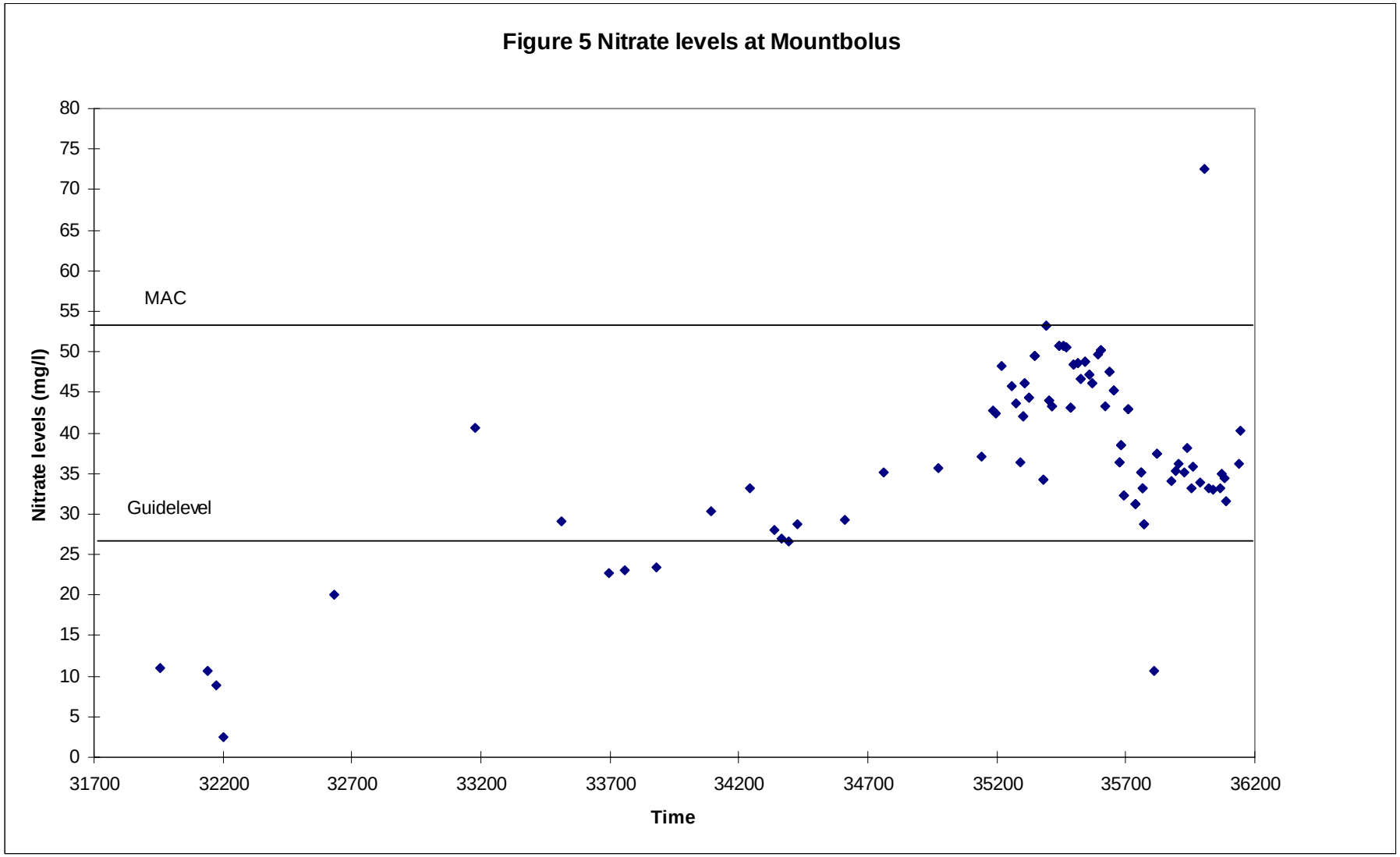
Figure 5 Nitrate levels at Mountbolus
Nitrate levels (mg/l)
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
MAC
Guidelevel
31700
32200
32700
33200
33700
34200
34700
35200
35700
36200
Time

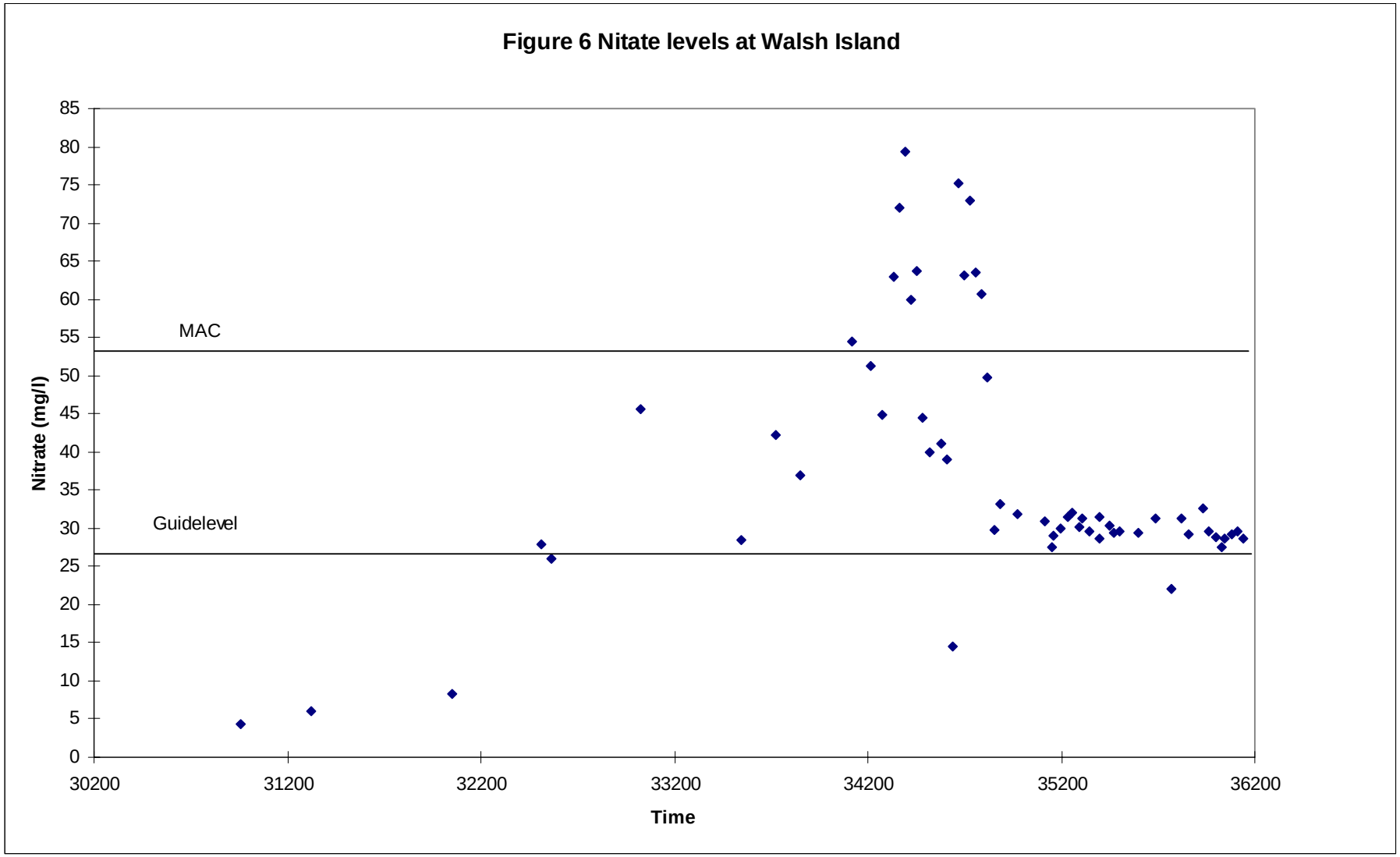
Figure 6 Nitate levels at Walsh Island
Nitrate (mg/l)
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
MAC
Guidelevel
30200
31200
32200
33200
34200
35200
36200
Time

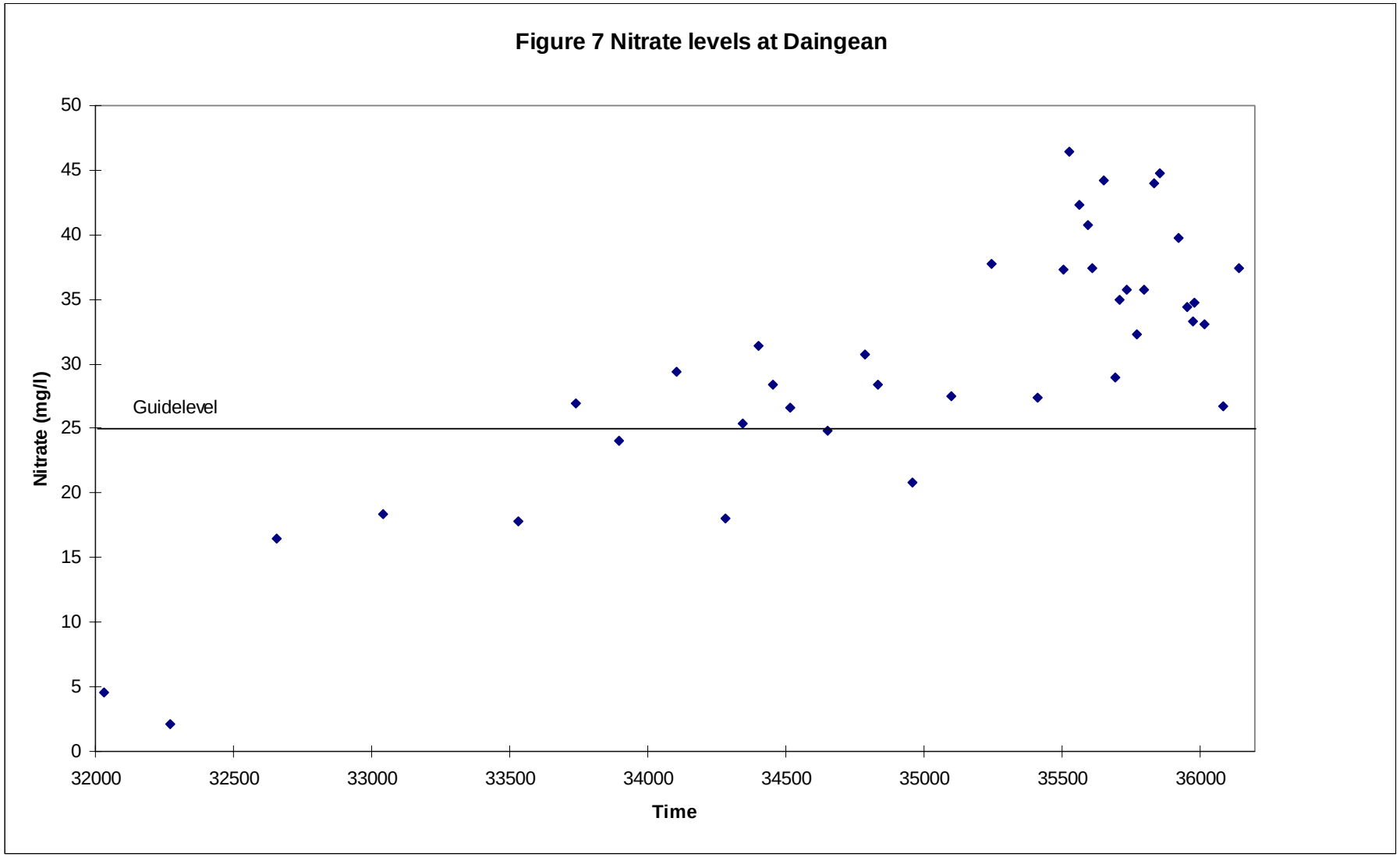
Figure 7 Nitrate levels at Daingean
Nitrate (mg/l)
50
45
40
35
30
25
20
15
10
5
0
Guidelevel
32000
32500
33000
33500
34000
34500
35000
35500
36000
Time

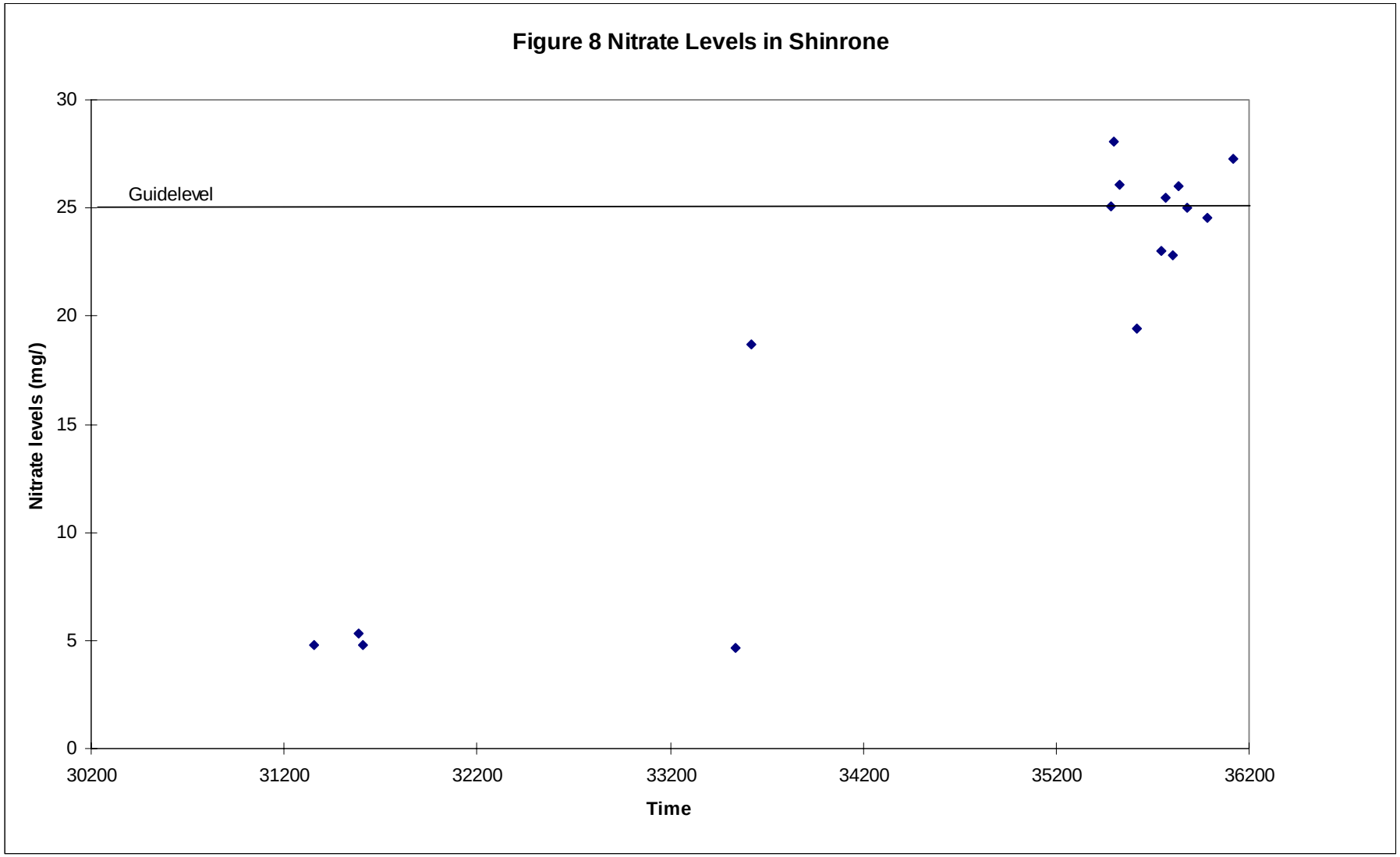
Figure 8 Nitrate Levels in Shinrone
Guidelevel
Nitrate levels (mg/l)
30
25
20
15
10
5
0
30200
31200
32200
33200
34200
35200
36200
Time

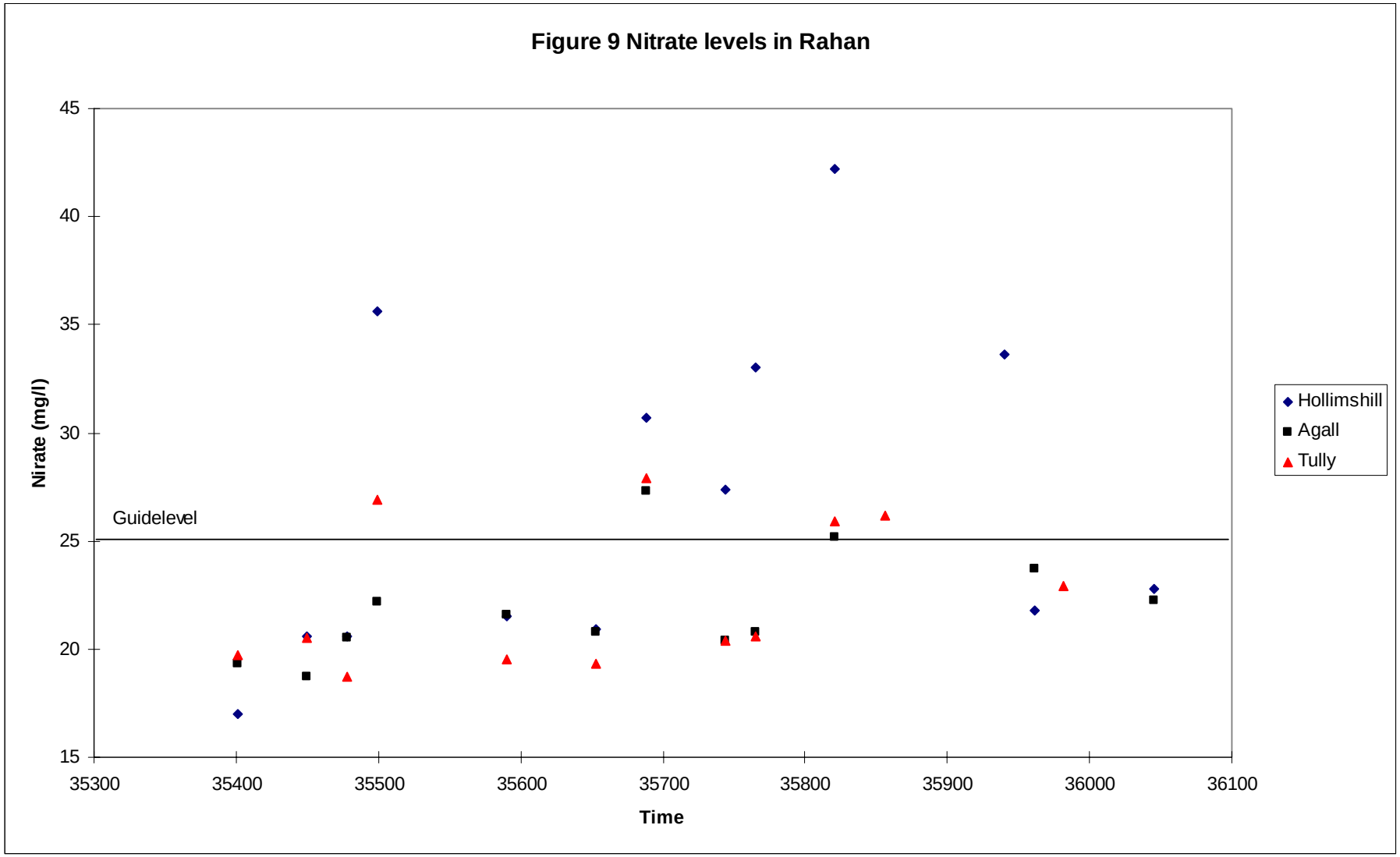
Figure 9 Nitrate levels in Rahan
Nirate (mg/l)
45
40
35
30
25
20
15
Guidelevel
35300
35400
35500
35600
35700
35800
35900
36000
36100
Time
Hollimshill
Agall
Tully