Water Quality Trends in the Manawatu-Wanganui Region 1989-2004

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CONTENTS

APPENDICES

FIGURES

TABLES

MAPS

Water Quality Trends in the Manawatu-Wanganui Region 1989-2004

Is the Water Quality of our rivers improving or degrading?
Until now the perennial question "In the long-term, are our rivers getting better or worse in quality?" has been answered using anecdotal evidence. As part of the requirements for State of the Environment (SoE), Horizons Regional Council (Horizons) has collected data relating to the water quality of its rivers. This report aims to identify the long-term trends, if any, at 22 SoE sampling sites in the four main catchments of our Region (Rangitikei, Manawatu, Whanganui and Whangaehu).

The analysis in this report uses all available data for the period 1989 – 2000. This report provides statistical evidence of trends, where they exist, and an indication of the significance of these trends. This information will provide a reference point for future policy to improve the quality of our waterways. This work is one part of the water quality research programme being carried out by Horizons, building on the SoE Report published in early 2005.

Four variables were initially investigated:

- *Escherichia coli* (*E. coli*) bacteria as an indicator for **contact recreation**;
- Dissolved reactive phosphorus [DRP] and nitrate [NO_3] as indicators of **nutrient enrichment**; and
- Turbidity (TURB) as an indicator of **physical stress**.

There were insufficient data for *E. coli* to undertake any trends analysis. Results in terms of significant trends and severity of trends are summarised in Table 1 below.

There are significant to highly significant increasing trends (indicating *decreasing* water quality) in concentrations of DRP, NO_3 and TURB at many sites in the Manawatu catchments - and, to a lesser extent, in the Whanganui catchment. Turbidity concentrations improved over time at one site in the Whangaehu catchment.

It is evident that the Manawatu catchment has the highest proportion of sites whose trends give greatest cause for concern. This can be seen across all three water quality indicators.

When data is not adjusted for flow, the Whanganui catchment shows significant increasing trends in DRP values at half of the surveyed sites, and the Estuary site has increasing turbidity. When data is flow-adjusted only the Kaiwhaiki site has highly significant increasing trends (for both DRP and turbidity). These results for the Kaiwhaiki site may be affected by the tidal location of its water quality sampling site.

The Rangitikei catchment shows a significant increase in DRP concentration at one site near the headwaters, but this is not observed at other sites.

The Whangaehu catchment has an increasing trend for DRP near the headwaters (for flow adjusted data), and the decrease in turbidity at the same site (in both tests) is pleasing to note.

Table 1. Summary of seasonal Kendall DRP, NO_3 and TURB trend testing by site and Severity score based on flow-adjusted or non flow-adjusted data.

SoE Site	Non flow-adjusted				Flow-adjusted			
	DRP	NO_3	TURB	Severity Score	DRP	NO_3	TURB	Severity Score
Rangitikei Catchment								
Rangitikei at River Valley	↑			1	↑			1
Hautapu upstream at Rangitikei				0				0
Rangitikei at Mangaweka				0				0
Rangitikei at Vinegar Hill				0				0
Rangitikei at Kakariki				0				0
Rangitikei at Scotts Ferry*				0				-
Manawatu Catchment								
Mangatera at Timber Bay	↓↓↓	↑↑		3				0
Makakahi at Konini		↑↑		3	↑↑	↑↑↑	↑↑	5
Mangatainoka at SH2		↑↑↑		5		↑↑↑		5
Manawatu at Hopelands	↑↑↑	↑↑↑	↑↑	13	↑↑↑	↑↑↑		10
Manawatu at Ashhurst Domain				-				-
Oroua at Nelson Street	↑↑		↑↑	6	↑↑↑	↑↑↑	↑↑	13
Oroua at Awahuri Bridge				0	↑↑↑		↑	8
Manawatu at Maxwells Line				0		↑↑	↑↑↑	8
Manawatu at 42 Mile				0				0
Manawatu at Whirokino*	↓	↑↑↑	↑↑↑	10				-
Whanganui Catchment								
Whanganui at Retaruke				0				0
Whanganui at Pipiriki	↑↑			3			↓	0
Whanganui at Kaiwhaiki	↑↑↑			1	↑↑↑		↑↑↑	10
Whanganui at Estuary opposite marina*			↑↑	3				-
Whangaehu Catchment								
Mangawhero at DoC National Park			↓	0	↑↑		↓↓↓	0
Mangawhero downstream at Makotuku confluence				0				0

* *Tidal sites were not tested as part of the flow-adjusted analysis.*

1. *Some flow data has been supplied by Genesis Energy and NIWA.*
2. *Red arrows (↑) represent an increasing trend in concentration of a given water quality indicator (ie. a degradation in water quality). Green arrows (↓) represent a decreasing trend (ie. an improvement in water quality).*
3. *↑/↓ indicates a significant trend (a probability of 90%)*
   ↑↑/↓↓ indicates a very significant trend (a probability of 95%)
   ↑↑↑/↓↓↓ indicates a highly significant trend (a probability of 99%)

1. Introduction

1.1 Scope of Report

This report focuses on using robust statistical techniques to identify any trends in water quality variables over time in three rivers of the Region. Where those trends exist, it seeks to provide a measure of their statistical significance. It is *not* the scope of this report to offer reasons for the observed trends although recent and concurrent studies, together with the finding in this report, provide some interpretation of these trends.

The study uses methodologies employed by both NIWA and Environment Waikato for water quality trend analyses, providing a comparison with other parts of New Zealand (see Chapter 4).

1.2 Background to Trends Analysis Work by Horizons

In 2002 initial work was carried out to prepare for a Trends Analysis study (Hodges 2002). A scan of sites and date ranges was carried out within Horizons' water quality databases (QUALARC and Hilltop). At first, four sites were selected to evaluate the data, on the basis of being major catchments and a good length of record. For these sites, QUALARC and Hilltop data were combined into common datasets within EXCEL. NIWA data was also added in, where available. Hodges (2002) suggested that at least 10 years of data would be required for analysis (the longer the record, then the more power or reliability that might be given to the result). However, NIWA Trends Analysis studies (Smith *et al.*1996) have used datasets spanning at least five years and this benchmark became the basis of the present study.

The author, Royal Society of New Zealand Teacher Fellow Ron Gibbard, reviewed best practice methodologies in trend analysis in New Zealand. The methodology used for this study is outlined in detail below and further methodology information is documented in the appendices.

2. Methods

2.1 Water Quality Sites

Horizons regularly monitors about 100 SoE water quality sites across the Manawatu-Wanganui Region (Map 1). NIWA also has sites within the Region. NIWA water quality sites were not analysed as part of this study. Flow data from some NIWA and Genesis Energy flow sites were utilised (with permission) to complete the flow adjustment of water quality data.

However, the number of these sites suitable for the trends investigation was limited by the longevity of the dataset available at each site. As a result, water quality trends were analysed at 22 river sites in the Horizons Region. These sites were in the Rangitikei, Manawatu, Whanganui and Whangaehu catchments.

2.2 Variables

Four variables were investigated - Dissolved reactive phosphorus (DRP), Nitrate (NO_3), *Escherichia coli* (*E. coli*) and turbidity (TURB).

Dissolved reactive phosphorus (DRP)
This is a measure of the soluble fraction of total phosphorus. These phosphates are the readily assimilated nutrients necessary to support algae and aquatic plants. High levels of these nutrients can lead to rapid growth of nuisance plants that change the dynamics of aquatic systems.

Nitrate (NO_3)
The level of nitrates present can control the amount of algae and plant growth in a river. The level of nutrient found in a river is strongly related to land use upstream of the site.

Escherichia coli (E. coli)
E. coli bacteria samples are the preferred indicator by the Ministry of Health of the level of faecal contamination (previously the *Enterococci* indicator was preferred). They are used to indicate the human health risk from harmful micro-organisms present in the water. The units of *E. coli* counts are the most probable number per 100 ml sample (MPN/100ml). A value of 260 MPN/100 ml (or greater) is considered unsatisfactory and triggers further investigation (Ministry of Health, 2002).

Turbidity
Turbidity is a measure of the murkiness of the water, reflecting the amount of suspended material in the river. Turbidity is measured using a technique called nephlometry, which measures the light reflected from the suspended material in the river. The units of measurement are *nephlometric turbidity units* (NTU). Low turbidity levels (eg. <= 5NTU) are indicative of high levels of clarity.

2.3 Datasets

The selected datasets varied in their time span and continuity of collection, especially the *E. coli* records. An indication of the length and continuity of data at the sites is given in Figure 1.

Figure 1 shows that the most complete records are held for the Manawatu and Whanganui River sites and that there are a number of sites that are visited during summer months only (for Contact Recreation Monitoring).

The State of the Environment monitoring programme has a core group of sites that are sampled every year, and also three groups of sites that are sampled one year out of every three years, referred to as rolling sites.

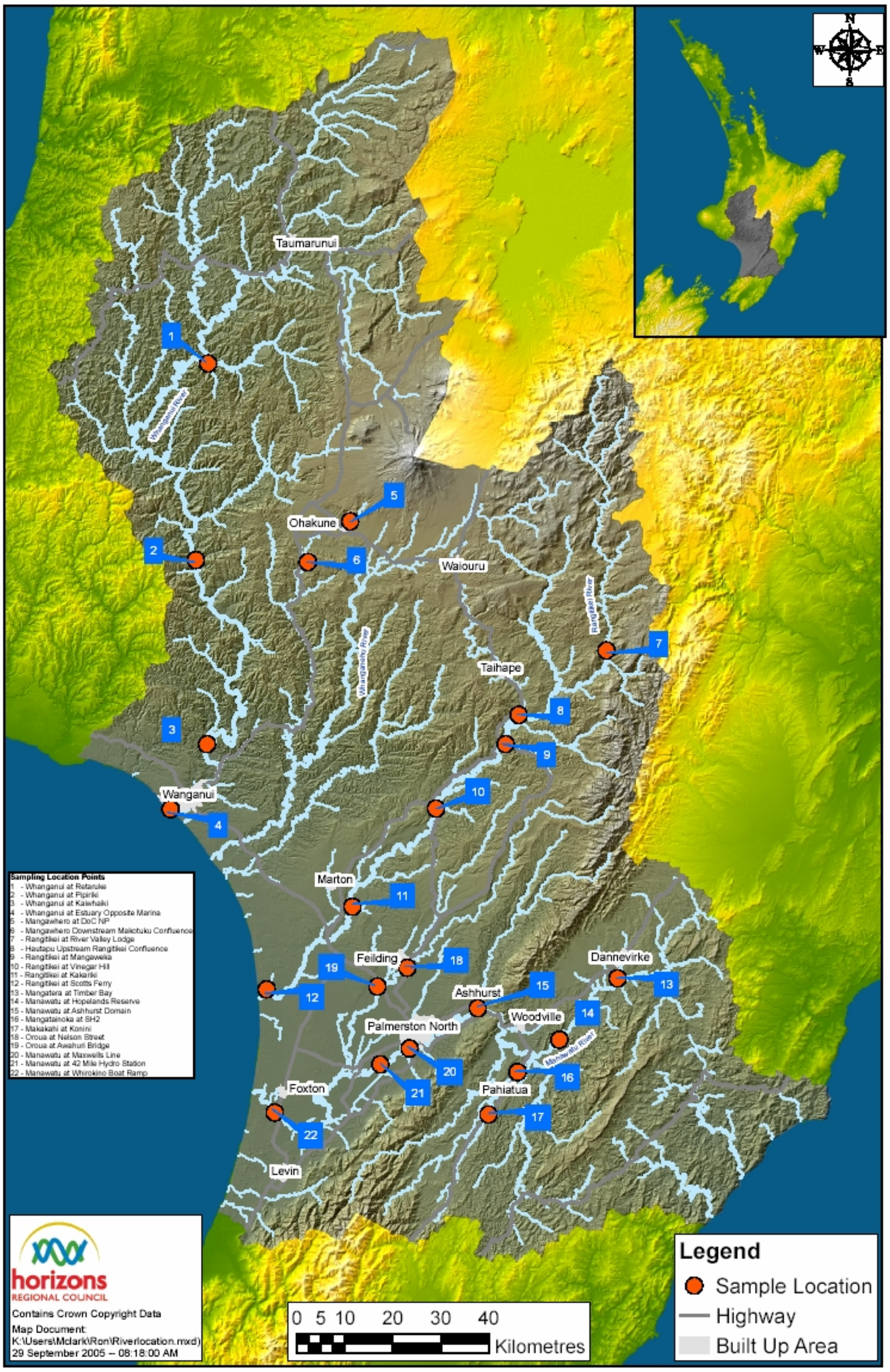
Smith *et al.* (1996) recommend that at least five years of water quality data (60 values) should be used to ascertain statistically significant long-term trends with adequate power, or reliability. On this basis, some sites have insufficient data to identify a trend, particularly those that are being sampled for only part of the year, recreational swimming sites, and those that are sampled on a three-year rotation (rolling sites). The number of data values used in each test is presented in the summary tables for each analysis. To facilitate decisions, sites that have less than 60 items in their dataset are entered in italics. No *E. coli* records were sufficiently long to make statistical decisions on their trends with any reasonable power.

2.4 Homogeneity of Data

No attempt was made to identify changes in measuring instruments, sampling methods or laboratory testing procedures that may have occurred over the lifespan of the data. Collection of data has always been done in accordance with an ISO quality system.

2.5 Organising and Presenting the Datasets

Non flow-adjusted data was brought into EXCEL from Horizons Quality Archives (QUALARC). It was reorganised into one data item per month, where available. Both of the non-parametric tests used were able to tolerate gaps in the monthly record. Where more than one data item was available in a given month, the data whose day corresponded closest to that of the data of the previous month was included. For example, where data was recorded at a site for 2 and 30 April, the latter was taken to represent the May value, if no other May value was available. This situation occurs regularly in the data record because of sampling scheduling over the Region.



Some flow data has been supplied by Genesis Energy and NIWA

Map 1. Location of Horizons State of the Environment water quality monitoring sites selected in this study.

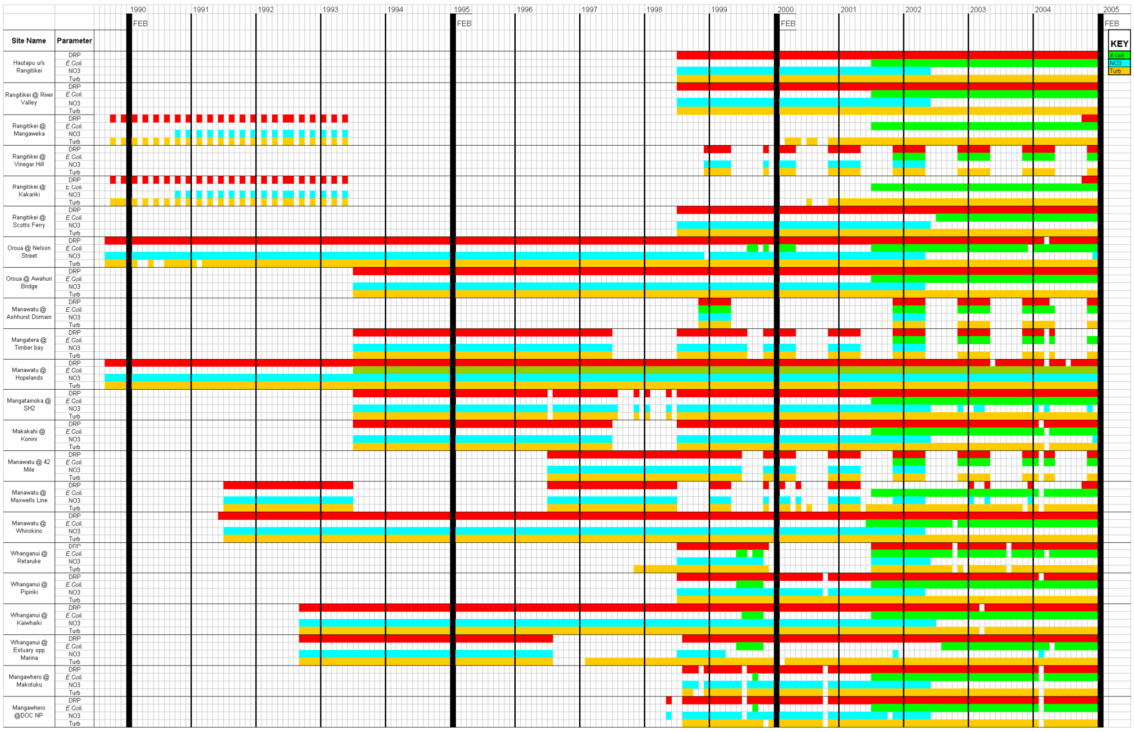


Figure 1. Availability of data from each site 1997-2004.

2.6 Statistical Analyses

A characteristic of many water quality variables is that they are not modelled well by a normal distribution. Consequently, analyses such as linear regression are not applicable, as required assumptions are not met by the data. Recent literature and studies (Smith *et al.,* 1996) indicate that non-parametric methods are the preferred mode of analysis for investigating trends as they do not require the data to have a normal distribution and they also allow for seasonal variation. These techniques deal with the ranks and signs of data, rather than the actual values.

Non-parametric statistical tests were applied to the data, namely the Seasonal Kendall Slope Estimator and the Kendall test for trends (see section 3.6 for more detail). Two phases of testing were carried out:

- use of non flow-adjusted data, with no allowance for flow variations (ie. the analysis does not account for the potential influence of flow); and
- use of flow-adjusted data, using the LOWESS procedure in Data Desk™ (see Appendices 1 and 2).

Smith *et al.* (1996) state that by removing the variation in water quality variables that is associated with flow, the overall variability is reduced and the possibility of correctly detecting a trend in the data increases.

There are two particular procedures that are useful in non-parametric trend analysis, as detailed in sections 2.6.1 and 2.6.2 below.

2.6.1 The Seasonal Kendall Slope Estimator (SKSE)

This indicates the size or magnitude of the annual trend. The SKSE is the median of all possible combinations of slopes between each possible pair of values for each month. For example, if there was five years of data there would be 5 x 4/2 = 10 possible pairs of results for each month. The 12 months would then provide 12 x 10 = 120 possible slope values.

When this data is ranked, the SKSE is the value of the median of the 60th and 61st values. A detailed explanation of the test is given by Smith *et al.* (1996).

2.6.2 The Seasonal Kendall Trend Test

This gives an indication whether or not the stated trend (SKSE) is statistically significant. Each of the slopes is allocated a sign (+ for a positive slope, - for a negative slope). The total count of the positive slopes is compared with the sum for the negatives. For example, 68 positive slopes and 50 negative slopes gives a net result of +18. When this sum is variance normalised, a z value can then be tested using the normal distribution tables.

If the variance normalised sum is near zero, the null hypothesis (that there is no trend) will not be rejected, the *P* value will be large and there is a high probability the trend happened merely by chance.

A high z value will mean that the null hypothesis can be rejected (ie. the observed trend is most unlikely to be attributed to chance alone). Smith *et al.* (1996) state that because many trends do not reach the 0.05 level of significance, recognition of the 0.10 level should be also be considered, if at least five years of data is available. This study follows that guideline, further details are described in Vant and Smith (2004).

Calculation of the SKSE and determination of the significance, or otherwise, of the trend was carried out using an EXCEL spreadsheet kindly provided by Bill Vant, Environment Waikato.

2.7 Flow Adjustment of Data

The values of water quality variables are often flow dependent. Smith *et al.* (1996) state that the possibility of correctly detecting a trend increases by removing the variation in water quality indicators that is associated with flow. Flow-adjustment of the data in this study was carried out using the **LOWESS** (**Lo**cally **We**ighted regression **S**catterplot **S**moothing) procedure developed by Cleveland (1979). The procedure carries out many calculations to fit a simple model to subsets of the data. At each point in the dataset a low level polynomial is fitted, giving more weight to other points near it, and less to others more distant.

The dataset of the flow-adjusted data for each variable can then be processed with the procedure used earlier on the non flow-adjusted data.

The weight function gives the most weight to the data points nearest the point of estimation and the least weight to the data points that are furthest away. The use of the weights is based on the idea that points near each other are more likely to be related to each other in a simple way than points that are further apart.

An example of the LOWESS smoothing procedure is given in Appendix 1. An outline of the procedure in using Data Desk^{TM} to flow adjust the data is given in Appendix 2.

2.8 Flow Records for Sites

22 flow records were required for the flow-adjustment process. Suitable flow data for the three tidal sites (*Rangitikei at Scotts Ferry*, *Manawatu at Whirokino* and *Whanganui at estuary opposite the marina*) was not available and possible trends at these were not investigated.

Flow data for each water quality site was established using the nearest available flow monitoring site (see Table 2). In several cases flow records were estimated using modelled flow series generated using more than one flow recorder on a particular river, reflecting the period of record available for these sites.

Using the LOWESS smoothing technique described above, the actual magnitude of flow is not as important as the rank position of that flow level in the long-term record. This means that the investigation should not be greatly affected using related flow records for some sites.

Table 2. Location of Flow Recorder Sites used to Flow Adjust Water Quality data.

Water Quality site	Water Quality Map reference	Flow record site	Flow Map reference
Rangitikei at River Valley	U21:713708	*Rangitikei at Pukeokahu*	U21:713708
Hautapu upstream at Rangitikei	T21:505669	*Hautapu at Alabasters* All [1, 2]	T21:486683
Rangitikei at Mangaweka	T22:503513	*Rangitikei at Mangaweka* [2]	T22:504513
Rangitikei at Vinegar Hill	T22:358379	*Rangitikei at Mangaweka* [2]	T22:504513
Rangitikei at Kakariki	S23:184175	*Rangitikei at Mangaweka* [2]	S23:201222
Rangitikei at Scotts Ferry	S23:005003	Tidal	-
Oroua at Nelson Street	S23:298048	*Oroua at Kawa Wool (modeled)*	S23:287038
Oroua at Awahuri Bridge	S23:243003	*Oroua at Awahuri bridge* (modelled)	S23:243002
Manawatu at Ashhurst Domain	T24:445964	*Manawatu at Teachers College*	T24:331892
Makakahi at Konini	T24:467743	*Makakahi at Hamua*	T25:424676
Manawatu at Hopelands	T24:615898	*Manawatu at Hopelands*	T24:616899
Mangatainoka at SH2	T24:528831	*Mangatainoka at Pahiatua Town Bridge* All [3]	T24:521824
Mangatera at Timber Bay	U23:736026	Modelled [4]	U23:736026
Manawatu at Maxwells Line	T24:303880	*Manawatu at Teachers College*	T24:331892
Manawatu at 42 Mile	S24:242847	*Manawatu at Teachers College*	T24:331892
Manawatu at Whirokino	S24:022747	Tidal	–
Whanganui at Retaruke	R19:883305	*Whanganui at Te Maire* [2 5]	S19:998490
Whanganui at Pipiriki	R21:858896	*Whanganui at Pipiriki* [6]	-
Whanganui at Kaiwhaiki	R22:881513	*Whanganui at Paetawa* [2 7]	S22:937566
Whanganui at Estuary opposite marina	R22:805378	Tidal	-
Mangawhero at DoC NP	S20:179977	*Mangawhero at Hagleys* All [8]	S20:148971
Mangawhero downstream at Makotuku confluence	S21:091892	*Mangawhero at Ore Ore* [2]	S21:045794

1 Record for *Hautapu at Alabasters* and *Hautapu at Taihape* flow recording sites were merged for this analysis using a 1:1 relationship.
2 Flow data provided by **NIWA**.
3 Record for Suspension Bridge and Pahiatua Town Bridge flow recording sites on the Mangatainoka were merged for this analysis using a 1:1 relationship.
4 Modelled as 12% of flow at *Manawatu at Weber Road* U23:751027 (r^2=0.9).
5 Flow data provided with permission from **Genesis Energy**.
6 Based on historical ratings applied to the continuous river level record for this site.
7 Water quality site may be tidally influenced. The flow site is above the tidal influence.
8 Record for *Mangawhero at Hagleys* and *Mangawhero at Burns street* flow recording sites were merged for this analysis using a 1:1 relationship.

3. Results

3.1 By Water Quality Variable

Statistical significance is inferred where the *P* value of a test is less than 0.10 or 10%. To help identify the level of importance of the trends the following convention was used in all tables:

For increasing trends (representing degradation in water quality):

↑↑↑	indicates significance at the 0.01 level	**'extremely significant'**
↑↑	indicates significance at the 0.05 level	**'very significant'**
↑	indicates significance at the 0.10 level	**'significant'**

Conversely, decreasing trends are indicated with ↓ signs.

Sites in italics indicate that the number of records involved in the test may be too low (<60) to establish a valid statistical trend for that river quality variable at that particular site. Accordingly, any significant trend result for such sites is not represented in bold in the tables.

3.1.1 Dissolved Reactive Phosphate (DRP)

3.1.1.1 Non flow-adjusted data

Five of the 22 sites indicate a significant increasing trend and two show a decrease (Table 3).

Highly significant increasing trends for DRP occur in the Manawatu (*Manawatu at Hopelands and Oroua at Nelson Street)* and Upper Whanganui (*Whanganui at Pipiriki*) catchments. It is also interesting that the *Mangatera at Timber Bay,* in spite of its high DRP median, has registered a highly significantly decreasing trend.

DRP Long Term Median values
In the Rangitikei catchment, the Hautapu upstream at Rangitikei has a much higher DRP median (0.2 g P m^{-3}) than all other sites.

In the Manawatu catchment the Mangatera at Timber Bay, a headwater site, has a high DRP median (0.14 g P m^{-3}) in relation to other sites. It is located downstream of the Dannevirke sewage discharge site.

The Whanganui River has similar DRP median values throughout its catchment.

Table 3. Results of seasonal Kendall Trend Testing on DRP non flow-adjusted data.

SoE Site	n	Median (g P m^{-3})	SKSE (Slope estimator)	SKSE % Annual Change	z value	P %	Trend
Rangitikei Catchment							
Rangitikei at River Valley	78	0.004	0.0005	12.50	1.6762	9.37	↑
Hautapu upstream at Rangitikei	78	0.02	-0.0004	-2.08	-0.5747	56.55	
Rangitikei at Mangaweka	*26*	*0.005*	*0.0000*	*0.00*	*0.3631*	*71.65*	
Rangitikei at Vinegar Hill	*36*	*0.007*	*0.0006*	*7.86*	*0.9971*	*31.87*	
Rangitikei at Kakariki	*26*	*0.007*	*0.0010*	*14.29*	*1.8157*	*6.94*	↑
Rangitikei at Scotts Ferry	78	0.0135	0.0000	0.00	0.2395	81.08	
Manawatu Catchment							
Mangatera at Timber Bay	90	0.1405	-0.0066	-4.67	-2.8833	0.39	↓↓↓
Makakahi at Konini	125	0.009	0.0000	0.00	0.6293	52.92	
Mangatainoka at SH2	129	0.01	0.0000	0.00	-0.0694	94.47	
Manawatu at Hopelands	183	0.023	0.0009	3.91	4.8003	0.00	↑↑↑
Manawatu at Ashhurst Domain	*25*	*0.016*	*0.0000*	*0.00*	*0.0000*	*100.0*	
Oroua at Nelson Street	183	0.01	0.0003	2.50	2.5045	1.23	↑↑
Oroua at Awahuri Bridge	138	0.1015	-0.0025	-2.46	-1.5966	11.04	
Manawatu at Maxwells Line	74	0.013	0.0001	0.67	0.3730	70.91	
Manawatu at 42 Mile	67	0.037	-0.0012	-3.24	-0.9467	34.38	
Manawatu at Whirokino	162	0.035	-0.0005	-1.43	-1.9462	5.16	↓
Whanganui Catchment							
Whanganui at Retaruke	*56*	*0.009*	*0.0005*	*5.56*	*1.1328*	*25.73*	
Whanganui at Pipiriki	76	0.007	0.0005	7.14	2.0785	3.77	↑↑
Whanganui at Kaiwhaiki	147	0.008	0.0003	3.13	1.8953	5.80	↑
Whanganui at Estuary opposite marina	124	0.009	0.0000	0.00	-0.3682	71.28	
Whangaehu Catchment							
Mangawhero at DoC National Park	75	0.012	0.0005	4.17	1.3055	19.17	
Mangawhero downstream at Makotuku confluence	73	0.01	0.0005	5.00	0.9950	31.98	

NB. ANZECC (2002) guidelines are 0.009 g P m^{-3} for upland streams and 0.010 g P m^{-3} for lowland streams.

DRP SKSE %

The SKSE % indicates the annual rate of change of a variable, measured as a percentage of the median value.

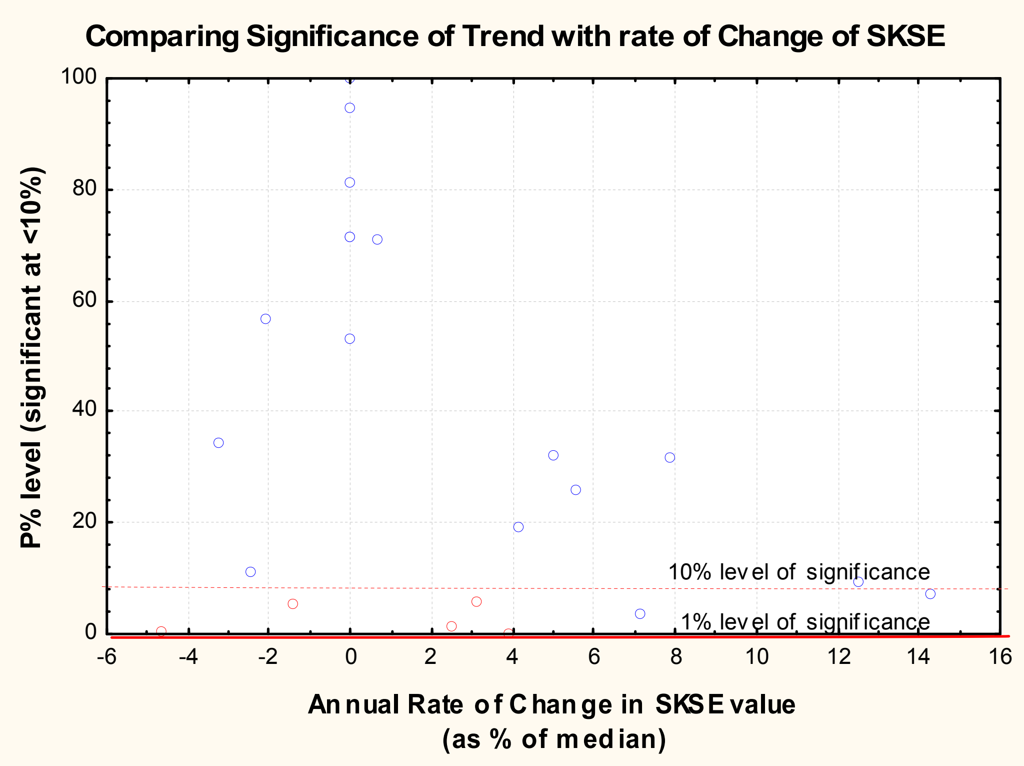


Figure 2. Comparison of trend significance and SKSE% annual rate of change.

An indication of the long term SKSE% rate of change of medians and their relationship to the significance of the trends is given in Figure 2. It can be seen that the most significant trends do not necessarily occur at sites with the highest annual SKSE% rate. Sites that have a higher variance of data are less likely to indicate a significant trend when compared with those sites whose data has less variance (marked in red). The Seasonal Kendall trend test takes account of this amount of variance. It is worthwhile to consider the SKSE% changes across the sites in each catchment.

Three of the six Rangitikei catchment sites indicate increases:

- Rangitikei at River Valley
- Rangitikei at Vinegar Hill
- Rangitikei at Kakariki

Three of the 10 Manawatu sites also record increases, but at a lower rate than the Rangitikei sites:

- Manawatu at Hopelands
- Oroua at Nelson Street
- Manawatu at Maxwells Line

Three of the four Whanganui sites also show long-term increases:

- Whanganui at Retaruke
- Whanganui at Pipiriki
- Whanganui at Kaiwhaiki

Both of the Whangaehu sites rates of increase are positive:

- Mangawhero at DoC NP
- Mangawhero downstream at Makotuku confluence

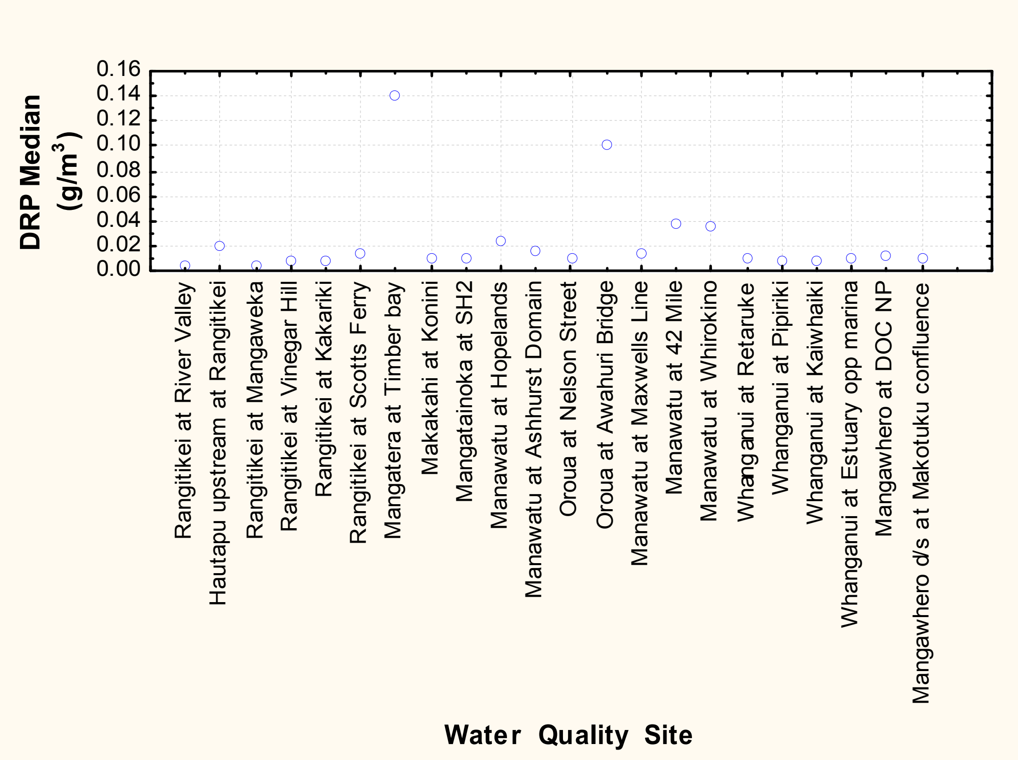


Figure 3. Plot of DRP medians at each site.

The median values in Figure 3 are for all data recorded at the site, usually on a monthly basis. The highest readings for DRP are occurring in the Manawatu catchment.

3.1.1.2 Flow-adjusted data

Seven of the sites indicate a significant increasing trend for DRP (as opposed to five sites before data was flow-adjusted). Four of these sites are in the Manawatu catchment and one is in each of the other three catchments. By comparison with the non flow-adjusted data, the Mangatera at Timber Bay no longer indicates a decreasing trend when flow is adjusted (Table 4).

Table 4. Results of seasonal Kendall Trend Testing on DRP flow-adjusted data.

SoE Site	n	Median (g P m^{-3})	SKSE (Slope estimator)	SKSE % Annual Change	z value	P %	Trend
Rangitikei Catchment							
Rangitikei at River Valley	70	0.003	.0005	16.25	1.854	6.4	↑
Hautapu upstream at Rangitikei	78	0.02	0.0006	3.09	0.718	47.3	
Rangitikei at Mangaweka	*26*	*0.0052*	*0*	*0.52*	*0.73*	*46.8*	
Rangitikei at Vinegar Hill	*36*	*0.0069*	*0.0003*	*4.52*	*0.537*	*59.1*	
Rangitikei at Kakariki	*26*	*0.0065*	*0.0013*	*20.22*	*1.453*	*14.6*	
Rangitikei at Scotts Ferry	Tidal						
Manawatu Catchment							
Mangatera at Timber Bay	90	0.1329	-0.0019	-1.45	-1.007	31.4	
Makakahi at Konini	125	0.0084	0.0002	2.93	2.082	3.7	↑↑
Mangatainoka at SH2	129	0.0095	0.0001	0.88	0.833	40.5	
Manawatu at Hopelands	181	0.0228	0.0008	3.71	5.654	0	↑↑↑
Manawatu at Ashhurst Domain	*25*	*0.0161*	*-0.0004*	*-2.61*	*-0.756*	*45.0*	
Oroua at Nelson Street	148	0.0094	0.0004	4.19	3.032	0.243	↑↑↑
Oroua at Awahuri Bridge	138	0.0968	-0.0034	-3.52	-3.046	0.232	↑↑↑
Manawatu at Maxwells Line	73	0.0126	0.0003	2.48	1.594	11.1	
Manawatu at 42 Mile	66	0.0370	-0.0006	-1.77	-1.424	15.4	
Manawatu at Whirokino	Tidal						
Whanganui Catchment							
Whanganui at Retaruke	*56*	*0.0088*	*0.0004*	*4.11*	*1.284*	*19.9*	
Whanganui at Pipiriki	76	0.0071	0.0004	5.8	1.584	11.3	
Whanganui at Kaiwhaiki	146	0.0078	0.0002	3.12	2.631	0.852	↑↑↑
Whanganui at Estuary opposite marina	Tidal						
Whangaehu Catchment							
Mangawhero at DoC National Park	75	0.0117	0.0009	7.26	2.561	1.045	↑↑
Mangawhero downstream at Makotuku confluence	64	0.01	0.0004	3.52	1.264	20.6	

Some flow data has been supplied by Genesis Energy and NIWA (see Table 2 for further details)
NB. ANZECC (2002) guidelines are 0.009 g P m^{-3} for upland streams and 0.010 g P m^{-3} for lowland streams.

3.1.2 Nitrates (NO_3)

3.1.2.1 Non flow-adjusted data

Nitrate Trends

Five of the 22 sites (23%) had significant increasing trends in nitrate values, and four of these sites tested were extremely significant (Table 5). All five sites are in the Manawatu River catchment. Four of these are in the eastern part of the catchment and the other is near the Manawatu River mouth at Whirokino.

No trends were evident in the Rangitikei, Whanganui or Whangaehu systems (*the Mangawhero at Makotuku* has insufficient data points for the test to be valid).

There was no decreasing trend for nitrate concentration found for any catchment.

Table 5. Results of seasonal Kendall Trend Testing on nitrate non flow-adjusted data.

SoE Site	n	Median (g N m^{-3})	SKSE (Slope estimator)	SKSE % Annual Change	z value	P %	Trend
Rangitikei Catchment							
Rangitikei at River Valley	*39*	*0.05*	*0*	*0*	*0.521*	*60.3*	
Hautapu upstream at Rangitikei	*47*	*0.09*	*0.01*	*11.11*	*0.70*	*48.17*	
Rangitikei at Mangaweka	*17*	*0.07*	*0.05*	*71.43*	*0.00*	*100*	
Rangitikei at Vinegar Hill	*22*	*0.025*	*0.00*	*0.00*	*0.15*	*7.74*	
Rangitikei at Kakariki	*17*	*0.07*	*0.06*	*85.71*	*0.45*	*65.47*	
Rangitikei at Scotts Ferry	*47*	*0.11*	*0.00*	*-3.03*	*-0.40*	*68.77*	
Manawatu Catchment							
Mangatera at Timber Bay	79	0.86	0.04	4.36	2.18	2.90	↑↑
Makakahi at Konini	96	0.74	0.04	5.74	3.84	0.01	↑↑↑
Mangatainoka at SH2	104	1	0.06	5.55	3.45	0.06	↑↑↑
Manawatu at Hopelands	153	0.84	0.02	2.43	3.04	0.24	↑↑↑
Manawatu at Ashhurst Domain	little data						
Oroua at Nelson Street	152	0.23	0.00	0.00	0.13	89.83	
Oroua at Awahuri Bridge	106	0.535	0.00	-0.30	-0.25	80.51	
Manawatu at Maxwells Line	71	0.47	0.01	1.65	0.79	42.94	
Manawatu at 42 Mile	*54*	*0.53*	*0.02*	*4.09*	*0.87*	*38.65*	
Manawatu at Whirokino	130	0.555	0.02	2.70	2.66	0.78	↑↑↑
Whanganui Catchment							
Whanganui at Retaruke	*27*	*0.21*	*-0.02*	*-11.11*	*-0.43*	*66.74*	
Whanganui at Pipiriki	*46*	*0.14*	*0.00*	*0.00*	*-0.21*	*83.66*	
Whanganui at Kaiwhaiki	117	0.16	0.00	0.00	-0.69	48.73	
Whanganui at Estuary opposite marina	*58*	*0.13*	*0.01*	*8.33*	*1.01*	*31.15*	
Whangaehu Catchment							
Mangawhero at DoC National Park	*45*	*0.1*	*0.00*	*0.00*	*-1.24*	*21.66*	
Mangawhero downstream at Makotuku confluence	*43*	*0.31*	*0.04*	*11.29*	*1.89*	*5.94*	↑

NB. ANZECC (2002) guidelines give default trigger values for 'slightly disturbed ecosystems' of 0.167 g N m^{-3} for upland streams and 0.444 g N m^{-3} for lowland streams.

Nitrate Medians

A comparison of the nitrate medians of the 22 sites is given in Figure 4. It can be seen that the Manawatu catchment sites recorded higher medians than almost all other sites, apart from the *Whanganui at Kaiwhaiki* site.

The *Manawatu at Ashhurst* site has insufficient data to be represented in the graph.

Figure 4. Plot of nitrate medians at each site.

In the Rangitikei catchment there is an improvement (lowering) in the median values below Mangaweka, possibly due to the dilution effect from downstream tributaries. The nitrate median values are relatively low.

The Manawatu catchment has higher nitrate median values on the eastern side of the Ruahine Ranges.

The Whanganui catchment nitrate medians are relatively low.

In the Whangaehu catchment there is a large difference for the Mangawhero sites at DoC Headquarters (0.01g m^{-3}) and downstream of the Makotuku confluence (0.31g m^{-3}).

3.1.2.2 Flow-adjusted data

When nitrate data was adjusted for flow, there was a small increase in the number of sites that registered significant increasing trends. All five major trend increases occur in the eastern parts of the Manawatu catchment (Table 6).

Trends at the following 3 sites **continued** to be significant, at either the 0.05 or 0.01 levels, when adjustments for flow were made:

- Makakahi River at Konini;
- Manawatu River at Hopelands; and
- Mangatainoka River at SH2.

Two more Manawatu River sites showed significant increasing trends:

- Oroua at Nelson Street; and
- Manawatu at Maxwells Line.

Mangatera at Timber Bay no longer records a significant increase and the tidal Whirokino site cannot be considered for flow adjustment testing.

Table 6. Results of seasonal Kendall Trend Testing of nitrate flow-adjusted data.

SoE Site	n	Median (g N m^{-3})	SKSE (Slope estimator)	SKSE % Annual Change	z value	P %	Trend
Rangitikei Catchment							
Rangitikei at River Valley	39	0.0492	-.0002	-0.44	0	100	
Hautapu upstream at Rangitikei	47	0.0836	-.0017	-2.07	-.603	54.6	
Rangitikei at Mangaweka	17	0.0648	.0065	10.6	0	100	
Rangitikei at Vinegar Hill	23	0.0028	.0011	4.76	0	100	
Rangitikei at Kakariki	17	0.0702	.0063	8.99	0	100	
Rangitikei at Scotts Ferry							
Manawatu Catchment							
Mangatera at Timber Bay	79	0.0098	.0199	204.2	1.248	21.2	
Makakahi at Konini	96	0.7500	.0529	7.03	4.484	.001	↑↑↑
Mangatainoka at SH2	104	0.9900	.0530	5.36	3.698	.022	↑↑↑
Manawatu at Hopelands	153	0.8684	.0251	2.89	2.731	.630	↑↑↑
Manawatu at Ashhurst Domain	Little data						
Oroua at Nelson Street	112	0.2197	.0130	5.9	2.992	.277	↑↑↑
Oroua at Awahuri Bridge	106	0.5200	.0110	2.14	.771	44.1	
Manawatu at Maxwells Line	71	0.4910	.0182	3.71	2.222	2.626	↑↑
Manawatu at 42 Mile	54	0.5480	.0190	3.48	1.66	9.7	↑
Manawatu at Whirokino							
Whanganui Catchment							
Whanganui at Retaruke	27	0.2080	-.0162	-8.05	-1.289	19.7	
Whanganui at Pipiriki	46	0.1459	-.0210	-14.06	-1.753	8.0	↓
Whanganui at Kaiwhaiki	117	0.1568	-.0001	-.06	0	100	
Whanganui at Estuary opposite marina							
Whangaehu Catchment							
Mangawhero at DoC National Park	45	0.0999	.0006	.56	.824	41.01	
Mangawhero downstream at Makotuku confluence	42	0.2974	.0153	5.13	.458	64.7	

Some flow data has been supplied by Genesis Energy and NIWA (see Table 2 for details).

NB. ANZECC (2002) guidelines give default trigger values for 'slightly disturbed ecosystems' of 0.167 g N m^{-3} for upland streams and 0.444 g N m^{-3} for lowland streams.

3.1.3 *E. coli*

Reference to the number of data points used for each site indicates that there is insufficient data to test effectively for *E. coli* trends at any site. The results for flow-adjusted *E coli.* data are not discussed further here as no sites included 60 data items.

3.1.4 Turbidity

3.1.4.1 Non flow-adjusted data

Four of the 22 sites indicated a statistically significant increasing trend, and one a decreasing pattern (Table 8). Three of those increasing are in the Manawatu catchment (*Manawatu at Hopelands, Oroua at Nelson Street, Manawatu at Whirokino*), and one is on the final reaches of the Whanganui River (*Whanganui at Estuary opposite marina*). The result for *Manawatu at Ashhurst Domain* is limited by the small size of the dataset (24).

There has been no significant trend of increasing turbidity in the Rangitikei catchment.

The Mangawhero at DoC National Park has shown a significant decrease (at the 0.10 level).

Table 7. Results of seasonal Kendall Trend Testing on turbidity non flow-adjusted data.

SoE Site	n	Median	SKSE	SKSE % annual Change	z value	P %	Trend
Rangitikei Catchment							
Rangitikei at River Valley	78	0.85	0.00	0.00	-0.0479	96.18	
Hautapu upstream at Rangitikei	78	4.70	0.02	0.35	0.0958	92.37	
Rangitikei at Mangaweka	78	6.55	-0.20	-2.98	-1.0787	28.07	
Rangitikei at Vinegar Hill	*36*	*2.95*	*0.08*	*2.54*	*0.0000*	*100*	
Rangitikei at Kakariki	75	7.70	-0.11	-1.40	-0.5430	58.71	
Rangitikei at Scotts Ferry	78	8.90	-0.24	-2.67	-0.2873	77.38	
Manawatu Catchment							
Mangatera at Timber Bay	92	5.30	0.16	2.98	1.0284	30.38	
Makakahi at Konini	125	2.70	0.04	1.65	1.0408	29.80	
Mangatainoka at SH2	129	2.00	-0.02	-0.83	-0.6248	53.21	
Manawatu at Hopelands	179	5.10	0.18	3.45	2.2075	2.73	↑↑
Manawatu at Ashhurst Domain	*24*	*5.30*	*2.13*	*40.09*	*2.9122*	*0.36*	↑↑↑
Oroua at Nelson Street	179	3.50	0.15	4.29	2.5085	1.21	↑↑
Oroua at Awahuri Bridge	138	4.85	0.02	0.38	0.1260	89.97	
Manawatu at Maxwells Line	104	7.90	-0.05	-0.63	-0.3156	75.23	
Manawatu at 42 Mile	67	5.50	0.08	1.36	0.4260	67.01	
Manawatu at Whirokino	162	17.50	0.91	5.18	3.0940	0.20	↑↑↑
Whanganui Catchment							
Whanganui at Retaruke	64	6.70	-0.34	-5.07	-1.326	18.5	
Whanganui at Pipiriki	*78*	*9.2*	*-0.65*	*-7.07*	*-0.862*	*38.87*	
Whanganui at Kaiwhaiki	147	13.60	0.20	1.47	1.3976	16.22	
Whanganui at Estuary opposite marina	141	20.00	0.92	4.58	2.0374	4.16	↑↑
Whangaehu Catchment							
Mangawhero at DoC National Park	75	0.80	-0.05	-6.25	-1.6750	9.75	↓
Mangawhero downstream at Makotuku confluence	72	1.48	0.00	0.00	0.2661	79.01	

Turbidity SKSE % Annual Changes

An indication of the average annual SKSE% changes in turbidity and their relationship to the significance of the trends at the 22 river sites is given in Figure 6.

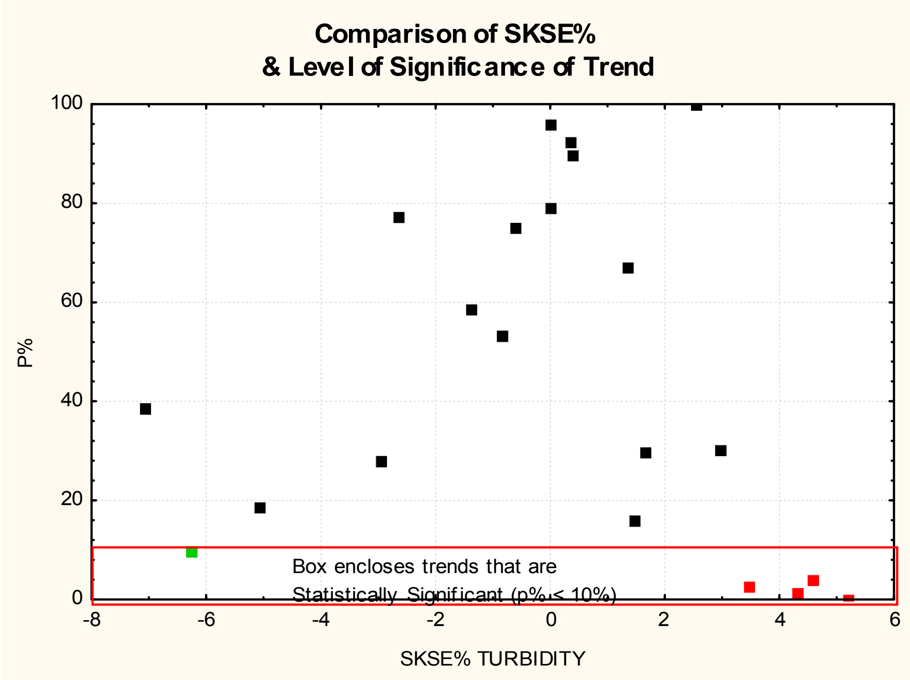


Figure 5. Comparison of SKSE% and level of significance of trend.

In contrast to DRP, sites here showing a statistically significant turbidity trend also have high SKSE% annual change magnitudes (red and green data points). This may mean that the scale of magnitude of nitrate scores, compared with DRP values, has some impact on trend test results.

Turbidity Medians

Turbidity medians were plotted for each site in Figure 7. The Whanganui catchment has higher turbidity medians than most other catchments and the highest turbidity readings for three of the four main rivers are in areas of tidal influence (*Rangitikei at Scott's Ferry, Manawatu at Whirokino and Whanganui at Estuary opposite marina*).

Turbidity in the Rangitikei River increases downstream, apart from the Vinegar Hill site.

There is also a progressive increase downstream for the Whanganui Catchment.

The two Whangaehu sites have very low turbidity values.

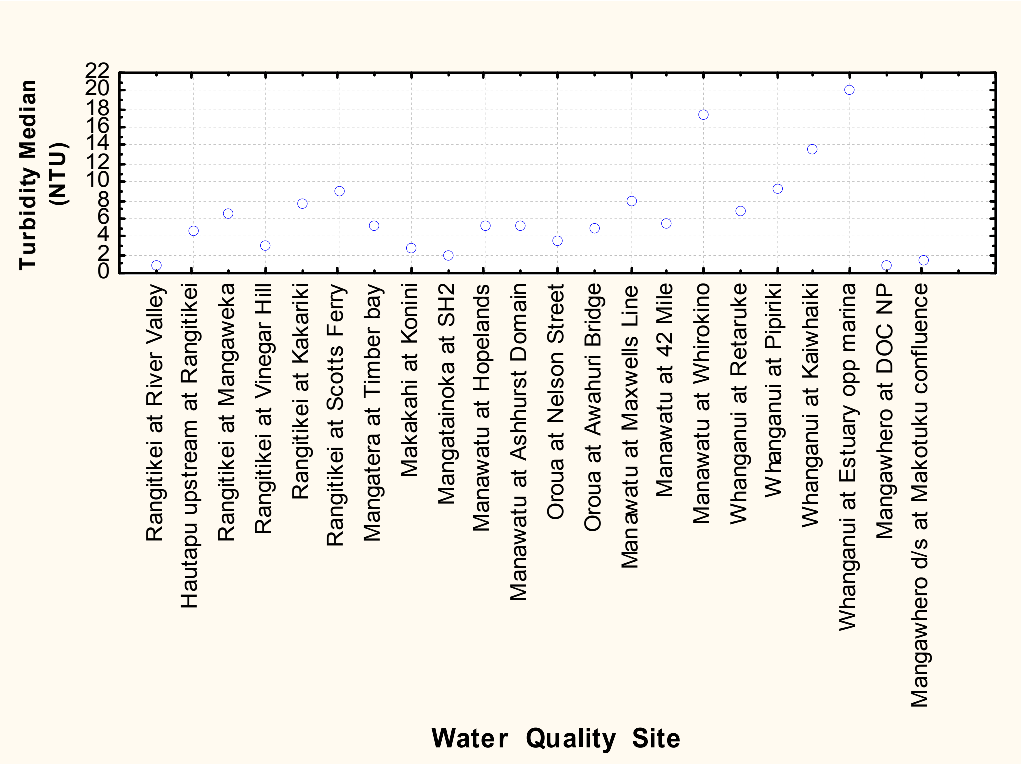


Figure 6. Long-Term Turbidity Medians by Water Quality site.

3.1.4.2 Flow-adjusted data

A comparison of results between the **non** flow-adjusted and flow-adjusted data for turbidity indicates the greatest variation of all three water quality variables.

Five sites indicated a significant increasing trend when flow-adjusted data was used:

- Makakahi at Konini;
- Oroua at Nelson Street (in both turbidity tests);
- Oroua at Awahuri;
- Manawatu at Maxwells Line (extremely significant); and
- Whanganui at Kaiwhaiki (extremely significant);

and two sites showed a decreasing trend:

- Mangawhero at DoC National Park (extremely significant); and
- Whanganui at Pipiriki.

No sites in the Rangitikei catchment registered any significant trend in flow-adjusted turbidity data.

Four of the Manawatu catchment sites indicate significant worsening trends when flow-adjusted data is used, although the *Hopelands* site is no longer showing any significant trend in turbidity levels.

In the Whanganui catchment the *Whanganui at Kaiwhaiki* registered an extremely significant increase in turbidity for flow-adjusted data, and the Whanganui *at Pipiriki* a significant decrease.

In the Whangaehu catchment the *Mangawhero at DoC Headquarters* site registered an extremely significant decreasing trend in turbidity levels.

The results for all sites are given in Table 8.

Table 8. Results of seasonal Kendall Trend Testing on turbidity flow-adjusted data.

SoE Site	Number of samples	Median	SKSE	SKSE % annual Change	z value	P %	Trend
Rangitikei Catchment							
Rangitikei at River Valley	70	0.737	-.0079	-1.07	-.393	69.4	
Hautapu upstream at Rangitikei	78	4.33	-.2385	-5.5	-1.389	16.5	
Rangitikei at Mangaweka	78	5.7	-.144	-2.49	-1.079	28.1	
Rangitikei at Vinegar Hill	*36*	*2.607*	*-.1544*	*-5.92*	*-.537*	*59.1*	
Rangitikei at Kakariki	75	6.55	.1873	2.86	1.185	23.6	
Rangitikei at Scotts Ferry	Tidal						
Manawatu Catchment							
Mangatera at Timber Bay	92	2.657	.0034	.13	.033	97.4	
Makakahi at Konini	125	2.46	.063	2.56	2.082	3.7	↑↑
Mangatainoka at SH2	129	1.92	-.0319	-1.66	-1.203	22.9	
Manawatu at Hopelands	177	4.246	.086	2.03	1.409	15.9	
Manawatu at Ashhurst Domain	*26*	*4.75*	*.6081*	*12.79*	*1.334*	*18.2*	
Oroua at Nelson Street	149	3.70	.16	4.33	2.414	1.535	↑↑
Oroua at Awahuri Bridge	138	4.480	.2055	4.59	1.786	7.416	↑
Manawatu at Maxwells Line	104	7.174	.2559	3.57	3.662	.025	↑↑↑
Manawatu at 42 Mile	67	5.36	.1207	2.25	1.231	21.8	
Manawatu at Whirokino	Tidal						
Whanganui Catchment							
Whanganui at Retaruke	64	5.17	-.3218	-6.23	-.631	52.8	
Whanganui at Pipiriki	78	7.75	-.6635	-8.56	-1.868	6.2	↓
Whanganui at Kaiwhaiki	147	11.8	.63	5.32	2.68	.736	↑↑↑
Whanganui at Estuary opposite marina	Tidal						
Whangaehu Catchment							
Mangawhero at DoC National Park	75	.651	-.1212	-18.63	-2.76	.575	↓↓↓
Mangawhero downstream at Makotuku confluence	65	.902	.0397	4.4	.432	66.5	

Some flow data has been supplied by Genesis Energy and NIWA (see Table 2 for further details)

4. Discussion by Monitoring Site and Catchment

For all parameters in this report a significant positive (or increasing) trend indicates a lowering in water quality over time.

Table 9. Results of seasonal Kendall Trend Testing on turbidity non flow-adjusted data.

SoE Site	Non flow-adjusted				Flow-adjusted			
	DRP	NO_3	TURB	Severity Score	DRP	NO_3	TURB	Severity Score
Rangitikei Catchment								
Rangitikei at River Valley	↑			1	↑			1
Hautapu upstream at Rangitikei				0				0
Rangitikei at Mangaweka				0				0
Rangitikei at Vinegar Hill				0				0
Rangitikei at Kakariki				0				0
Rangitikei at Scotts Ferry*				0				-
Manawatu Catchment								
Mangatera at Timber Bay	↓↓↓	↑↑		3				0
Makakahi at Konini		↑↑		3	↑↑	↑↑↑	↑↑	5
Mangatainoka at SH2		↑↑↑		5		↑↑↑		5
Manawatu at Hopelands	↑↑↑	↑↑↑	↑↑	13	↑↑↑	↑↑↑		10
Manawatu at Ashhurst Domain				-				-
Oroua at Nelson Street	↑↑		↑↑	6	↑↑↑	↑↑↑	↑↑	13
Oroua at Awahuri Bridge				0	↑↑↑		↑	8
Manawatu at Maxwells Line				0		↑↑	↑↑↑	8
Manawatu at 42 Mile				0				0
Manawatu at Whirokino*	↓	↑↑↑	↑↑↑	10				-
Whanganui Catchment								
Whanganui at Retaruke				0				0
Whanganui at Pipiriki	↑↑			3			↓	0
Whanganui at Kaiwhaiki	↑↑↑			1	↑↑↑		↑↑↑	10
Whanganui at Estuary opposite marina*			↑↑	3				-
Whangaehu Catchment								
Mangawhero at DoC National Park			↓	0	↑↑		↓↓↓	0
Mangawhero downstream at Makotuku confluence				0				0

* *Tidal sites were not tested as part of the flow-adjustment process.*

1. *Some flow data has been supplied by Genesis Energy and NIWA.*
2. *Red arrows (↑) represent an increasing trend in concentration of a given water quality indicator (ie. a degradation in water quality). Green arrows (↓) represent a decreasing trend (ie. an improvement in water quality).*
3. *↑/↓ indicates a significant trend (a probability of 90%)*
   ↑↑/↓↓ indicates a very significant trend (a probability of 95%)
   ↑↑↑/↓↓↓ indicates a highly significant trend (a probability of 99%)

For non flow-adjusted data it can be seen that there are significant increasing trends in the Manawatu catchment - particularly at *Hopelands* and *Oroua at Nelson Street* - and, to a lesser extent, in the Whanganui catchment (Table 10).

When data is flow-adjusted it can be seen that there are again significant increases in the Manawatu catchment. Twelve (50%) of a possible 24 tests show an increasing trend at either the extremely significant or very significant level for this catchment. There are also increasing trends at the *Whanganui at Kaiwhaiki* site, although tidal influences may affect results for the turbidity variable.

4.1 The impact of flow-adjusting the data

When flow-adjusted data was used in trends testing, a greater number of sites recorded significant changes. More significant increases were identified at *Makakahi at Konini, Oroua at Nelson Street, Oroua at Awahuri Bridge*, Whanganui at Kaiwhaiki and Mangawhero at DoC National Park.

However, there was not always a consistent pattern. Trends that became no longer significant occurred at *Mangatera at Timber Bay* and *Whanganui at Pipiriki*.

For non flow-adjusted DRP data there were significant increases at five sites and decreases at two sites. Testing with flow-adjusted data indicated increases at seven sites. The *Rangitikei at River Valley, Manawatu at Hopelands, Oroua at Nelson Street and Whanganui at Kaiwhaiki* sites gave significant results in both tests.

All concerns with Nitrate trends are confined to the Manawatu catchment.

The testing of flow-adjusted turbidity data indicated more sites with significant increasing trends than the testing on non flow-adjusted data. This is in agreement with the studies by Smith *et al.* (1996) and Vant and Smith (2004). Most of these sites were in the Manawatu catchment. *Makakahi at Konini* and *Manawatu at Maxwells Line* were newly identified sites with significant increasing trends. However, *Manawatu at Hopelands* no longer registered a significant increase using the flow-adjusted data

4.2 Identification of Problem Sites

To rank the sites in terms of severity of trends, a numerical scale was developed based on the significance of the P level of the trend:

1 = **significant** increase in trend, at 0.10 level
3 = **very significant** increase in trend, at 0.05 level
5 = **extremely significant** increase in trend, at 0.01 level

Note: A decrease at a site was not scored.

4.2.1 Non flow-adjusted data

The 22 sites fall into three groups, in terms of the severity of trends (Table 10).

Table 10. Sites ranked by severity of trends based on non flow-adjusted data.

SoE Site Description	Score (Max = +15)
Manawatu at Hopelands	+13
Manawatu at Whirokino	+10
Oroua at Nelson Street	+6
Mangatainoka at SH2	+5
Makakahi at Konini	+3
Mangatera at Timber Bay	+3
Whanganui at Estuary opposite marina	+3
Whanganui at Pipiriki	+3
Rangitikei at River Valley	+1
Whanganui at Kaiwhaiki	+1
Hautapu upstream at Rangitikei	0
Rangitikei at Mangaweka	0
Rangitikei at Vinegar Hill	0
Rangitikei at Kakariki	0
Rangitikei at Scotts Ferry	0
Manawatu at Ashhurst	0
Oroua at Awahuri Bridge	0
Manawatu at Maxwells Line	0
Manawatu at 42 Mile	0
Whanganui at Retaruke	0
Mangawhero at DoC National Park	0
Mangawhero downstream at Makotuku Confluence	0

Group 1:
These have registered significant increasing trends for two or three variables, at a 0.05 or 0.01 level (very significant or extremely significant). The *Manawatu at Hopelands* site has serious increasing trends for all three variables. Data for this site extends back to 1987 for these variables in an almost unbroken sequence. It may be instructive to carry out the same test for more recent data to see whether changes made since the implementation of the Manawatu Catchment Water Quality Regional Plan (1998) has ameliorated the above trend. The *Oroua at Nelson Street* site has very significant increasing trends for both DRP and turbidity. The tidal *Manawatu at Whirokino* site also has highly significant trends for both Nitrate and turbidity.

Group 2:
These have registered highly significant increasing trends for one variable, at a very significant or extremely significant level. Three of this group are in the Manawatu catchment, east of the Ruahine Ranges (*Makakahi at Konini, Mangatainoka at SH2, Mangatera at Timber Bay*) and two are in the Whanganui catchment (*Whanganui at Pipiriki, Whanganui at Estuary opposite marina*).

Group 3:
These sites have shown either no statistically significant increase, or for one variable at the 0.10 level only.

It should also be noted that there has been a significant improvement in DRP levels at Mangatera at Timber Bay and a minor improvement at the Manawatu at Whirokino site. However, their median levels remain high in absolute terms and in relation to other sites.

4.2.2 Flow-adjusted data

Table 11. Ranked by severity of trends using flow-adjusted data.

SoE Site Description	Score (Max = +15)
Oroua at Nelson Street	+13
Manawatu at Hopelands	+10
Whanganui at Kaiwhaiki	+10
Manawatu at Maxwells Line	+8
Oroua at Awahuri Bridge	+6
Mangatainoka at SH2	+5
Makakahi at Konini	+5
Rangitikei at River Valley	+1
Hautapu upstream at Rangitikei	0
Rangitikei at River Valley	0
Rangitikei at Mangaweka	0
Rangitikei at Vinegar Hill	0
Rangitikei at Kakariki	0
Mangatera at Timber Bay	0
Manawatu at 42 Mile	0
Whanganui at Pipiriki	0
Whanganui at Retaruke	0
Mangawhero at DoC National Park	0
Mangawhero downstream at Makotuku confluence	0
Rangitikei at Scotts Ferry	Tidal
Manawatu at Whirokino	Tidal
Whanganui at Estuary opposite marina	Tidal

Some flow data was provided by Genesis Energy and NIWA

Results for flow-adjusted data indicate a growth in the number of **Group 1** sites - those that have registered significant increasing trends for two or three variables, at a very significant or extremely significant level (Table 11).

These sites are:

- Oroua at Nelson Street;
- Manawatu at Hopelands;

- Whanganui at Kaiwhaiki;
- Manawatu at Maxwells Line; and
- Oroua at Awahuri Bridge.

Four of these sites are in the Manawatu catchment.

4.2.3 Ranking of Severity of Trends by Catchment

It is evident that the Manawatu catchment has the highest proportion of sites whose trends give greatest cause for concern. This can be seen across all three water quality indicators.

When data is not adjusted for flow, the Whanganui catchment has significant increasing trends in DRP values at 50% of the surveyed sites, and the Estuary site has increasing turbidity. When data is flow-adjusted only the Kaiwhaiki site has highly significant increasing trends (for both DRP and turbidity). These results for Kaiwhaiki may be affected by the tidal location of its water quality sampling site.

The only increasing trend in the Rangitikei catchment is with DRP values at the River Valley site and this is at the lowest level of significance.

The Whangaehu catchment has an increasing trend for DRP near the headwaters (for flow adjusted data), and the decrease in turbidity at the same site (in both tests) is pleasing to note.

4.3 Interpretation of Trends

This report has focused on the trends in the data rather than proposing reasons for those trends. However, the increasingly intensive use of agricultural land in the Horizons' Region over the past 20 years has coincided with the increasing trends that have been identified. In a NIWA investigation of the national dataset for 1989 to 2001 Snelder *et al.* (2003) state that DRP concentrations have increased significantly in catchments whose land cover is dominated by pasture.

Regardless, the current *state* of the water quality within the catchments reflects, to some degree, the results of past activities, ie. there is a time lag between an activity within the catchment, its effect on the river (eg. nitrogen or sediment entering into the river), and an environmental indicator being measured. Thus, the trends shown here would be indicative of past activities and these may well change (for better or worse) as a result of current activities.

Gaining an historical perspective of development within the Manawatu catchment, for example, would aid interpretation of the trends shown here as well as likely future trends.

This report links strongly with a concurrent study in the upper Manawatu catchment that examined the proportion of point source and non-point source contributions of nitrogen and phosphorous (Ledein, 2006) and recent regional-scale analysis which identified sub-catchments with degraded water quality (Ausseil *et al.*, 2005).

5. Relationship of Findings to other River Studies in NZ

5.1 NIWA study of NZ Rivers 1996

A NIWA study was made on water quality trends in New Zealand Rivers (using data for 1989 to 1993) that had a Mean Annual Low Flow (MALF) of at least 15 $m^3 s^{-1}$ (Smith *et al.,* 1996). It employed similar testing methods and levels of significance to the present study.

Sites in this analysis include rivers considerably smaller than a MALF of 15 $m^3 s^{-1}$. Also, there is not a close match between the dates of the data used in the two surveys. Although both studies have a similar start date (1989) this Horizons' study uses data up to the end of 2004. There is also the problem that the North Island sites studied by NIWA were one per river, whereas the Horizons' survey includes multiple sites for each of the four rivers studied. As part of its SoE monitoring role, Horizons is interested in trends at a variety of sites along each river.

Informal comparisons have been made below using the results of the NIWA study for North Island rivers and this report (Table 12).

Table 12. Comparisons of findings by NIWA and Horizons for DRP, nitrates and turbidity.

	NIWA (NI rivers)	**Horizons** Non-flow adjusted	Flow adjusted
DRP	No trend	No trend	Increasing trend in Manawatu Catchment
Nitrates	Decreasing trend	Increasing trend in Manawatu Catchment	Increasing trend in Manawatu Catchment
Turbidity	No trend	Increasing trend in Manawatu Catchment	Increasing trend in Manawatu Catchment

This suggests results for the Horizons' Region are not in step with the NIWA findings of overall downward trends in Nitrate for North Island rivers.

5.2 Trends in River Water Quality in the Waikato Region 2004

The Waikato report covers a more similar time span to this Horizons study, although significance was identified at only the 0.05 and 0.01 levels of probability. The following comparison is made between Horizons' data and the data for all Environment Waikato except the Waikato River itself (Table 13).

Environment Waikato found significant results ($P < 0.05$) in flow-adjusted data for 44% of its records. 22% of these significant results were not evident when **non** flow-adjusted data was tested. This indicates that flow-adjusting of the data increases the likelihood of a trend being recognised.

Using the same type of data **and** levels of significance the present Horizons' study identified significant results in 28% of the water quality records. 30% of significant results for flow-adjusted data did not appear in the **non** flow-adjusted data.

Table 13. Comparisons of percentage of findings showing significant increase or decrease by Environment Waikato and Horizons for DRP, nitrates and turbidity.

	Trend	Waikato	Horizons
DRP	Significant Increase	28%	14%
	Significant Decrease	19%	5%
Nitrates	Significant Increase	33%	23%
	Significant Decrease	20%	0%
Turbidity	Significant Increase	8%	19%
	Significant Decrease	19%	5%

DRP trends in the Waikato Region have been more decisive. However, both regions have had more increasing than decreasing trends that were significant.

Nitrate trends in the Waikato Region are again more clear-cut. However, both regions have had more increasing than decreasing trends that were significant.

A higher proportion of sites in the Horizons Region experienced significant increases in turbidity trend results, compared with the Waikato results.

6. Conclusions

Trends for concentrations of DRP, NO_3 and turbidity are increasing at many sites in the Manawatu catchment (ie. water quality for these indicators is degrading).

The Rangitikei catchment shows a significant increase in DRP concentration at one site near the headwaters, but this is not observed at other sites.

The Whanganui catchment shows differing trends depending on the use of flow-adjusted or non flow-adjusted data. For non flow-adjusted data DRP concentrations increased at two sites (middle and lower reaches) and there is increasing turbidity at the tidal site. When data is flow-adjusted only the lower river site (Kaiwhaiki) has highly significant increasing trends (for both DRP and turbidity). It is noted that this site may be under tidal influence.

The Whangaehu catchment has an increasing trend for DRP near the headwaters (for flow adjusted data), and a decrease in turbidity at the same site (in both tests).

The increasingly intensive use of agricultural land in the Horizons' Region over the past 20 years has coincided with the increasing trends presented here. That association links strongly with a concurrent study in the upper Manawatu catchment that examined the proportion of point source and non-point source contributions of nitrogen and phosphorous and recent regional-scale analysis which identified sub-catchments with degraded water quality.

7. References

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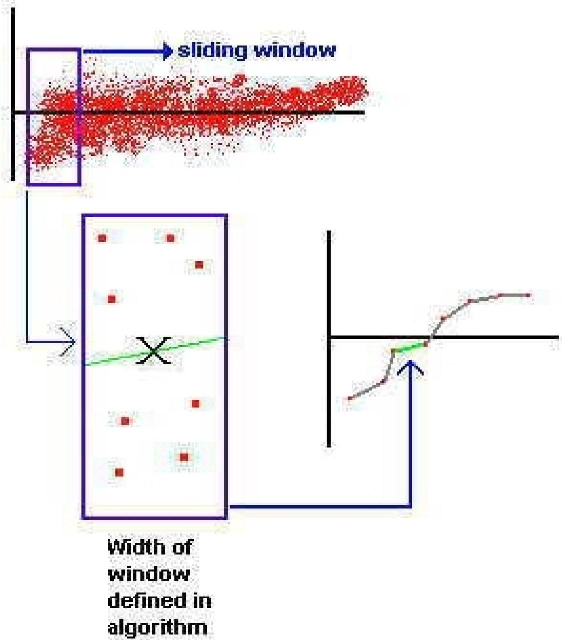
LOWESS SMOOTHING PROCEDURE

A simple example of a Lowess Smoothing is shown below:

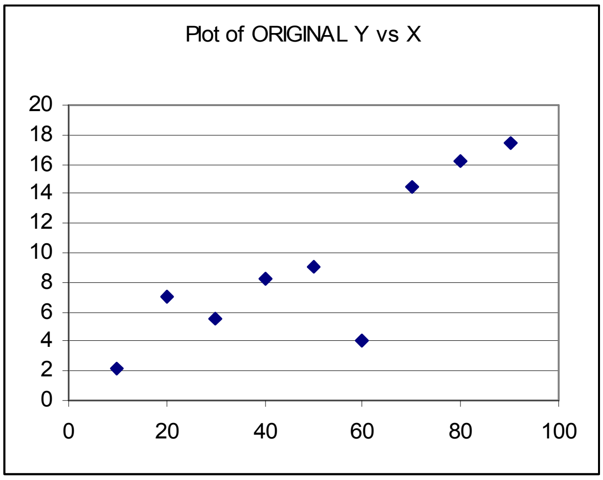


Non flow-adjusted data

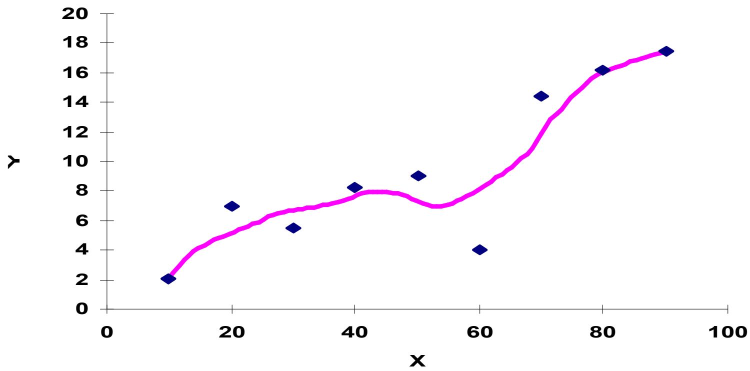
Original X	Original Y
10	2.1
20	7
30	5.5
40	8.2
50	9
60	4
70	14.4
80	16.2
90	17.5

Plot of flow-adjusted data

Note: (20,7) is well above the general trend and (60,4) is well below the trend.



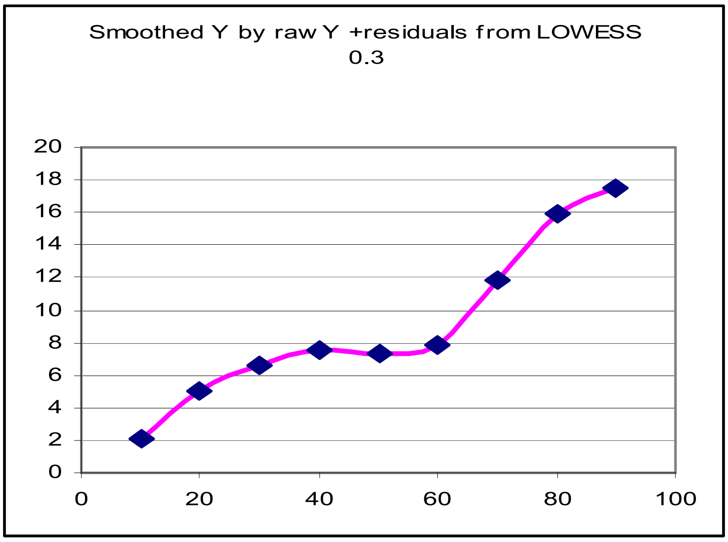
Direct generation of lowess curve from LOWESS package



When the LOWESS curve is generated **a residual value is given for each raw Y value**. This indicates the distance that the raw value is from the Smoothed LOWESS Curve (eg. when X = 60 the residual for our lower than expected Y = 4 is **-3.90233**). When this amount is **subtracted** from Y=4 the value is adjusted upwards to **+7.90233**. Higher than trend values, eg. Y = 7 in (20,7) are adjusted downwards.

Non Flow-adjusted Data		LOWESS	Smoothed Y
X Orig X	**Y**	Residual	= (raw Y-residual)
10	2.1	0	2.1
20	**7**	**1.999011**	**5.000989476**
30	5.5	-1.08452	6.584516025
40	8.2	0.68647	7.513530314
50	9	1.692847	7.307152676
60	**4**	**-3.90233**	**7.902326945**
70	14.4	2.533881	11.866119
80	16.2	0.280128	15.91987209
90	17.5	0	17.5

When the original X value is plotted with the Smoothed Y, we get the following LOWESS curve:



A data value above the LOWESS trend graph will have a +ve residual. When each Residual is added to the median of all the data this dataset can now be processed to find the SKSE and tested to identify the significance or otherwise of any trend.

Further details of the process are given in *Trends in river water quality in the Waikato Region, 1987-2002. Environment Waikato Technical Report 2004/02, prepared by B. Vant and P. Smith.*

APPENDIX 2

LOCATION OF SUPPORTING DATA FILES

It is envisaged that this trends study should be replicated every five years, or as datasets grow to sufficient size (60 items) to be analysed. Changes in water scientist personnel can lead to a loss of information as to how a previous work has been carried out, affecting the ability to relate future investigations to those carried out in the past.

- Files of the reorganised data are stored in:

  <Councildata/Research /Water_Quality/Trends/Processed data>

- Calculation of the SKSE and determination of the significance:

  <Councildata/Research/Water_Quality/Trends/Bill Vant EMPTY seasonal_Kendall_trend_analysis spreadsheet >

Steps to follow to carry out SKSE Trend Testing on flow-adjusted data using EXCEL and Data Desk ™

Non flow-adjusted data and flow data in Excel Spreadsheet

1. In the **EXCEL** file try to have your FLOW data as the RIGHT HAND column OF THE PAIR (makes it the X variable quickly in Data Desk ™). Leave 2 blank columns to the right of the FLOW COLUMN where we later store the Data Desk™ residuals of the dependent variable [eg. DRP] and then the residual + overall median value.
2. Copy files onto clipboard including the variable headings using CTRL-C.

Using Data Desk ™

3. Open Data Desk ™ and go to FILE, NEW DATAFILE.
4. Click inside File box at top right.
5. Paste using CTRL-V.
6. It will give you a “The first row of the data is” … option and shows it in the next box below.
7. Click on USE THESE VARIABLE NAMES.
8. Your data should now be copied into Data Desk ™.
9. Setting the LOWESS DEFAULT VALUES AT 30%.
   a. SELECT plot then PLOT OPTIONS then SMOOTHING OPTIONS.
   b. Set LOWESS SPAN at 30%.
   c. Tick the box next to LOWESS ROBUST SMOOTHING and clear the TREWESS box.
   d. Set this as the DEFAULT SETUP by ticking that box.
   e. Press OK. This will usually stay as default, but it pays to check!

10. Click and drag a rectangle across the two clipboard files – X must be on the FLOW set.
11. Select PLOT, SMOOTHING and LOWESS. A graph with DRP FLOW and LOWESS smoothing curve will appear at top left of screen.
12. CLICK on the Arrowhead ► at the top left of the graph.
13. Select SMOOTHING, COMPUTE ROUGH (this is the set of residual values we want to copy back next to the original columns in the EXCEL file) Note that a new file now appears in the CLIPBOARD called LOWESS… and is labeled Y. This is a set of the residuals for all the sequence of, eg. DRP values. We now need to copy this file, and paste it into EXCEL.
14. Click on the LOWESS file box and select EDIT, COPY VARIABLES. Select YES for “Are variables in top row?” question.

Returning to Original Excel Spreadsheet

15. Return to EXCEL and click cell where you want to copy the heading and residuals back into position, carefully matching by dates.
16. Use CTRL-V to paste the residuals in. You need to check this column before entering into the Bill Vant program. Any blanks in the middle of the data sent to DataDesk returns with a ▪ symbol. This will cause the BV program to fail to process the data. You need to locate each of these and CLEAR ALL their positions. Do not use the DELETE key as your dates will not match.
17. In the final empty column next to the residuals calculate a new variable – (the flow-adjusted data) = residual +overall median of the variable. This median has been calculated for you already in the Bill Vant spreadsheet when the raw data was used in it.

Bill Vant Program for Seasonal Kendall Testing

18. Go to the Bill Vant spreadsheet and paste the flow-adjusted data into their matching date positions, using Paste Special, Values (Paste in the flow-adjusted data only (not the date also and do not paste the headings)).
19. The results of the test can then be copied down.
20. It is worth clearing the pasted data column from the Bill Vant program at this stage as it is possible, especially with non-contiguous data, to not paste completely over the previous data.
21. If ‘VALUE’ appears in the summary cells you may need to carefully CLEAR (All) the blank cells in the data column.