A Survey on the Quality of Potable Water in Mauritius

March 2010

MRC MAURITIUS RESEARCH COUNCIL

Executive Summary

Background

In September 2009, the Ministry of Industry, Science and Research (MoISR) requested the Mauritius Research Council (MRC) to report on the impact of the use of fertilizers on the water table and on the health of the population, with a view to elaborating a policy and developing a strategy for subsequent adoption.

In this context, the MRC set up a Task Group comprising stakeholders with responsibilities for the sourcing, supply and distribution of water, as well as for monitoring the quality of water distributed for domestic and industrial uses. The Task Group also included representation of institutions involved in research and development.

In December 2009, the Ministry of Renewable Energy and Public Utilities (MoREPU) was informed of the request made to the MRC, and gave its approval for the Council to conduct a survey on the quality of potable water in Mauritius.

This report of the Task Group therefore presents the preliminary findings based on the results of the statistical analysis carried out between September 2009 and February 2010 on data obtained from various stakeholders.

Methodology

Information (reports and publications) were provided by MSIRI and WRU. Data were obtained from CWA and NEL.

For the purposes of the first phase of this project, data from the CWA were utilised for statistical analysis, given that these represent the most comprehensive sets of measurements of the 30 parameters that are monitored for treated water quality.

In the first phase of this project, data representing 21 boreholes were plotted to generate trends (over the period 2007 – 2009) of the 30 measured parameters. Out of the 30 parameters, only four showed significant variations, namely pH, Nitrate, Sulphate and Ammonia. Subsequently, these parameters were selected for more refined and extended statistical analysis to cover the period 1989 to 2009.

Results

The main findings of the first phase of this project are as follows:

- Nitrate, Sulphate and Ammonia have varied within the limits set by the WHO guidelines.
- There are recent trends for a majority of sampled boreholes during the period 2007-2009 showing rising Nitrate and Sulphate and decreasing pH and Ammonia levels.
- However, out of the four parameters considered, only pH showed a tendency of moving towards the lower acceptable safety limit of 6.5 set by CWA (based on the WHO guidelines).
- Between 2007 and 2009, around 76% of the 21 boreholes examined during this phase of the project were found to have pH values less than 6.5 which are therefore lower than the acceptable safety limits set by CWA.
- These boreholes with low pH are located across the country, which suggests that the observed lowering of pH is not restricted to specific geographical locations.

Recommendations

On the basis of the results of the first phase of the project and the discussions held by the Task Group, the following recommendations for the way forward are:

- To conduct an evaluation of additional data on the quality of water (e.g., untreated water obtained from the same set of boreholes, water quality audits conducted by the Ministry of Health and Quality of Life) for comparison with the current analysis effected on treated water.

- To evaluate the potential influence of seasonal variations (e.g., rainfall) over the period 1989 – 2009, on the levels of pH, Nitrate, Sulphate and Ammonia, as well as other parameters recorded.

- To undertake a close monitoring of boreholes where low pH have been recorded, including additional parameters that could help elucidate possible causes (e.g., dissolved carbon dioxide and sulphur dioxide, seismic profiling). Simultaneously, a comparative exercise could be conducted in collaboration with the relevant authorities of Reunion Island.

- To conduct further statistical analysis, including modelling through the inclusion of seasonal sets of data (e.g. rainfall, cyclones, temperature, etc.) and information obtained from other stakeholders (e.g., Mauritius Meteorological Services, Ministry of Agro Industry, Food Production and Security, Ministry of Housing and Lands).

- To carry out a study on the distribution and flow-paths of water from the aquifers to boreholes.

The Task Group has also recommended that such studies be led by institutions with responsibility and experience in the assessment and monitoring of water quality in Mauritius.

Acknowledgements

The MRC would like to thank the CWA, WRU, MSIRI, NEL, AREU, MMS and their staff members for their valuable contribution to this project. This project has benefitted from the help of various ministries namely, MoAIFS, MoHL, MoHQL, MoISR and MoREPU. This project has also gained the support of Dr M. Nowbuth of the University of Mauritius.

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Abbreviations

- MRC – Mauritius Research Council
- AREU - Agricultural Research Extension Unit
- CWA - Central Water Authority
- MSIRI - Mauritius Sugar Industry Research Institute
- MoISR - Ministry of Industry, Science and Research
- NEL - National Environmental Laboratory
- WRU - Water Resources Unit
- UOM – University of Mauritius
- MMS – Mauritius Meteorological Services
- MoHQL – Ministry of Health and Quality of Life
- MoAIFS – Ministry of Agro Industry, Food Production and Security
- MoREPU – Ministry of Renewable Energy and Public Utilities
- MoHL – Ministry of Housing and Lands
- WHO – World Health Organisation

Acronyms

- CV – Coefficient of Variation
- SD – Standard Deviation
- ANOVA – Analysis of Variance
- SPSS – Statistical Package for Social Scientist
- DWS – District Water Supply
- MAV – Mare aux Vacoas
- Aq – Aquifer
- Bh - Borehole

Bibliography

1. *WHO Guidelines & Drinking Water Standards : CWA*

2. *Map of Mauritius & Boreholes in operation :CWA, January 2010*

3. *Ile Maurice Carte Géologique au 1: 50 000 Schéma hydrogéologique – Loic Giorgi, Ministere des affaires Etrangeres Coopération et Francophonie France ; Serge Borchiellini ; Laurent Delucchi, GEOLAB/ BURGEAP France : Projet Franco-Mauricien « Appui a la Gestion des Ressources en eau et a la preservation de leur qualité : GEOLAB JUILLET 1999, WRU*

4. *Data Book, National Environmental Monitoring Programme, Assessment of Trends of Fresh Water Quality (Boreholes) :NEL*

5. *Final Report, National Environmental Monitoring Programme, Assessment of Trends of Fresh Water Quality (Boreholes) :NEL*

6. *End of mission draft report of Dr Elisa Sacchi on "Use of Isotope Techniques in Assessing Groundwater Contamination in Mauritius;13 – 17 April 2009" – (IAEA-TCR-04635) : NEL*

7. *Chemical Analysis of Water and Reference Method:CWA*

8. *Map of Mauritius with boreholes Showing low pH: CWA, Pollution Control Laboratory, June 2009*

9. *Measurement and Prediction of agrochemical movement in tropical sugarcane production: project undertaken between 1997 – 2001 with the joint collaboration of the MSIRI and the Queensland Department of Natural Resources and Mineswith funding support from the Australian Centre for International Agricultural Research*

Introduction

In September 2009, the Ministry of Industry, Science and Research (MoISR) requested the Mauritius Research Council (MRC) to report on the impact of the use of fertilizers on the water table and on the health of the population, with a view to elaborating a policy and developing a strategy for subsequent adoption.

In this context, the MRC set up a Task Group comprising stakeholders with responsibilities for the sourcing, supply and distribution of water, as well as for monitoring the quality of water distributed for domestic and industrial uses. The Task Group also included representation of institutions involved in research and development, with a focus on the utilisation of water for agricultural purposes.

In December 2009, the Ministry of Renewable Energy and Public Utilities (MoREPU) was informed of the request made to the MRC, and gave its approval for the Council to conduct a survey on the quality of potable water in Mauritius.

Between September 2009 and February 2010, the MRC (i) obtained the collaboration of various organisations for the provision of data pertaining to water quality over the period 1989 - 2009, and (ii) analysed the data made available through a series of statistical tools, with a view to identifying trends and quantifying the changes recorded, in relation to the safety criteria established for potable water in Mauritius.

This preliminary report therefore presents the results of the statistical analysis carried out between September 2009 and February 2010 on data obtained from various stakeholders. The data and the preliminary results have been discussed by the Task Group, the outcome of which is also included in the report as a list of recommendations for further action.

Methodology

Setting up of a Task Group

In view of the multidisciplinary nature of this project, the MRC set up a Task Group comprising the following stakeholders:

- Agricultural Research Extension Unit (AREU)
- Central Water Authority (CWA)
- Mauritius Sugar Industry Research Institute (MSIRI)
- National Environmental Laboratory (NEL)
- Water Resources Unit (WRU)

A first meeting of the Task Group was organised on 19 October 2009. The purpose of this meeting was to take cognisance of the various issues to be considered for the preparation of a report on the quality of potable water resources in Mauritius.

Task Group discussions and planning of Phase I of the project

The following points were noted by the Task Group with regard to the type of information available, and the processes and procedures that are in place for measuring/monitoring the quality of water:

- CWA operates a sampling programme covering boreholes and surface water, whereby data based on several parameters are collected every three weeks. Such data are available for the past 10 to 15 years.

- MSIRI has conducted several studies, including some in collaboration with the Queensland Department of Natural Resources (Australia) and the Australian Centre for International Agricultural Research.[1] Reports of these studies would be made available to the MRC for carrying out statistical analysis.

[1] Measurement and Prediction of agrochemical movement in tropical sugarcane production (project undertaken between 1997 – 2001)

- NEL has conducted a survey on the assessment of trends of freshwater quality (boreholes). A copy of the report would be provided to the MRC.

- WRU recently conducted a water resources mapping exercise, with technical assistance from France.[2] A copy of the report would be made available to the MRC to assist in the data analysis.

On the basis of the discussions, the Task Group agreed to phasing the project, whereby in Phase I, the data to be made available to the MRC would be analysed primarily to determine the trends in the various parameters measured over time.

The Task Group indicated that as a subsequent stage (Phase II), the data could be further examined in relation to information gathered from other sources (e.g., meteorological services, industrial and urban development programmes, agricultural development and practices, audits conducted by health authorities, deployment of sewage networks).

The subsequent sections of this report constitute activities undertaken for Phase I of the project.

Data collection

Information (reports and publications) were provided by MSIRI and WRU. Data were obtained from CWA and NEL.

For the purposes of the first phase of this project, data from the CWA were utilised for statistical analysis, given that these represent the most comprehensive sets of measurements of the 30 parameters that are monitored for treated water quality.[3] The data consist of recordings of measurements effected from 50 boreholes and 90 surface

[2] Ile Maurice Carte Géologique au 1:50 000 Schéma hydrogéologique (GEOLAB, July 1999)
[3] The parameters monitored by CWA are listed under Annex 11.

water sites located across the island. The data, which relate to treated water, were provided in the form of log books (covering the period 1989-1992, 1994, 1997) and a soft copy (covering the period 2007 to 2009). Data from the log books were entered into Excel/SPSS[4] format by the staff of MRC, for the purposes of statistical analysis.

Certain data are currently only available in hand-written format and are yet to be transferred by CWA to log books / soft copies. These data were therefore not available for analysis in Phase I.

<u>Data cleaning and verification</u>

Data cleaning is a necessary step for removing redundant and corrupt data from a database to make it more reliable and consistent. This is the most time-consuming part when dealing with raw data, and in the present case the following issues arose:

1. *Gaps in data*

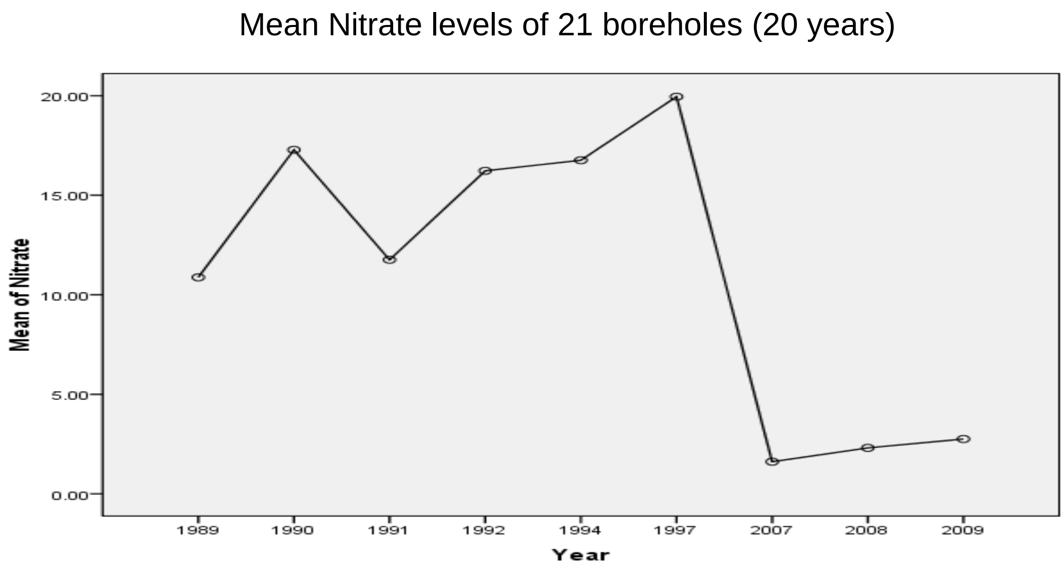
   Comprehensive data sets were not available for the years 1993, 1995 – 1996, and 1998 – 2006. The few data that were available for these periods were in hand-written form and were difficult to construe.

2. *Change in measuring unit*

   The measuring unit for Nitrate changed from NO_3- to N, as from 2007. This change was detected only after plotting graphs for Nitrate which showed much lower values for Nitrate as from 2007. The following graph shows the effect of the change in measuring unit as from year 2007. It is clear that all the readings had been decreased by a certain factor. Hence, data for 2007-2009 were readjusted for the change in unit.

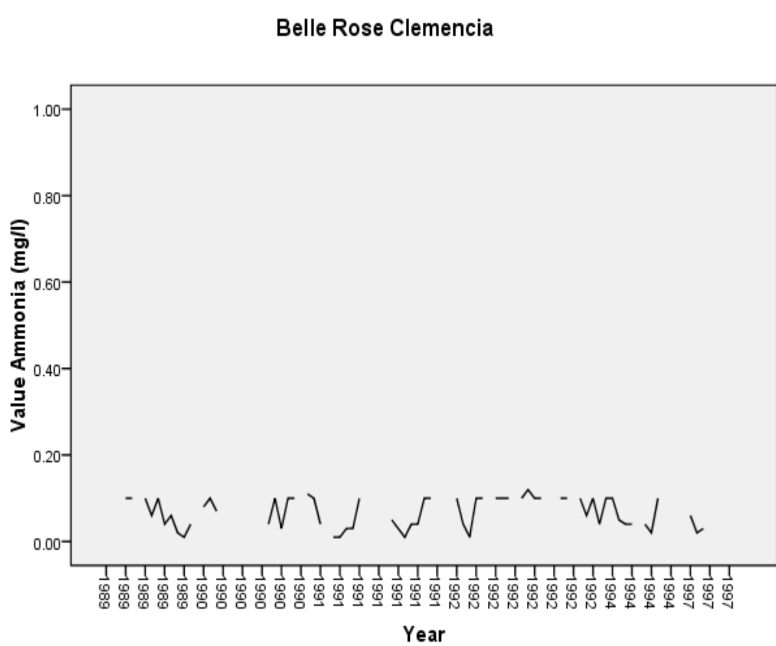
   For e.g.: 1.3 mg/l of nitrate as N = 1.3*64/14 = 5.94 mg/l of nitrate as NO_3-

[4] Excel 2007 and SPSS 16.0

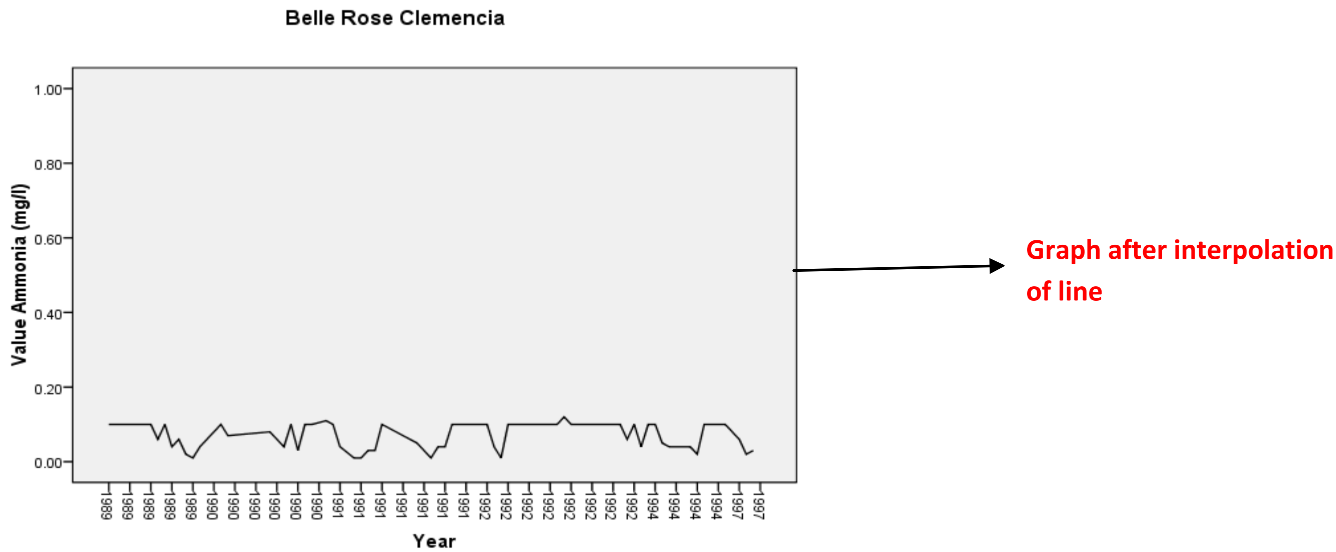


3. *Missing values*

Around 12% of data were missing from the whole database. Out of these, Ammonia readings contribute to around 39% of missing values. Interpolation lines were used to join the different points on graphs where data are missing.



Graph before interpolation of line



4. Data entry errors

Data entry errors were detected while plotting graphs and conducting frequency analysis, including:

- "Zero" values in data sets, especially for Ammonia;
- "Date" entered instead of the numerical value of the measurement;
- Typographical errors (e.g., 0.6 entered instead of 6 for pH).

5. Range of data

Simple descriptive statistics performed on the data indicated the possibility of errors during data collection. For instance, Nitrate readings for the same borehole were found to range from 0.2 to 48 mg/l within the same year. Similar observations were made for Sulphate values. Variations of this magnitude have not yet been explained by the concerned stakeholder and still remain to be verified through further discussion. On the other hand, data for pH and Ammonia remained within a valid range. Please refer to Annex 1 for the detailed statistics.

6. *Changes in boreholes codes*

   Consultation with the WRU revealed that certain boreholes codes had been wrongly assigned on geographical map acquired from the CWA. For example, the code of Camp La Boue borehole was coded as SW26 instead of 226; Grand Bassin borehole was coded as 642 instead of 87, and Barkly borehole was coded as 51 instead of 664.

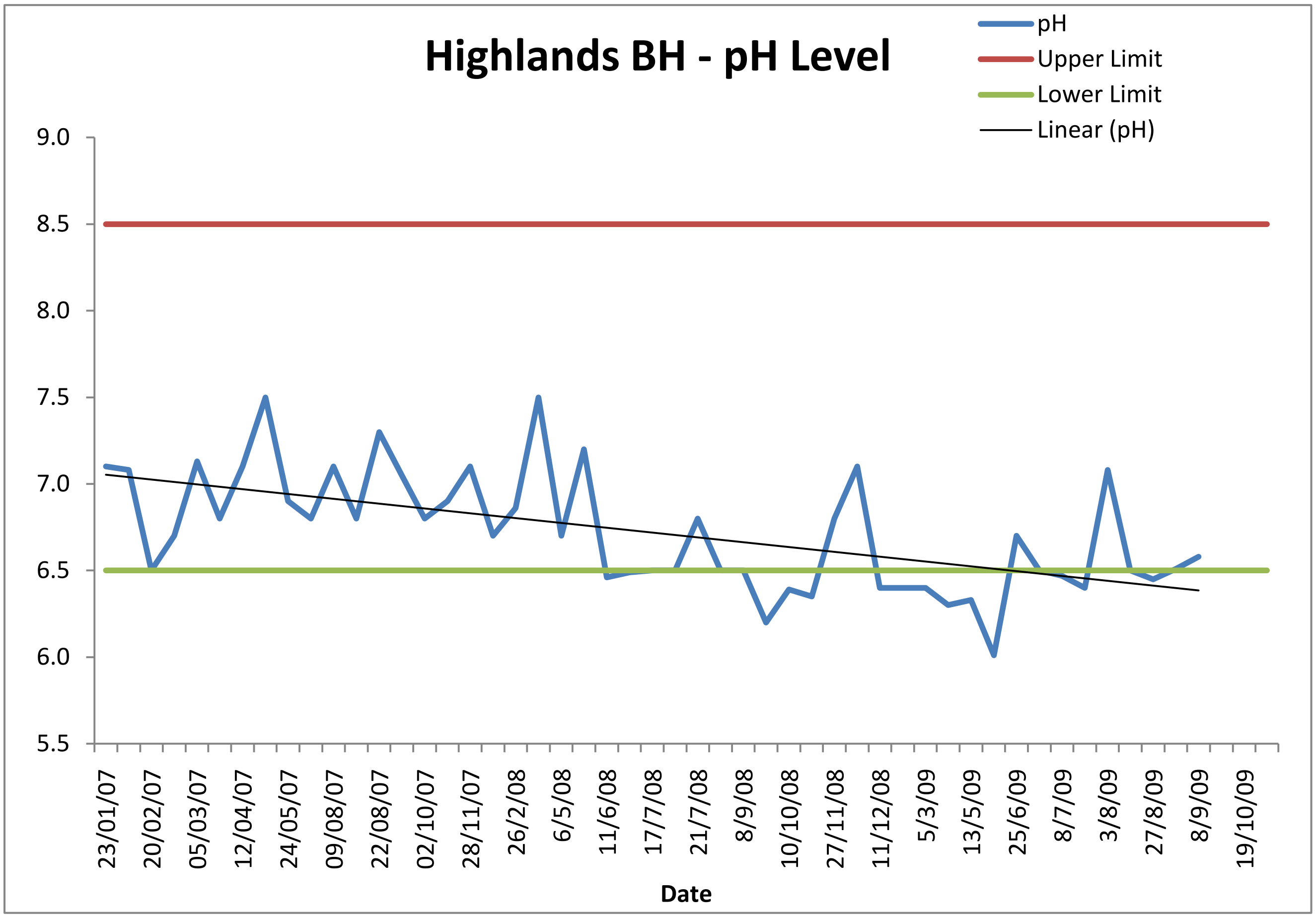
   Given the importance of the correctly assigned code as a unique identifier, it was necessary to verify their accuracy and consistency over time.

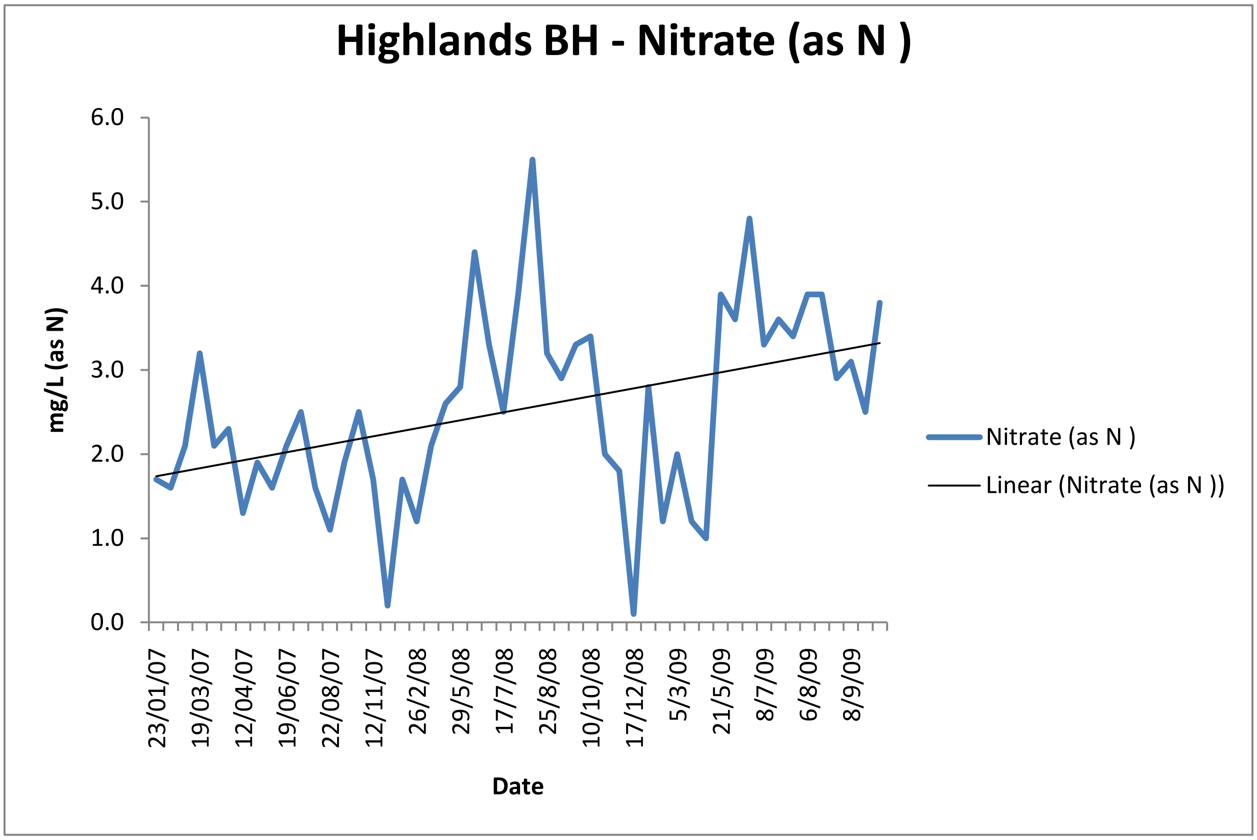
Results

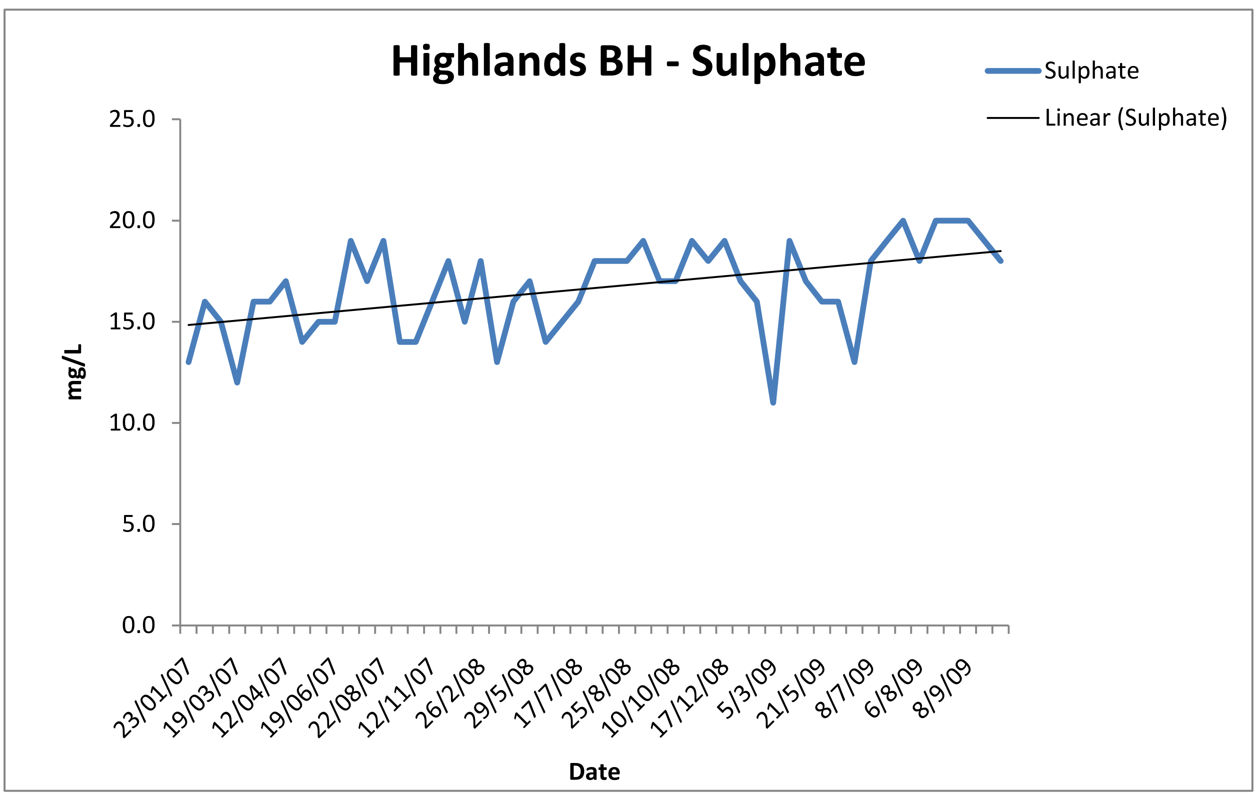
Initial data analysis

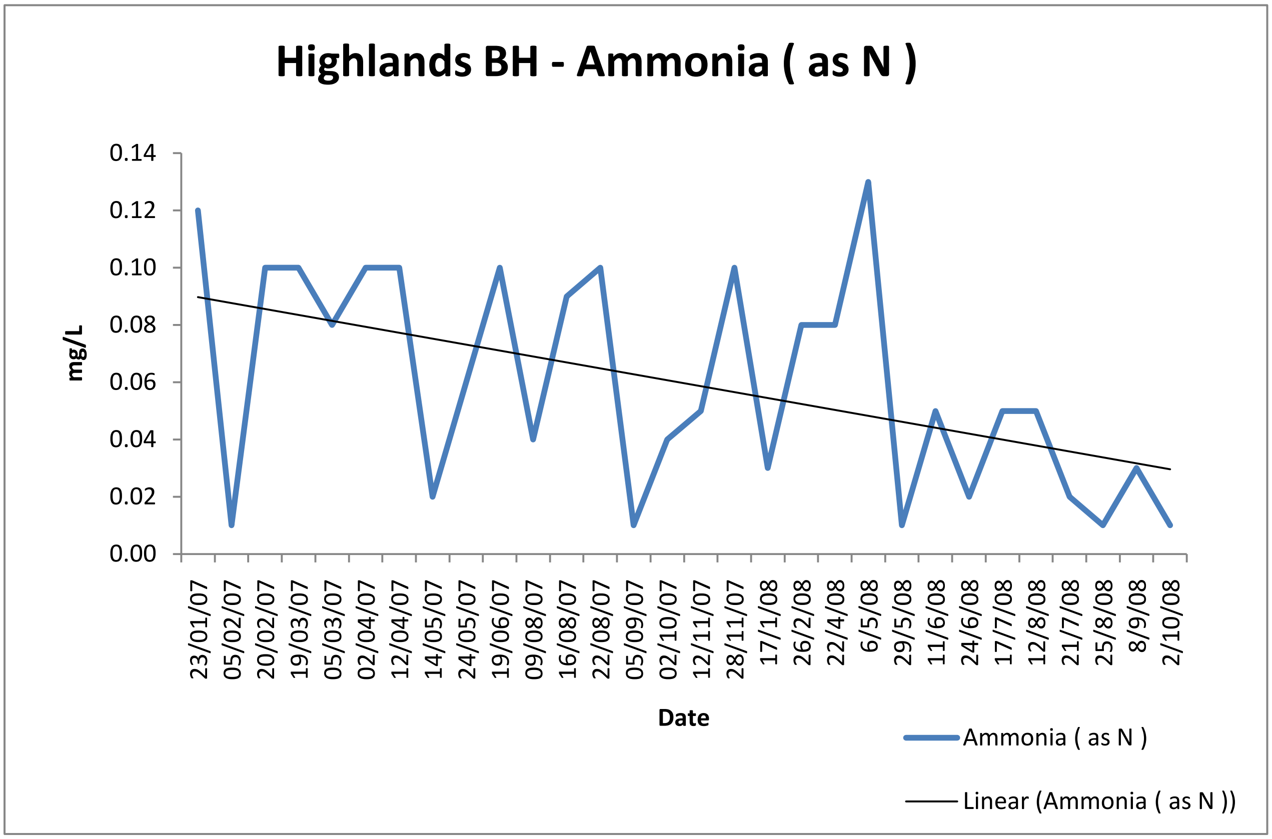
As a first analysis, data representing 21 boreholes (obtained from CWA as soft copy) were plotted to generate trends (over the period 2007 – 2009) of the 30 measured parameters. Out of the 30 parameters, only four showed significant variations, namely pH, Nitrate, Sulphate and Ammonia. Consequently, on this basis, and given that these are also important determinants of the quality of potable water, these parameters were selected for more refined statistical analysis.

Time series have been generated for each element and boreholes. The graphs generated for Highlands borehole (BH) are represented as follows:




Highlands BH - Nitrate (as N)
mg/L (as N)
6.0
5.0
4.0
3.0
2.0
1.0
0.0
23/01/07
19/03/07
12/04/07
19/06/07
22/08/07
12/11/07
26/2/08
29/5/08
17/7/08
25/8/08
10/10/08
17/12/08
5/3/09
21/5/09
8/7/09
6/8/09
8/9/09
Date
Nitrate (as N)
Linear (Nitrate (as N))


Highlands BH - Sulphate
Sulphate
Linear (Sulphate)
mg/L
25.0
20.0
15.0
10.0
5.0
0.0
23/01/07
19/03/07
12/04/07
19/06/07
22/08/07
12/11/07
26/2/08
29/5/08
17/7/08
25/8/08
10/10/08
17/12/08
5/3/09
21/5/09
8/7/09
6/8/09
8/9/09
Date



As per World Health Organisation (WHO) guidelines for potable drinking water[5], to which the CWA adheres, all the elements were found to lie within the safe acceptable limits for human consumption, except pH. Maximum acceptable limits are:

- 50 mg/l for Nitrate;
- 250 mg/l for Sulphate;
- 1.5 mg/l for Ammonia.

The safe acceptable limits for pH lie within 6.5 and 8.5.

[5] Please refer to Annex 2 for a copy of WHO guidelines.

Boreholes where pH values < 6.5 were recorded between 2007 and 2009 are listed below:

- Haute Rive
- Belle Rose
- Caroline
- Choisy
- Clunny
- Fond Du Sac No1
- Highlands
- Petit Camp
- Trois Boutique
- Constance
- Barkly
- Camp La Boue
- Café
- Bananes
- Grand Bassin
- Camp Ithier

Barkly BH had a highest percentage of readings below 6.5 (60%) followed by Highlands BH (40%), Haute Rive BH (33%) and Choisy BH (32%).

<u>Correlations</u>

The data were further analysed on SPSS and correlations between the 4 elements were carried out. The results are as follows:

		pH Level	Nitrate Level	Ammonia Level	Sulphate Level
pH Level	Pearson Correlation	1	-.040	-.034	.021
	Sig. (2-tailed)		.232	.420	.521
	N	924	918	574	906
Nitrate Level	Pearson Correlation	-.040	1	.003	**.355****
	Sig. (2-tailed)	.232		.940	.000
	N	918	931	578	913
Ammonia Level	Pearson Correlation	-.034	.003	1	-.011
	Sig. (2-tailed)	.420	.940		.796
	N	574	578	582	574
Sulphate Level	Pearson Correlation	.021	**.355****	-.011	1
	Sig. (2-tailed)	.521	.000	.796	
	N	906	913	574	919

**. Correlation is significant at the 0.01 level (2-tailed)

The Pearson Correlation shows a significant positive linear relationship between Nitrate and Sulphate at 1% level of significance.

Analysis of water quality data across the years

The following three statistics were calculated and tested for the pH values:

	2007	2008	2009
SD	0.45	0.50	0.48
Mean	6.9	6.9	6.69
CV	6.5	7.28	7.23

The Coefficient of Variation (CV) shows that there is a non-significant variation between the readings within the same year, implying that all readings within one single year revolve around their mean. Furthermore, Levene's test of homogeneity confirms that the variances are similar across the years.

Levene's Test of Equality of Error Variances[a]

Dependent Variable:pH Level

F	df1	*df2*	Sig.
2.630	2	921	.073

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Yr

The same tests were performed for Nitrate, Sulphate and Ammonia, confirming that the variances of readings for the three different years are not same. Please refer to Annex 3 for statistical results.

Analysis Of Variance (ANOVA)

The means of the four parameters were tested for the years 2007, 2008 and 2009. The results show that there is no statistically significant mean difference for Ammonia. On the other hand, a significant difference was noted for the mean of pH between year 2007 vs 2009, and 2008 vs 2009, as shown below:

Multiple Comparisons

pH Level

LSD

(I) Year	(J) Year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
2007	2008	.0338	.03729	.365	-.0394	.1070
	2009	**.2385***	.04046	.000	.1591	.3179
2008	2007	-.0338	.03729	.365	-.1070	.0394
	2009	**.2047***	.03953	.000	.1271	.2822
2009	2007	**-.2385***	.04046	.000	-.3179	-.1591
	2008	**-.2047***	.03953	.000	-.2822	-.1271

Based on observed means.

The error term is Mean Square (Error) = .232.

*. The mean difference is significant at the 0.05 level.

For Nitrate, means for all the three years differ from each other at 5% of significance level. The mean of Sulphate for the year 2007 differs significantly from the means for the years 2008 and 2009. Please refer to Annex 4 for “Multiple Comparisons” tables.

Geographical location of boreholes

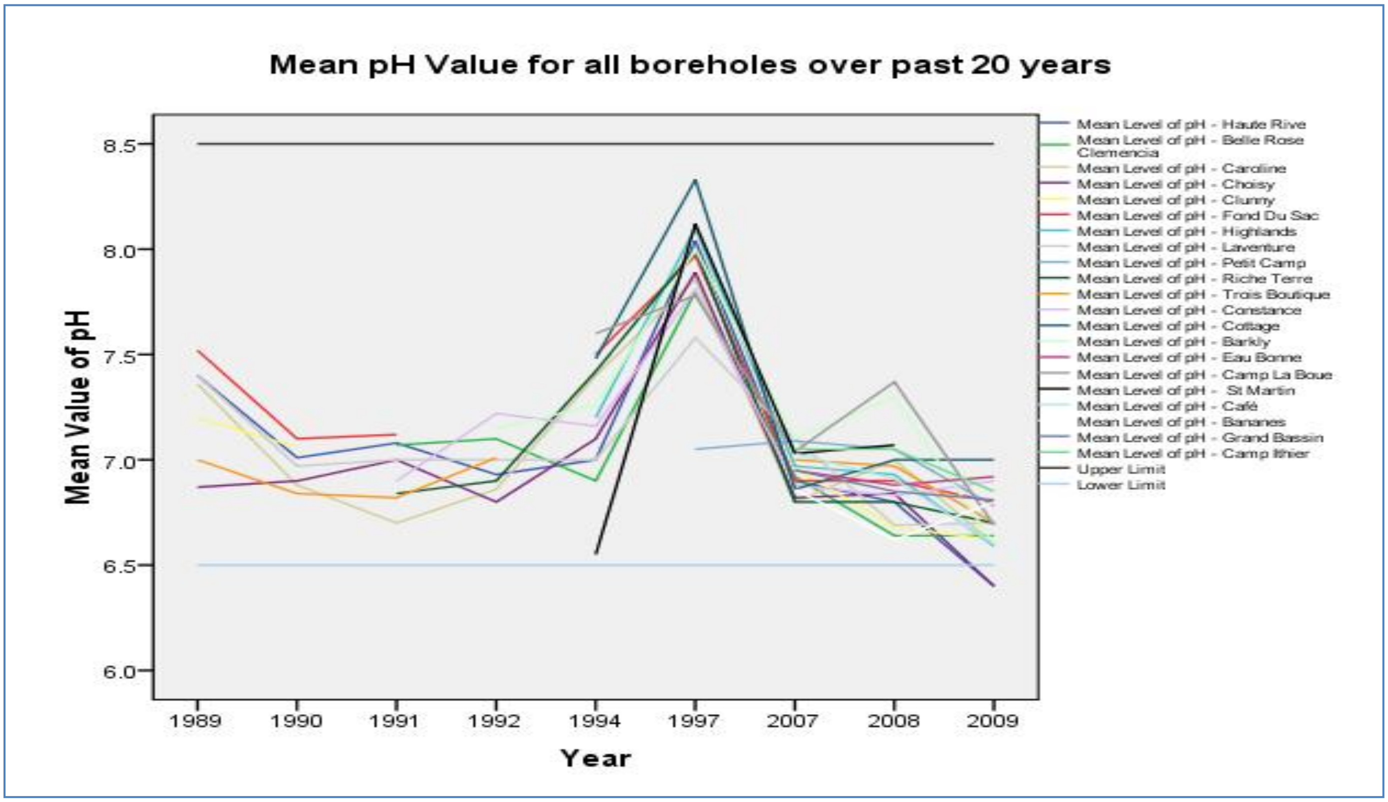
The 21 boreholes were identified on a map received from the CWA. The list of boreholes with low pH is spread across the country, suggesting that the observed lowering of pH is probably not restricted to specific geographical locations. Please refer to Annex 5 for boreholes with low pH.

Extended Analysis

Following the above analysis, similar data obtained for previous years were analysed to determine the extent of variation of the four selected parameters over time. All data analysed were for the years 1989 - 1992, 1994, 1997 and 2007-2009. At this stage of the survey, no information was available for the period 1997 to 2007.

A further step taken during data processing was to arrange the whole data set in SPSS and analyse the variance of the four parameters for each borehole, from 1989 to 2009. Best fit lines were derived for each graph to determine the evolution of the parameters over time. The individual graphs reveal that pH is the only element which has departed from the WHO Guidelines over the past 20 years. Please refer to Annex 6 for graphs of pH for the 21 boreholes.

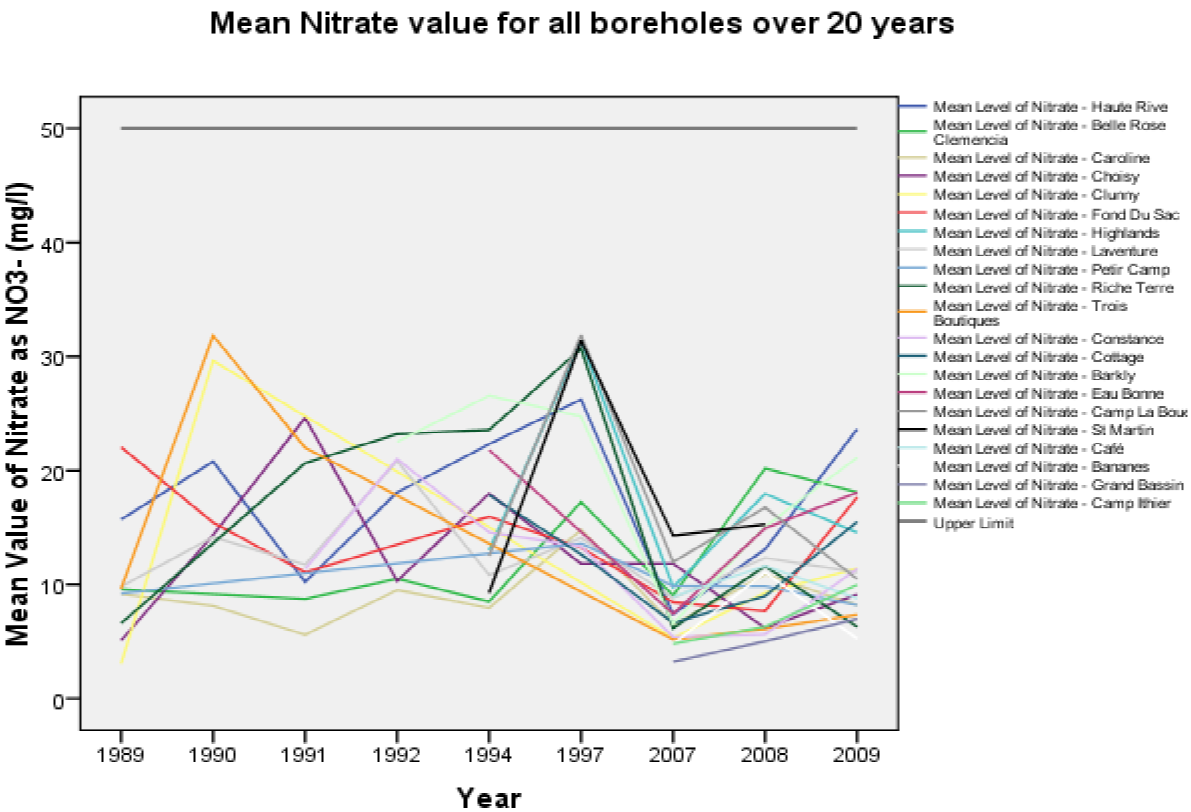
The following graph shows the average pH for each borehole over the 20 year period:



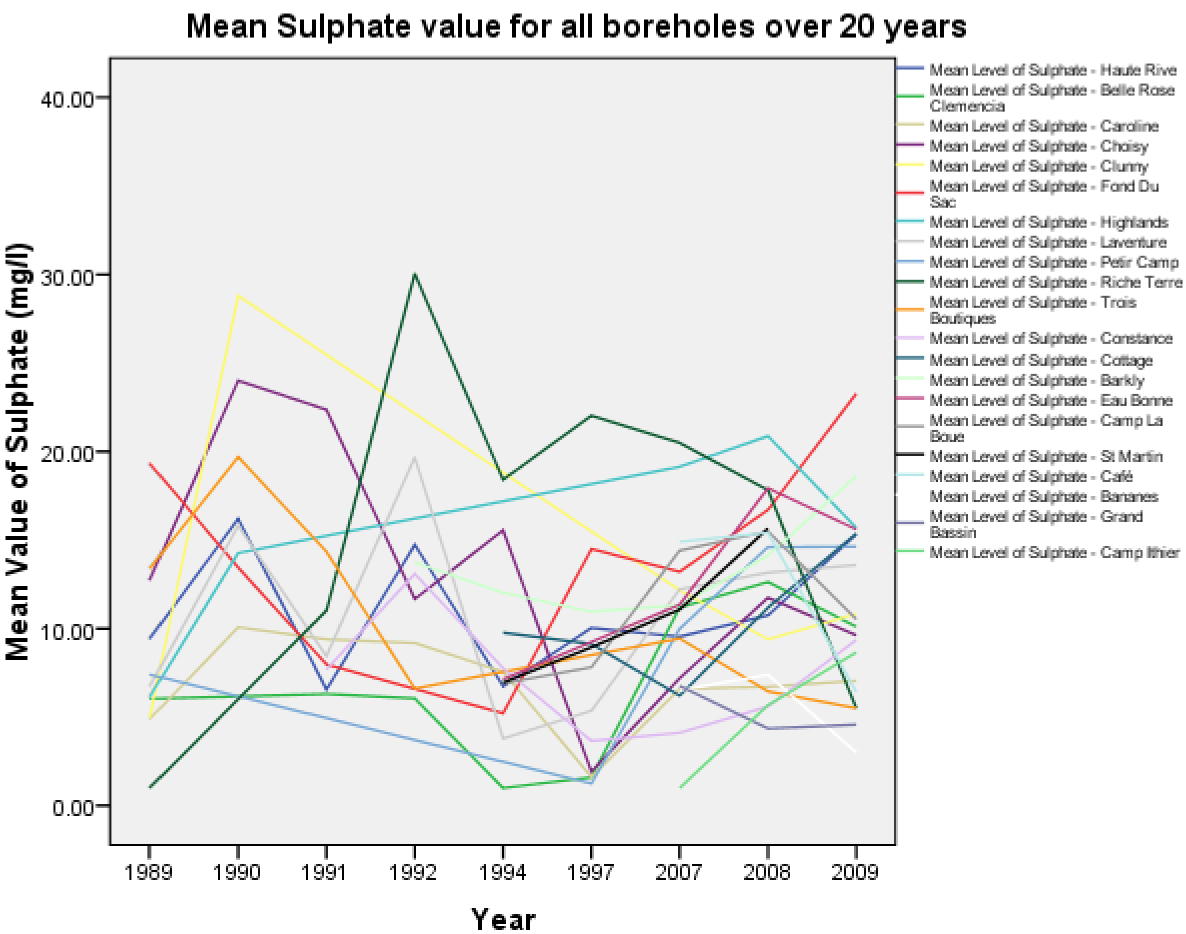
All boreholes show indications of the highest recorded measurement of pH in the year 1997. As from 2007, pH has declined for nearly all boreholes, with some boreholes indicating average annual readings below the minimum safe limit of 6.5.

Nitrate, as illustrated below, increased between 1989 and 1997, although the variations recorded remained below the maximum safe limit established by the WHO. A significant decrease in Nitrate was noted between 1997 and 2007 – however, in the absence of data during that period, this observation remains to be clarified. In contrast, the increasing trend of Nitrate as from 2007 can be observed in nearly all boreholes.

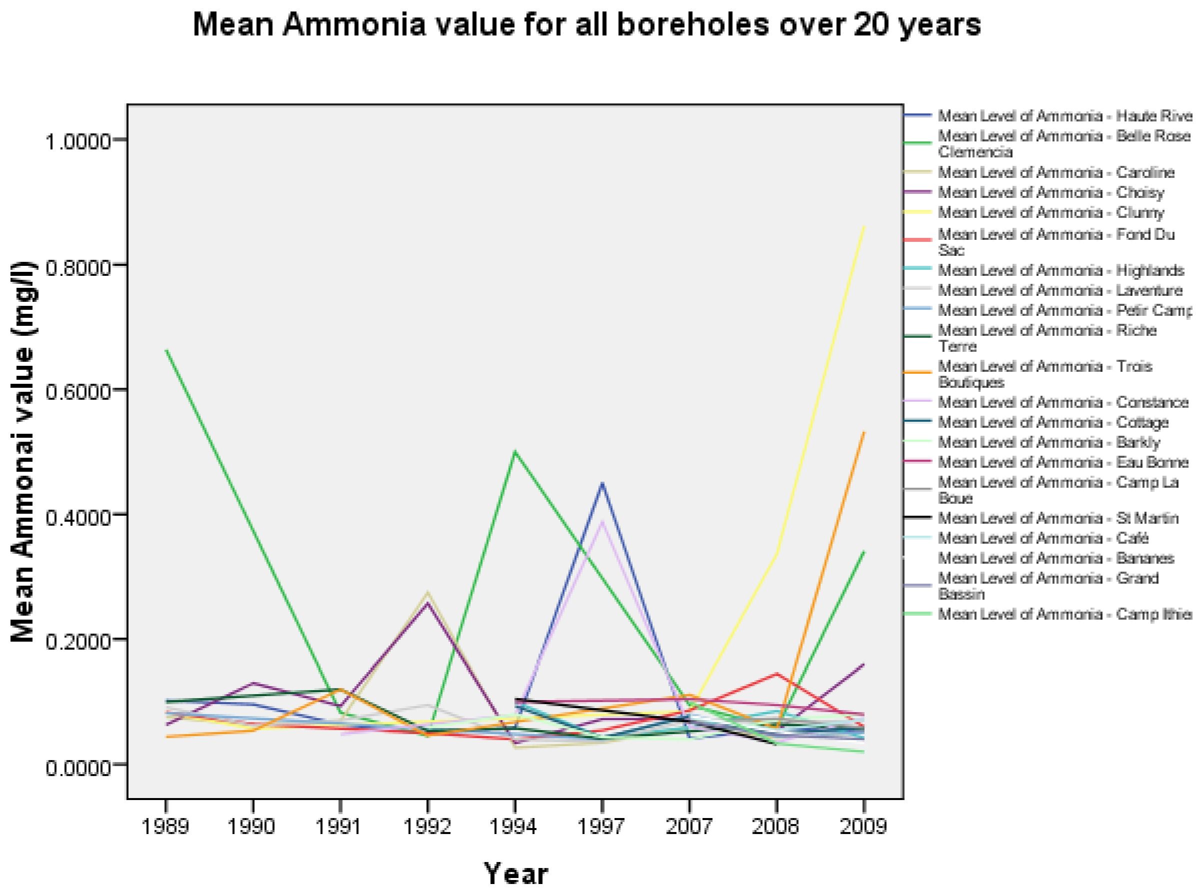
Of interest, both Nitrate and pH were recorded as maximum levels in the year 1997.


Mean Nitrate value for all boreholes over 20 years
Mean Value of Nitrate as NO3- (mg/l)
0
10
20
30
40
50
1989
1990
1991
1992
1994
1997
2007
2008
2009
Year
Mean Level of Nitrate - Haute Rive
Mean Level of Nitrate - Belle Rose Clemencia
Mean Level of Nitrate - Caroline
Mean Level of Nitrate - Choisy
Mean Level of Nitrate - Clunny
Mean Level of Nitrate - Fond Du Sac
Mean Level of Nitrate - Highlands
Mean Level of Nitrate - Laventure
Mean Level of Nitrate - Petir Camp
Mean Level of Nitrate - Riche Terre
Mean Level of Nitrate - Trois Boutiques
Mean Level of Nitrate - Constance
Mean Level of Nitrate - Cottage
Mean Level of Nitrate - Barkly
Mean Level of Nitrate - Eau Bonne
Mean Level of Nitrate - Camp La Boux
Mean Level of Nitrate - St Martin
Mean Level of Nitrate - Café
Mean Level of Nitrate - Bananes
Mean Level of Nitrate - Grand Bassin
Mean Level of Nitrate - Camp Ithier
Upper Limit

The recorded levels of Sulphate showed an upward trend for some boreholes, including Fond Du Sac, Cottage, Camp Ithier, Constance and Barkly. However, the levels of Sulphate have decreased as from 2008 for the majority of boreholes. Since the maximum acceptable limit is 250 mg/l for Sulphate as per the WHO Guidelines, the observed variations are still within norms.



As illustrated below, Ammonia readings are mostly between the values 0 (i.e., non-detected) and 0.2, and remain below the maximum limit set by the WHO Guidelines (1.5 mg/l). It was observed, however, that Ammonia values have increased considerably for individual boreholes at Trois Boutique, Clunny, Camp Ithier and Choisy.



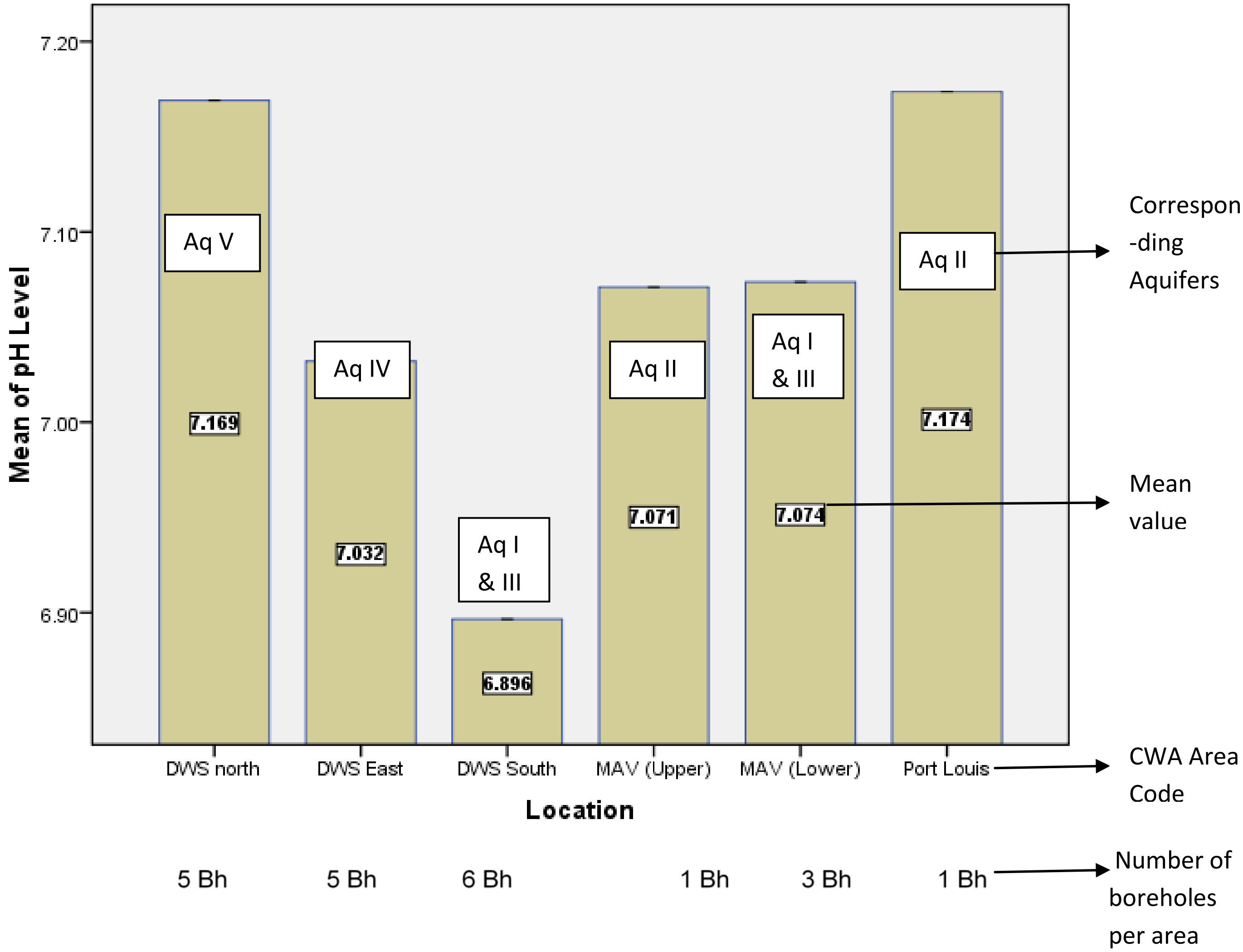
Regional distribution of pH, Nitrate, Sulphate and Ammonia over the period 1989 - 2009

For further analysis, the data were regrouped by regions, as per the CWA Area Code and Aquifers. Please refer to Annex 5 for the CWA Area code and Annex 6 for location of Aquifers I – V.

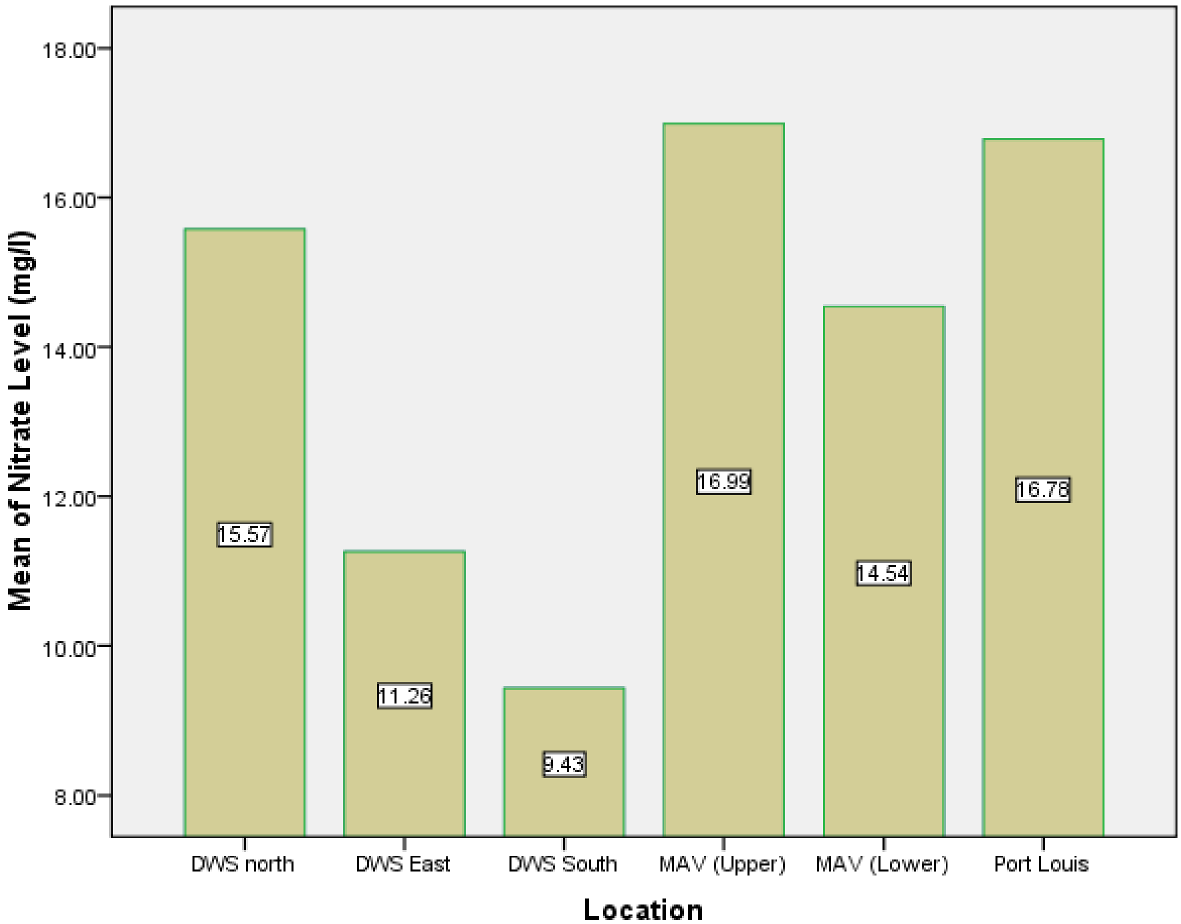
Regional distribution of pH (1989 – 2009)

The following figure shows that the mean pH value for the Southern region of the island has remained lower compared to other regions over the past 20 years. This is also confirmed by an ANOVA (see the Multiple Comparisons table in Annex 7), showing that the mean value of pH for DWS South is statistically different from all the other regions at 5% level of significance.

Note: The aquifers and number of boreholes remain the same for the following graphs of regional distribution of Nitrate, Sulphate and Ammonia.

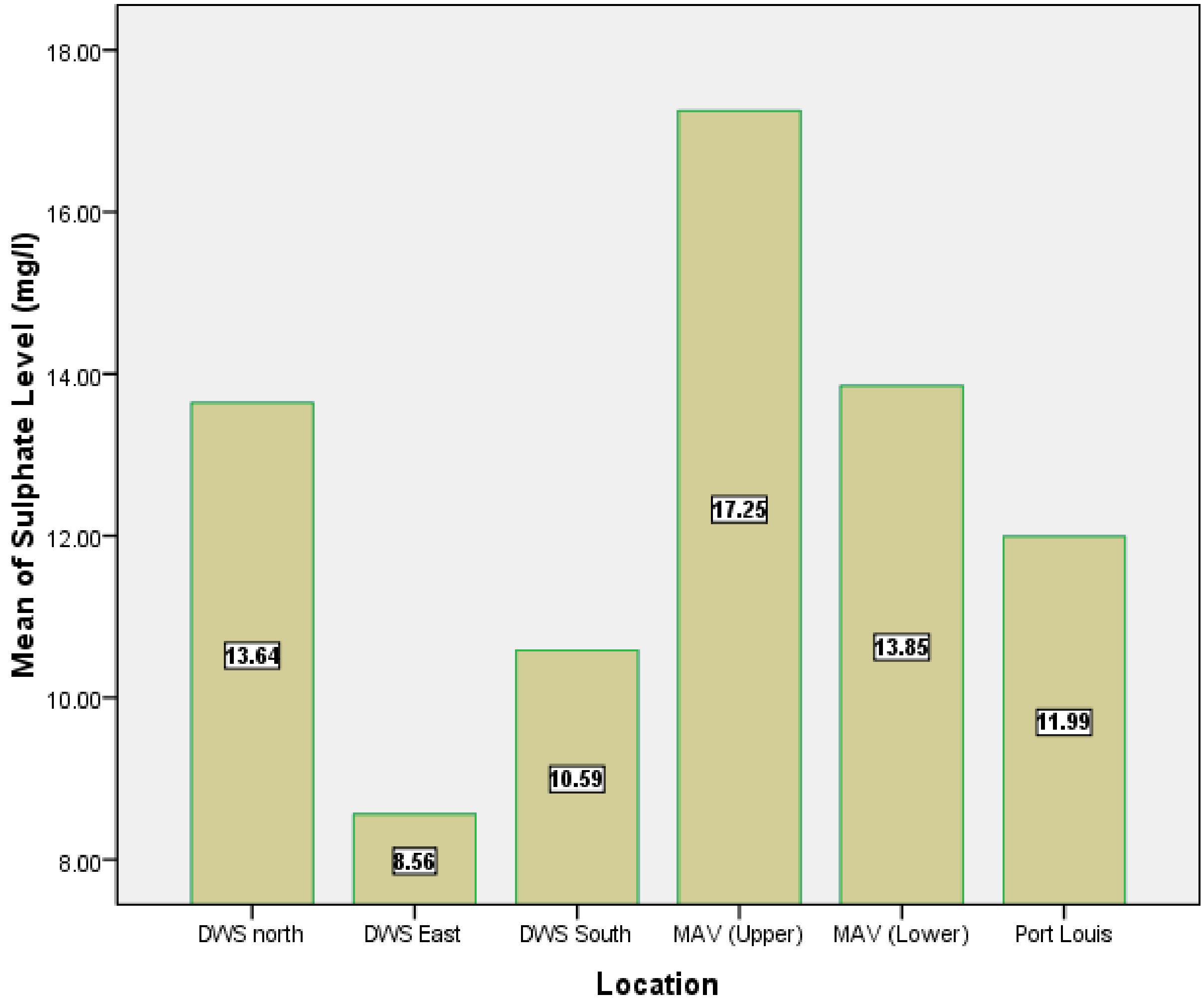


Regional distribution of Nitrate (1989 – 2009)



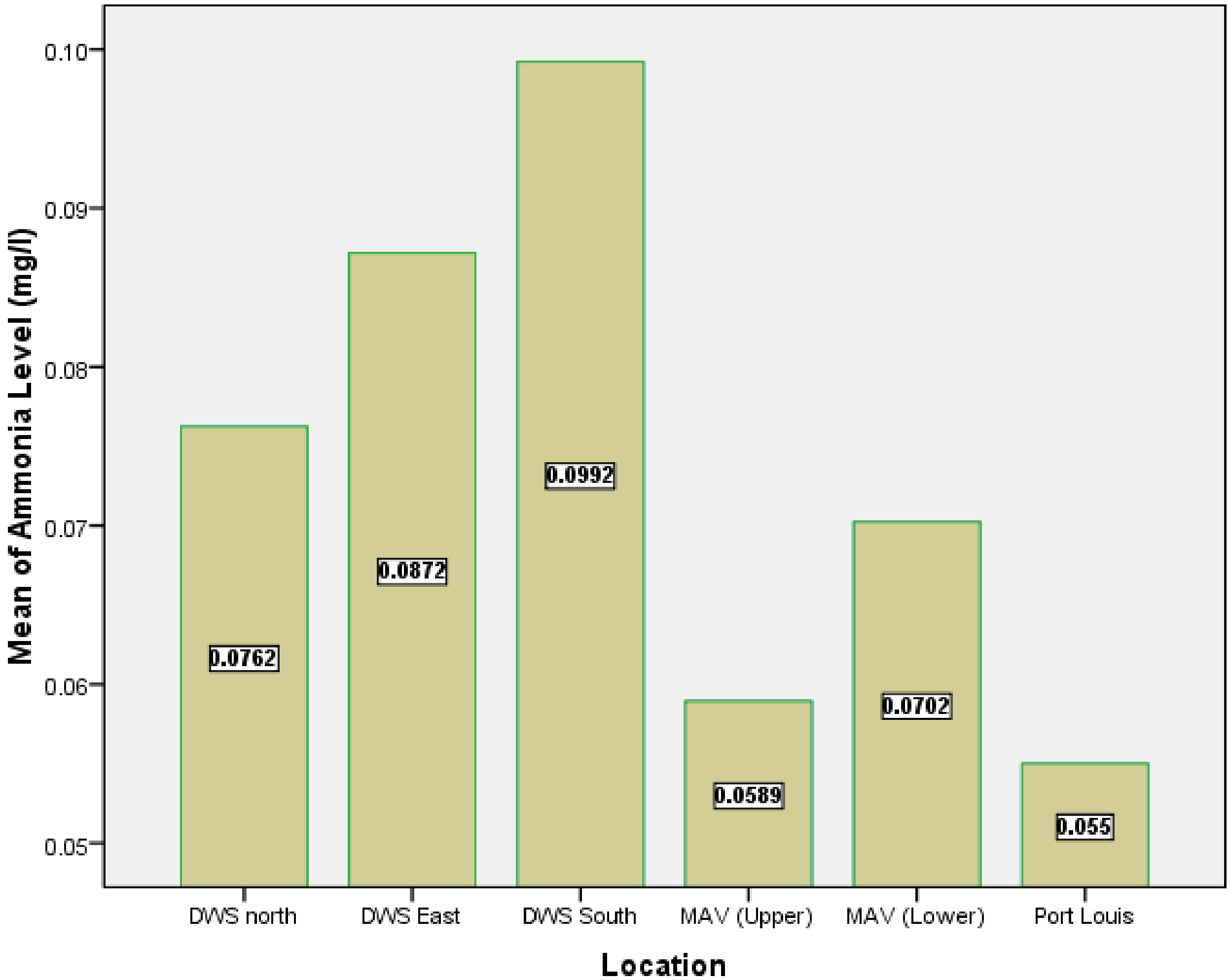
The mean Nitrate levels recorded for DWS East and DWS South are statistically different from the means of the other regions over the 20-year period, at 5% level of significance. On the other hand, the multiple comparisons table in Annex 8 shows that there is no significant difference between the mean values for DWS North, MAV (Upper) and Port Louis.

Regional distribution of Sulphate (1989 – 2009)



Similarly, mean comparisons have been done for Sulphate values recorded over 20 years (please refer to Annex 9). The ANOVA test reported no significant difference between the means.

Regional distribution of Ammonia (1898 – 2009)



The results of the comparison of means for Ammonia recorded over the 20-year period are presented in Annex 10 (the ANOVA test reported no significant difference between the means).

Discussion

During the first phase of the study, the Council carried out a series of rigorous statistical tests on data supplied by the CWA, while building-in information provided by the MSIRI, NEL and WRU. However, interpretation of the results and more importantly, the process of identifying the possible causes in the variations that have been observed, require a broader understanding of the issues involved.

In this context, the results of the first phase of this project were presented for discussion at the second meeting of the Task Group held at the MRC on 18 February 2010. In addition to the institutions represented at the first meeting, representatives from the Albion Fisheries Research Centre (AFRC), Mauritius Meteorological Services (MMS), Mauritius Standards Bureau (MSB), Ministry of Renewable Energy and Public Utilities (MoREPU), and University of Mauritius (UoM), were also present. The following sections include the comments and suggestions made by the Task Group at the second meeting.

Whereas it is considered that, in general, the variations observed over the period 1989 – 2009 for Nitrate, Sulphate and Ammonia, were within acceptable safety limits for potable water used by the CWA (which are based on WHO Guidelines), it would be useful to monitor some of the individual boreholes where significant trends have been observed for the years 2007 – 2009, and before. For example, the decrease in Nitrate noted between 1997 and 2007 (although compounded by the absence of data during that period) remains to be clarified.

With regard to the pH profile of the 21 boreholes examined in the first phase of this study, there is consensus on the need to consider a wider set of data, including those available from the MMS, to help evaluate the complex relationships that exist between precipitation, supply of the aquifers and the influence of geological structures on the flow-paths leading to boreholes, amongst others. The Task Group considered that the decreasing pH observed for a number of boreholes as from 2007 represents a trend that requires more detailed investigations, namely (i) to confirm the observed trends, and (ii) determine their possible causes.

Mapping of additional information that could be sourced from various Ministries and institutions, such as the extent of urban/industrial development, agricultural practices, activities relating to waste disposal, and the expansion of sewage networks, would also assist in identifying possible causes for such changes. The importance of undertaking further work is emphasised by examples such as the peak pH values recorded during the year 1997, which appear to be independent of the geographical location of the boreholes, and the subsequent trends observed in all the boreholes selected for this study.

A similar approach is envisaged for understanding the variations observed on a regional basis, which are based on annual mean values calculated for the 20-year period and therefore may be less dependent on short-term variations induced artificially (i.e., human-driven) or naturally (e.g., cyclones).

Recommendations

On the basis of the results of the first phase of the project and the discussions held, the Task Group recommended that the following be carried out as the way forward:

- To conduct an evaluation of additional data on the quality of water (e.g., untreated water obtained from the same set of boreholes, water quality audits conducted by the Ministry of Health and Quality of Life) for comparison with the current analysis effected on treated water.

- To evaluate the potential influence of seasonal variations (e.g., rainfall) over the period 1989 – 2009, on the levels of pH, Nitrate, Sulphate and Ammonia, as well as other parameters recorded.

- To undertake a close monitoring of boreholes where low pH have been recorded, including additional parameters that could help elucidate possible causes (e.g., dissolved carbon dioxide and sulphur dioxide, seismic profiling). Simultaneously, a comparative exercise could be conducted in collaboration with the relevant authorities of Reunion Island.

- To conduct further statistical analysis, including modelling through the inclusion of seasonal sets of data (e.g. rainfall, cyclones, temperature, etc.) and information obtained from other stakeholders (e.g., Mauritius Meteorological Services, Ministry of Agro Industry, Food Production and Security, Ministry of Housing and Lands).

- To carry out a study on the distribution and flow-paths of water from the aquifers to boreholes.

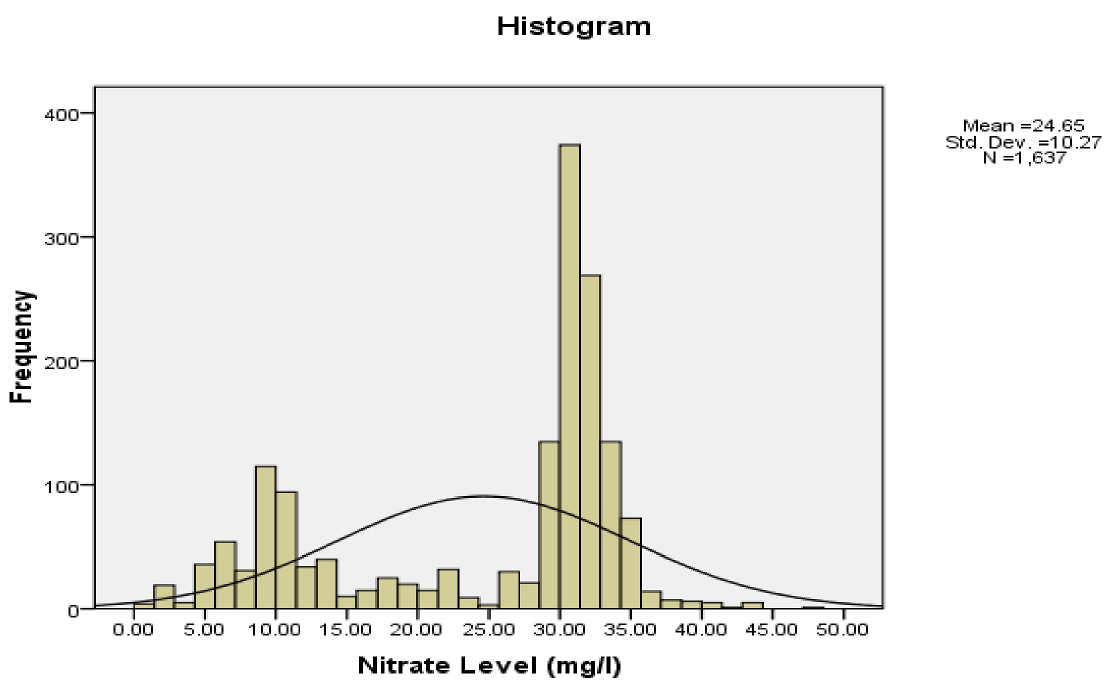
The Task Group further recommended that such studies be led by institutions with responsibility and experience in the assessment and monitoring of water quality in Mauritius.

Annex 1 – Descriptive Statistics

Statistics

Nitrate Level (mg/l)

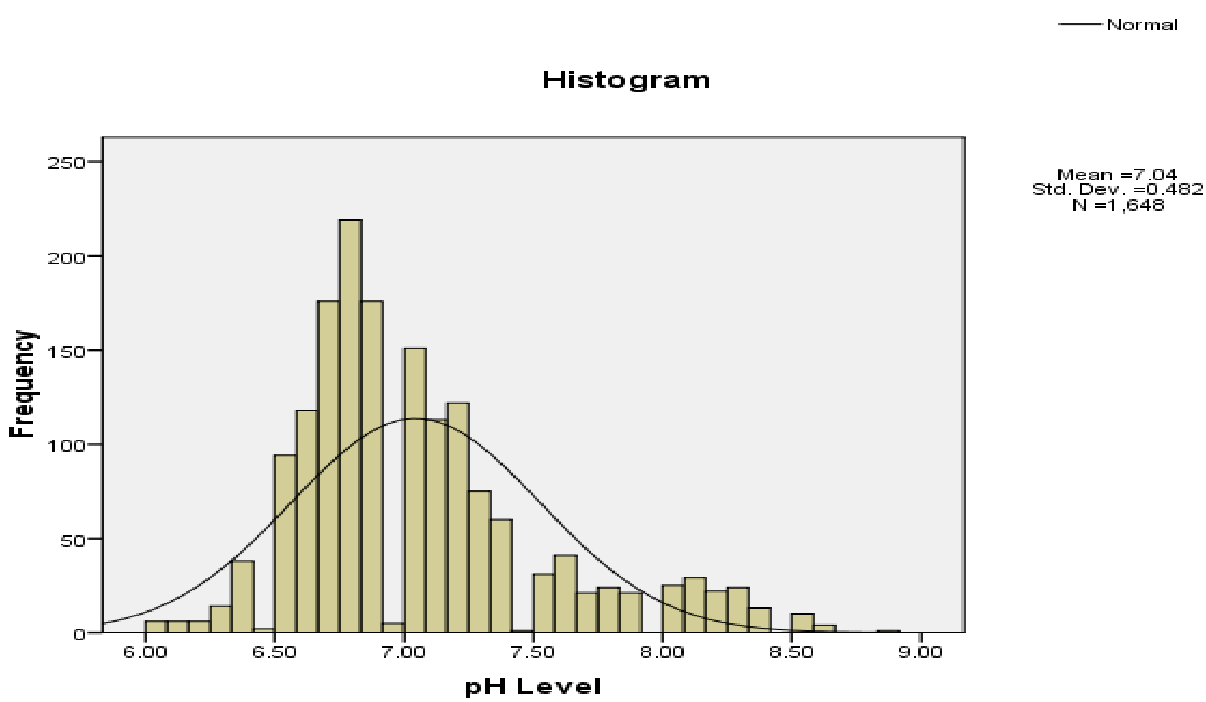
N	Valid	1637
	Missing	40
Mean		24.6477
Median		30.1700
Mode		30.63
Minimum		.20
Maximum		48.00



Statistics

pH Level

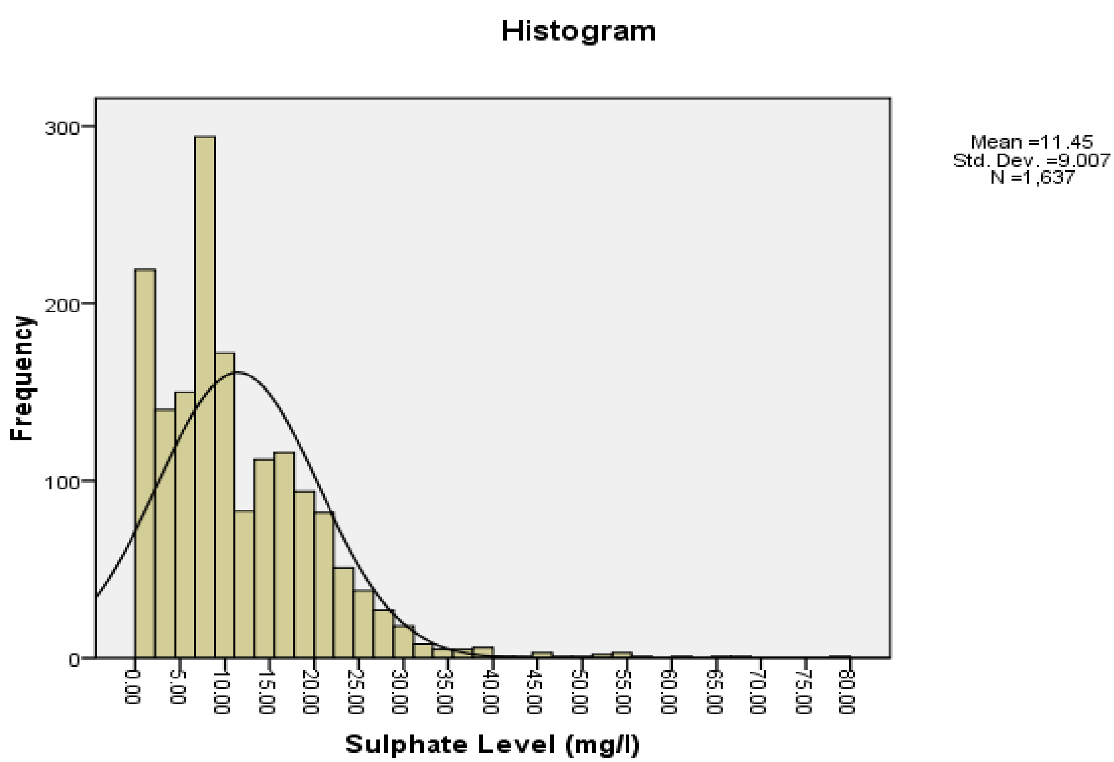
N	Valid	1648
	Missing	29
Mean		7.0445
Median		6.9000
Mode		6.80
Minimum		6.00
Maximum		8.90



Statistics

Sulphate Level (mg/l)

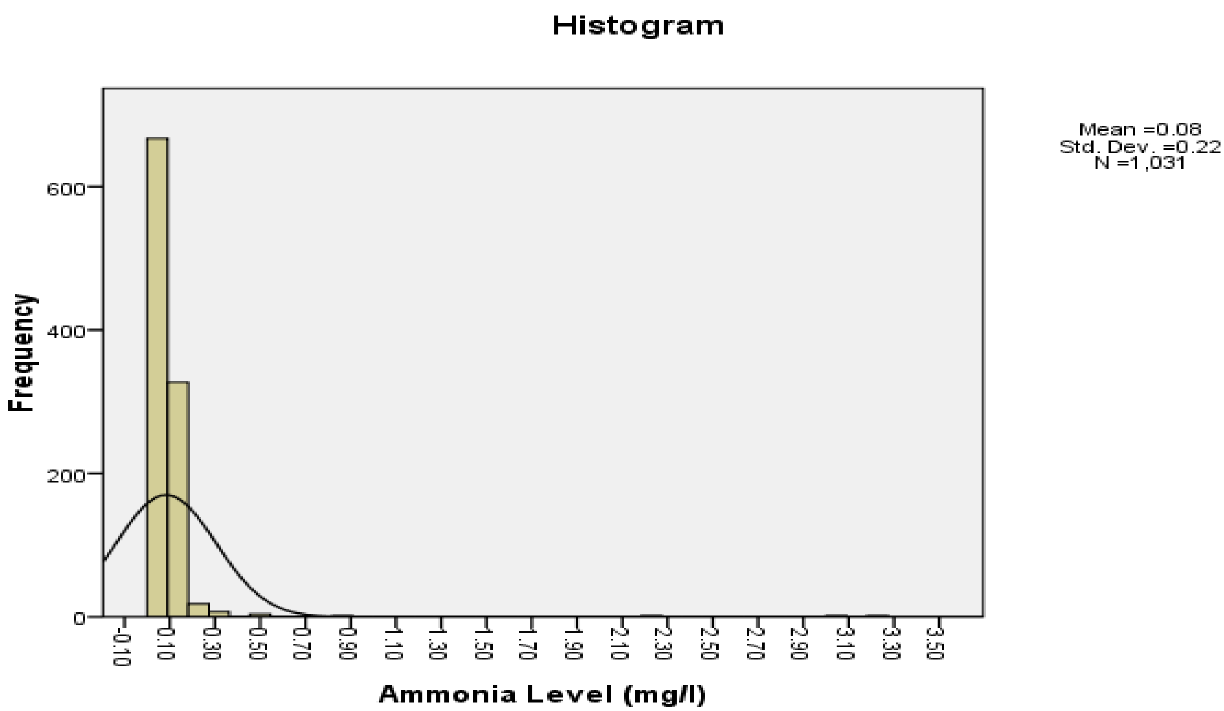
N	Valid	1637
	Missing	40
Mean		11.4491
Median		9.0000
Mode		8.00
Minimum		.10
Maximum		79.00



Statistics

Ammonia Level (mg/l)

N	Valid	1031
	Missing	659
Mean		.0836
Median		.0600
Mode		.10
Minimum		.01
Maximum		3.20



Annex 2 – WHO Guidelines

Attn : Keshma

WHO guidelines.

Annex 2

Table A2.5. Substances and parameters in drinking-water that may give rise to complaints from consumers

	Levels likely to give rise to consumer complaints[a]	Reasons for consumer complaints
Physical parameters		
colour	15 TCU[b]	appearance
taste and odour	--	should be acceptable
temperature	–	should be acceptable
turbidity	5 NTU[c]	appearance, for effective terminal disinfection, median turbidity ≤1NTU, single sample ≤5NTU
Inorganic constituents		
aluminium	0.2 mg/l	depositions, discoloration
ammonia	1.5 mg/l	odour and taste
chloride	250 mg/l	taste, corrosion
copper	1 mg/l	staining of laundry and sanitary ware (health-based provisional guideline value 2 mg/litre)
hardness	–	high hardness: scale deposition, scum formation low hardness: possible corrosion
hydrogen sulfide	0.05 mg/l	odour and taste
iron	0.3 mg/l	staining of laundry and sanitary ware
manganese	0.1 mg/l	staining of laundry and sanitary ware (health-based provisional guideline value 0.5 mg/litre)
dissolved oxygen	–	indirect effects
pH	–	low pH: corrosion high pH: taste, soapy feel preferably <8.0 for effective disinfection with chlorine
sodium	200 mg/l	taste
sulfate	250 mg/l	taste, corrosion
total dissolved solids	1000 mg/l	taste
zinc	3 mg/l	appearance, taste
Organic constituents		
toluene	24–170 µg/l	odour, taste (health-based guideline value 700 µg/l)
xylene	20–1800 µg/l	odour, taste (health-based guideline value 500 µg/l)
ethylbenzene	2–200 µg/l	odour, taste (health-based guideline value 300 µg/l)
styrene	4–2600 µg/l	odour, taste (health-based guideline value 20 µg/l)
monochlorobenzene	10–120 µg/l	odour, taste (health-based guideline value 300 µg/l)
1,2-dichlorobenzene	1–10 µg/l	odour, taste (health-based guideline value 1000 µg/l)
1,4-dichlorobenzene	0.3–30 µg/l	odour, taste (health-based guideline value 300 µg/l)
trichlorobenzenes (total)	5–50 µg/l	odour, taste (health-based guideline value 20 µg/l)
synthetic detergents	–	foaming, taste, odour
Disinfectants and disinfectant by-products		
chlorine	600–1000 µg/l	taste and odour (health-based guideline value 5 mg/l)
chlorophenols		
2-chlorophenol	0.1–10 µg/l	taste, odour
2,4-dichlorophenol	0.3–40 µg/l	taste, odour
2,4,6-trichlorophenol	2–300 µg/l	taste, odour (health-based guideline value 200 µg/l)

[a] The levels indicated are not precise numbers. Problems may occur at lower or higher values according to local circumstances. A range of taste and odour threshold concentrations is given for organic constituents.

[b] TCU, true colour unit.

[c] NTU, nephelometric turbidity unit.

MERCURY	0.001 mg/l
TOTAL CHROMIUM	0.05 mg/l
ZINC	3.0 mg/l
NICKEL	0.02 mg/l

MAXIMUM LIMITS FOR

DRINKING WATER STANDARDS

Anions	
CHLORIDE	250 mg/l
FLUORIDE	1.5 mg/l
SULPHATE	250 mg/l
NITRATE	50 mg/l (as NO_3^-)
NITRITE	3 mg/l (as NO_3^-)
Pesticides	
ALDRIN AND DIELDRIN	0.03 microgram/l
DDT	2 microgram/l
LINDANE	2 microgram/l
HCB	1 microgram/l
METHOXYCHLOR	20 microgram/l
HEPTACHLOR AND HEPTACHLOR OXIDE	0.03 microgram/l

EPA Act 1996 Attn: Reshma

MAXIMUM LIMITS FOR

DRINKING WATER STANDARDS

Microbial	
E. Coli	must not be detectable in any 100 ml sample
COLIFORM ORGANISMS	0 in 95 % samples examined throughout the year. In the case of quantities of water needed for distribution throughout the year, when not less than 50 samples are examined for each period of 30 days, 3 in an occasional sample, but not in consecutive samples.
Physico-Chemical	
pH	6.5 - 8.5
TOTAL DISSOLVED SOLIDS	1000 mg/l
TURBIDITY	5 NTU
Organo Leptic	
COLOUR	20 Pt - Co
TASTE AND ODOUR	Not objectionable
Trace Metals	
ALUMINIUM	0.2 mg/l
ARSENIC	0.01 mg/l
CADMIUM	0.003 mg/l
COPPER	1 mg/l
LEAD	0.01 mg/l
MERCURY	0.001 mg/l
TOTAL CHROMIUM	0.05 mg/l
ZINC	3.0 mg/l
NICKEL	0.02 mg/l

Annex 3 – Univariate Analysis of Variance

Univariate Analysis of Variance - pH

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[DataSet1] C:\Documents and Settings\user\Desktop\CWA DATA\pH analysis_2.sav
```

Between-Subjects Factors

		N
Year	2007	316
	2008	352
	2009	256

Descriptive Statistics

Dependent Variable:pH Level

Year	Mean	Std. Deviation	N
2007	6.9358	.44964	316
2008	6.9019	.50420	352
2009	6.6973	.48645	256
Total	6.8568	.49094	924

Levene's Test of Equality of Error Variances[a]

Dependent Variable:pH Level

F	df1	df2	Sig.
2.630	2	921	.073

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Yr

Estimated Marginal Means

Year

Dependent Variable:pH Level

Year	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
2007	6.936	.027	6.883	6.989
2008	6.902	.026	6.852	6.952
2009	6.697	.030	6.638	6.756

Tests of Between-Subjects Effects

Dependent Variable:pH Level

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	9.203[a]	2	4.601	19.872	.000
Intercept	42544.041	1	42544.041	1.837E5	.000
Yr	9.203	2	4.601	19.872	.000
Error	213.257	921	.232		
Total	43664.929	924			
Corrected Total	222.460	923			

a. R Squared = .041 (Adjusted R Squared = .039)

Post Hoc Tests

Year

Multiple Comparisons

pH Level

LSD

(I) Year	(J) Year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
2007	2008	.0338	.03729	.365	-.0394	.1070
	2009	.2385*	.04046	.000	.1591	.3179
2008	2007	-.0338	.03729	.365	-.1070	.0394
	2009	.2047*	.03953	.000	.1271	.2822
2009	2007	-.2385*	.04046	.000	-.3179	-.1591
	2008	-.2047*	.03953	.000	-.2822	-.1271

Based on observed means.

The error term is Mean Square(Error) = .232.

*. The mean difference is significant at the .05 level.

Univariate Analysis of Variance – Nitrate as N

```
[DataSet1] C:\Documents and Settings\user\Desktop\CWA DATA\pH analysis_2.sav
```

Between-Subjects Factors

		N
Year	2007	315
	2008	355
	2009	261

Descriptive Statistics

Dependent Variable:Nitrate Level

Year	Mean	Std. Deviation	N
2007	1.6057	1.21363	315
2008	2.3113	1.53988	355
2009	2.7548	2.36470	261
Total	2.1969	1.78155	931

Levene's Test of Equality of Error Variances[a]

Dependent Variable:Nitrate Level

F	df1	df2	Sig.
13.220	2	928	.000

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Yr

Estimated Marginal Means

Year

Dependent Variable:Nitrate Level

Year	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
2007	1.606	.097	1.415	1.796
2008	2.311	.091	2.132	2.491
2009	2.755	.107	2.545	2.964

Tests of Between-Subjects Effects

Dependent Variable:Nitrate Level

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	195.970[a]	2	97.985	32.996	.000
Intercept	4531.496	1	4531.496	1.526E3	.000
Yr	195.970	2	97.985	32.996	.000
Error	2755.771	928	2.970		
Total	7445.030	931			
Corrected Total	2951.741	930			

a. R Squared = .066 (Adjusted R Squared = .064)

Post Hoc Tests

Year

Multiple Comparisons

Nitrate Level

LSD

(I) Year	(J) Year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
2007	2008	-.7056*	.13339	.000	-.9673	-.4438
	2009	-1.1491*	.14424	.000	-1.4321	-.8660
2008	2007	.7056*	.13339	.000	.4438	.9673
	2009	-.4435*	.14051	.002	-.7193	-.1678
2009	2007	1.1491*	.14424	.000	.8660	1.4321
	2008	.4435*	.14051	.002	.1678	.7193

Based on observed means.

The error term is Mean Square(Error) = 2.970.

*. The mean difference is significant at the .05 level.

Univariate Analysis of Variance - Sulphate

```
[DataSet1] C:\Documents and Settings\user\Desktop\CWA DATA\pH analysis_2.sav
```

Between-Subjects Factors

		N
Year	2007	312
	2008	352
	2009	255

Descriptive Statistics

Dependent Variable:Sulphate Level

Year	Mean	Std. Deviation	N
2007	10.4590	6.40330	312
2008	11.9375	7.15052	352
2009	11.8106	6.85305	255
Total	11.4003	6.84788	919

Levene's Test of Equality of Error Variances[a]

Dependent Variable:Sulphate Level

F	df1	df2	Sig.
5.405	2	916	.005

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Yr

Estimated Marginal Means

Year

Dependent Variable:Sulphate Level

Year	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
2007	10.459	.386	9.701	11.217
2008	11.938	.364	11.224	12.651
2009	11.811	.427	10.972	12.649

Tests of Between-Subjects Effects

Dependent Variable:Sulphate Level

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	420.969[a]	2	210.484	4.523	.011
Intercept	117392.596	1	117392.596	2.523E3	.000
Yr	420.969	2	210.484	4.523	.011
Error	42627.281	916	46.536		
Total	162488.330	919			
Corrected Total	43048.250	918			

a. R Squared = .010 (Adjusted R Squared = .008)

Post Hoc Tests

Year

Multiple Comparisons

Sulphate Level

LSD

(I) Year	(J) Year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
2007	2008	-1.4785*	.53043	.005	-2.5195	-.4375
	2009	-1.3516*	.57589	.019	-2.4818	-.2214
2008	2007	1.4785*	.53043	.005	.4375	2.5195
	2009	.1269	.56098	.821	-.9740	1.2279
2009	2007	1.3516*	.57589	.019	.2214	2.4818
	2008	-.1269	.56098	.821	-1.2279	.9740

Based on observed means.

The error term is Mean Square(Error) = 46.536.

*. The mean difference is significant at the .05 level.

Univariate Analysis of Variance - Ammonia

Between-Subjects Factors

		N
Year	2007	174
	2008	267
	2009	141

Descriptive Statistics

Dependent Variable:Ammonia Level

Year	Mean	Std. Deviation	N
2007	.0771	.04770	174
2008	.0709	.15173	267
2009	.0994	.36401	141
Total	.0797	.20803	582

Levene's Test of Equality of Error Variances[a]

Dependent Variable:Ammonia Level

F	df1	df2	Sig.
3.294	2	579	.038

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Yr

Estimated Marginal Means

Year

Dependent Variable:Ammonia Level

Year	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
2007	.077	.016	.046	.108
2008	.071	.013	.046	.096
2009	.099	.018	.065	.134

Tests of Between-Subjects Effects

Dependent Variable:Ammonia Level

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	.077[a]	2	.038	.885	.413
Intercept	3.692	1	3.692	85.271	.000
Yr	.077	2	.038	.885	.413
Error	25.067	579	.043		
Total	28.838	582			
Corrected Total	25.144	581			

a. R Squared = .003 (Adjusted R Squared = .000)

Post Hoc Tests

Year

Multiple Comparisons

Ammonia Level

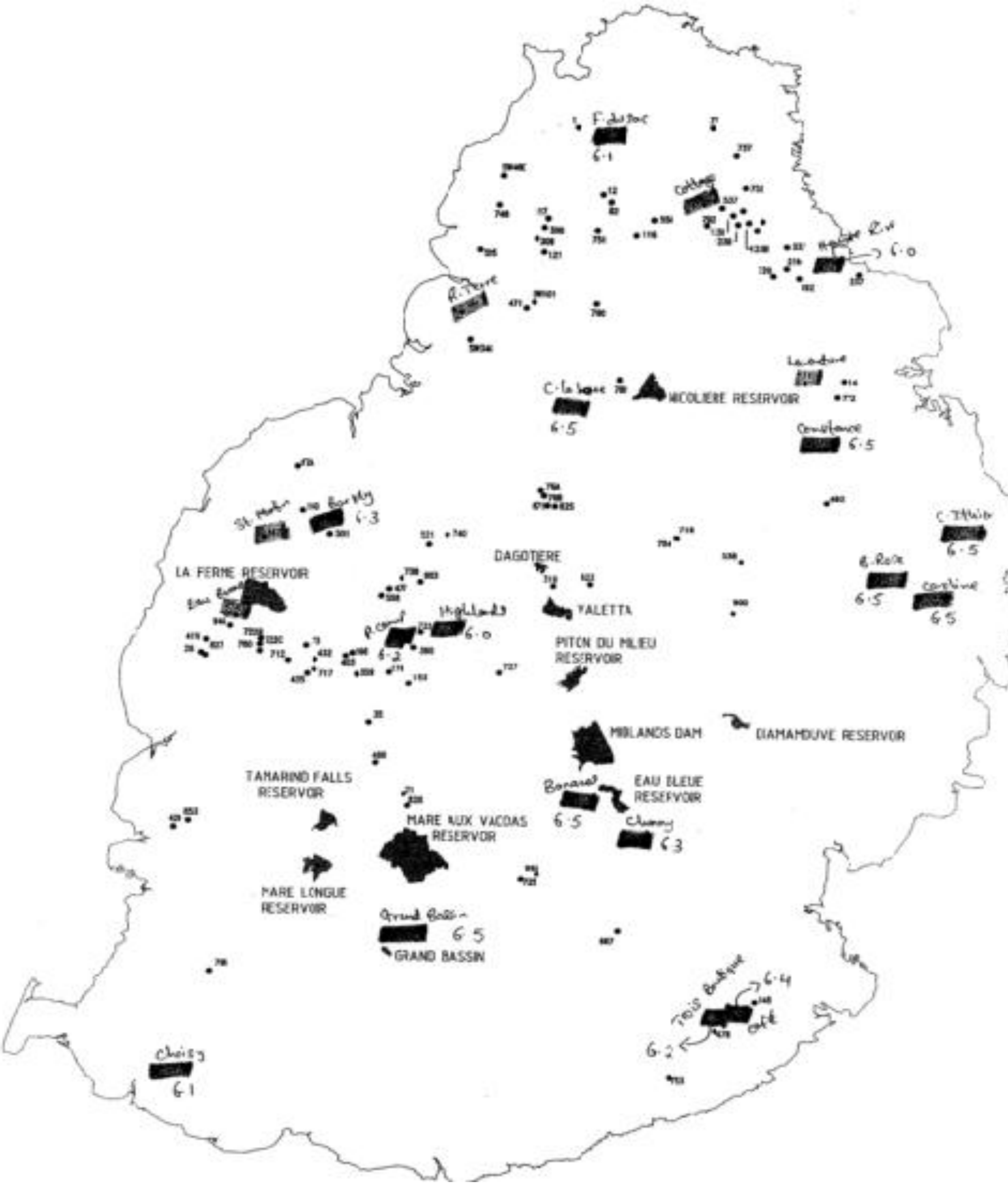
LSD

(I) Year	(J) Year	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
2007	2008	.0061	.02027	.762	-.0337	.0459
	2009	-.0224	.02358	.343	-.0687	.0239
2008	2007	-.0061	.02027	.762	-.0459	.0337
	2009	-.0285	.02166	.189	-.0710	.0140
2009	2007	.0224	.02358	.343	-.0239	.0687
	2008	.0285	.02166	.189	-.0140	.0710

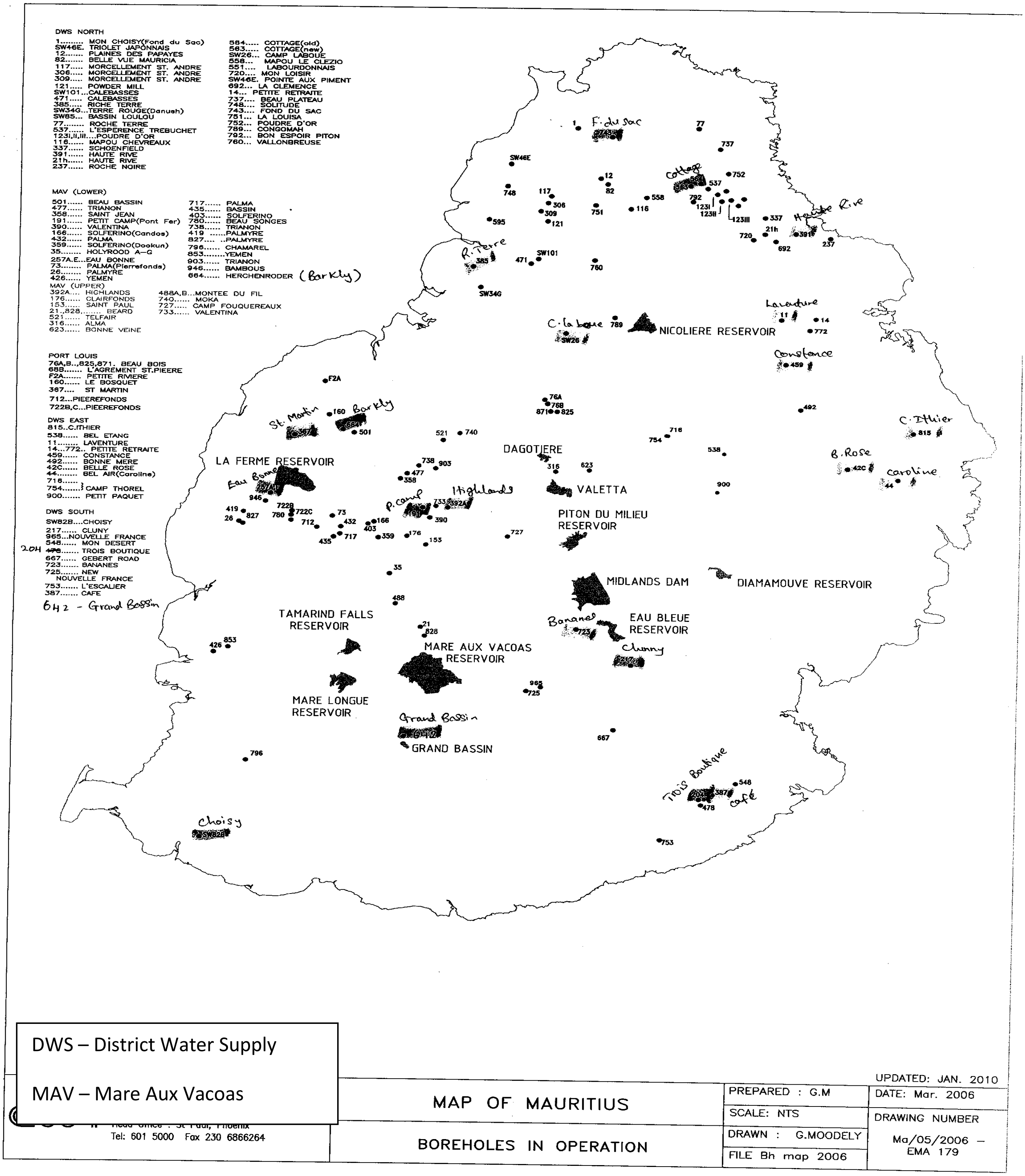
Based on observed means.

The error term is Mean Square(Error) = .043.

Annex 4 – Boreholes with low pH



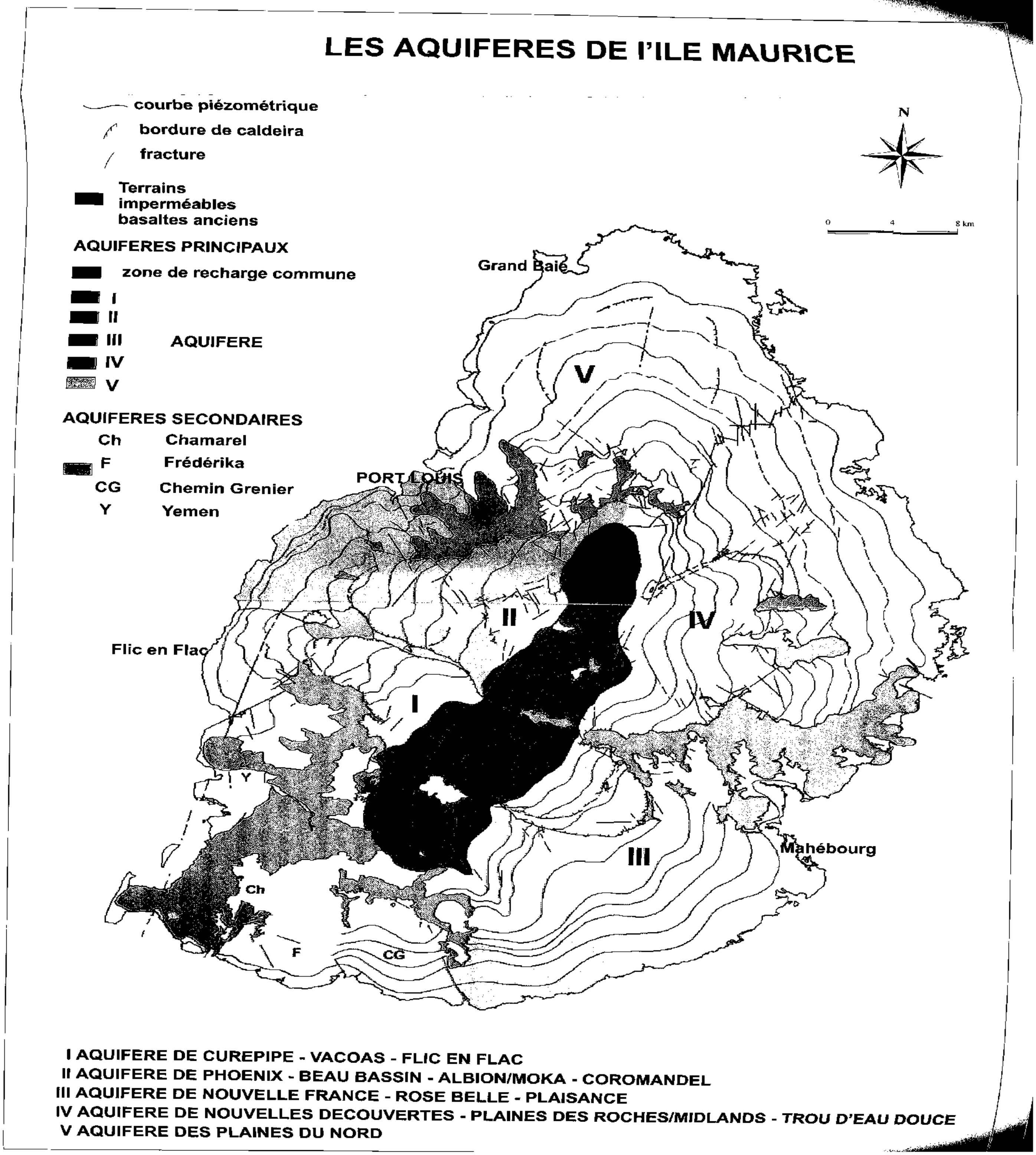
Annex 5 – CWA Area Codes



DWS – District Water Supply

MAV – Mare Aux Vacoas

Annex 6 – Aquifers



Annex 7 – One way Analysis of Variance - pH

Oneway

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[DataSet1] C:\Documents and Settings\user\Desktop\CWA DATA\Recent workings\pH analysis
_2.sav
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Descriptives

pH Level

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maxim
					Lower Bound	Upper Bound		
DWS north	480	7.1692	.54518	.02488	7.1203	7.2181	6.00	
DWS East	509	7.0320	.43522	.01929	6.9941	7.0699	6.00	
DWS South	425	6.8965	.38668	.01876	6.8596	6.9334	6.00	
MAV (Upper)	69	7.0710	.64981	.07823	6.9149	7.2271	6.00	
MAV (Lower)	138	7.0737	.44968	.03828	6.9980	7.1494	6.30	
Port Louis	27	7.1737	.52027	.10013	6.9679	7.3795	6.10	
Total	1648	7.0445	.48217	.01188	7.0212	7.0678	6.00	

Test of Homogeneity of Variances

pH Level

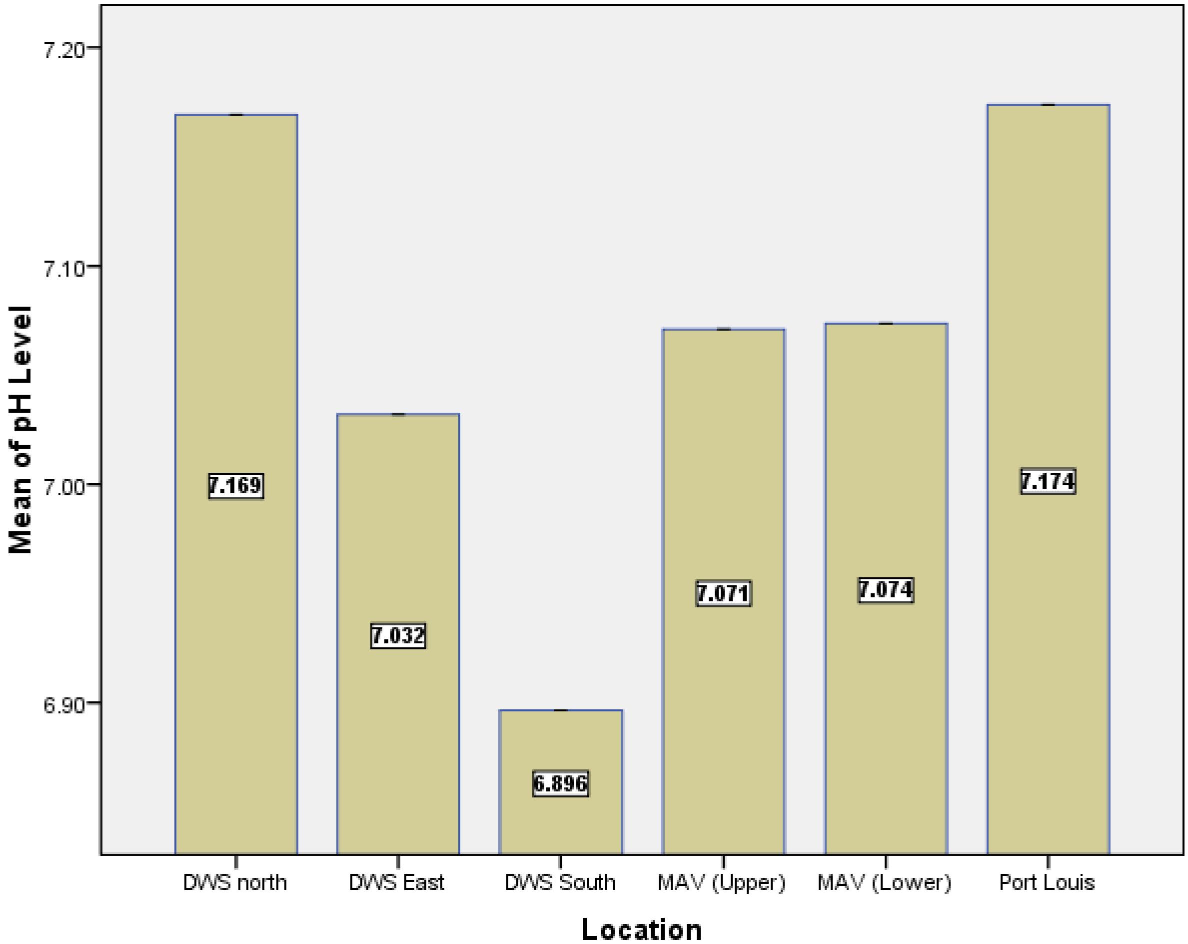
Levene Statistic	df1	df2	Sig.
14.185	5	1642	.000

ANOVA

pH Level

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	17.469	5	3.494	15.698	.000
Within Groups	365.442	1642	.223		
Total	382.910	1647			

Means Plots



7.20
7.10
7.00
6.90
Mean of pH Level
7.169
7.032
6.896
7.071
7.074
7.174
DWS north
DWS East
DWS South
MAV (Upper)
MAV (Lower)
Port Louis
Location

Post Hoc Tests

Multiple Comparisons

pH Level LSD

(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
DWS north	DWS East	.13716*	.03002	.000	.0783	.1960
	DWS South	.27269*	.03142	.000	.2111	.3343
	MAV (Upper)	.09817	.06074	.106	-.0210	.2173
	MAV (Lower)	.09549*	.04557	.036	.0061	.1849
	Port Louis	-.00452	.09331	.961	-.1875	.1785
DWS East	DWS north	-.13716*	.03002	.000	-.1960	-.0783
	DWS South	.13553*	.03100	.000	.0747	.1963
	MAV (Upper)	-.03899	.06052	.519	-.1577	.0797
	MAV (Lower)	-.04167	.04528	.358	-.1305	.0471
	Port Louis	-.14168	.09317	.129	-.3244	.0411
DWS South	DWS north	-.27269*	.03142	.000	-.3343	-.2111
	DWS East	-.13553*	.03100	.000	-.1963	-.0747
	MAV (Upper)	-.17452*	.06123	.004	-.2946	-.0544
	MAV (Lower)	-.17720*	.04622	.000	-.2679	-.0865
	Port Louis	-.27721*	.09363	.003	-.4609	-.0936
MAV (Upper)	DWS north	-.09817	.06074	.106	-.2173	.0210
	DWS East	.03899	.06052	.519	-.0797	.1577
	DWS South	.17452*	.06123	.004	.0544	.2946
	MAV (Lower)	-.00268	.06956	.969	-.1391	.1337
	Port Louis	-.10269	.10709	.338	-.3127	.1074
MAV (Lower)	DWS north	-.09549*	.04557	.036	-.1849	-.0061
	DWS East	.04167	.04528	.358	-.0471	.1305
	DWS South	.17720*	.04622	.000	.0865	.2679
	MAV (Upper)	.00268	.06956	.969	-.1337	.1391
	Port Louis	-.10001	.09928	.314	-.2947	.0947

Port Louis	DWS north	.00452	.09331	.961	-.1785	.1875
	DWS East	.14168	.09317	.129	-.0411	.3244
	DWS South	.27721*	.09363	.003	.0936	.4609
	MAV (Upper)	.10269	.10709	.338	-.1074	.3127
	MAV (Lower)	.10001	.09928	.314	-.0947	.2947

*. The mean difference is significant at the 0.05 level.

Annex 8 – One way Analysis of Variance – Nitrate as NO_3^-

Oneway

[DataSet1] C:\Documents and Settings\user\Desktop\CWA DATA\Recent workings\pH analysis _2.sav

Descriptives

Nitrate Level (mg/l)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maxim
					Lower Bound	Upper Bound		
DWS north	467	15.5734	10.08118	.46650	14.6567	16.4901	.46	
DWS East	504	11.2597	7.40558	.32987	10.6116	11.9078	.40	
DWS South	415	9.4336	7.81221	.38349	8.6798	10.1874	.20	
MAV (Upper)	74	16.9873	10.14134	1.17891	14.6377	19.3369	1.37	
MAV (Lower)	138	14.5430	7.60374	.64727	13.2630	15.8229	.46	
Port Louis	27	16.7789	10.46064	2.01315	12.6408	20.9170	4.11	
Total	1625	12.6644	8.95016	.22203	12.2289	13.0999	.20	

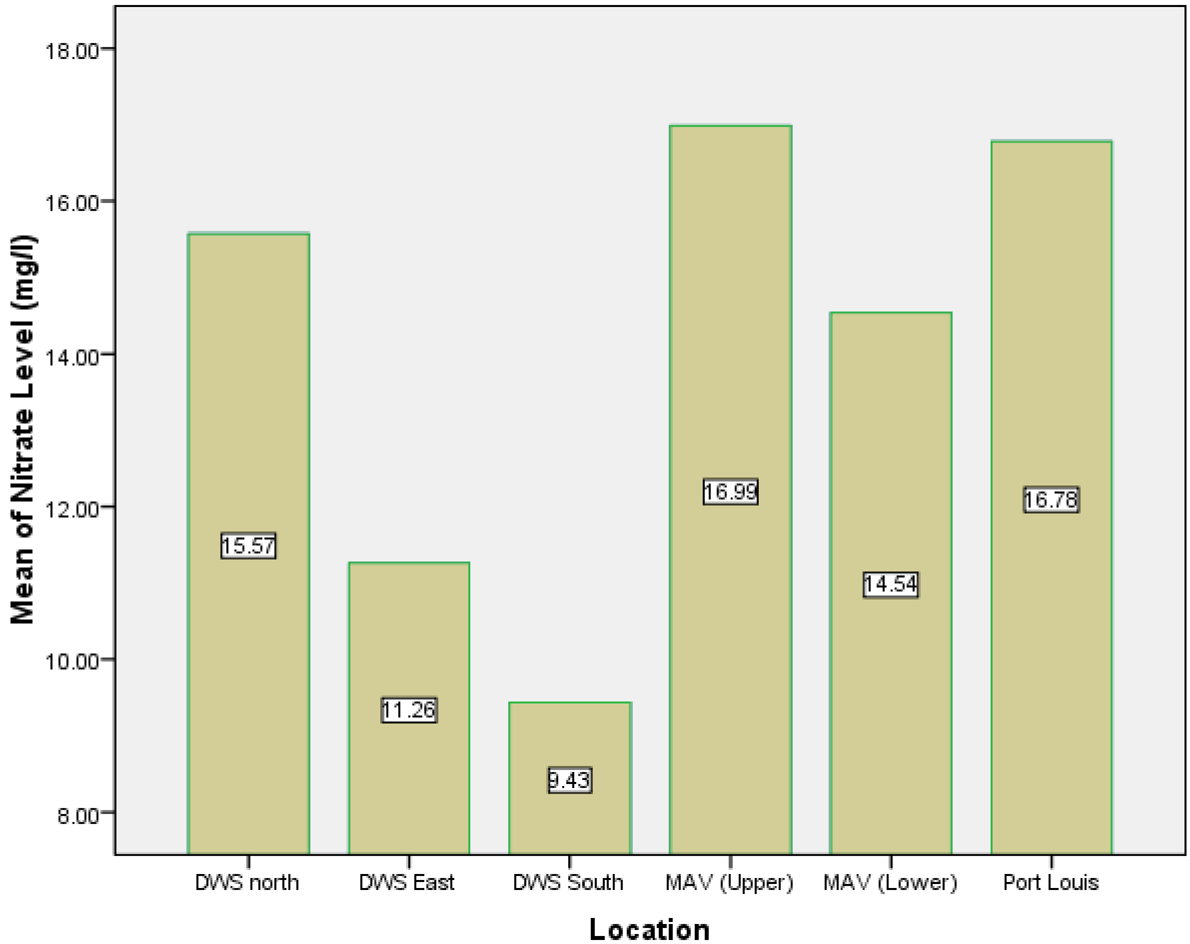
ANOVA

Nitrate Level (mg/l)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	11605.193	5	2321.039	31.715	.000

Within Groups	118485.956	1619	73.185		
Total	130091.149	1624			

Means Plots



Post Hoc Tests

Multiple Comparisons

Nitrate Level (mg/l) LSD

(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
DWS north	DWS East	4.31370*	.54947	.000	3.2360	5.3915
	DWS South	6.13984*	.57711	.000	5.0079	7.2718
	MAV (Upper)	-1.41387	1.07037	.187	-3.5133	.6856
	MAV (Lower)	1.03046	.82888	.214	-.5953	2.6562
	Port Louis	-1.20546	1.69330	.477	-4.5267	2.1158
DWS East	DWS north	-4.31370*	.54947	.000	-5.3915	-3.2360
	DWS South	1.82613*	.56706	.001	.7139	2.9384
	MAV (Upper)	-5.72758*	1.06498	.000	-7.8165	-3.6387
	MAV (Lower)	-3.28325*	.82191	.000	-4.8954	-1.6711
	Port Louis	-5.51917*	1.68990	.001	-8.8338	-2.2046
DWS South	DWS north	-6.13984*	.57711	.000	-7.2718	-5.0079
	DWS East	-1.82613*	.56706	.001	-2.9384	-.7139
	MAV (Upper)	-7.55371*	1.07950	.000	-9.6711	-5.4363
	MAV (Lower)	-5.10938*	.84064	.000	-6.7582	-3.4605
	Port Louis	-7.34530*	1.69909	.000	-10.6779	-4.0127
MAV (Upper)	DWS north	1.41387	1.07037	.187	-.6856	3.5133
	DWS East	5.72758*	1.06498	.000	3.6387	7.8165
	DWS South	7.55371*	1.07950	.000	5.4363	9.6711
	MAV (Lower)	2.44433*	1.23260	.048	.0267	4.8620
	Port Louis	.20841	1.92341	.914	-3.5642	3.9811
MAV (Lower)	DWS north	-1.03046	.82888	.214	-2.6562	.5953
	DWS East	3.28325*	.82191	.000	1.6711	4.8954
	DWS South	5.10938*	.84064	.000	3.4605	6.7582
	MAV (Upper)	-2.44433*	1.23260	.048	-4.8620	-.0267
	Port Louis	-2.23592	1.80024	.214	-5.7670	1.2951
Port Louis	DWS north	1.20546	1.69330	.477	-2.1158	4.5267
	DWS East	5.51917*	1.68990	.001	2.2046	8.8338
	DWS South	7.34530*	1.69909	.000	4.0127	10.6779

	MAV (Upper)	-.20841	1.92341	.914	-3.9811	3.5642
	MAV (Lower)	2.23592	1.80024	.214	-1.2951	5.7670

*. The mean difference is significant at the 0.05 level.

Annex 9 – One way Analysis of Variance - Sulphate

Oneway

```
[DataSet2] C:\Documents and Settings\user\Desktop\CWA DATA\Recent workings\pH analysis
_2.sav
```

Descriptives

Sulphate Level (mg/l)

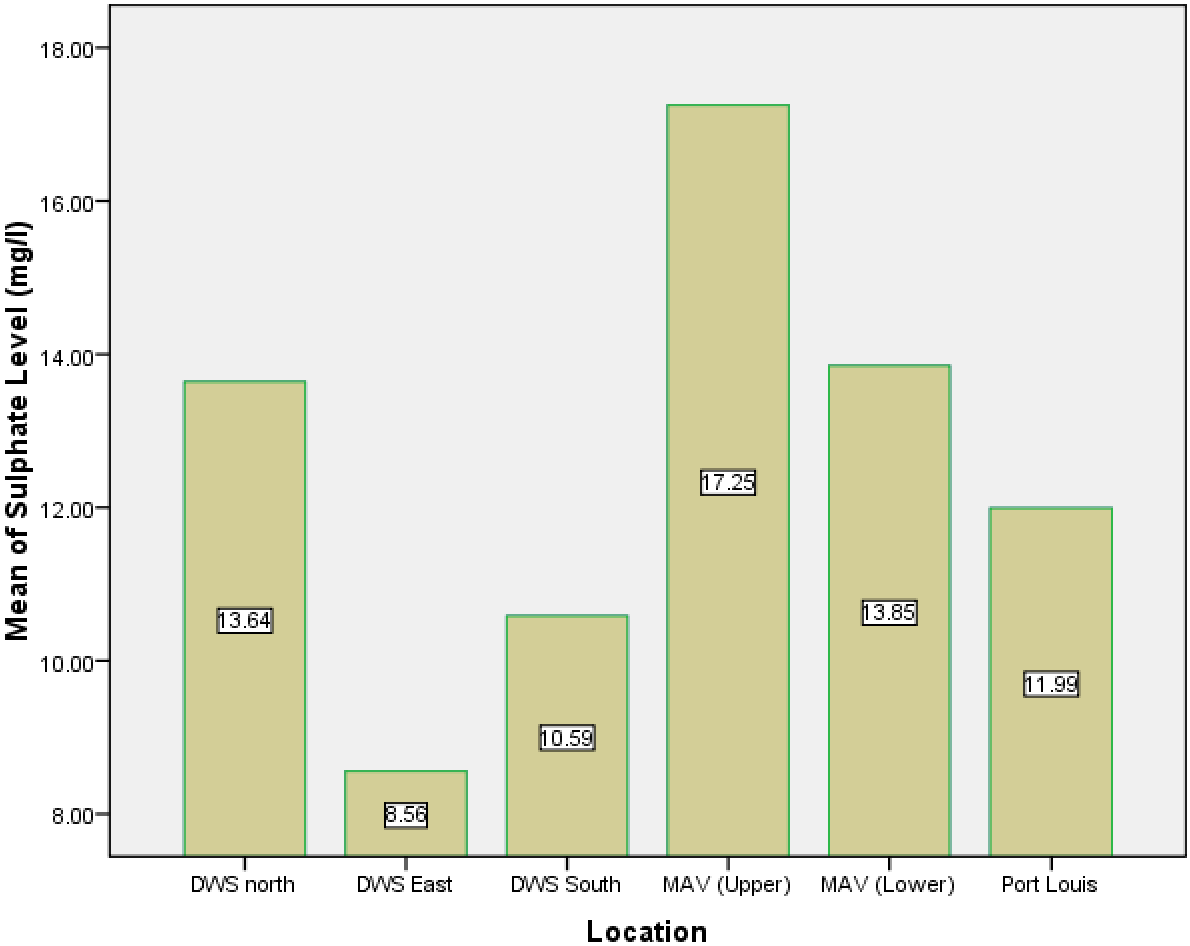
					95% Confidence Interval for Mean			
	N	Mean	Std. Deviation	Std. Error	Lower Bound	Upper Bound	Minimum	Maximum
DWS north	473	13.6406	10.81308	.49719	12.6636	14.6176	.10	79.00
DWS East	504	8.5563	7.89898	.35185	7.8651	9.2476	.20	55.00
DWS South	418	10.5852	8.08101	.39526	9.8082	11.3621	.30	39.80
MAV (Upper)	74	17.2500	6.01294	.69899	15.8569	18.6431	.30	30.00
MAV (Lower)	141	13.8504	6.22084	.52389	12.8146	14.8861	.50	30.50
Port Louis	27	11.9889	5.38197	1.03576	9.8599	14.1179	2.40	22.00
Total	1637	11.4491	9.00710	.22262	11.0124	11.8857	.10	79.00

ANOVA

Sulphate Level (mg/l)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	10112.119	5	2022.424	26.902	.000
Within Groups	122613.153	1631	75.177		
Total	132725.271	1636			

Means Plots



18.00
16.00
14.00
12.00
10.00
8.00
Mean of Sulphate Level (mg/l)
13.64
8.56
10.59
17.25
13.85
11.99
DWS north
DWS East
DWS South
MAV (Upper)
MAV (Lower)
Port Louis
Location

Post Hoc Tests

Multiple Comparisons

Sulphate Level (mg/l) LSD

(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
DWS north	DWS East	5.08424*	.55506	.000	3.9955	6.1730
	DWS South	3.05542*	.58205	.000	1.9138	4.1971
	MAV (Upper)	-3.60941*	1.08390	.001	-5.7354	-1.4834
	MAV (Lower)	-.20976	.83193	.801	-1.8415	1.4220
	Port Louis	1.65170	1.71559	.336	-1.7133	5.0167
DWS East	DWS north	-5.08424*	.55506	.000	-6.1730	-3.9955
	DWS South	-2.02882*	.57359	.000	-3.1539	-.9038
	MAV (Upper)	-8.69365*	1.07938	.000	-10.8108	-6.5765
	MAV (Lower)	-5.29401*	.82603	.000	-6.9142	-3.6738
	Port Louis	-3.43254*	1.71274	.045	-6.7919	-.0731
DWS South	DWS north	-3.05542*	.58205	.000	-4.1971	-1.9138
	DWS East	2.02882*	.57359	.000	.9038	3.1539
	MAV (Upper)	-6.66483*	1.09350	.000	-8.8097	-4.5200
	MAV (Lower)	-3.26519*	.84440	.000	-4.9214	-1.6090
	Port Louis	-1.40372	1.72168	.415	-4.7807	1.9732
MAV (Upper)	DWS north	3.60941*	1.08390	.001	1.4834	5.7354
	DWS East	8.69365*	1.07938	.000	6.5765	10.8108
	DWS South	6.66483*	1.09350	.000	4.5200	8.8097
	MAV (Lower)	3.39965*	1.24462	.006	.9584	5.8409
	Port Louis	5.26111*	1.94942	.007	1.4375	9.0847
MAV (Lower)	DWS north	.20976	.83193	.801	-1.4220	1.8415
	DWS East	5.29401*	.82603	.000	3.6738	6.9142
	DWS South	3.26519*	.84440	.000	1.6090	4.9214
	MAV (Upper)	-3.39965*	1.24462	.006	-5.8409	-.9584
	Port Louis	1.86147	1.82140	.307	-1.7111	5.4340
Port Louis	DWS north	-1.65170	1.71559	.336	-5.0167	1.7133
	DWS East	3.43254*	1.71274	.045	.0731	6.7919
	DWS South	1.40372	1.72168	.415	-1.9732	4.7807

	MAV (Upper)	-5.26111*	1.94942	.007	-9.0847	-1.4375
	MAV (Lower)	-1.86147	1.82140	.307	-5.4340	1.7111

*. The mean difference is significant at the 0.05 level.

Annex 10 – One way Analysis of Variance - Ammonia

Oneway

```
[DataSet1] C:\Documents and Settings\user\Desktop\CWA DATA\Recent workings\pH analysis
_2.sav
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Descriptives

Ammonia Level (mg/l)

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
DWS north	287	.0762	.19231	.01135	.0539	.0986	.01	
DWS East	325	.0872	.26269	.01457	.0585	.1158	.01	
DWS South	258	.0992	.25338	.01577	.0682	.1303	.01	
MAV (Upper)	56	.0589	.04275	.00571	.0475	.0704	.01	
MAV (Lower)	89	.0702	.04129	.00438	.0615	.0789	.01	
Port Louis	16	.0550	.03795	.00949	.0348	.0752	.01	
Total	1031	.0836	.22000	.00685	.0702	.0971	.01	

Test of Homogeneity of Variances

Ammonia Level (mg/l)

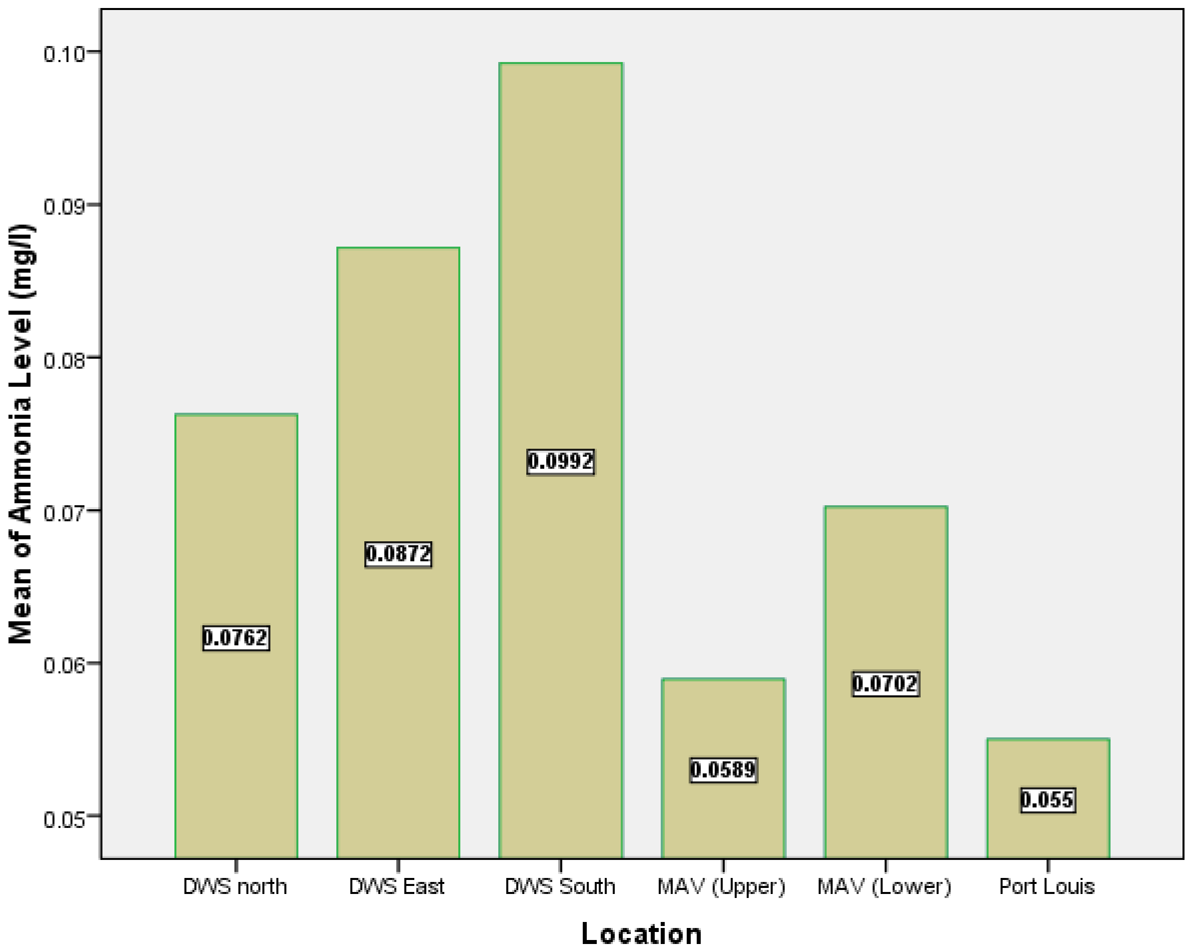
Levene Statistic	df1	df2	Sig.
.819	5	1025	.536

ANOVA

Ammonia Level (mg/l)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.146	5	.029	.601	.699
Within Groups	49.707	1025	.048		
Total	49.852	1030			

Means Plots



Post Hoc Tests

Multiple Comparisons

Ammonia Level (mg/l) LSD

(I) Location	(J) Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
DWS north	DWS East	-.01093	.01784	.540	-.0459	.0241
	DWS South	-.02299	.01889	.224	-.0601	.0141
	MAV (Upper)	.01731	.03217	.591	-.0458	.0804
	MAV (Lower)	.00601	.02672	.822	-.0464	.0584
	Port Louis	.02124	.05657	.707	-.0898	.1322
DWS East	DWS north	.01093	.01784	.540	-.0241	.0459
	DWS South	-.01206	.01836	.512	-.0481	.0240
	MAV (Upper)	.02824	.03186	.376	-.0343	.0908
	MAV (Lower)	.01694	.02635	.520	-.0348	.0686
	Port Louis	.03217	.05639	.568	-.0785	.1428
DWS South	DWS north	.02299	.01889	.224	-.0141	.0601
	DWS East	.01206	.01836	.512	-.0240	.0481
	MAV (Upper)	.04030	.03246	.215	-.0234	.1040
	MAV (Lower)	.02900	.02707	.284	-.0241	.0821
	Port Louis	.04422	.05673	.436	-.0671	.1556
MAV (Upper)	DWS north	-.01731	.03217	.591	-.0804	.0458
	DWS East	-.02824	.03186	.376	-.0908	.0343
	DWS South	-.04030	.03246	.215	-.1040	.0234
	MAV (Lower)	-.01130	.03756	.764	-.0850	.0624
	Port Louis	.00393	.06242	.950	-.1186	.1264
MAV (Lower)	DWS north	-.00601	.02672	.822	-.0584	.0464
	DWS East	-.01694	.02635	.520	-.0686	.0348
	DWS South	-.02900	.02707	.284	-.0821	.0241
	MAV (Upper)	.01130	.03756	.764	-.0624	.0850
	Port Louis	.01522	.05980	.799	-.1021	.1326
Port Louis	DWS north	-.02124	.05657	.707	-.1322	.0898
	DWS East	-.03217	.05639	.568	-.1428	.0785
	DWS South	-.04422	.05673	.436	-.1556	.0671

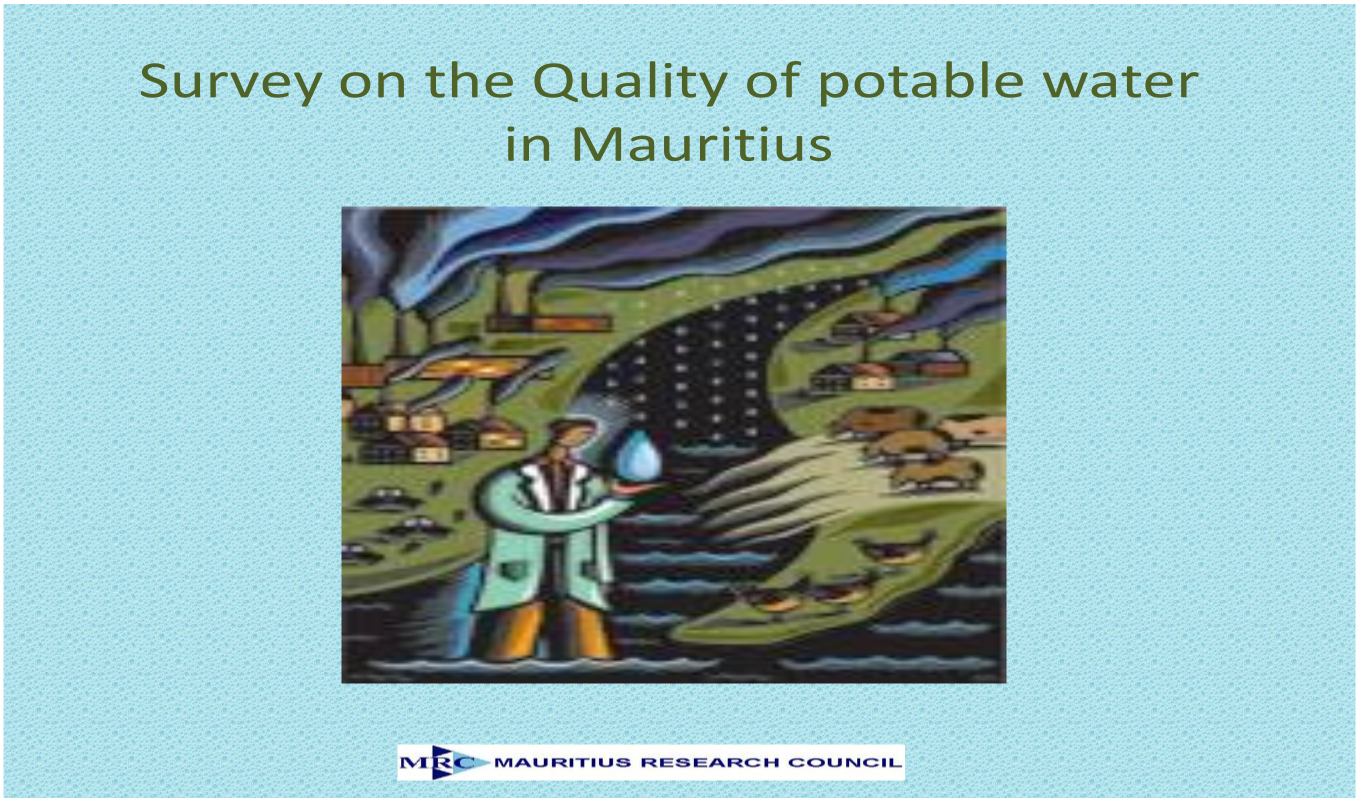
	MAV (Upper)	-.00393	.06242	.950	-.1264	.1186
	MAV (Lower)	-.01522	.05980	.799	-.1326	.1021

*. The mean difference is significant at the 0.05 level.

Annex 11 – List of 30 Parameters monitored by CWA

1. Residual Cholrine
2. Appearance
3. Colour (Hazen)
4. Turbidity (NTU)
5. pH (No Unit)
6. E. Conductivity
7. Free Carbon Dioxide
8. Acidity
9. Alkalinity Total
10. Alkalinity Phenolphthalein
11. Total Hardness
12. Calcium Hardness
13. Magnesium Hardness
14. Carbonate Hardness
15. Non Carbonate hardness
16. Chloride
17. Nitrate (as N)
18. Nitrite (as N)
19. Phosphate
20. Sulphate
21. Ammonia (as N)
22. Calcium
23. Iron (Total)
24. Magnesium
25. Silica
26. Zinc
27. Total Dissolved Solids
28. Sodium
29. Potassium
30. COD

Annex 12 – Copy of PowerPoint presentation for 2nd task Group committee meeting



Project authorisation

- Initial request from Ministry of Industry, Science and Research (Oct 2009)
- Approval to conduct the survey from Ministry of Renewable Energy and Public Utilities (Dec 2009)

Methodology – 1

Task Group 1st working session

- Task Group meeting – 19th October 2009
- Stakeholders represented:
  - AREU
  - CWA
  - MSIRI
  - NEL
  - WRU
- Purpose: To take cognisance of the various issues to be considered in the preparation of a report on the quality of water resources.

Methodology – 2
Data collection

- MSIRI: Reports of studies, publications
- CWA: Data on treated water (boreholes and surface water)
- NEL:Data on raw water collected in 1997 - 1999
- WRU: Reports of water mapping exercise

Methodology – 3

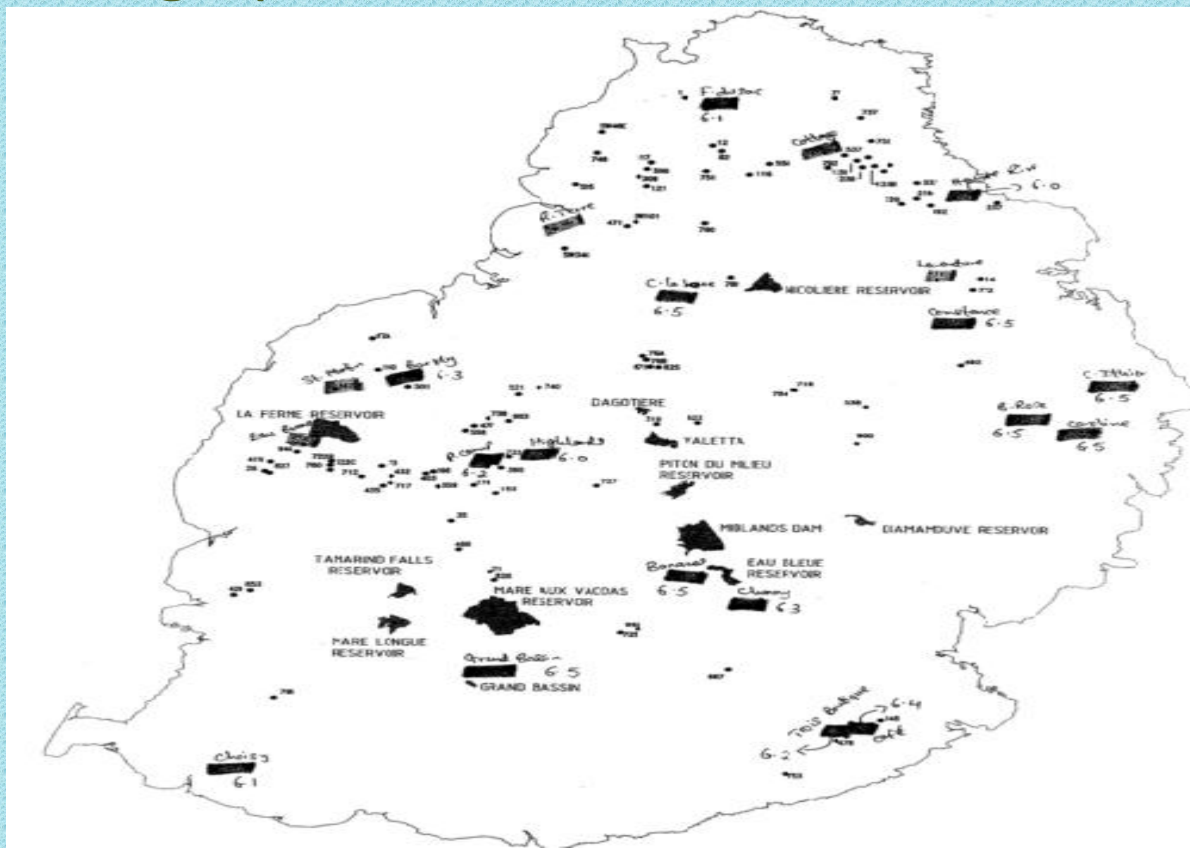
Data from CWA

Data for treated water made available as:

- Log books (1989 – 1992, 1994, 1997)
- Soft copy (2007-2009)
- Initial statistical analysis: sample of 21 boreholes (representing most consistent data set)

Note: Hand-written data recordings were not used.

Geographical Location of Boreholes



Parameters considered

- pH
- Nitrate
- Sulphate
- Ammonia

Methodology – 4

Data cleaning

- Gaps in data: no information available for years 1993, 1995 – 1996, 1998 – 2006.
- Measuring unit of nitrate: changed from NO_3^- to N (as from 2007)
- Data entry errors: detected while plotting graphs and conducting frequency analysis.

Methodology – 5

Data cleaning

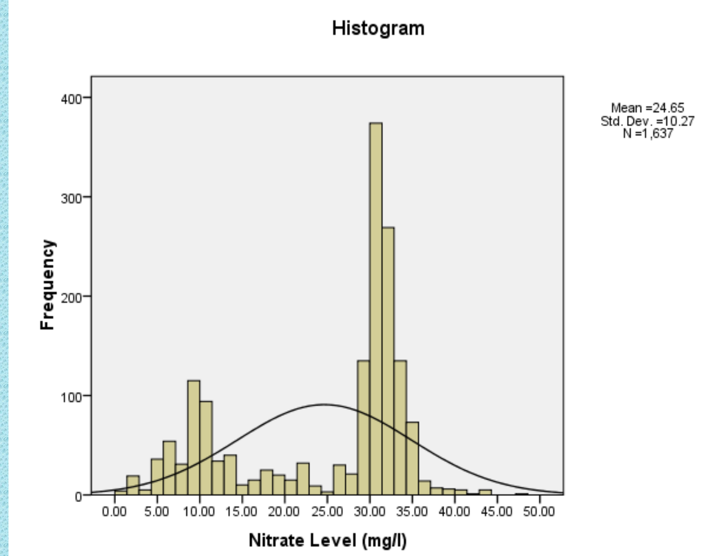
- Many “zero” values in data sets, especially for ammonia
- Missing values: around 12%
- Date inserted instead of numerical measured value
- Typographical errors: e.g., 0.6 entered instead of 6.0 for pH
- Range of data

Range of Data – Nitrate (mg/l)

Statistics

Nitrate Level (mg/l)

N	Valid	1637
	Missing	40
Mean		24.6477
Median		30.1700
Mode		30.63
Minimum		.20
Maximum		48.00

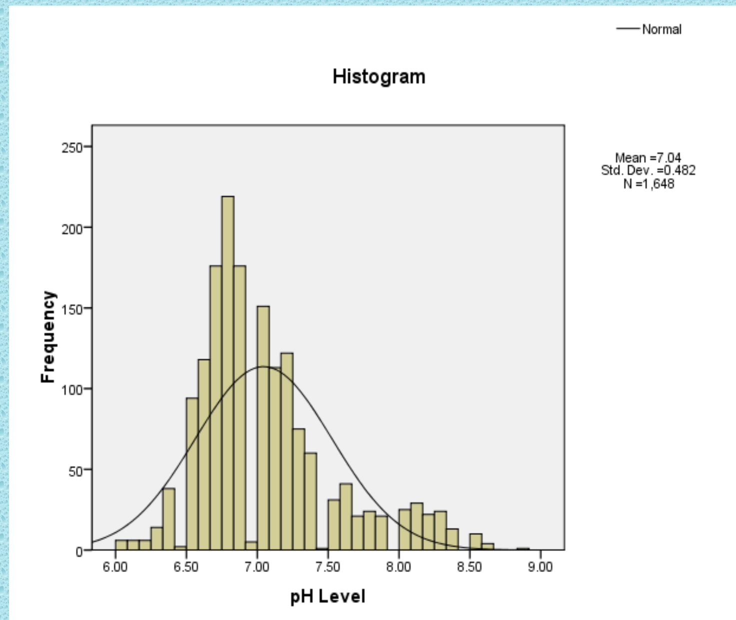


Range of Data - pH

Statistics

pH Level

N	Valid	1648
	Missing	29
Mean		7.0445
Median		6.9000
Mode		6.80
Minimum		6.00
Maximum		8.90

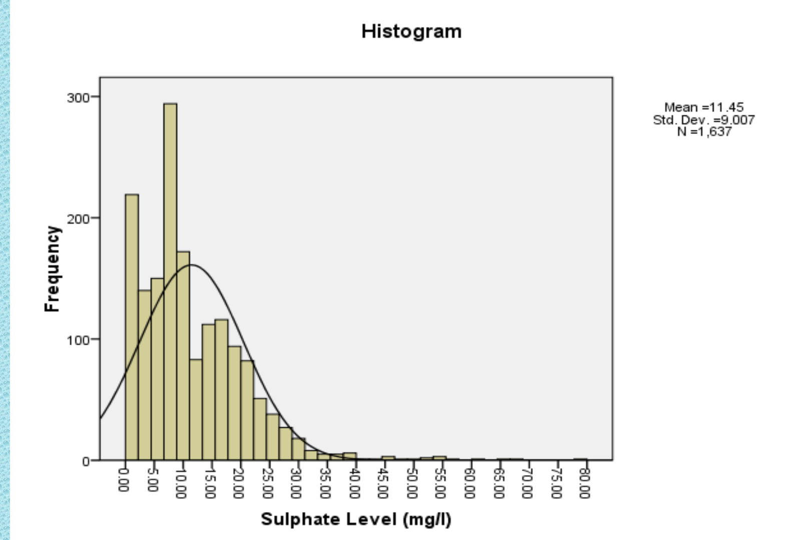


Range of Data – Sulphate (mg/l)

Statistics

Sulphate Level (mg/l)

N	Valid	1637
	Missing	40
Mean		11.4491
Median		9.0000
Mode		8.00
Minimum		.10
Maximum		79.00

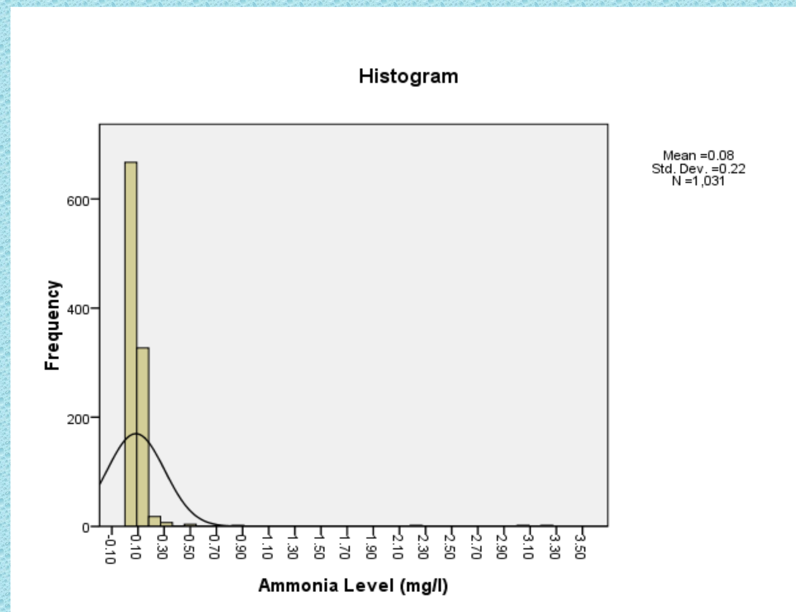


Range of Data – Ammonia (mg/l)

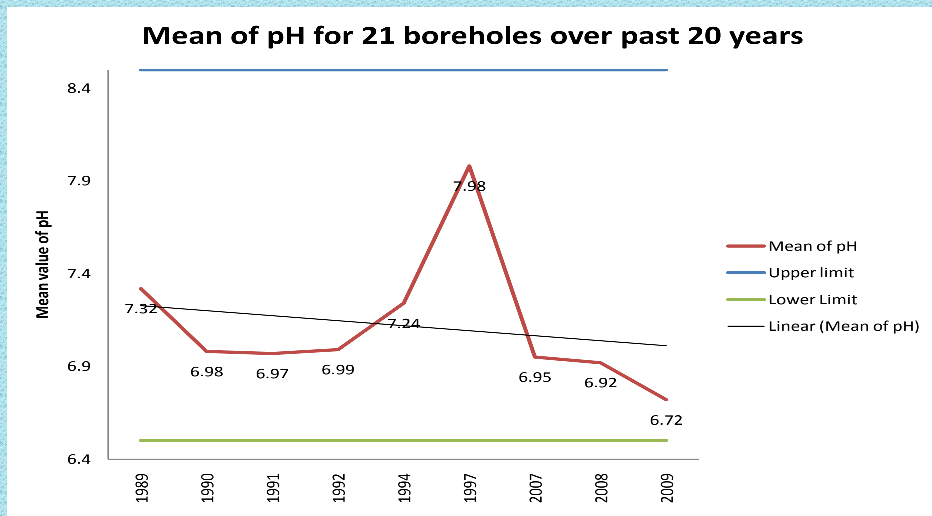
Statistics

Ammonia Level (mg/l)

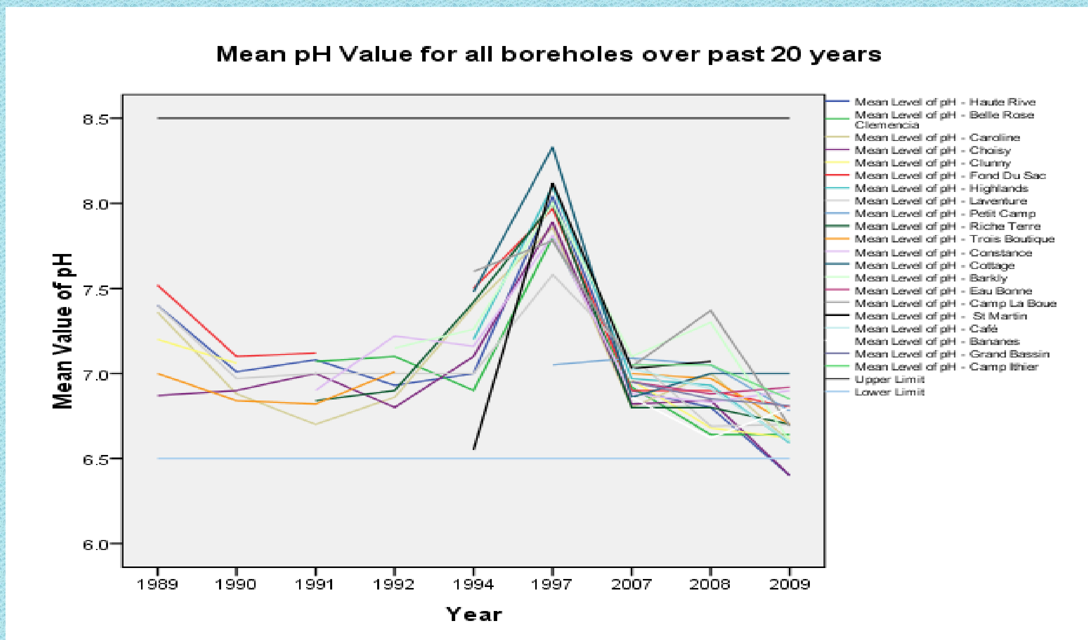
N	Valid	1031
	Missing	659
Mean		.0836
Median		.0600
Mode		.10
Minimum		.01
Maximum		3.20



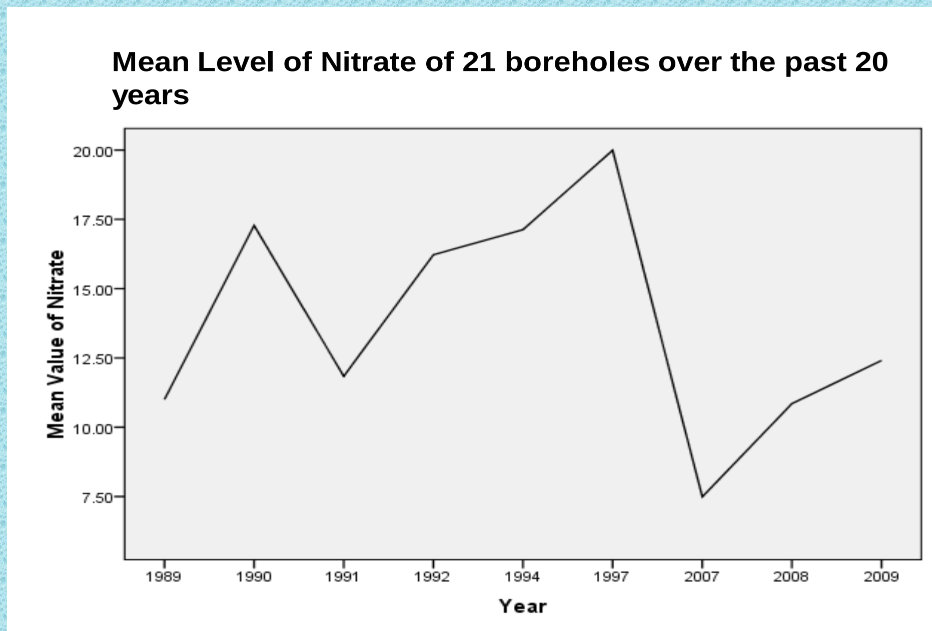
General Trends



General Trends : What happened in 1997???

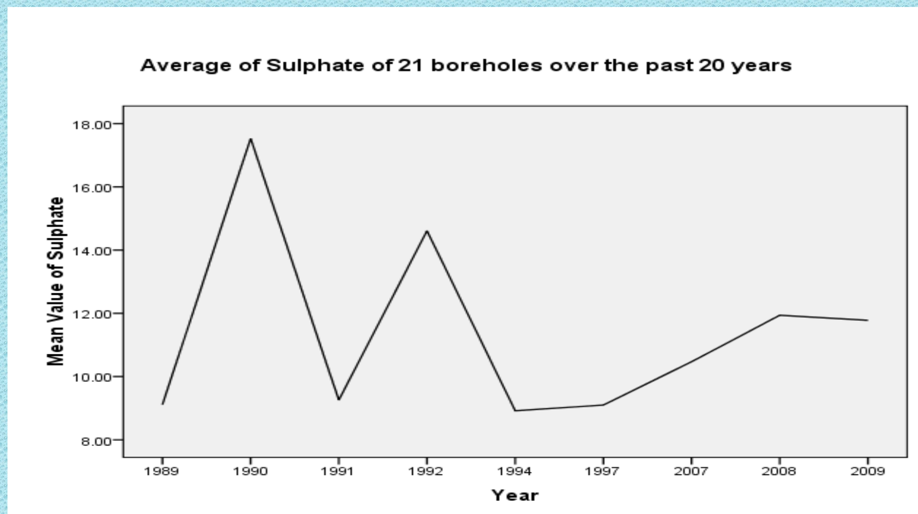


General Trends



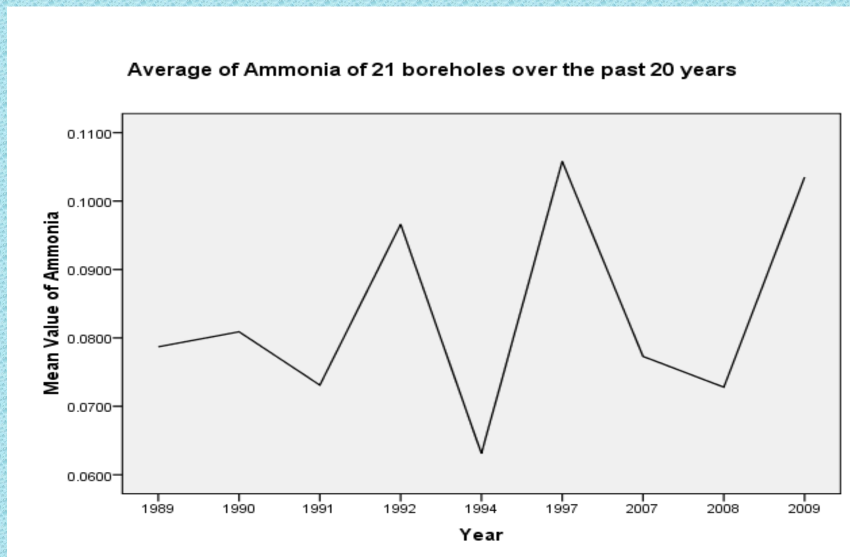
Upper limit for Nitrate – 50 mg/l

General Trends



Upper limit for Sulphate – 250 mg/l

General Trends



Upper limit for Ammonia – 1.5 mg/l

Correlation between the elements

Correlations

		pH Level	Nitrate Level (mg/l)	Sulphate Level (mg/l)	Ammonia Level (mg/l)
pH Level	Pearson Correlation	1	.227**	-.054*	-.030
	Sig. (2-tailed)		.000	.031	.347
	N	1648	1599	1608	1009
Nitrate Level (mg/l)	Pearson Correlation	.227**	1	.467**	.036
	Sig. (2-tailed)	.000		.000	.253
	N	1599	1625	1588	999
Sulphate Level (mg/l)	Pearson Correlation	-.054*	.467**	1	.007
	Sig. (2-tailed)	.031	.000		.835
	N	1608	1588	1637	1011
Ammonia Level (mg/l)	Pearson Correlation	-.030	.036	.007	1
	Sig. (2-tailed)	.347	.253	.835	
	N	1009	999	1011	1031

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Boreholes which have already gone below the minimum pH value since 2007:

- **Barkly** (60%)
- **Highlands** (40%)
- **Haute Rive** (33%)
- **Choisy** (32%)
- **Belle Rose Clemencia**
- **Caroline**
- **Choisy**
- **Clunny**
- **Fond Du Sac No1**
- **Petit Camp**
- **Riche Terre**
- **Trois Boutique**

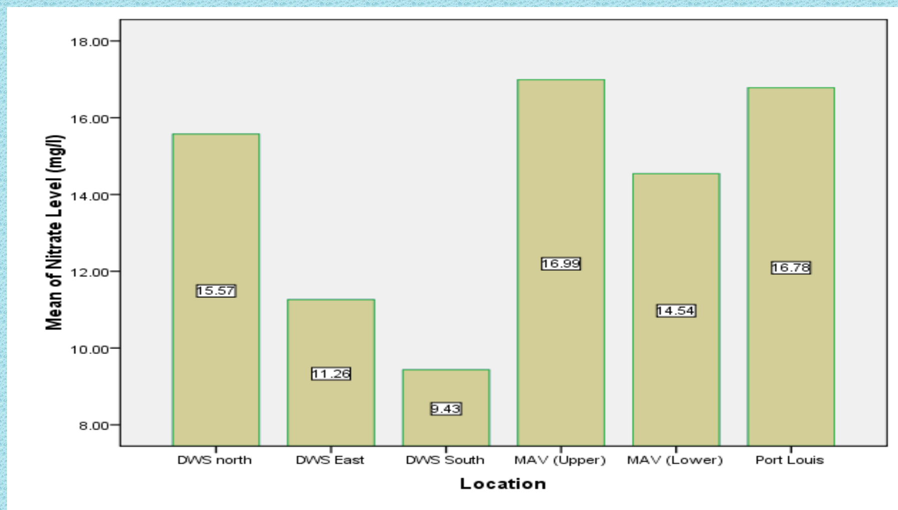
Boreholes which have already gone below the minimum pH value since 2007

- **Constance**
- **Cottage**
- **Eau Bonne**
- **Camp La Boue**
- **St Martin**
- **Café**
- **Bananes**
- **Grand Bassin**
- **Camp Ithier**

Regional representation of pH

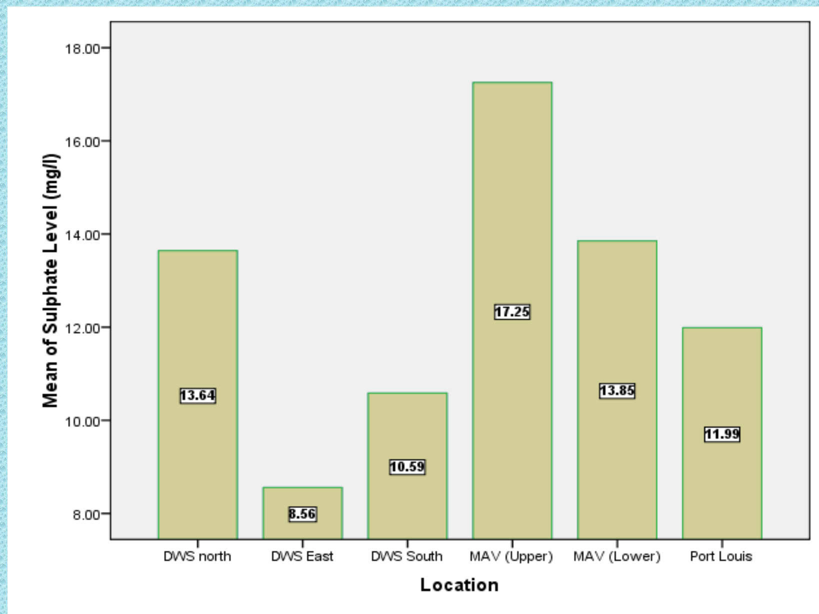
Please refer to handout for statistical significance of multiple comparisons

Regional representation of Nitrate



Please refer to handout for statistical significance of multiple comparisons

Regional representation of Sulphate

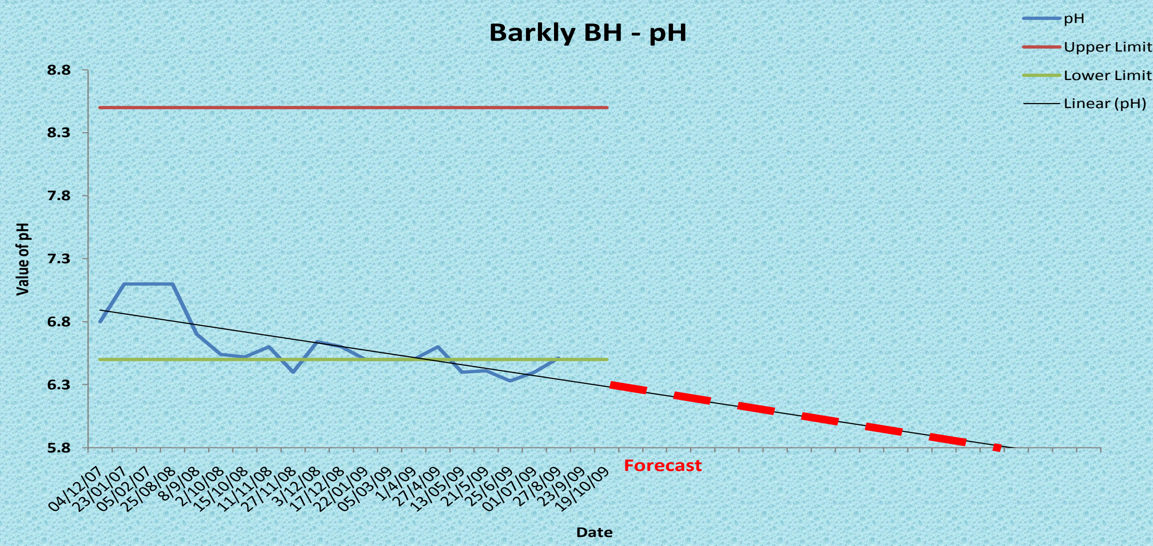


Please refer to handout for statistical significance of multiple comparisons

Regional representation of Ammonia

Please refer to handout for statistical significance of multiple comparisons

Forecast of pH for Barkly BH



Next step

- Request of data from:
- Ministry of Housing and Lands
- Ministry of Agro Industry, Food Production and Security
- Ministry of Quality of Health &Quality of Life

Thank you for your attention