5 City of Ryde Water Quality and Macroinvertebrate Sampling

The City of Ryde monitoring program was undertaken by Sydney Water and other consultants from 2004-11 and included macroinvertebrate and water quality sampling in five of the 14 catchments within the LGA. The initial program, which began in spring 2004, included water quality and macroinvertebrate sampling at 5 core sites (Figure 13).

As shown in Table 5, the water quality and macroinvertebrate sampling occurred either two or three times each season, for example in spring 2010 sampling occurred in 29 September and 27 October. The water quality program was expanded in 2008 to include sampling at a further three sites along Shrimptons Creek, three sites on Porters Creek and two sites on Buffalo Creek (Figure 13). The last sampling undertaken was in autumn 2011.

This assessment of water quality and macroinvertebrate data presented in this section, reviews all of the data from 2004 to 2011, as provided by Council in a spreadsheet.

Table 5: The number of either water quality or macroinvertebrate samples for each season at each site. Note the expansion of the water quality program in Autumn 2008.

Site			Season													
			2004	2005		2006		2007		2008		2009		2010		2011
			Sp	Aut	Sp	Aut	Sp	Aut	Sp	Aut	Sp	Aut	Sp	Aut	Sp	Aut
Terrys Ck	Macro	Site 1	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	WQ	Site 1	3	3	3	3	3	2	2	2	2	2	2	2	2	2
Shrimptons Ck	Macro	Site 2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	WQ	Site 2	3	3	3	3	3	2	2	2	2	2	2	2	2	2
		Kent Rd								2	2	2	2	2	2	2
		Bridge St								2	2	2	2	2	2	2
		Quarry Rd								2	2	2	2	2	2	2
Porters Creek	Macro	Site 3	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	WQ	Site 3		3	3	3	3	2	2	2	2	2	2	2	2	2
		Wicks Rd								2	2	2	2	2	2	2
		Main Branch								2	2	2	2	2	2	2
		Spur								2	2	2	2	2	2	2
Buffalo Ck	Macro	Site 4	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	WQ	Site 4	3	3	3	3	3	2	2	2	2	2	2	2	2	2
		d/s Burrows Pk								2	2	2	2	2	2	2
		u/s Burrows Pk								2	2	2	2	2	2	2
Archers Ck	Macro	Site 5	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	WQ	Site 5	3	3	3	3	3	2	2	2	2	2	2	2	2	2

Figure 13: Sampling locations in the City of Ryde, showing both the core sites in red (named "Site X") and the satellite sites in yellow (named by street location).

5.1 Ecological status of City of Ryde waterways

A total of 4727 macroinvertebrate animals representing 78 different families were collected and identified by consultants (primarily Sydney Water) from The City of Ryde waterways from 2004 to 2011. This aquatic macroinvertebrate samples clearly established that Ryde waterways are strongly ecologically degraded when compared to other reference waterways in the Sydney Basin. Water quality data collected in 2004-2011 from the same waterways confirmed that several water quality attributes were stressful to aquatic ecosystems.

This current review of the macroinvertebrate data utilised several approaches. Firstly all macroinvertebrate data was analysed for spatial and temporal variations in community structure using multivariate data analysis (i.e. all macroinvertebrate family data). Macroinvertebrate biotic indices were also calculated. This included the number of families in the sensitive three EPT orders: Mayflies (*Ephemeroptera*), Stoneflies (*Trichoptera*) and Stoneflies (*Plecoptera*). Other biotic indices included family richness, abundance, SIGNAL and AUSRIVAS scores.

5.1.1 Community analysis

Macroinvertebrate data was analysed using multivariate data analysis. Non-metric multidimensional scaling (nMDS) was used, using the PRIMER Version 6 software (Clarke, 1993). This analysis compared the ecological differences of freshwater macroinvertebrates collected. An R-value of 1.000 indicates that the comparison of samples shared no common macroinvertebrate families. An R-value of 0.000 indicates that the comparison of samples shared the same families.

Macroinvertebrate community structure in The City of Ryde waterways (2004-11) varied highly significantly from waterway to waterway (Global R=0.624). The largest ecological differences were between Porters Creek and Shrimptons Creek (Table 6), with an R-value of 0.816. The R-value indicates that there were large community differences between samples collected from the two waterways, and the difference was highly statistically significant. The most ecologically similar were Porters and Buffalo Creek with an R-value of 0.413 (Table 6). Ecological differences between macroinvertebrates at all waterways were always statistically significant.

Table 6: ANOSIM R values for ecological differences between waterways (2004-2011)

	Archers	Buffalo	Porters	Shrimptons	Terrys
Archers Ck	X	X	X	X	X
Buffalo Ck	0.720	X	X	X	X
Porters Ck	0.697	0.431	X	X	X
Shrimptons Ck	0.679	0.755	0.816	X	X
Terrys Ck	0.721	0.417	0.510	0.754	X

Macroinvertebrate ecological data showed that the spatial (waterway by waterway) differences was larger (Global R=0.624) than were differences over time (Global R=0.51). The spatial ordination (Figure 14, by waterway) shows that sampling sites tended to form distinct groups, with some overlap between sites. In comparison, the temporal differences (by sampling occasion) showed more overlap in groups (Figure 15, by year). There were smaller ecological differences (Global R=0.268) according to season of sampling (Figure 16, by season).

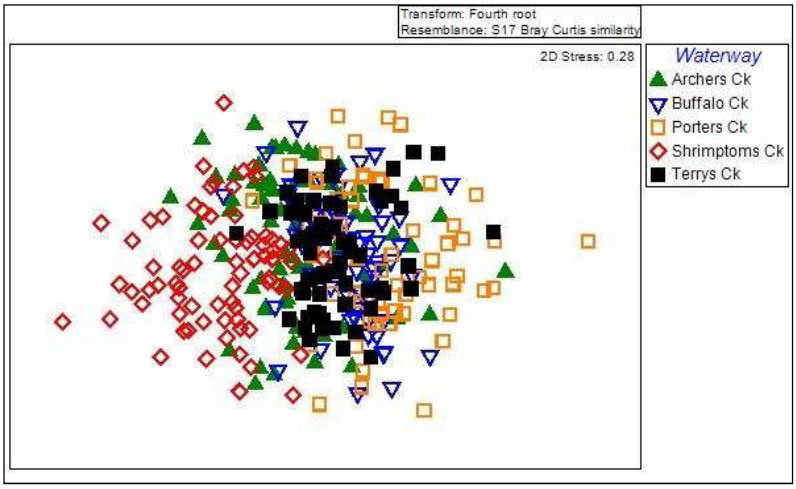

Figure 14: Stream macroinvertebrate nMDS ordination for samples collected from the 5 waterway sampling sites within the City of Ryde LGA waterways (2004-2011), by waterway (see legend).

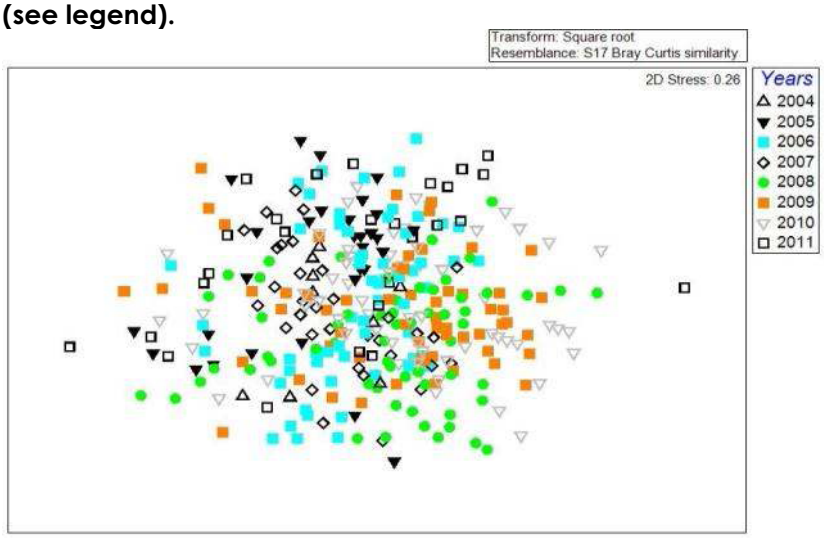

Figure 15: Stream macroinvertebrate nMDS ordination for samples collected from the 5 waterway sampling sites within the City of Ryde LGA waterways (2004-2011), by year of sampling (see legend).

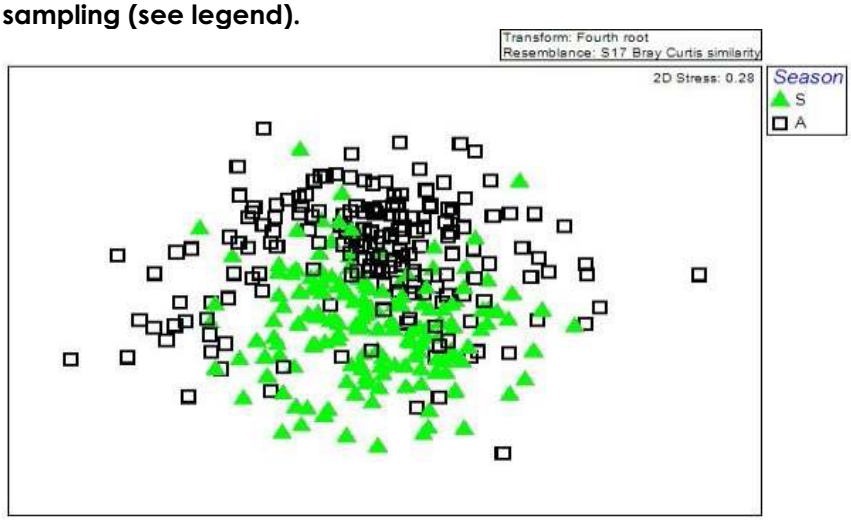

Figure 16: Stream macroinvertebrate nMDS ordination for samples collected from the 5 waterway sampling sites within the City of Ryde LGA waterways (2004-2011), by season of sampling (green triangles represent spring and unshaded squares represent autumn).

5.1.2 Macroinvertebrate biotic indices

The SIGNAL biotic index is perhaps the best known index, in Australia, for measuring ecosystem health, and provides several categories of likely pollution from 'clean water', which has a high abundance and richness of pollution sensitive invertebrates present (Chessman, 1995 and 2003). Lower categories are 'mild pollution', 'moderate pollution' and 'severe pollution with each category representing a growing scarcity or absence of pollution sensitive macroinvertebrate guilds. In addition, the index and four categories also reflect the opposite trend (from clean water, mild, moderate and severe pollution) of a growing abundance of pollution tolerant animals. Obviously the 'severe pollution; category has very few pollution sensitive invertebrates and many pollution tolerant groups. The overall SIGNAL score over 6 represents 'clean water'. SIGNAL 5 to 6 is mild pollution. SIGNAL 4 to 5 is moderate pollution. Less than 4 is severe pollution.

The EPT (Ephemeroptera, Plecoptera and Trichoptera) abundance index was calculated from the macroinvertebrate results. EPT is a widely used biotic index, particularly in the northern hemisphere, based on the abundance of three common and sensitive macroinvertebrate orders (e.g. Rosenberg & Resh, 1993; Lenat & Penrose, 1996). The interpretation of this index is simple: polluted waters have few or no EPT animals and clean waters have large numbers of EPT animals. It is easy to calculate and has been widely found to be effective for measurement of water pollution on macroinvertebrates (e.g. Metzeling *et al.*, 2006; Wright & Burgin, 2009).

The AUSRIVAS biotic index has been developed for different parts of Australia and uses an extensive database of macroinvertebrate data collected from unimpacted waterways to generate a model for macroinvertebrate biodiversity. The AUSRIVAS biotic index compares macroinvertebrate data (termed 'observed') with the results from the model (termed 'expected'). This is expressed as a ratio of 'observed/expected' and is expressed as a ratio from 0 to 1.0. The closer to 1.0 signifies that the sample had similar results to that from modelled clean waterways. In addition, there are four overall categories termed 'bands'. Band 'A' represents clean waterways suffering from minimal disturbance. Bands 'B', 'C' and 'D' represent progressively more disturbed categories.

5.1.3 Macroinvertebrate biotic assessment

The biotic index results confirm that the macroinvertebrate communities in The City of Ryde waterways had consistently degraded ecosystem health. The levels of ecosystem health recorded at City of Ryde waterways are typical of urban streams in the Sydney area (e.g. Davies et al. 2010 in Ku-ring-gai Council; Tippler, Wright and Hanlon 2012a,b) in the Georges River catchment of southern and south-western Sydney. In particular, the macroinvertebrate communities had a very low level of sensitive taxonomic groups. For example, the three sensitive invertebrate orders comprising Mayflies (*Ephemeroptera*), Stoneflies (*Trichoptera*) and Stoneflies (*Plecoptera*) were represented by only 5 families and they were very rare, or were missing from Ryde samples (Figure 17). These levels indicate an impoverished richness of sensitive families. In comparison, clean reference streams in the Blue Mountains had up to 20 'EPT' families present (Wright & Burgin, 2009). Archers Creek had the highest proportion of EPT invertebrate families (mean of 5.6%; Figure 17).

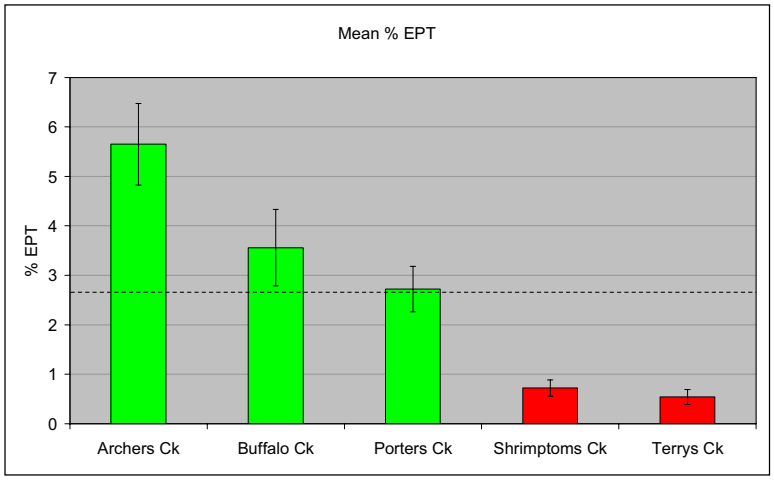

Figure 17: The mean Ephemeroptera / Plecoptera / Trichoptera (EPT) % (plus/minus standard error) of stream macroinvertebrate samples collected from the 5 waterway sampling sites within the City of Ryde LGA waterways (2004-2011). Waterways with a mean EPT % level above the overall average (2.7%) are coloured green, and waterways with mean EPT % level below the average (2.7%) are coloured red.

At Shrimptons and Terrys Creek the three sensitive EPT orders accounted for less than 1% of the total abundance of invertebrate animals collected (Figure 1.4). This is very similar to the level of EPT animals collected from highly urbanised streams (mean = 1.96 %) in the Georges River catchment (Tippler *et al.*, 2012). In comparison, the naturally vegetated non-urban streams in the Georges River had a mean EPT level of 31.1%. Hornsby LGA urban streams had a slightly higher proportion of EPT invertebrates (mean 3.2 %) and much higher levels of EPT invertebrates in reference streams (mean 41.9%) (Consultants report for Hornsby Council, 2011).

Additional evidence that the Ryde streams had depleted levels of ecosystem health are that all waterways had very low SIGNAL SF and AUSRIVAS levels and lower family richness and abundance than is expected at natural unmodified streams flowing in largely natural unmodified catchments (Figure 18, Figure 19 and Figure 20).

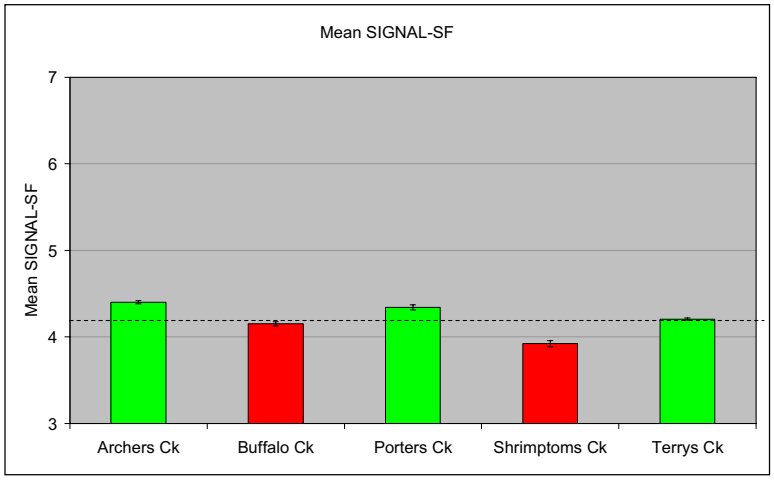

Figure 18: The mean SIGNAL-SF (plus/minus standard error) of stream macroinvertebrate samples collected from the 5 waterway sampling sites within the City of Ryde LGA waterways (2004-2011). Waterways with a mean SIGNAL-SF score above the overall average (4.2%) are coloured green, and waterways with mean EPT % level below the average (4.2%) are coloured red.

The biotic indices showed some variation, but were consistent with degraded stream ecosystems, over the period 2004-2011. The EPT richness (Figure 22) showed significant variation over time, with 2005 recording the lowest EPT score (0.12 %) rising to the highest in 2009 (4.1%). In contrast, the SIGNAL SF scores were very similar (and indicative of degraded conditions) from year to year (Figure 23). The lowest average SIGNAL level was 4.08 in 2008 and the highest was 4.31 in 2004 (Figure 23). Taxonomic richness varied from 12.1 families per sample in 2008 to 16.3 families in 2004 (Figure 24). Macroinvertebrate abundance varied from a low of just under 60 animals per sample in 2008 to 127 animals per sample in 2005 (Figure 25).

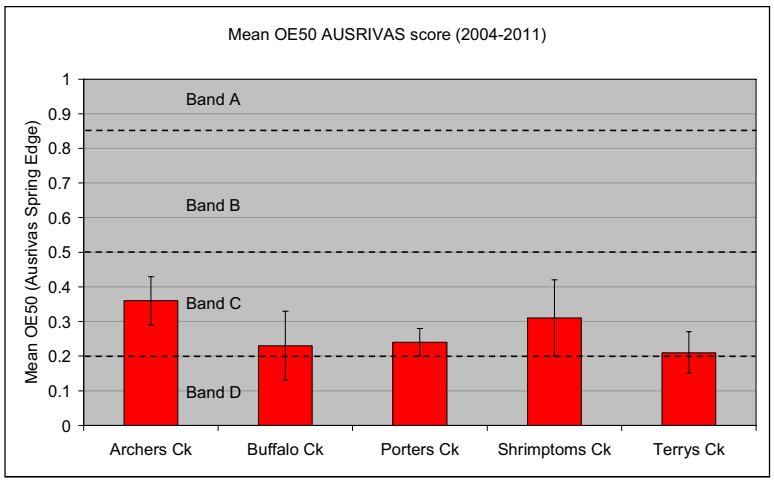

Figure 19: The mean AUSRIVAS OE50 (plus/minus standard error) of stream macroinvertebrate samples collected from the 5 waterway sampling sites within the City of Ryde LGA waterways (2004-2011).

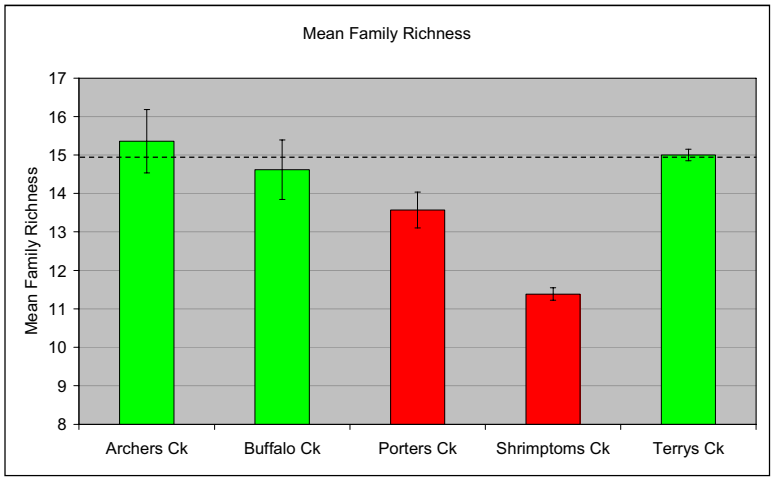

Figure 20: The mean Family Richness (plus/minus standard error) of stream macroinvertebrate samples collected from the 5 waterway sampling sites within the City of Ryde LGA waterways (2004-2011). Waterways with a mean Richness level above the overall average (14 families/sample) are coloured green, and waterways with mean EPT % level below the average (14 families/sample) are coloured green.

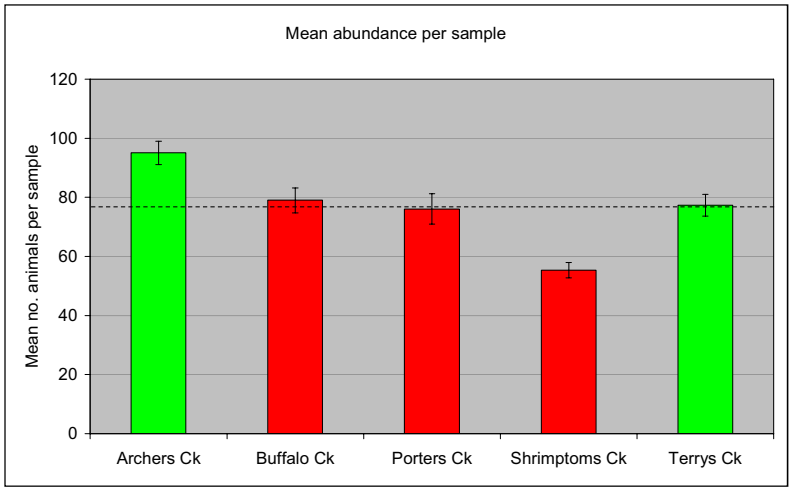

Figure 21: The abundance (plus/minus standard error) of stream macroinvertebrate samples collected from the 5 waterway sampling sites within the City of Ryde LGA waterways (2004-2011). Waterways with a mean abundance level above the overall average (76.5 animals/sample) are coloured green, and waterways with mean abundance level below the average (76.5 animals/sample) are coloured green.

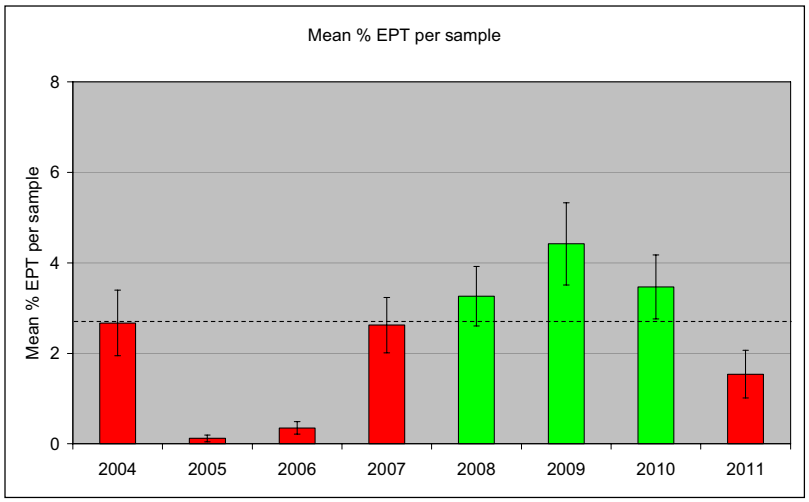

Figure 22: The mean Ephemeroptera / Plecoptera / Trichoptera (EPT) % (plus/minus standard error) of stream macroinvertebrate samples collected, by year, from the 5 waterway sampling sites within the City of Ryde LGA waterways (2004-2011). Waterways with a mean EPT % level above the overall average (2.7%) are coloured green, and waterways with mean EPT % level below the average (2.7%) are coloured red.

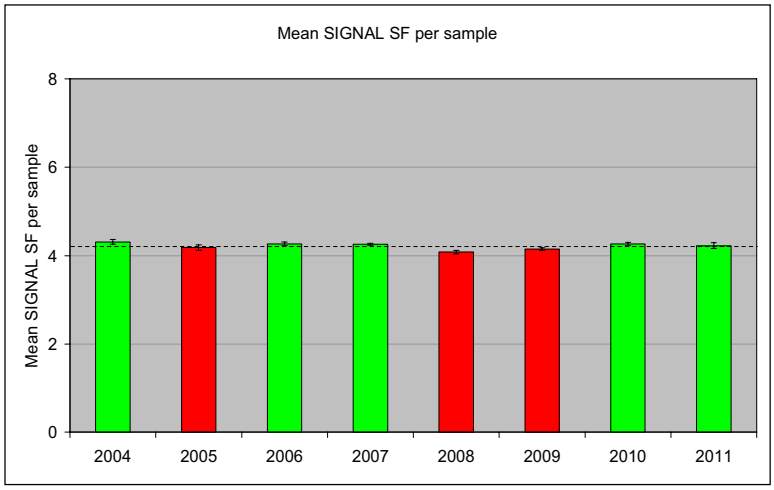

Figure 23: The mean SIGNAL SF (plus/minus standard error) of stream macroinvertebrate samples collected from all waterway sampling sites, for each year, within the City of Ryde LGA waterways (2004-2011). Waterways with a mean abundance level above the overall average (4.2) are coloured green, and waterways with mean abundance level below the average (4.2) are coloured red.

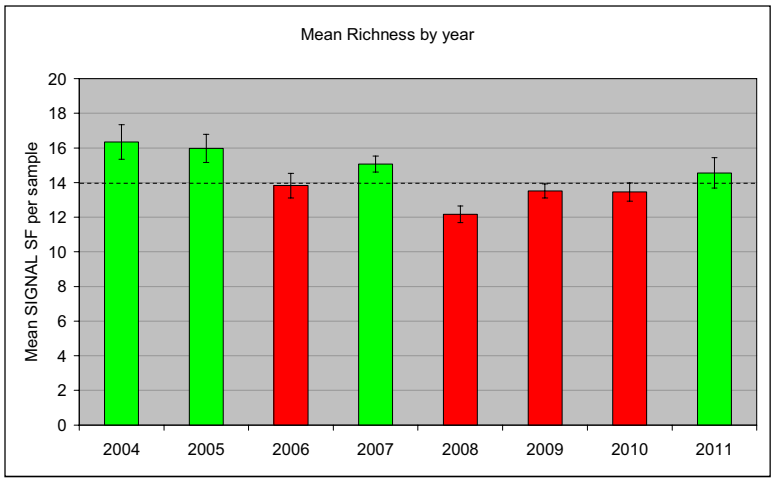

Figure 24: The mean Family Richness (plus/minus standard error) of stream macroinvertebrate samples collected from the 5 waterway sampling sites, by year, within the City of Ryde LGA waterways (2004-2011). Years with a mean Richness level above the overall average (14 families/sample) are coloured green, and years with mean Richness level below the average (14 families/sample) are coloured green.

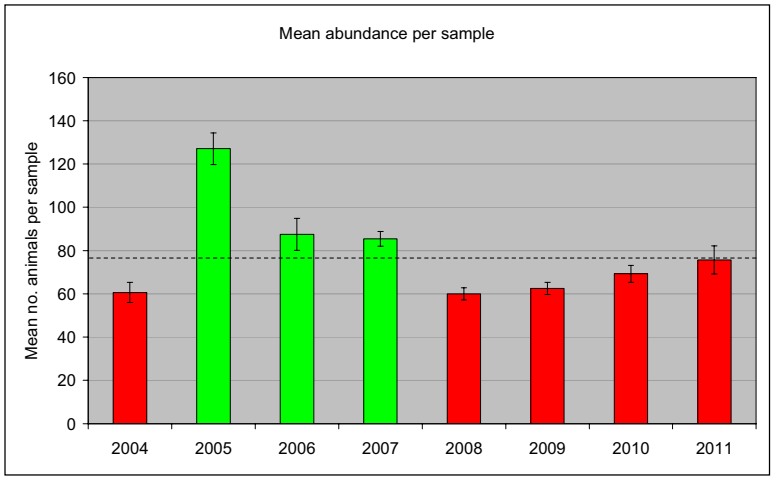

Figure 25: The abundance (plus/minus standard error) of stream macroinvertebrate samples collected from all waterway sampling sites, for each year, within the City of Ryde LGA waterways (2004-2011). Waterways with a mean abundance level above the overall average (76.5 animals/sample) are coloured green, and waterways with mean abundance level below the average (76.5 animals/sample) are coloured green.

5.2 Water Chemistry status of City of Ryde waterways

The following ANZECC (2000) guidelines were used in this analysis:

- Total Phosphorus (< 50 *µg/L*) for ecosystem protection in lowland rivers
- NOx (<40 *µg/L*) for ecosystem protection in lowland rivers
- Total Nitrogen (<500 *µg/L*) for ecosystem protection in lowland rivers
- Ammonia (<900 *µg/L*) for ecosystem protection (protection of 95 % of species from mildly disturbed streams) in lowland rivers
- Dissolved oxygen (85-110% saturation) for ecosystem protection in lowland rivers
- pH (6.5-8.0) for ecosystem protection in lowland rivers
- Electrical conductivity (<350 *µs*/cm) ecosystem protection of lowland freshwater streams
- Turbidity (<5 lower maximum and <50 NTU upper maximum) for ecosystem protection in lowland rivers
- Faecal coliforms (<1000 cfu/100 ml) for secondary contact recreation.

5.2.1 Oxidised Nitrogen status of The City of Ryde surface waters (2004-2011)

Mean oxidised nitrogen (NOx) was consistently elevated in all Ryde waterways and at all sampling sites above the ANZECC (2000) guideline for ecosystem protection (40 µg/L) (Figure 26). Across the five catchments, the lowest mean NOx levels was recorded at Terry's Creek (mean 172 µg/L) and Archers Creek (mean 258 µg/L), however both were more than 4 times higher than the guideline. The three catchments with multiple sites revealed different patterns in mean NOx levels, and each of these catchments had at least one site above 600 µg/L (15 times above the ecosystem protection guideline). The highest mean NOx level recorded in the period 2004-2011 was 1120 µg/L at Porters Site 3, which was 28 times higher than the ecosystem protection guideline. This site is in close proximity to the Ryde Waste Transfer Station, and landfill leachate is associated with high nitrate levels. Such elevated levels of NOx may contribute to over stimulated plant growth in urban streams. This has adverse implications for riparian and channel weeds, algae and occasional depleted levels of dissolved oxygen.

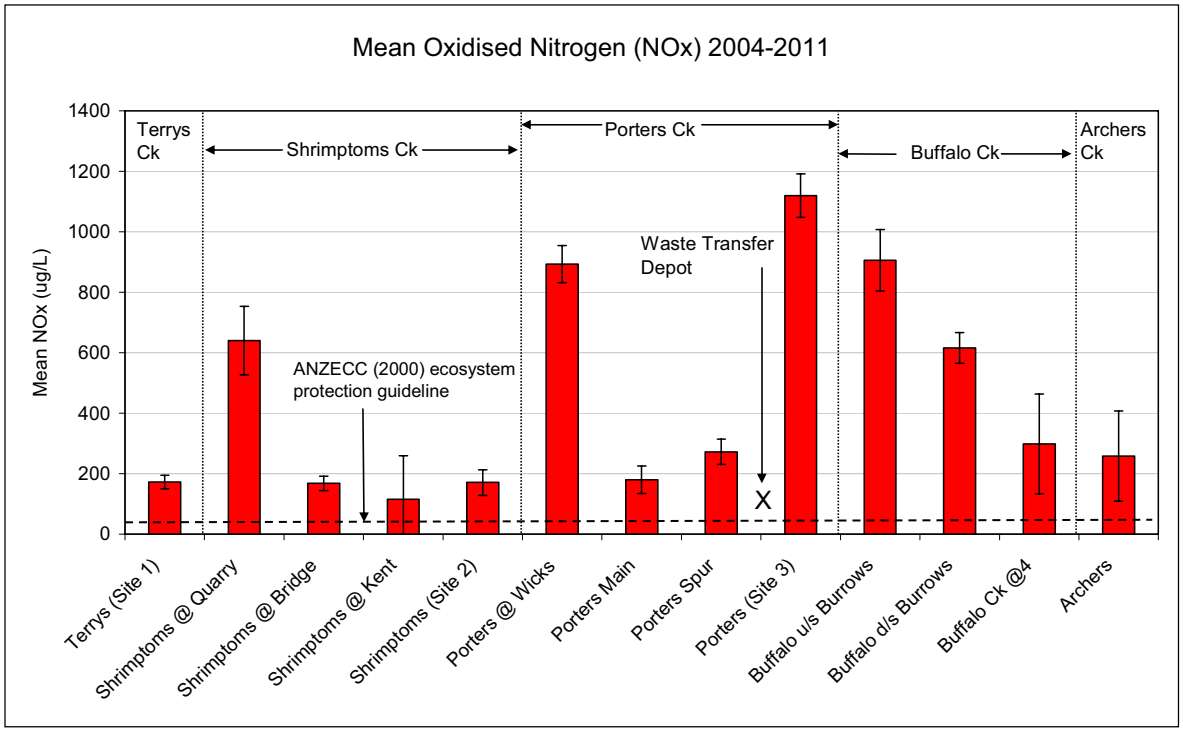

Figure 26: The mean (plus/minus standard error) Oxidised Nitrogen (NOx) level of water samples collected from the 13 sampling sites within the City of Ryde LGA waterways (2004-2011). The sampling sites are grouped according to waterway. The ANZECC guideline for ecosystem protection (40 µg/L) is indicated. The mean level of NOx from all samples above the ANZECC guideline is coloured red.

5.2.2 Total Nitrogen status of The City of Ryde surface waters (2004-2011)

Mean total nitrogen (TN) was consistently elevated in all Ryde waterways and at all sampling sites above the ANZECC (2000) guideline for ecosystem protection (500 µg/L) (Figure 27). Across the five catchments, the lowest mean TN levels were recorded at Terry's Creek (mean 615 µg/L) and Archers Creek (mean 661 µg/L), and were 23 to 32 % higher than the guideline. The three catchments with multiple sites revealed different patterns in mean TN levels, and each of these catchments had at least one site above 1000 µg/L (2 times above the ecosystem protection guideline). The highest mean TN level recorded in the period 2004-2011 was 2408 µg/L at Porters Site 3, which was nearly 5 times higher than the ecosystem protection guideline. This site is in close proximity to the Ryde Waste Transfer Station, and landfill leachate is associated with high nitrate levels (contributing to total nitrogen). A further detailed catchment assessment should be carried out to determine the cause of high nitrogen at other sites (see Appendix D).

5.2.3 Total Phosphorus status of The City of Ryde surface waters (2004-2011)

Mean total phosphorus (TP) was elevated in some Ryde waterways, above the ANZECC (2000) guideline for ecosystem protection (50 µg/L) (Figure 28). Across the five catchments, only two of the catchments had waterways consistently (ie mean levels) below the guideline (Terrys Creek and Archers Ck). All mean sampling sites on Shrimptons Creek were higher than the guideline. The highest mean TP level in the entire 2004 – 2011 was Shrimptons Creek at Quarry (172 µg/L), which was more than 3 times higher than the guideline. The lowest mean TP level was recorded at Porters Creek at site 3 (mean 26.7 µg/L) below the waste transfer station. The second highest mean TP level recorded in the period 2004-2011 was 143 µg/L at Porters Creek (spur)(Figure 28). A further detailed catchment assessment should be carried out to determine the cause of high phosphorus at other sites (see Appendix D).

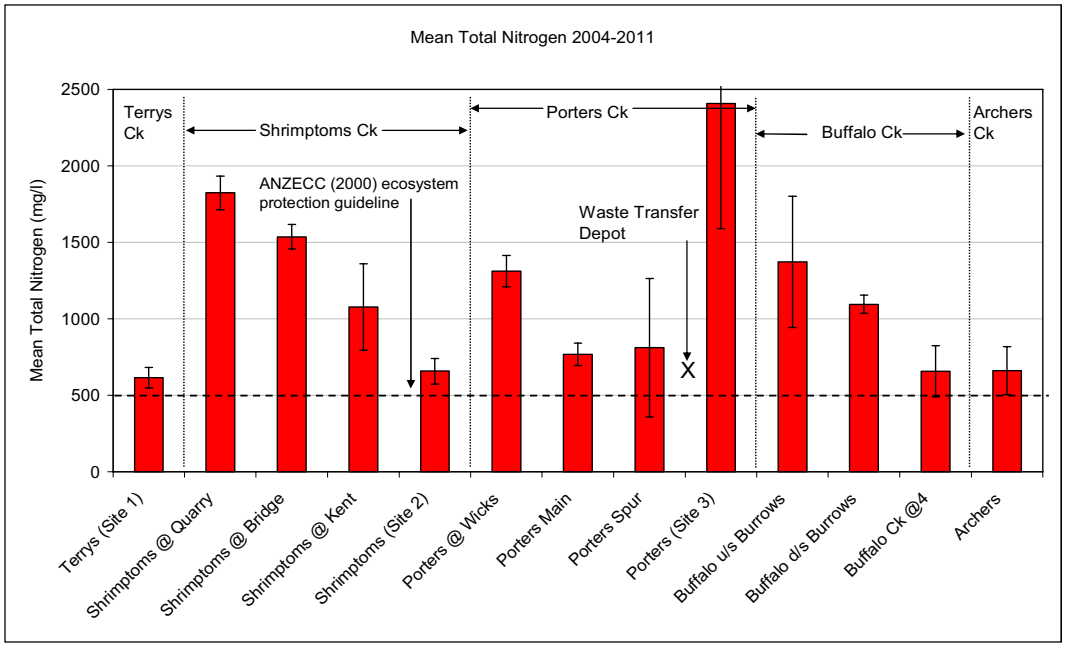

Figure 27: The mean (plus/minus standard error) Total Nitrogen (TN) level of water samples collected from the 13 sampling sites within the City of Ryde LGA waterways (2004-2011). The sampling sites are grouped according to waterway. The ANZECC guideline for ecosystem protection (500 µg/L) for TN is indicated. The mean level of TN from all samples within the ANZECC guideline is coloured green, and the mean level above the guideline is coloured red.

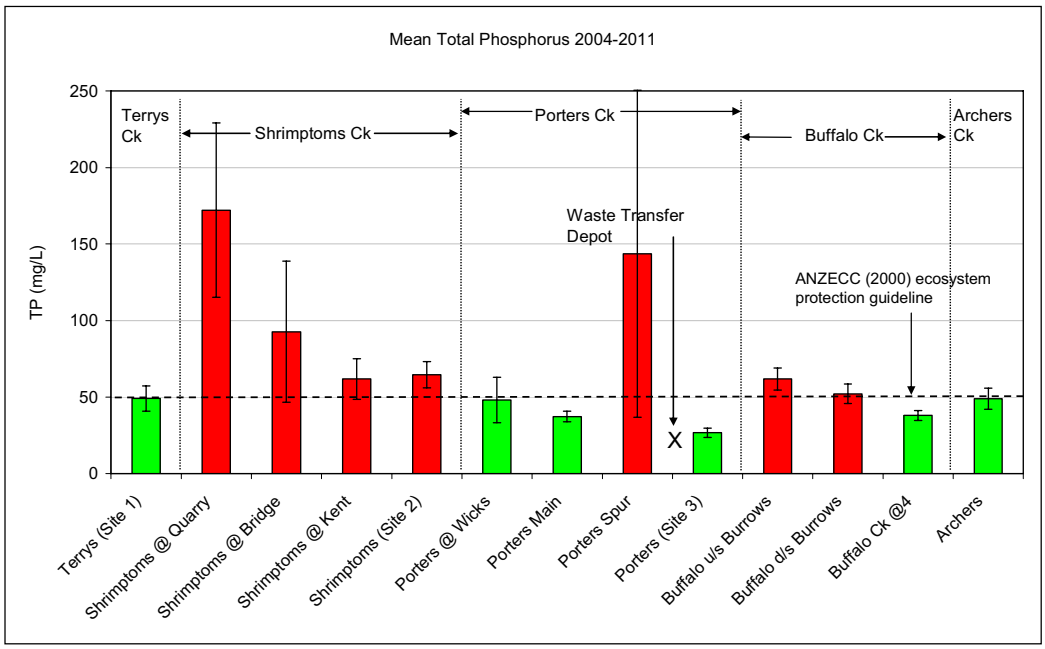

Figure 28: The mean (plus/minus standard error) Total Phosphorus (TP) level of water samples collected from the 13 sampling sites within the City of Ryde LGA waterways (2004-2011). The sampling sites are grouped according to waterway. The ANZECC guideline for ecosystem protection for TP (50 µg/L) is indicated. The mean level of TP from all samples within the ANZECC guideline is coloured green, and the mean level above the guideline is coloured red.

5.2.4 Salinity (Electrical Conductivity) status of The City of Ryde surface waters (2004-2011)

Mean salinity (electrical conductivity) in Ryde waterways was generally within ecosystem guidelines according to ANZECC (2000) guidelines for ecosystem protection (350 µS/cm)(Figure 29). However across the five catchments, only one of the catchments (Shrimptons Ck) had salinity levels consistently below the guideline. The four most saline sites (according to mean levels) were Porters Creek (Site 3) downstream of the waste transfer station with an average salinity of 1720 (µS/cm); then Buffalo Creek (Site 4) with a mean salinity of 679 µS/cm; Archers Creek 479 µS/cm and Terrys Creek (395 µS/cm).

The lowest salinity levels in three of the sampling sites on Shrimptons Creek were extraordinarily low for urban waterways, and the lowest, at Kent Rd, had a mean value of 44.8 µS/cm. The source of the elevated salinity levels in some Ryde waterways requires further analysis. Any dissolved (ionic) source is potentially contributing to the elevated levels. As with some of the other elevated pollutants, it is recommended that further longitudinal sampling is conducted to locate the 'hot-spot' of contamination (In this case salinity). Once detected, it is recommended that water samples are sent to a laboratory for major anion and cation analysis to provide clues as to their nature and possible source. Extensive use of concrete is associated with elevated salinity and ionic analysis also reveals elevated calcium and bicarbonate concentrations (Wright et. al, 2011).

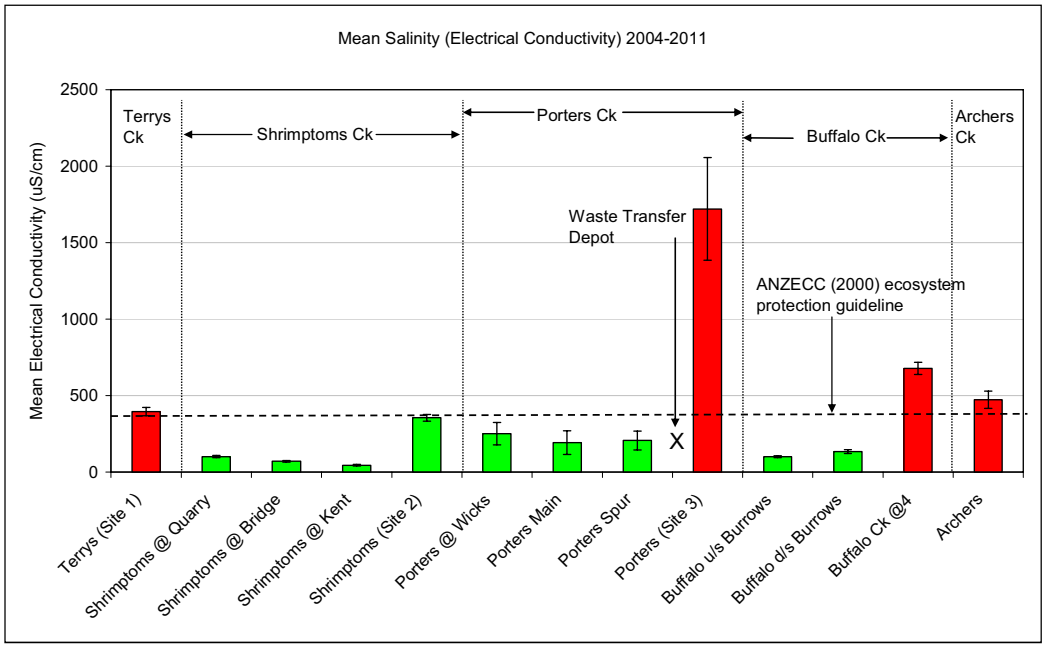

Figure 29: The mean (plus/minus standard error) Salinity (EC: Electrical Conductivity) level of water samples collected from the 13 sampling sites within the City of Ryde LGA waterways (2004-2011). The sampling sites are grouped according to waterway. The ANZECC guideline for ecosystem protection for EC (350 µS/cm) is indicated. The mean level of EC from all samples within the ANZECC guideline is coloured green, and the mean level above the guideline is coloured red.

5.2.5 pH status of The City of Ryde surface waters (2004-2011)

Stream pH levels at The City of Ryde streams were generally within guidelines according to ANZECC (2000) guidelines for ecosystem protection (6.5-8.0 pH units)(Figure 30). Mean pH at the sampling sites varied in a narrow band from a minimum of 6.95 (at Terrys Creek) to a maximum of 7.79 at Porters Creek (at Wicks Rd). Such pH levels are actually elevated above natural vegetated catchments in northern Sydney and probably represent the influence of concrete stormwater infrastructure. Recent research has shown that concrete leaches minerals and raises water pH (Wright et al., 2011)

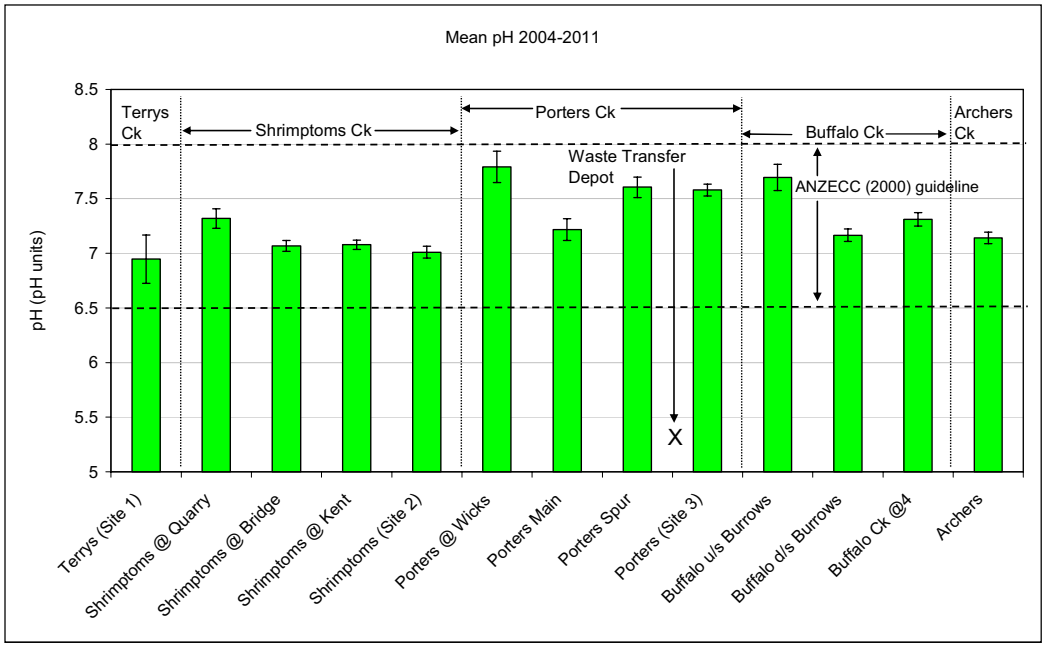

Figure 30: The mean (plus/minus standard error) pH level of water samples collected from the 13 sampling sites within the City of Ryde LGA waterways (2004-2011). The sampling sites are grouped according to waterway. The ANZECC guideline for ecosystem protection for pH (6.5-8.0 pH units) is indicated. The mean level of pH from all samples within the ANZECC guideline is coloured green.

5.2.6 Turbidity status of the City of Ryde surface waters (2004-2011)

Mean turbidity (NTU) in Ryde streams was generally lower than the "upper maximum" turbidity ecosystem guideline according to ANZECC (2000) guidelines for ecosystem protection (50 NTU) (Figure 31). Only one site (Porters Creek at Spur) had a mean turbidity level marginally higher than the highest guideline level (coloured red). Across the five catchments, only two of the catchments (Terrys Creek and Archers Creek) had waterways consistently below the "lower maximum" ecosystem protection guideline (<5 NTU). Archers Creek had the lowest average turbidity levels (3.9 NTU). The majority of sampling sites had mean turbidity levels (coloured yellow) that were within the two guideline levels.

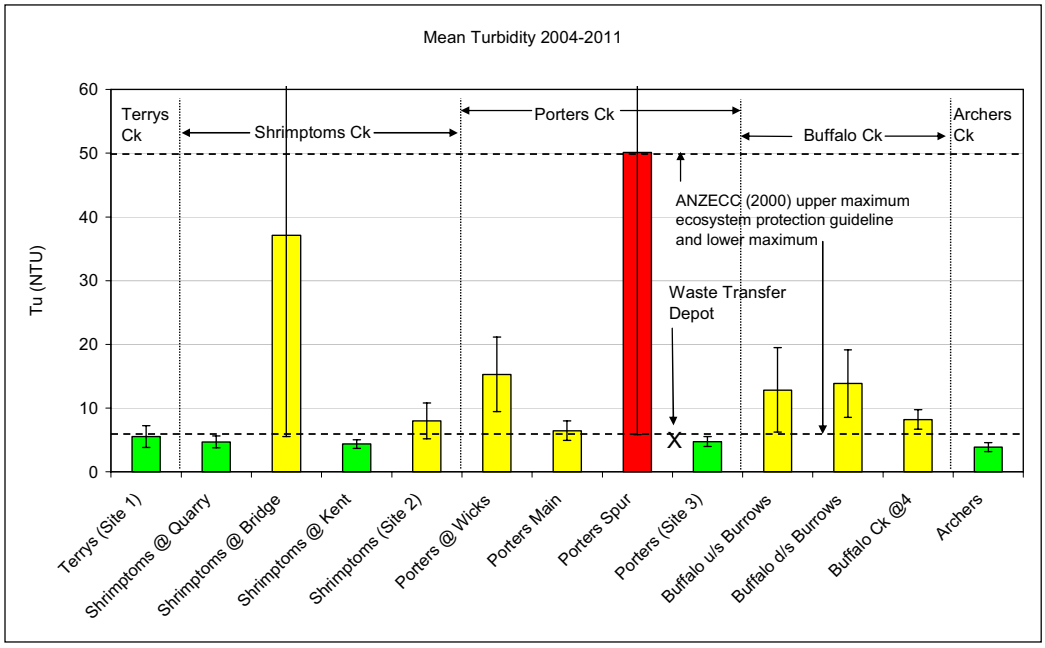

Figure 31: The mean (plus/minus standard error) turbidity level of water samples collected from the 13 sampling sites within the City of Ryde LGA waterways (2004-2011). The sampling sites are grouped according to waterway. The ANZECC guidelines for ecosystem protection for turbidity (lower maximum of 5 or upper maximum of 50 NTU) is indicated. The mean level of turbidity from all samples below the lower ANZECC guideline is coloured green. The mean level of turbidity from 5 to 50 NTU (the upper ANZECC guideline) is coloured yellow. The mean level of turbidity from all samples above the upper ANZECC guideline (50 NTU) is coloured red.

5.2.7 Dissolved Oxygen status of the City of Ryde surface waters (2004-2011)

Mean levels of dissolved oxygen (DO mg/L) in Ryde waterways were generally above the ANZECC (1992) ecosystem protection guidelines (Figure 32). There were two sampling sites on Shrimptons Creek (at Kent Rd and site 3) that had mean dissolved oxygen levels well below the guideline (4.5 and 4.2 mg/L respectively), and such levels indicate major ecological stress. The sampling site on Archers Creek was borderline with a mean DO level of 6.0 mg/L. The highest DO level in the study occurred at Porters Creek Spur (9.8 mg/L).

The mean levels of DO saturation for Archers Creek, Buffalo Creek, Shrimptons Creek and Terrys Creek were below the ANZECC (1992) ecosystem protection guidelines of 85% saturation (Figure 33). Interestingly all of the Porters Creek samples were within the DO saturation guideline of 85% and 110%. Specific issues around dissolved oxygen and the role of riparian zones are outlined in Sections 6.3 and 6.7 respectively.

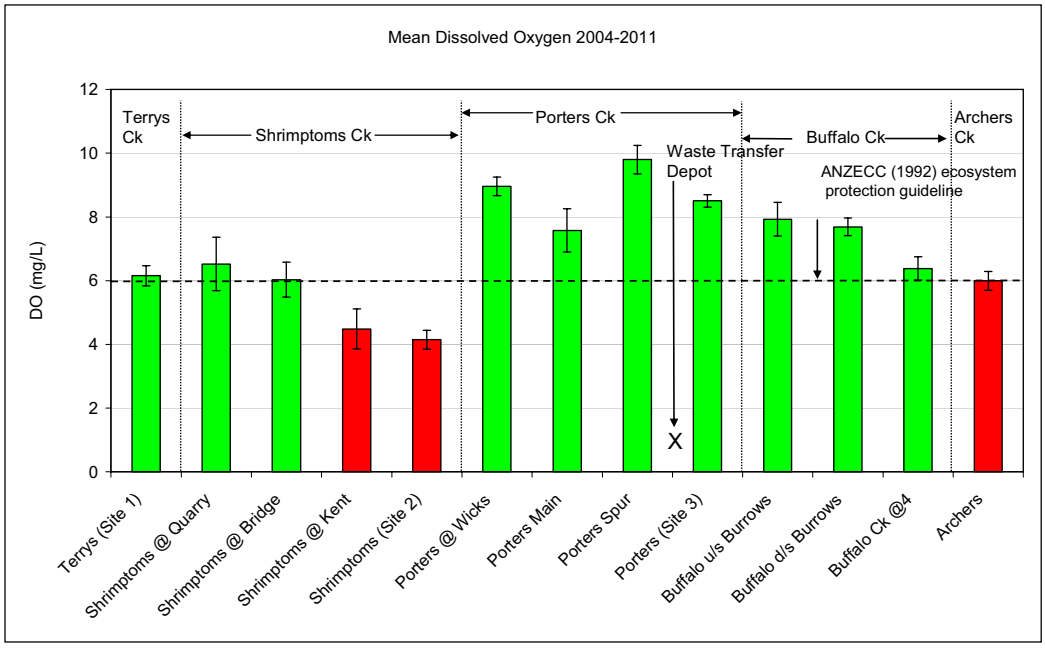

Figure 32: The mean (plus/minus standard error) Dissolved Oxygen (DO) level of water samples collected from the 13 sampling sites within the City of Ryde LGA waterways (2004-2011). The sampling sites are grouped according to waterway. The ANZECC guideline (1992) for ecosystem protection for Dissolved Oxygen (minimum of 6 mg/L) is indicated. The mean level of DO from all samples above the lower ANZECC guideline is coloured green. The mean level of DO from all samples below the higher ANZECC guideline is coloured red.

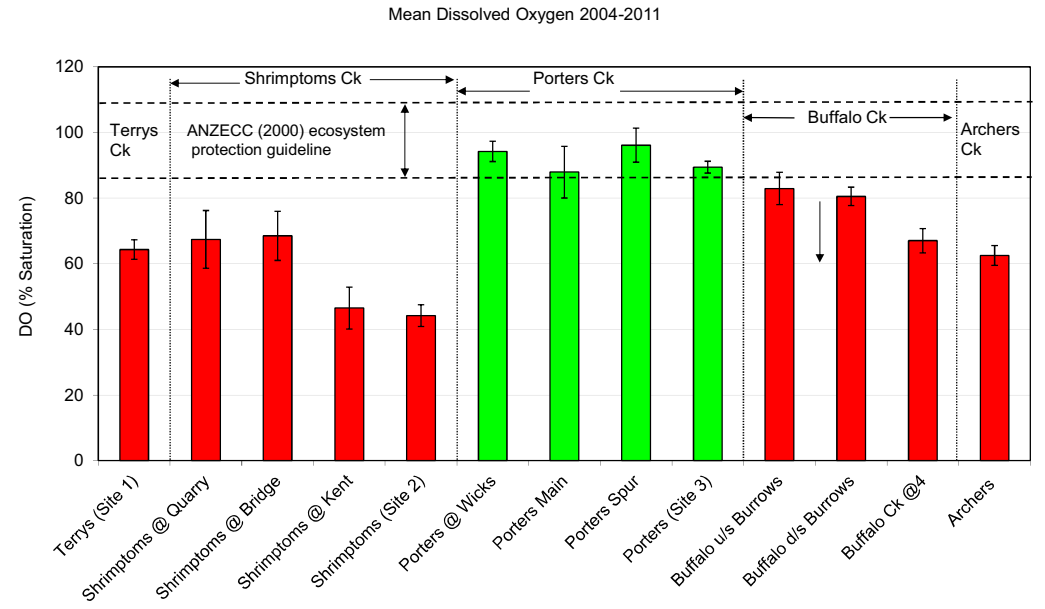

Figure 33: The mean (plus/minus standard error) Dissolved Oxygen (DO) level of water samples collected from the 13 sampling sites within the City of Ryde LGA waterways (2004-2011). The sampling sites are grouped according to waterway. The ANZECC guideline (1992) for ecosystem protection for Dissolved Oxygen (between 85 and 110 % Saturation) is indicated. The mean level of DO from all samples above the lower ANZECC guideline is coloured green. The mean level of DO from all samples below the higher ANZECC guideline is coloured red.

5.2.8 Ammonia status of the City of Ryde surface waters (2004-2011)

Mean levels of ammonia (µg/L) in The City of Ryde waterways were all below the ANZECC (2000) ecosystem protection guidelines of 900 µg/L (for protection of 95 % of species) (Figure 34). Four sampling sites had higher mean levels. These included 3 sites on Shrimptons Creek and one on Porters Creek (Site 3). Buffalo Creek generally had the lowest ammonia levels ranging from 26 to 57 µg/L. The mean ammonia levels of the three upstream Porters Creek site ranged from 50 to 117 µg/L. This rose to a mean of 756 µg/L at the most downstream site, in the vicinity of the waste transfer depot. The large error bars are indicative of occasional peaks in ammonia levels that could promote toxic conditions.

Ammonia is highly toxic to aquatic life (ANZECC, 2000). One short episode of high ammonia in a waterway may be devastating to invertebrate animals and fish. The source of ammonia is generally the biodegradation of putrescible waste, such as household rubbish or sewage. A survey of water quality in a stream that has occasional ammonia 'peaks' should examine nutrient, dissolved oxygen and faecal coliforms (to detect the possible impact of sewer overflows).

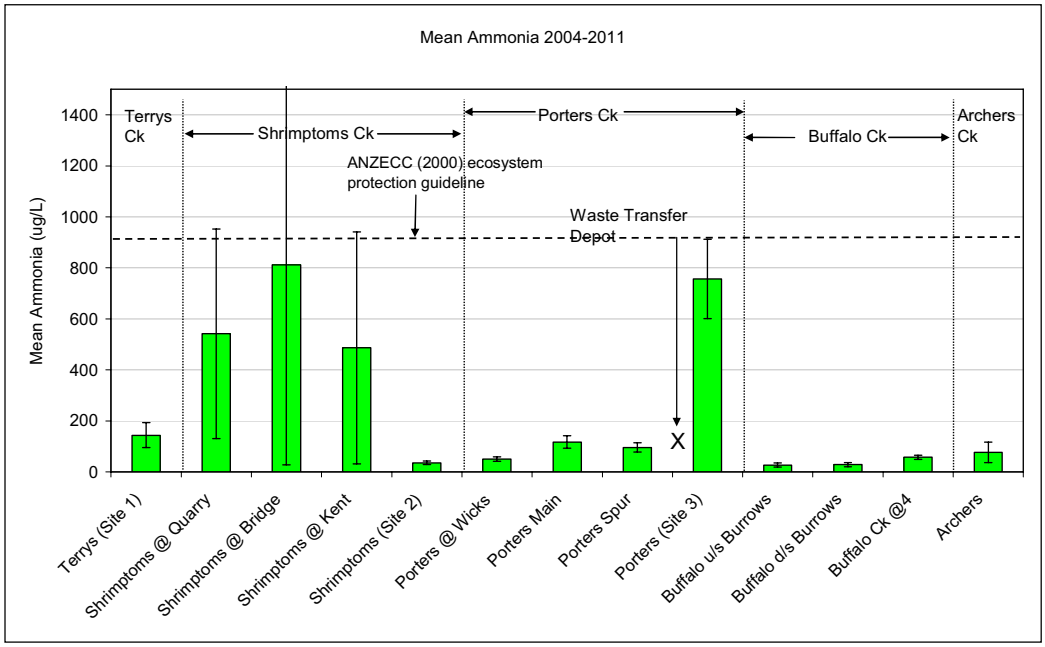

Figure 34: The mean (plus/minus standard error) Ammonia level of water samples collected from the 13 sampling sites within the City of Ryde LGA waterways (2004-2011). The sampling sites are grouped according to waterway. The ANZECC guideline (2000) for ecosystem protection for 95 % of species from slightly disturbed streams (maximum of 900 µg/L) is indicated. The mean level of ammonia from all samples below the ANZECC guideline is coloured green. The mean level of ammonia from all samples above the ANZECC guideline is coloured red.

5.2.9 Faecal Coliform status of the City of Ryde surface waters (2004-2011)

Mean levels of faecal coliforms (cfu/100mL) in Ryde waterways were generally all above the ANZECC (2000) secondary contact guidelines of (1000 cfu/100mL) (Figure 35). Three sampling sites had mean faecal coliform levels 2 times higher than the guideline (Terrys Ck; Shrimptons Creek at Quarry and Porters Creek in the vicinity of the waste transfer depot. One of the possible sources of consistent elevated faecal coliforms is sewage, and these sampling sites should be investigated for possible sewage leaks or overflows. Faecal contamination and relationship with sewer overflows in each catchment is further discussed in Section 6.4.

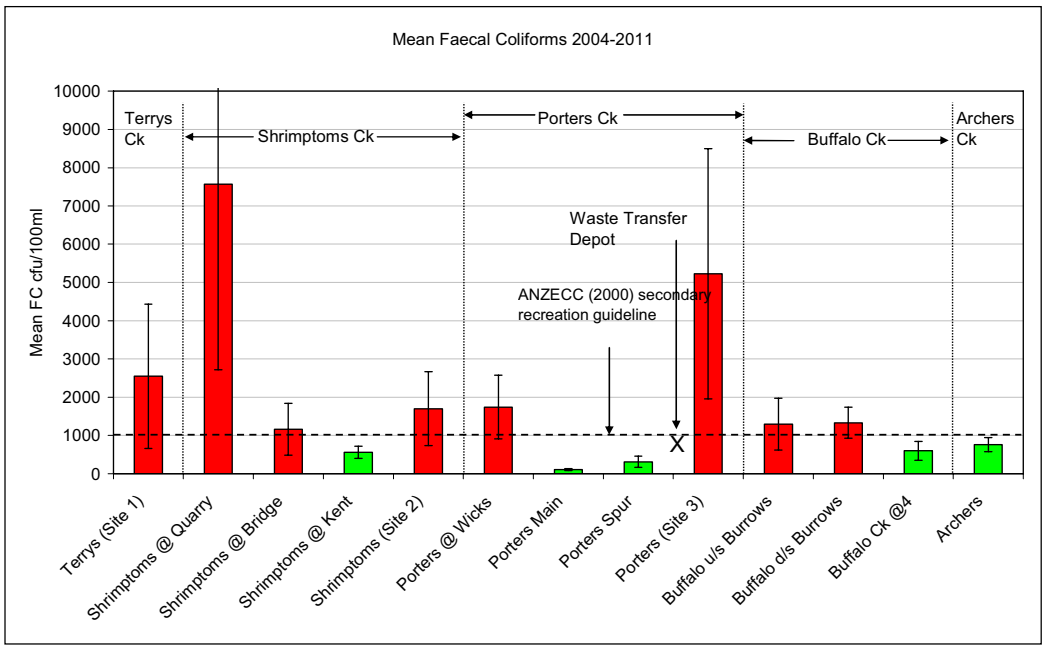

Figure 35: The mean (plus/minus standard error) Faecal Coliform level (cfu/100 mL) of water samples collected from the 13 sampling sites within the City of Ryde LGA waterways (2004-2011). The sampling sites are grouped according to waterway. The ANZECC guideline (2000) for secondary contact recreation (maximum of 1000 *cfu*/100mL) is indicated. The mean level of Faecal Coliforms from all samples below the ANZECC guideline is coloured green. The mean level of Faecal Coliforms from all samples above the ANZECC guideline is coloured red.

5.2.10 Alkalinity status of the City of Ryde surface waters (2004-2011)

Mean levels of alkalinity (mg/L) in City of Ryde streams (2004-2011) generally ranged in a band from 50 to 100 mg/L (Figure 36). Only one sampling site was an exception. Porters Creek Main had a mean alkalinity level of 142 mg/L. There are no guidelines that apply (ANZECC, 2000) for alkalinity. Comparison of these results with other studies from the Sydney area (Davies *et al.* 2010; Tippler *et al,* 2012) indicate that these waterways all have much higher alkalinity than would be expected in non-urban reference sites. Reference sites in naturally vegetated catchments in northern Sydney (Ku-ring-gai and Warringah) had a mean and maximum alkalinity of 4.6 and 9.0 mg/L. Comparable naturally vegetated streams in the Georges River catchment had mean and maximum alkalinity levels of 4.1 and 33 mg/L. Elevated alkalinity levels have also been discovered in other urban streams in Sydney (e.g. Wright et al., 2011). It is strongly suspected that concrete stormwater infrastructure contributes to this elevation of urban waterway alkalinity (Wright et al., 2011).

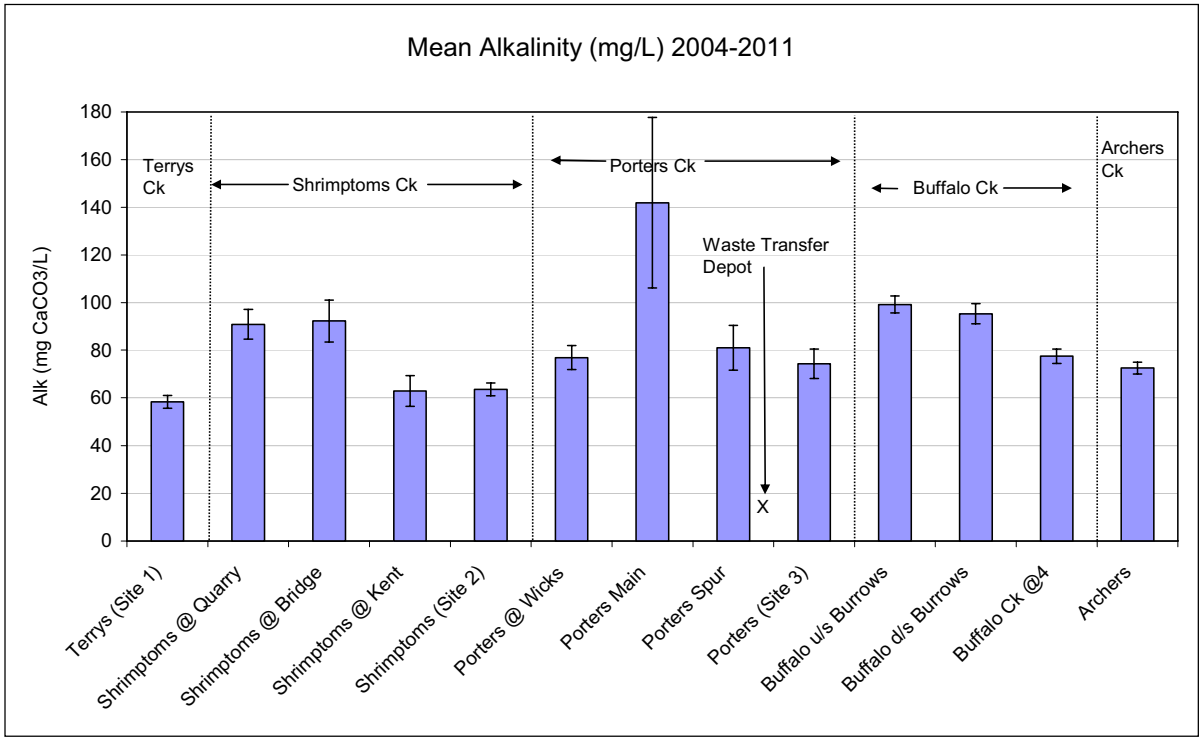

Figure 36: The mean (plus/minus standard error) Alkalinity level (mg/L) of water samples collected from the 13 sampling sites within the City of Ryde LGA waterways (2004-2011). The sampling sites are grouped according to waterway.