Institute for Applied Ecology

ACT Waterwatch data review

Dr Evan Harrison, Dr Fiona Dyer, Dr Bernd Gruber,
Dr Susan Nichols and Alica Tschierschke

To

Waterwatch Upper Murrumbidgee & ACT

August 2013

Ecological Solutions for a Healthy Environment

UNIVERSITY OF CANBERRA
AUSTRALIA'S CAPITAL UNIVERSITY

ACT Waterwatch Data Review

Report prepared for: Waterwatch Upper Murrumbidgee and ACT

Report prepared by: Dr Evan Harrison, Dr Fiona Dyer, Dr Bernd Gruber, Dr Susan Nichols and

Alica Tschierschke

This report should be cited as: **Harrison, E**., Dyer, F., Nichols, S., Gruber, B. & Tschierschke, A. (2013) *Waterwatch data and catchment health indicator data review*. Prepared for ACT Government

Produced by:

Institute for Applied Ecology

University of Canberra, ACT 2601

Telephone: (02) 6201 2795

Facsimile: (02) 6201 5305

Website: www.appliedecology.edu.au

ABN: 81 633 873 422

Inquiries regarding this document should be addressed to:

Dr Evan Harrison

Phone: 02 6201 2080

Email: Evan.Harrison@canberra.edu.au

Front cover photographs from ACT Waterwatch

Document history and status

Version	Date Issued	Reviewed by	Approved by	Revision Type
Draft 1	July 2013	Project team	Fiona Dyer	Internal
FINAL	August 2013	ACT Waterwatch		Client
FINAL REVISED	August 2014	External Reviewer	Fiona Dyer	FINAL

Contents

List of tables

List of figures

Introduction

Waterwatch in the Australian Capital Territory is a part of national water quality monitoring program that engages with the community to raise awareness, educate, monitor, restore and protect waterways. Local catchment groups, Landcare groups, local residents, schools and landowners are regularly involved in the monitoring of local creeks, wetlands, lakes, rivers and stormwater drains as a part of Waterwatch monitoring. The objectives of Waterwatch in the ACT are:

- To engage the community in the environment through monitoring and caring for catchments;
- Educating and raising awareness in schools and the community on issues concerning catchment health; and
- Using data collected by volunteers to inform policy and on-ground catchment management.

Monitoring programs are typically classified as one of three types (Walker and Reuter 2006). These are:

- Compliance
  - Using indicators to assess deviations from acceptable limits.
- Diagnostic
  - Indicators that identify the cause of deviation from acceptable limits
- Early warning
  - Indicators that signal an impending decline of conditions.

The type of program will influence the selection of indicators and the study design.

ACT Waterwatch data are used as compliance monitoring data in the ACT Government Water Report as extra data on the condition of ACT waterways and as early warning monitoring for changes in water quality (i.e. Neighborhood Watch for water quality). Waterwatch data are also regularly accessed by multiple sources, for example, councils, governments, private consultants, schools and non government organizations. An example of Waterwatch data being used to inform catchment management is the use of volunteer collected turbidity data in the Upper Murrumbidgee Actions for Clean Water Plan (Murrumbidgee CMA 2012).

Given the current uses of ACT Waterwatch data and as new systems are implemented for entering, storing and displaying the data, it is timely to look at what, where, how and data are collected and assess data quality against the purposes for which it is collected and look for future opportunities.

This report is presented in two parts. Part 1 reviews the strengths and weaknesses of Waterwatch data and part 2 reviews the Catchment Health Indicators Program (CHIP) used by Waterwatch ACT to provide an indication of catchment health.

The specific questions addressed by part 1 are:

a. Who uses the Waterwatch data and for what purpose?
b. Do Waterwatch data give a similar indication of trends in catchment health as other datasets?
c. Collation and analysis of water quality data (matching sites, regression and trend analysis)
    i. Are the measurements, frequency of collection and quality controls for Waterwatch data adequate?
    ii. Is the coverage of sites sufficient?
d. Are the data sufficiently rigorous for the purposes they are collected? (spatial coverage; methods; measurements; frequency; quality controls).

Part 2 reviews the definition of catchment health currently used by CHIP, methods of scoring catchment health and the timing of sample collection. Strengths and weakness of the current CHIP program are identified and the program assessed regarding the adequacy of current data collection. We identify opportunities for other uses of the data and any inappropriate uses of the collected data.

Part 1 – Strengths and weaknesses of Waterwatch data

Methods

Data comparison

Water quality data collected from 2003 onwards by Waterwatch was compared with equivalent data collected by the ACT Government[1] and the University of Canberra (hereafter referred to as Government data). The water quality variables compared at river/creek sites were electrical conductivity, pH, turbidity and dissolved oxygen. Total phosphorus data were only compared for sites on Lake Tuggeranong and Lake Ginninderra because there was insufficient matching data for river/creek sites. There was insufficient matching total nitrogen data available in the Government and Waterwatch data sets to facilitate meaningful comparison.

Waterwatch data were matched with the nearest Government monitoring site on the same river/creek or in the same lake and to the nearest period of +/- 10 days. To avoid any duplication of data (i.e. Waterwatch data already entered in the ACT Government database), sites sampled on the same day were only matched when there was only one equal water quality value. While sites with a one to ten day gap were only matched with up to two equal water quality values.

Using these matching criteria, 30 river sites had matching data and 1356 matching records in total (Figure 1, Appendix 1). Two lake sites (Lake Tuggeranong and Lake Ginninderra) had 97 matching records.

Data analysis

Matching water quality data from four river sites are presented in this report because they represent trends across all matching sites (Table 1, see excel file attachment). Total phosphorus data are analysed for two matching lake sites on Lake Tuggeranong and Lake Ginninderra.

Data analysis comprised four steps:

1. Analysis of site density and frequency for both the Government and Waterwatch data sets.
2. Comparison of temporal variability: all data points (i.e. full data record) for matched sites were plotted as a time series and visually compared to identify differences in the observed patterns. This indicates the ability of the data sets to provide the same information about temporal patterns.
3. Comparison of sample populations: data for each matched site and variable were plotted as box plots to compare means and sample distributions. The closeness of the means and

[1] Including data collected by contracted parties on behalf of the ACT Government

sample distributions indicates whether the different sampling methods are indicating that they are sampling from the same population.

4. Analysis of the strength of relationships between the two data sets. If the data sets were a perfect match, it is expected that they would conform to a 1:1 relationship. Linear regressions, with 90 and 95% confidence intervals, were used to compare data for each site and variable with a 1:1 trend line plotted on the same scatter plot. Outliers identified as possible data entry or equipment failure errors were removed from both datasets before analysis, because outliers can have a large influence on linear regression analysis.

5. Workshop: A half-day workshop was held with ACT Government and ACT Waterwatch representatives to discuss the uses of Waterwatch data, including the strengths and weaknesses of the data and proposed future uses of Waterwatch data.

Table 1. Matching Waterwatch and Government sites used as examples for this report.

Location	Waterwatch site number	Government site numbers
Uriarra Crossing	CMM150	MUR207
Coppins Crossing	CMM100	MOL407
Casuarina Sands	CMM200	MUR200
Point Hut Crossing	CTM310	MUR778
Lake Tuggeranong	TLC 100	248
Lake Ginninderra	GIN010	318,321

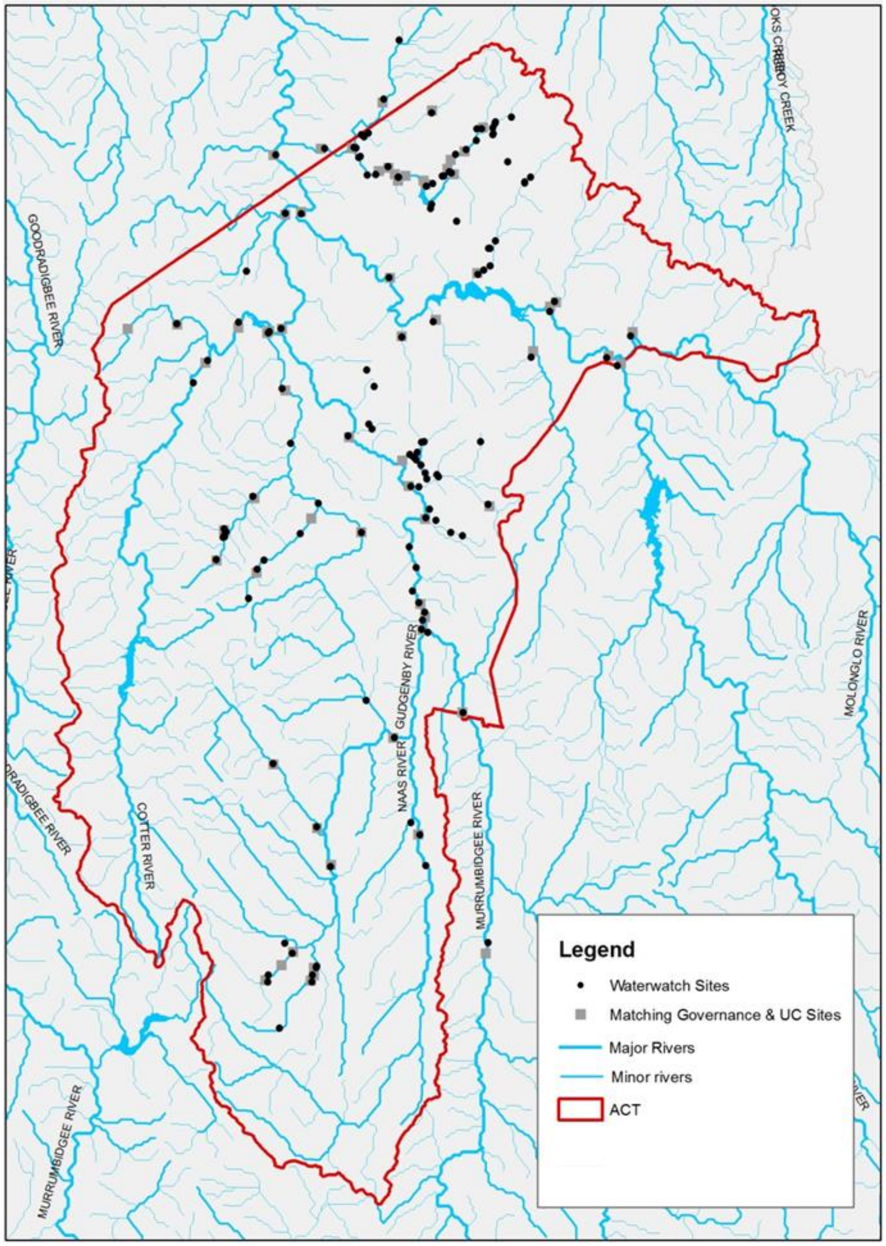


Figure 1. Waterwatch and matching Government water quality sites within the ACT region.

Results

Site density and sampling frequency

From 2003 – 2012 the majority of Waterwatch sites were sampled between 1-50 times (Figure 2) and greatest sampling density was in the northern half of the ACT, primarily in urban and rural areas. The frequency of sampling at Government sites ranged from 1-50 up to 651-1597 times (Figure 2). The greatest sampling density for Government sites was in the Lower Cotter Catchment, followed by urban and rural areas of the ACT (Figure 2).

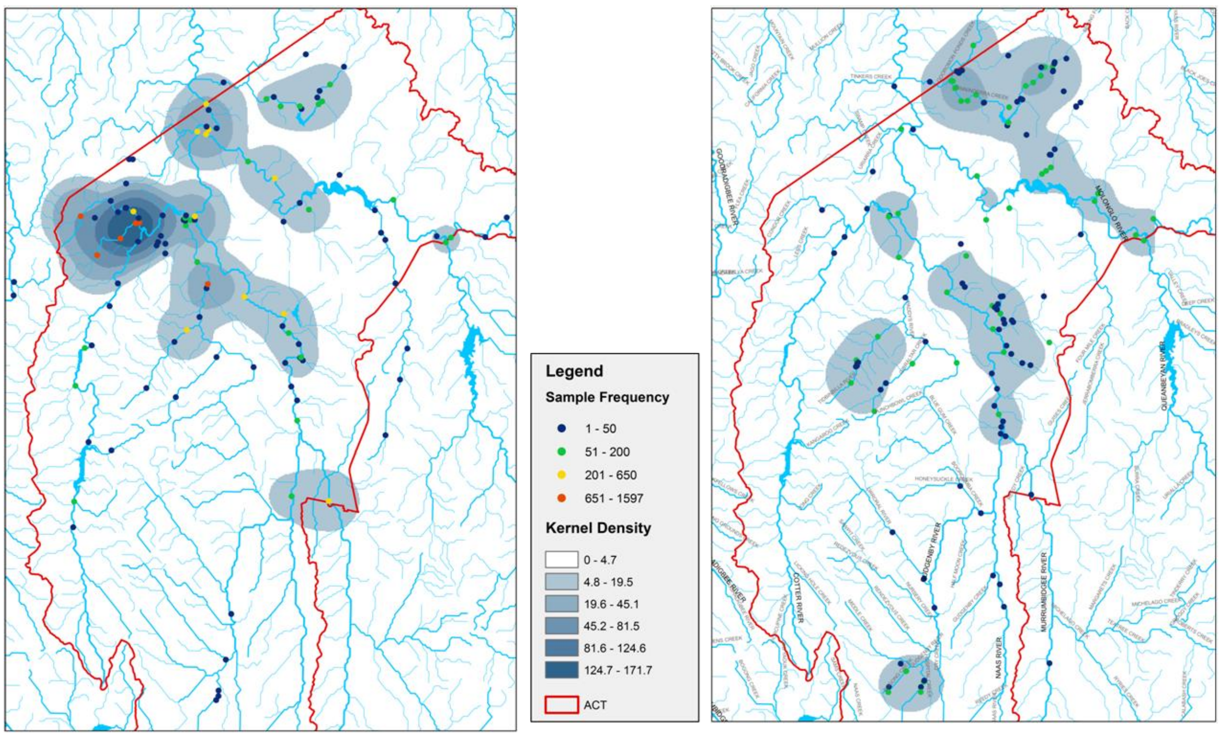


Figure 2. Sampling frequency and density of Government (left) and Waterwatch (right) water quality sampling sites in the ACT region.

Matching sites – data quality

Electrical conductivity

Waterwatch and government collected electrical conductivity data showed similar temporal patterns and both data sets had similar distributions (see Figure 3 and Figure 8 as example data sets). Moderate to strong linear relationships (close to 1:1 for some sites) were evident between Waterwatch and government collected data for matching data (see Figure 13 as an example data set). Some differences between the two data sets occur with variability in the relationship between the two data sets resulting in wide confidence intervals for some sites (Figure 13) but do not show evidence of a systematic bias. For example the government collected data displayed a series of 'spikes' of high EC which were not observed by the waterwatchers at both Uriarria Crossing and Casuarina Sands, yet at Coppins Crossing and Point Hut crossing the occasional 'spike' was observed within the Waterwatch data but not in the government data. Such occasional differences are possibly the result of differences in sampling times or recorder error in either the government or Waterwatch data sets (Figure 13).

Turbidity

Waterwatch and government collected turbidity data displayed similar distributions, however because of differences in sampling days in relation to flow events (before, during or after high turbidity events), the temporal patterns for both data sets were not always the same (Figure 4 and Figure 9). The linear relationship between the two data sets ranged from weak to strong (Figure 14) with some sites suggesting an overestimation of turbidity (notably Uriarra Crossing and Casuarina Sands). The low strength of the relationship between the two data sets at some sites (Figure 14) is likely to be a function of method differences (Waterwatch samplers use turbidity tubes and government samplers use water quality probes) and differences in the time and date on which the data were collected.

pH

The range of pH values observed across sites was between 6.5 and 8.5. In the time series analysis Waterwatch and government collected pH data differed by up to 1.5 pH units (Figure 5). At Casuarina Sands, there is evidence of systematic bias in the data with pH consistently underestimated by half to one pH unit (Figure 5 and Figure 10), which is unlikely to have much practical significance. However, for all other sites matched data had similar distributions (Figure 10). The small data range limited the regression analysis and a 1:1 relationship between Waterwatch and government collected data for matching data was not observed (Figure 15).

Dissolved oxygen

Waterwatch and government collected dissolved oxygen data showed similar temporal patterns for the full period of data and both data sets had similar distributions (Figure 6 and Figure 11).

Waterwatchers were inclined to slightly underestimate the DO values by about 0.5-1mg/L (Figure 11). Outlier dissolved oxygen values (very high and very low values) in the Waterwatch data set are likely the result of data entry error or equipment failure (Figure 6).There were moderately strong linear relationships between Waterwatch and government collected data with all sites displaying relationships close to the 1:1 trend line and narrow confidence intervals (Figure 16) . Such a strong relationship is exceptionally good given diurnal variations in DO

Total Phosphorus

For the two lake sites at which total phosphorus data could be compared, Waterwatch and government collected total phosphorus data did not show similar temporal patterns for the full period of data and both data sets did not have similar distribution (Figure 7 and Figure 12). Waterwatch collected data was also more variable than government collected data (Figure 7). The relationship between both data sets was also weak (Figure 17). This is most likely because of differences in analysis and reporting methods; government data are comprised of laboratory analysed data and report data from a continuous distributions whereas Waterwatch data are collected using a field kits and report data from discrete categories.

Workshop outcomes – uses of Waterwatch data

A summary of the uses of Waterwatch data in relation to the types of monitoring defined by Walker and Reuter (2006) are listed in Table 2.

Table 2. Types of monitoring and Waterwatch data uses discussed at the workshop and data requirements.

Monitoring type	Waterwatch data use	Data requirements
Compliance	ACT Government Water Report – background and extra data	Collection of samples that are representative of the time period being considered. A study design (event based or other design) that can be used to determine if the compliance point is exceeded.
Early warning	Trigger for investigations by the Environment Protection Authority	Monthly sampling from control and test sites to allow confidence in concluding what changes are expected to occur at test sites. To determine long-term trends a baseline dataset of at least 3 years to determine natural variations in water quality levels Trigger values that are set will be dependent of natural variability in particular locations and the management objectives for a location and the level of disturbance.

Participants at the workshop confirmed that one of the main uses of Waterwatch data is to supplement data collected for the ACT Government Water Report (http://www.environment.act.gov.au/water/act_water_reports), a report to provide the community with information about the state of water resource management in the ACT. Opportunity exists for greater use of the Waterwatch data within the Water Report, for example, using case studies such as water quality data collected before and after the Mitchell industrial fire. Waterwatch data is also used to identify actions for Catchment Groups, but it this use is not widely publicised.

Waterwatch data are used by the Environment Protection Authority (EPA) to trigger investigations (as early warning monitoring) and provide corroborating evidence for investigation being conducted by the EPA. However, the data does not have legal standing because test samples require analysis by an accredited independent laboratory for that purpose.

Waterwatch data is useful as an early warning indicator. A previous example is elevated phosphorus concentration in Tidbinbilla River in the early 1990s as a result of feral pig activity and illegal sand mining. An opportunity exists for Waterwatch to collect data from conservation areas in the southern half of the ACT, where currently no government data are collected (Figure 2).

Waterwatch turbidity data lack accuracy for values <10 NTU because of the turbidity tube method used. Guideline values for turbidity in upland streams within the ACT are 10 NTU (Environment Protection Regulations SL2005-38). The current methods for sampling turbidity identify when the turbidity is above or below the guideline level. They data do not facilitate identifying if turbidity at a site is either approaching the guideline level or changing below 10NTU. Depending on the use of the data and the relevance of turbidity measurements to ecosystem health, the purchase of turbidity probes for water watchers may be advantageous so turbidity value can be accurately compared with guideline values.

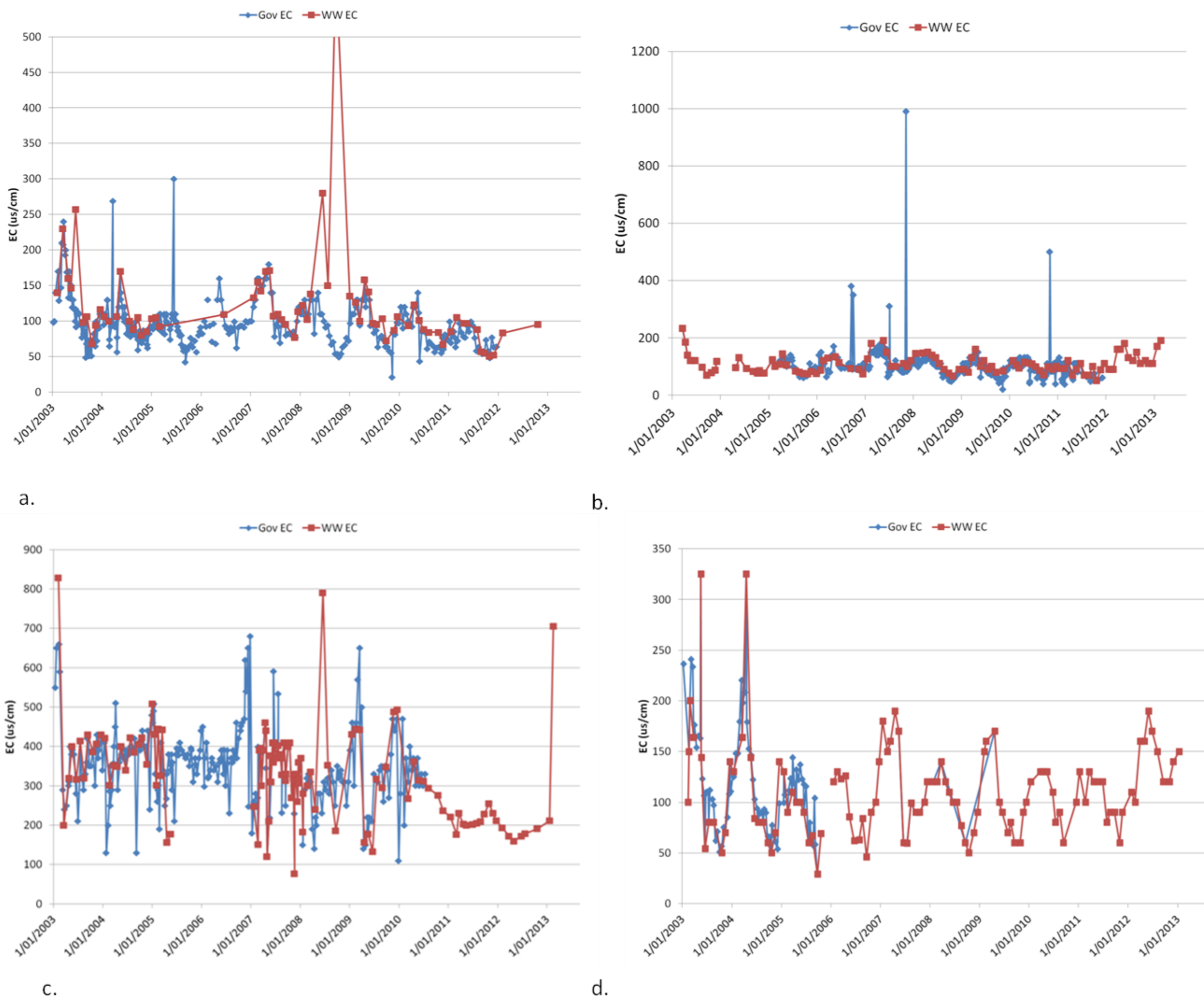


Figure 3. Full record of electrical conductivity)data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at (a) Uriarra Crossing;(b) Casuarina Sands (c) Coppins Crossing and (d) Point Hut Crossing.

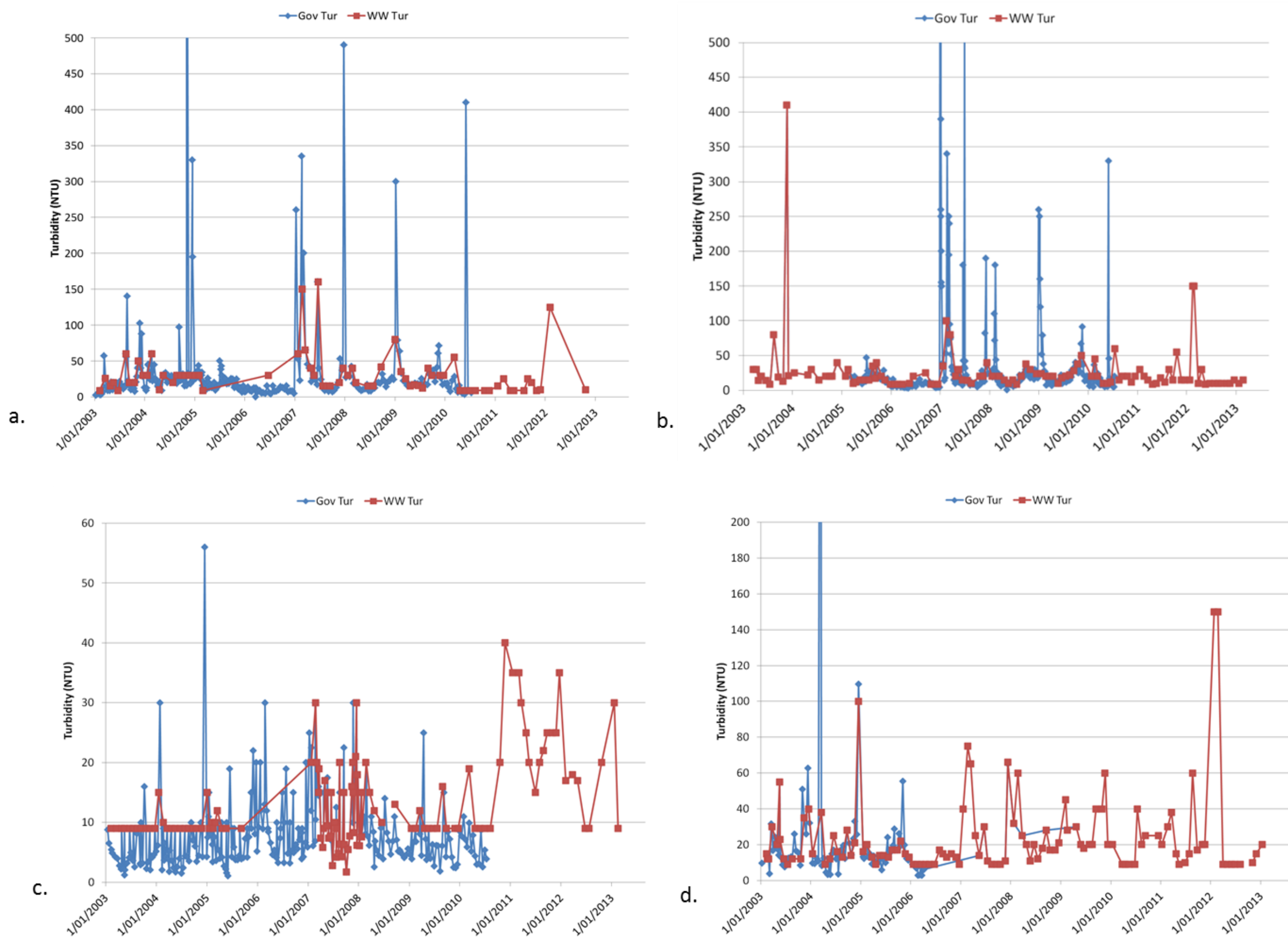


Figure 4. Full record of turbidity data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at (a) Uriarra Crossing;(b) Casuarina Sands (c) Coppins Crossing and (d) Point Hut Crossing.

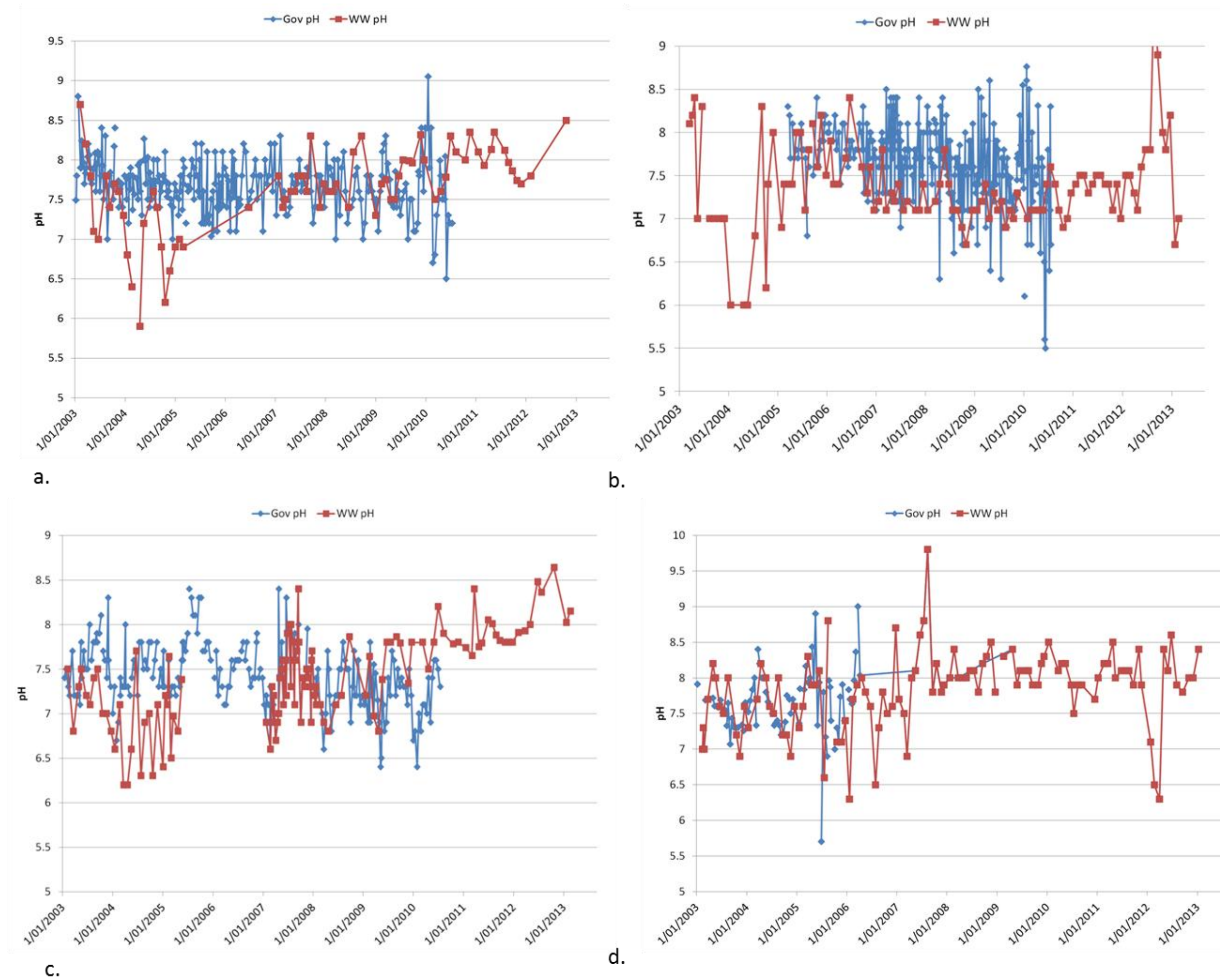


Figure 5. Full record of pH data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at (a) Uriarra Crossing;(b) Casuarina Sands (c) Coppins Crossing and (d) Point Hut Crossing.

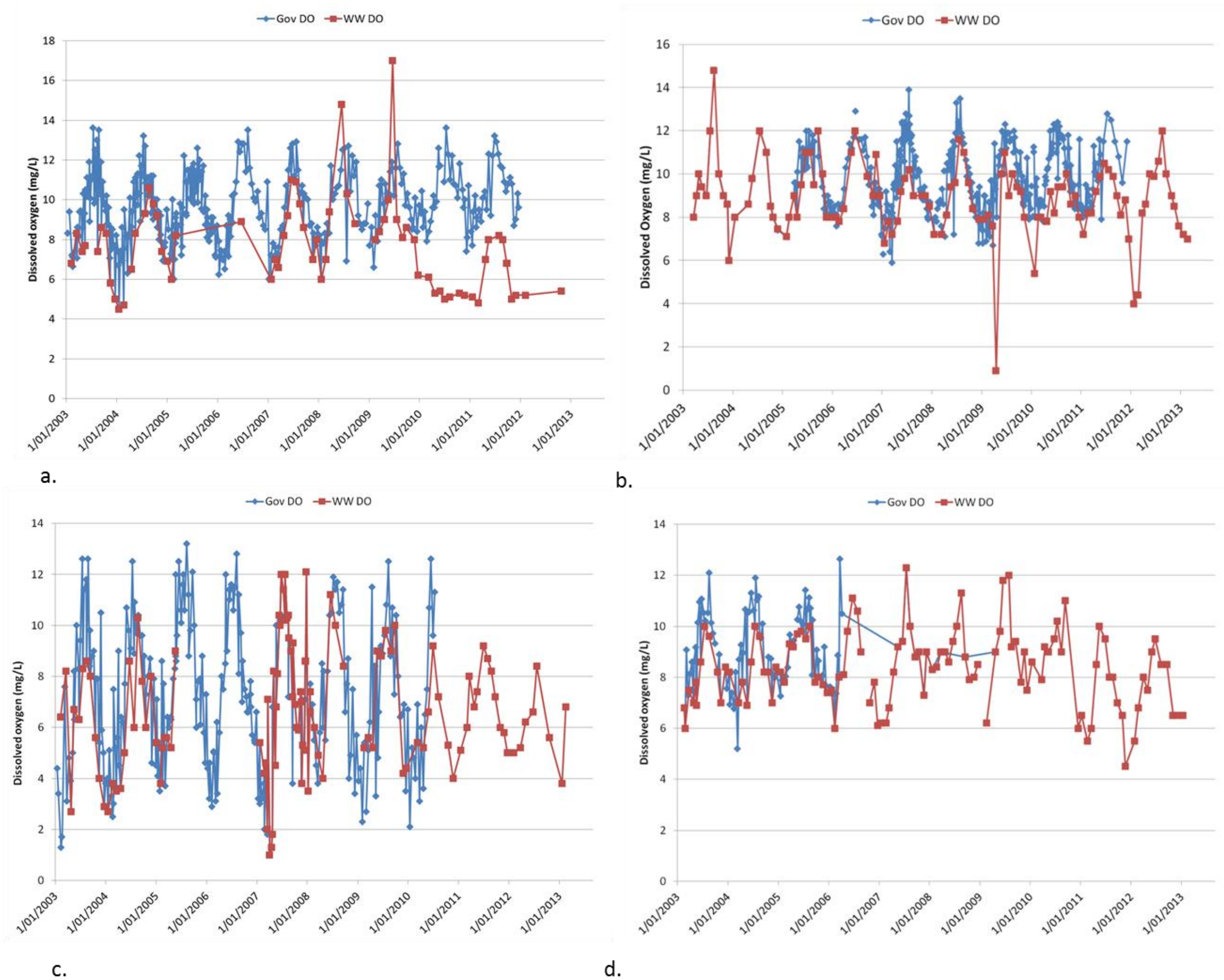
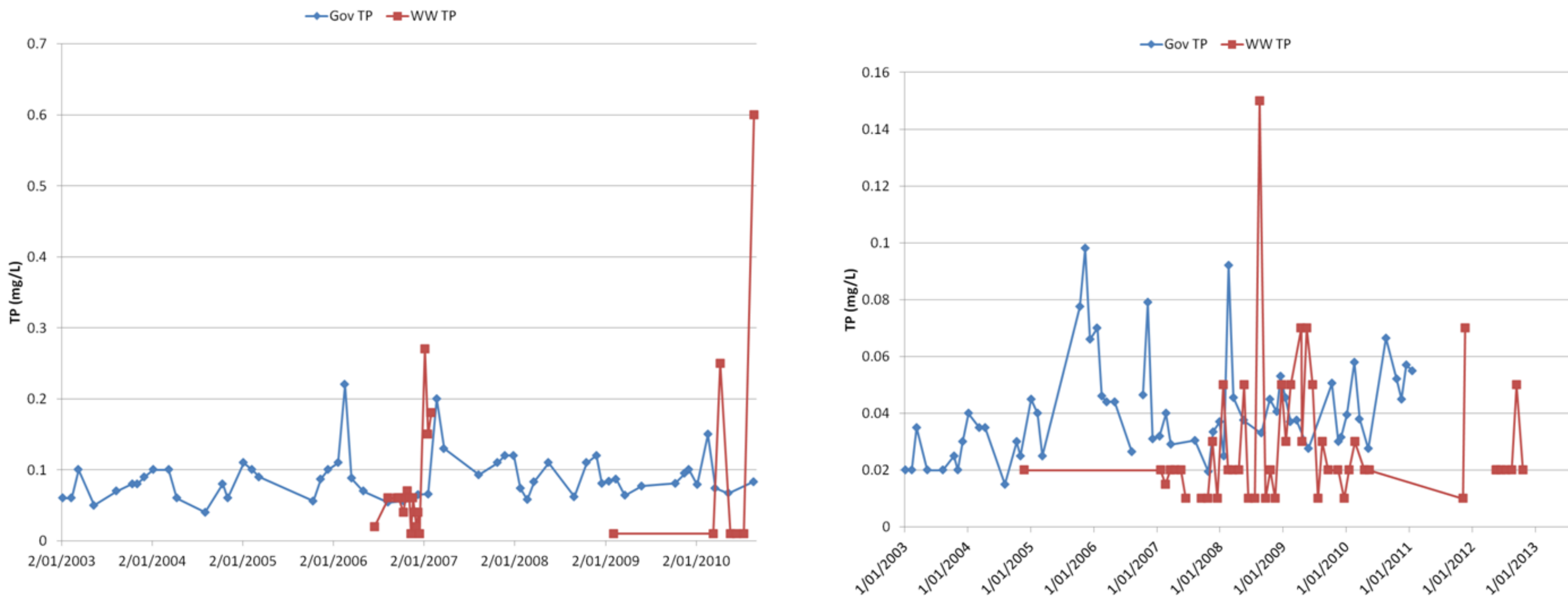


Figure 6. Full record of dissolved oxygen data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at (a) Uriarra Crossing;(b) Casurina Sands (c) Coppins Crossing and (d) Point Hut Crossing.



a. b.

Figure 7. Full record of total phosphorus data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at (a) Lake Tuggeranong and (b) Lake Ginninderra.

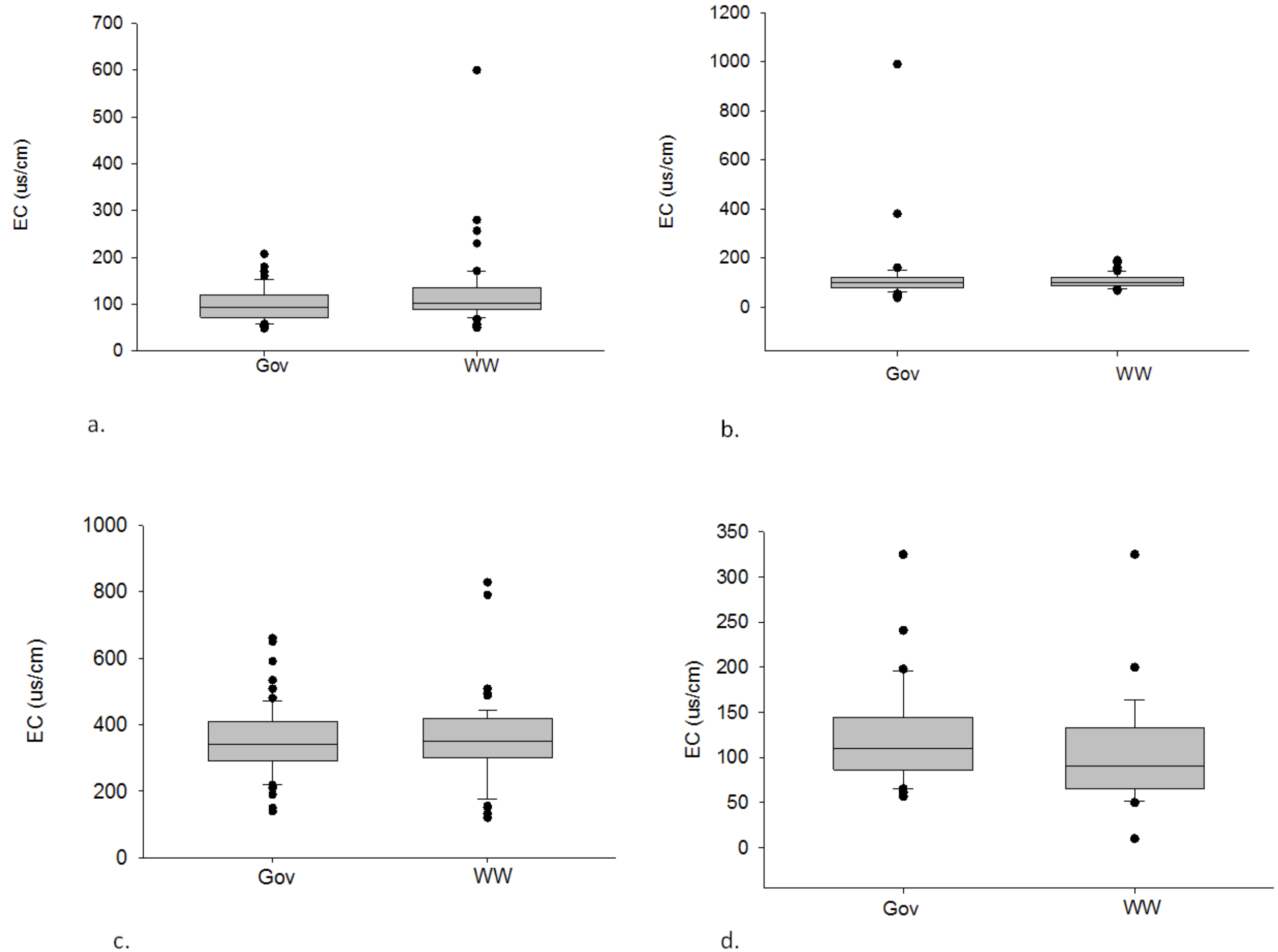


Figure 8. Box and whisker plots of matching electrical conductivity data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at a) Uriarra Crossing;(b) Casuarina Sands (c) Coppins Crossing and (d) Point Hut Crossing. Boxes represent 25th and 75th percentiles, central line is the median, whiskers are the 10th and 90th percentiles and black dots are outliers.

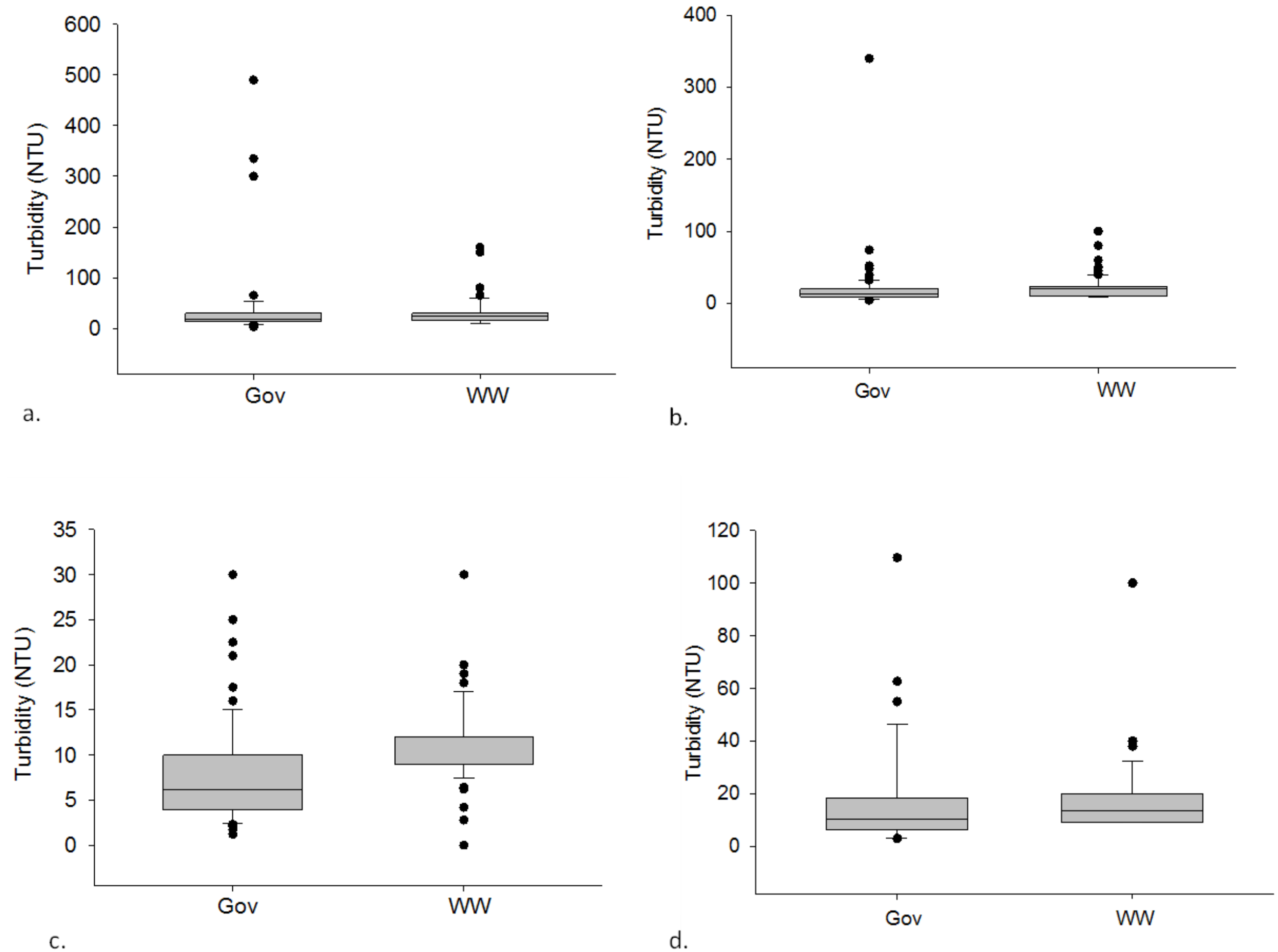


Figure 9. Box and whisker plots of matching turbidity data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at a) Uriarra Crossing;(b) Casuarina Sands (c) Coppins Crossing and (d) Point Hut Crossing. Boxes represent 25th and 75th percentiles, central line is the median, whiskers are the 10th and 90th percentiles and black dots are outliers. Note in Fig 9c. the 25th percentile and the median are identical.

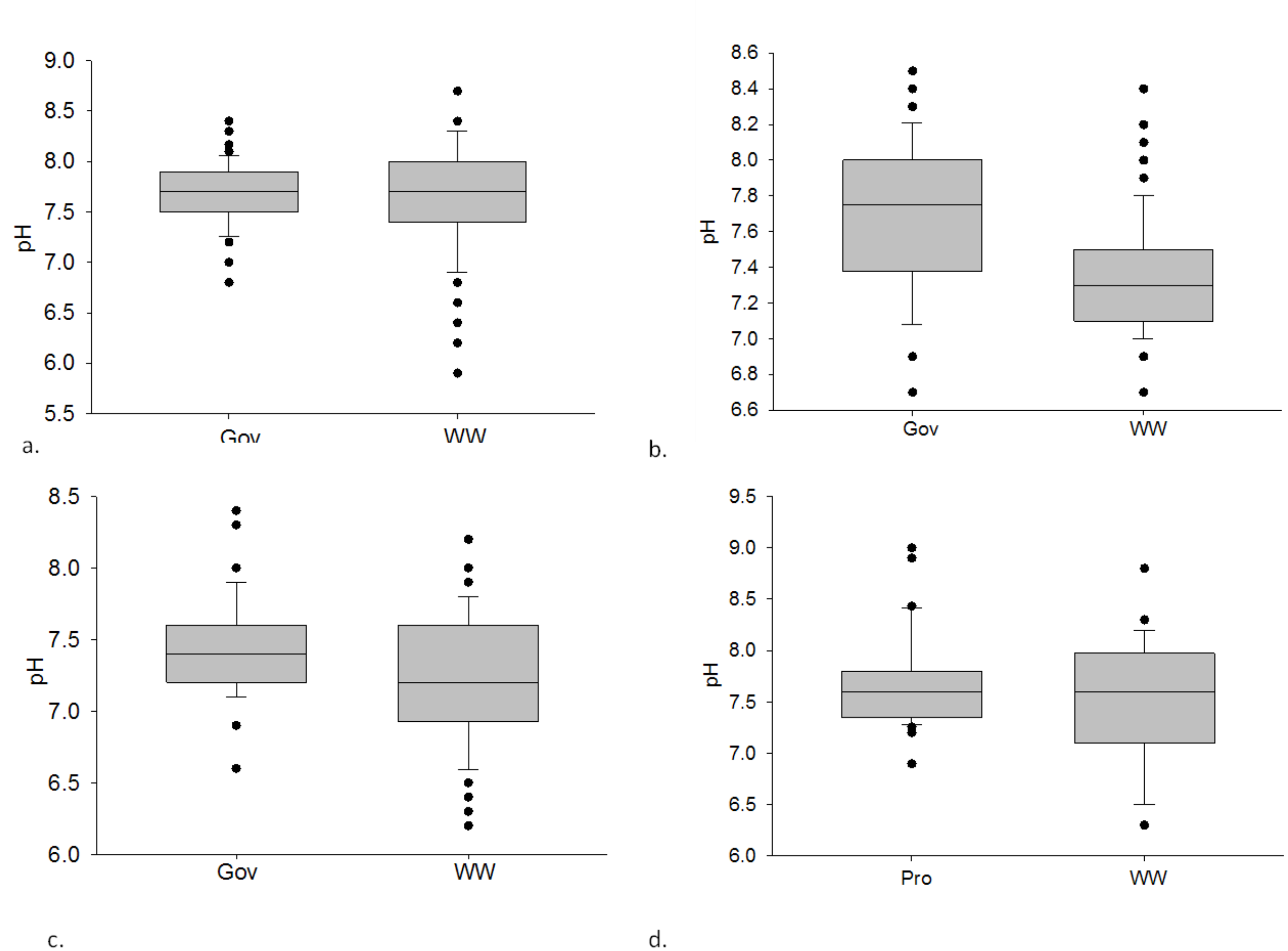


Figure 10. Box and whisker plots of matching pH data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at a) Uriarra Crossing;(b) Casuarina Sands (c) Coppins Crossing and (d) Point Hut Crossing. Boxes represent 25th and 75th percentiles, central line is the median, whiskers are the 10th and 90th percentiles and black dots are outliers.

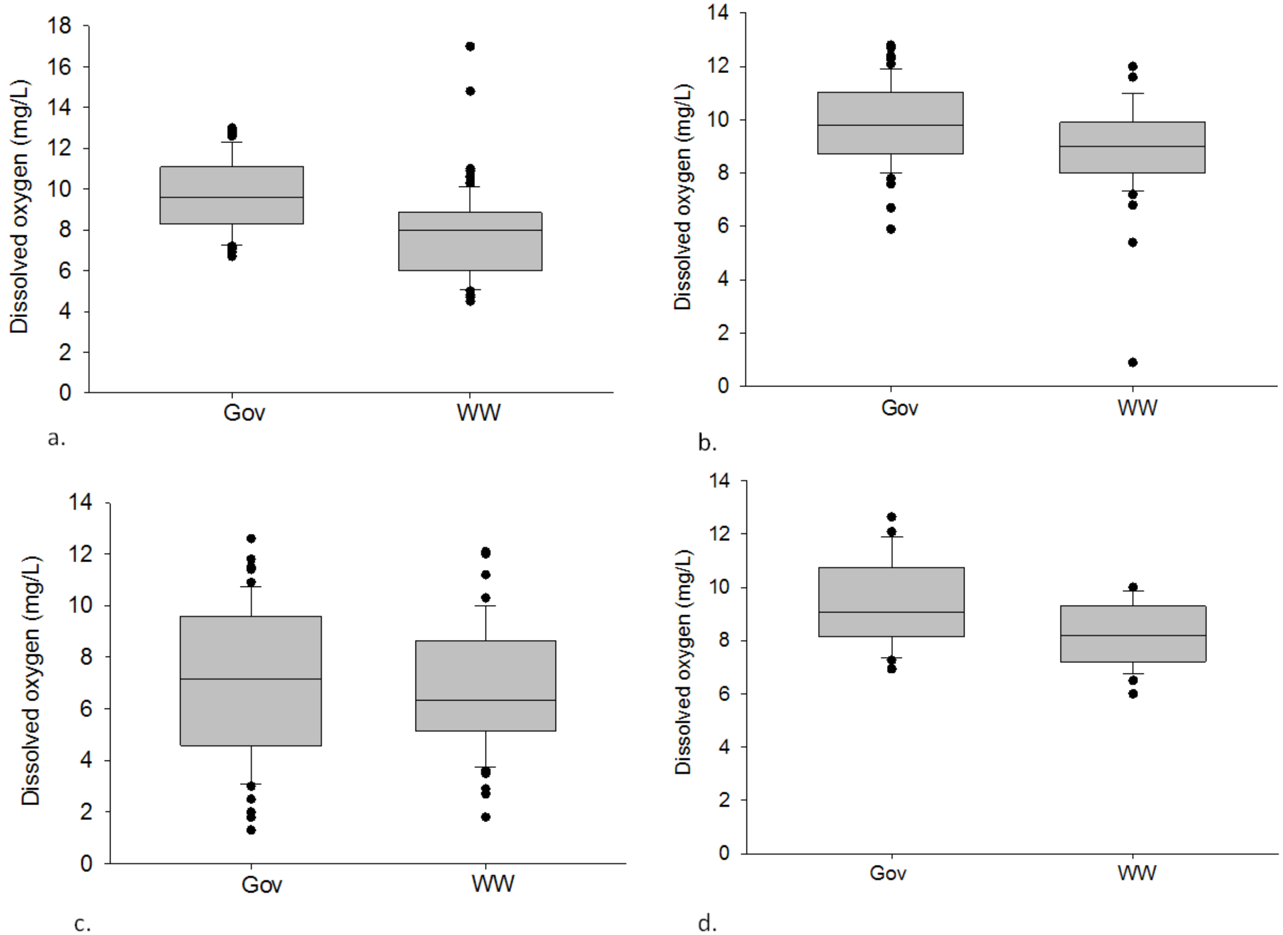


Figure 11. Box and whisker plots of matching dissolved oxygen data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at a) Uriarra Crossing;(b) Casurina Sands (c) Coppins Crossing and (d) Point Hut Crossing. Boxes represent 25th and 75th percentiles, central line is the median, whiskers are the 10th and 90th percentiles and black dots are outliers.

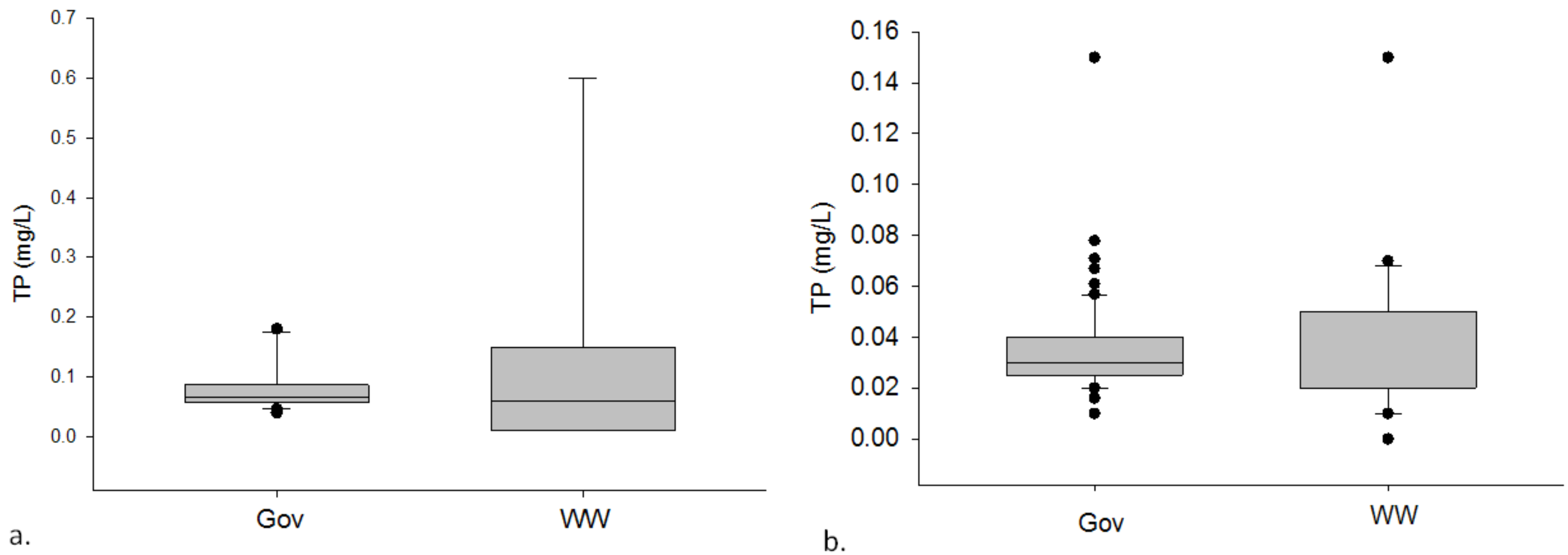


Figure 12. Box and whisker plots of matching total phosphorus data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at (a) Lake Tuggeranong and (b) Lake Ginninderra. Boxes represent 25th and 75th percentiles, central line is the median, whiskers are the 10th and 90th percentiles and black dots are outliers. Note in Fig 12b. the 25th percentile and the median are identical.

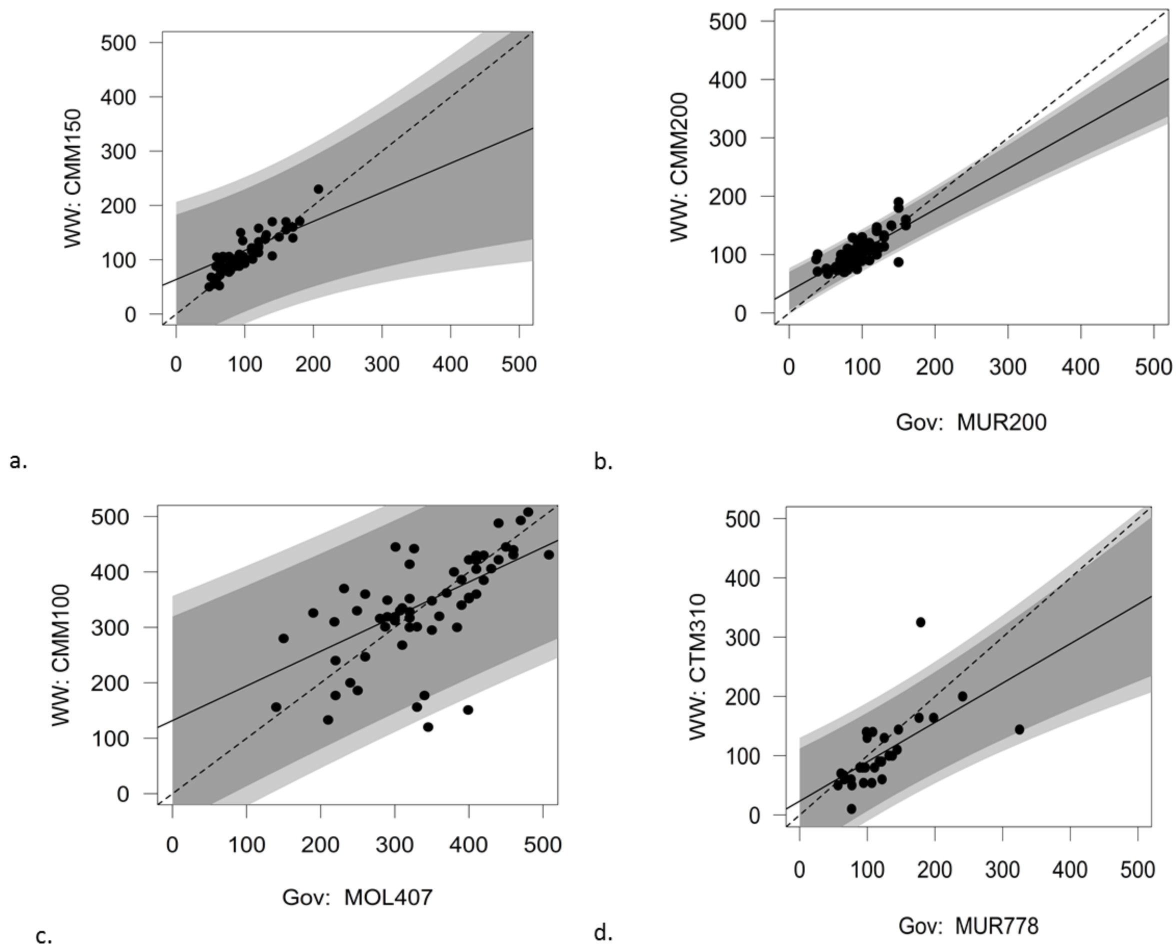


Figure 13. Linear regressions of matching electrical conductivity (µs/cm) data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at a) Uriarra Crossing ;(b) Casuarina Sands (c) Coppins Crossing and (d) Point Hut Crossing. Solid black line = linear regression line; dark grey shading = 95% confidence interval; light grey shading = 90% confidence interval; dashed black line = 1:1 relationship.

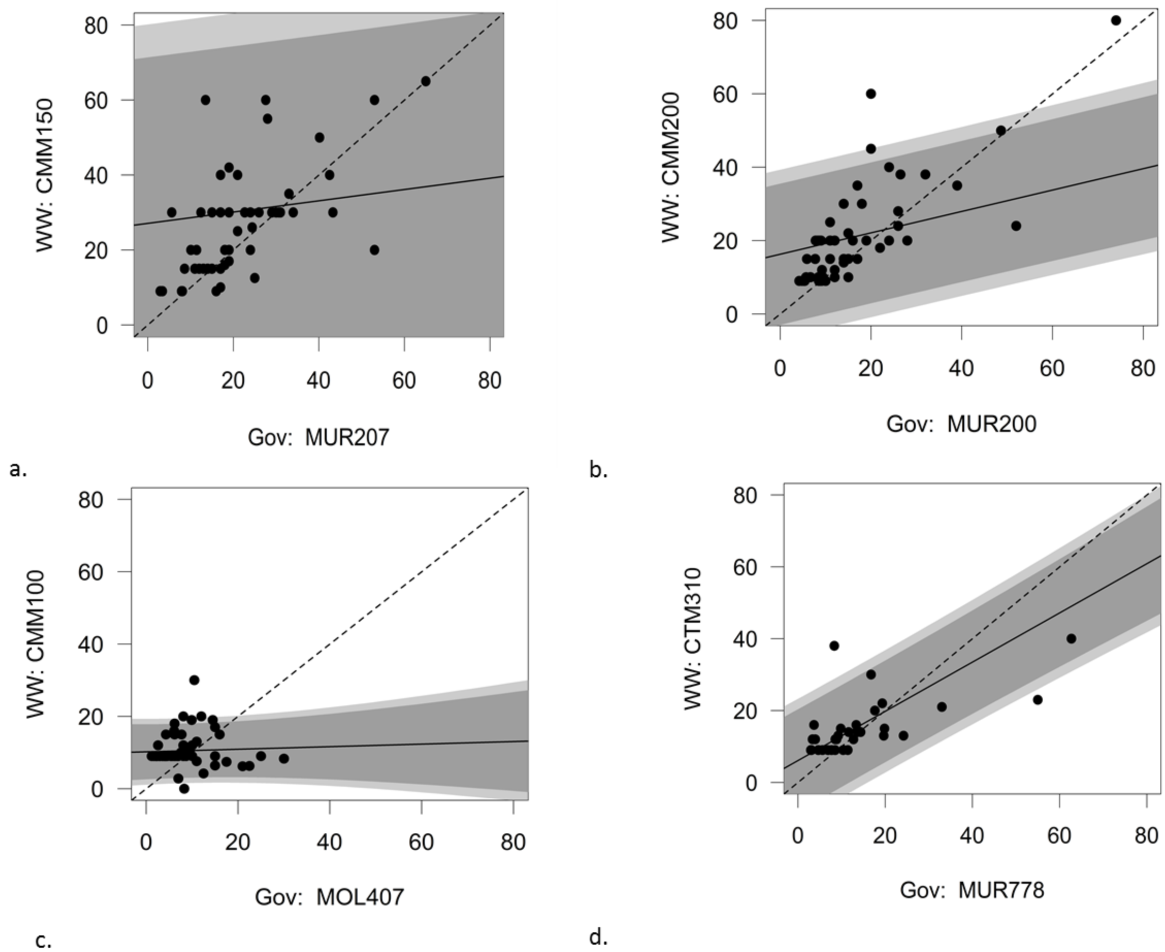


Figure 14. Linear regressions of matching turbidity (NTU) data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at a) Uriarra Crossing;(b) Casuarina Sands (c) Coppins Crossing and (d) Point Hut Crossing. Solid black line = linear regression line; dark grey shading = 95% confidence interval; light grey shading = 90% confidence interval; dashed black line = 1:1 relationship.

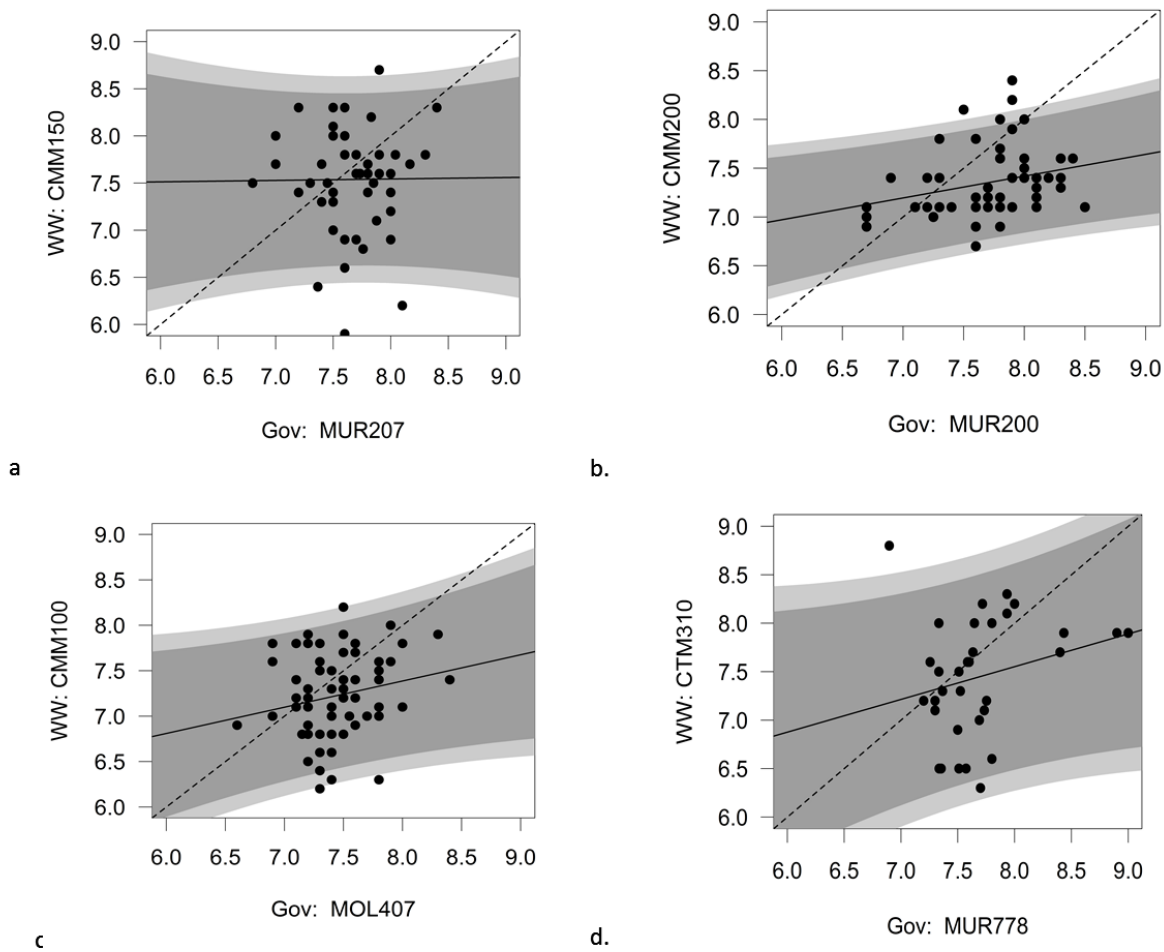


Figure 15. Linear regressions of matching pH data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at a) Uriarra Crossing;(b) Casuarina Sands (c) Coppins Crossing and (d) Point Hut Crossing. Solid black line = linear regression line; dark grey shading = 95% confidence interval; light grey shading = 90% confidence interval; dashed black line = 1:1 relationship.

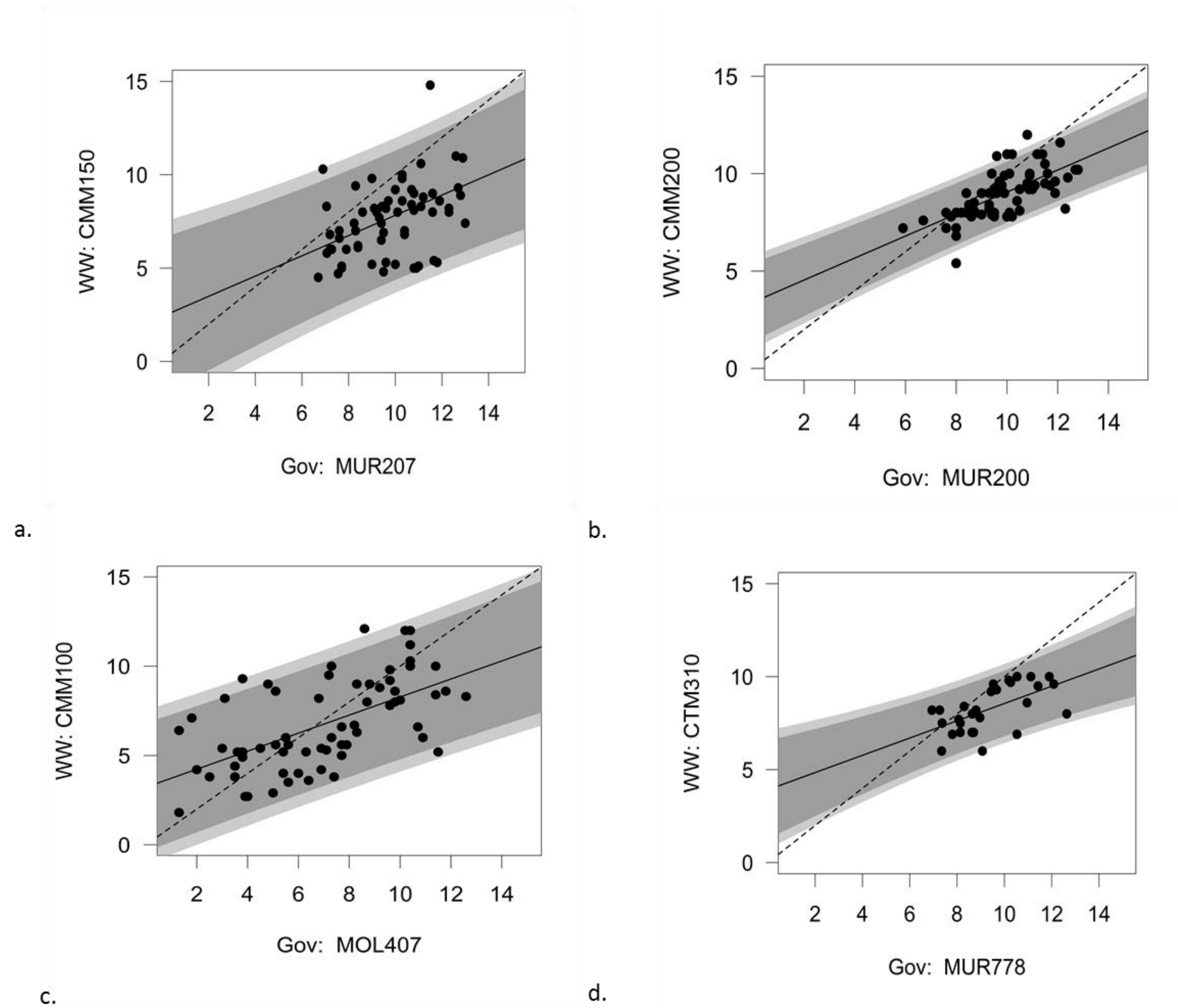


Figure 16. Linear regressions of matching dissolved oxygen (mg/L) data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at a) Uriarra Crossing;(b) Casuarina Sands (c) Coppins Crossing and (d) Point Hut Crossing. Solid black line = linear regression line; dark grey shading = 95% confidence interval; light grey shading = 90% confidence interval; dashed black line = 1:1 relationship.

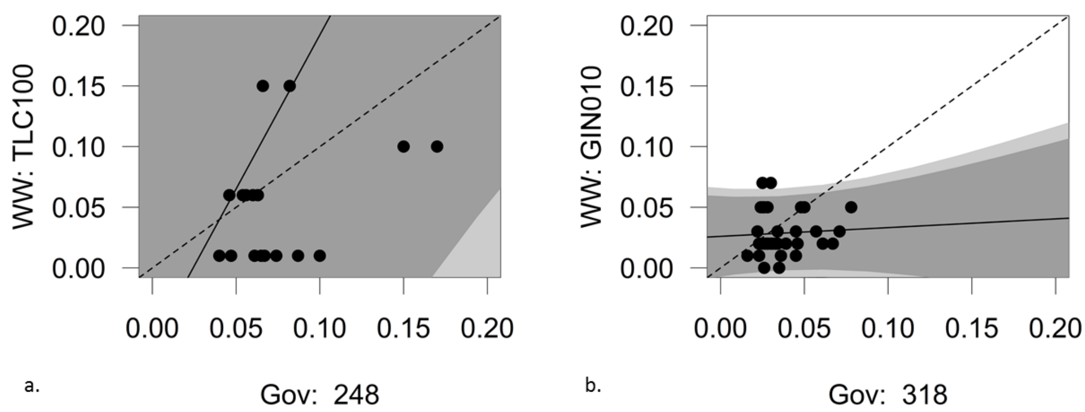


Figure 17. Linear regressions of matching Total Phosphorus (mg/L) data from 2003-2013 for Government (Gov) and Waterwatch (WW) samples at a) Lake Tuggeranong and (b) Lake Ginninderra Black line = linear regression trend line; dark grey shading = 95% confidence interval; light grey shading = 90% confidence interval;dashed black line = 1:1 relationship;.

Discussion and Conclusion – Waterwatch data quality and use

Waterwatch data are used by a wide range of community and government organisations predominantly as early warning monitoring. It is occasionally used to contribute to the prioritisation of works across the catchment.

Similar distributions between Waterwatch and Government collected water quality data for electrical conductivity, pH, turbidity and dissolved oxygen, show the Waterwatch database provides a good quality baseline data set for monitoring water quality in the ACT. Weaker correlations with turbidity and total phosphorus data sets are likely caused by differences in the method used to collect the data or differences in sampling times.

At some sites, where there is sufficiently regular collection (data collected for several years, capturing seasonal and annual patterns for different climatic conditions) of data, it is possible to use the Waterwatch data in an early warning context. Sites that have intermittent data collection do not have sufficient length of dataset or frequency of sampling to identify temporal patterns and therefore are unable to provide a baseline against which to identify an anomaly. To identify temporal patterns at a site there would need to be at least 3 years of continuous monthly data collection to understand seasonal patterns in water quality. For the purposes of providing an early warning, it is possible to combine Waterwatch data with government data to provide a longer record or to identify a need to take additional action.

In terms of using the Waterwatch data to set priorities across the catchment, it must be recognised that the data are not collected from a suitably designed study to inform prioritisation and is likely compromised by the spatial coverage of the data. For instance, to assess the effectiveness of works designed to improve water quality, such as constructed urban wetlands, requires an adequate distribution of monitoring points within the system to represent the system and account for natural variability before water quality improvement could be identified. Having sampling upstream/downstream of a pollution source or water quality improvement point such as a wetland would provide high inferential power for indentifying changes in water quality

The QA/AC process used by Waterwatch should identify (and possibly remove) “unusual” data points (e.g. DO outlier values caused by equipment or recorder error), however, the data base does not contain a long data record to allow the identification of such outliers. Long term monitoring sites should be maintained because they facilitate capacity to QA/QC data sets and to provide early warning of adverse changes.

The quality of Waterwatch data provides an opportunity to extend site coverage to parts of the ACT that are not well sampled at the moment (e.g. conservation areas in the southern half of the ACT) to augment existing monitoring effort. Extending the data collection into these areas would allow regular sampling of ‘reference sites’, which will help to disentangle the effects of natural or climatic process on water quality from these caused by human activities within the ACT.

Part 2 – Catchment Health Indicators Program review

Part 2 of this report reviews the Catchment Health Indicator Program (CHIP).

In this section we:

- Review the definition of catchment health used by the CHIP and how it compares to other definitions of catchment health
- Review the methods of scoring used in the CHIP and timing of sampling
- Outline future opportunities for CHIP in terms of the strengths and weakness of the current program, assessment of adequacy of current data collection; opportunities for other uses of the data; areas for improvement; inappropriate end uses of the data collected

Our review of the CHIP includes outcomes from the workshop held with ACT Government and Waterwatch representatives.

CHIP background and definition of catchment health

The CHIP is based on the work of Walker and Reuter (1996). A healthy catchment is defined by Walker and Reuter (1996) as being:

1. able to recover from stressors that are natural or man-made made (resilient);
2. economically viable; and
3. environmentally self-sustaining.

CHIP was developed as a simple and practical method community groups could use to:

- measure the health of their local catchment;
- provide input into sub-catchment management planning and enable groups to practice adaptive management;
- identify early warning signals of environmental problems;
- identify options for remedial action based signals of environmental problems;
- monitor and evaluate the effectiveness of their on-ground projects; and
- measure trends in the condition of the natural resources in their catchment over time.

The CHIP uses a sub-catchment scoring systems for:

- Water (water quality);
- Riparian** (algae, macroinvertebrates, frogs, riparian vegetation, instream condition); and
- Land (land-use, ground cover, soil quality/structure, weeds)

Definitions of Catchment Health

Natural resource managers and river managers have adopted the concept of 'health' for reporting the state of their natural assets (for examples see programs for the Sydney Catchment Authority; Fitzroy River Basin; St Georges Basin; and Melbourne Water in Table 3). The term is seen by many to have obvious parallels with concepts of human health and is considered to provide a useful mechanism to communicate with the general public. The World Health Organisation (www.who.int/about/definition/en/print.html) defines good human health as '*state of complete physical, mental and social well-being and not merely the absence of disease or infirmity*'. People readily accept that there are multiple components to human health and thus can understand that the health of a catchment or river is also made up of multiple components (Norris and Thoms 1999).

While there are many programs that report on river and catchment health, few provide clear definitions of what they consider to be river or catchment 'health' or why attributes have been chosen to represent river health (Table 3). Rivers are a popular end point for assessing catchment health, because rivers are strongly influenced by the landscapes that they flow through (Hynes 1975, Alan 2004). For instance, many organisations have a river health rather than catchment health programs and some have 'condition' programs where they are assessing the condition of rivers in relation to some predefined benchmark or reference state (e.g. Index of Stream Condition – Ladson et al. 1999, Tasmanian River Condition Assessment – DPIPWE 2012, Australian River Assessment System [AUSRIVAS] – Simpson and Norris 2000).

***Currently in the CHIP riparian includes instream and stream bank vegetation indicators. Traditionally the riparian zone is defined as any land which adjoins, directly influences or is influenced by a body of water (Boulton and Brock 1999). See further comments regarding this in the sampling and scoring method review section on page 40.*

Table 3. Examples of other Australian river/catchment health assessment programs

Program	Link	Definitions	Indicators used
Georges River, River Health Program	http://www.georgesriver.org.au/River-Health-Monitoring-Program.html	No clear definition: "A healthy catchment is one that is still able to function as a catchment should. It should be able to filter and clean water as it flows overland and seeps through the ground, and there should be lots of opportunities for water to seep into the ground so that it can be used by plant".	water quality; vegetation and macroinvertebrates
Fitzroy basin	http://riverhealth.org.au/report_card/methods/program_design/cquA/document.pdf	A healthy aquatic ecosystem is characterised by the presence of integrity, resilience and vigour in different components of the freshwater ecosystem.	Water quality, nutrient cycling, ecosystem processes, macroinvertebrates fish, macrophytes, algae
Sydney catchment Authority	http://www.sca.nsw.gov.au/the-catchments/healthy-catchments-strategy-2009_2012/healthy-catchments/catchment-health-problems	The overall environmental health of a catchment depends on the condition of its ecosystems and water management systems, such as sewerage and stormwater systems.	Macroinvertebrates, water quality, fish, physical habitat assessment
South East Queensland Ecological; Health Monitoring Program	http://www.healthywaterways.org/IntegratedPartnershipHealthycatchments-healthywaterways.aspx	Ecosystem health condition an aggregate of the impacts of point (industrial emissions and wastewater treatment plants), diffuse sources (urban stormwater, agricultural run-off and natural systems run-off) from the catchments and the assimilative capacity (internal processing) of our waterways. Within this program, healthy waterways are defined as having three important attributes: 1)Vigour – Healthy streams have appropriate rates of ecological processes, e.g. slow/steady algal growth 2)Organisation – Healthy streams have a complex biological structure, e.g. high biodiversity, complex food webs 3)Resilience – Healthy streams have the capacity to maintain their ecological structure and function in the presence of stress, e.g. they recover after a major disturbance such as drought or flood	Water quality, nutrient cycling, ecosystem processes, macroinvertebrates fish

Index of stream condition	http://www.water.vic.gov.au/monitoring/river-health/isc	The Index of Stream Condition (ISC) is the first consistent statewide study of the environmental condition of rivers anywhere in Australia and was also the first integrated measure of river condition in Australia. It integrates the condition of river hydrology, water quality, streamside zone (vegetation), physical form (bed and bank condition and instream habitat) and aquatic life	Flow regime, water quality, channel condition, riparian vegetation condition, macroinvertebrates
Melbourne Water	http://www.melbournewater.com.au/content/rivers_and_creeks/river_health/measuring_environmental_condition_of_rivers/measuring_environmental_condition_of_rivers.asp	The Index of River Condition (IRC) is based on the ISC developed by Department of Sustainability and Environment for rural rivers and creeks. It has been modified to account for the urban rivers and creeks in Melbourne Water's operating area The IRC program is a tool designed to provide an overall integrated measure of the environmental condition of rivers.	Flow regime, water quality, channel condition, riparian vegetation condition, macroinvertebrates
Tasmanian River Condition Index	http://www.dpipwe.tas.gov.au/internnsf/WebPages/LBUN-4YG9G9?open	The Tasmanian River Condition Index (TRCI) assesses four key components (or sub-indices) of river condition, providing an integrated approach to compare current condition to a pre-European reference.	Aquatic life - fish, macroinvertebrates and algae Hydrology - flow patterns such as low flows, floods, flow seasonality, overbank flows Physical form - physical character of the channel, bank and bed material and flow types Streamside zone - riparian vegetation

Purpose of CHIP and how does it compare

CHIP was established with a clear set of purposes in mind. Table 4 outlines a set of requirements against which we will assess the CHIP for each purpose. An underlying objective was for the CHIP to be suitable for use by community groups, which means the level of complexity and range of measurements must be suited to groups with basic training.

Table 4. Purposes of CHIP and requirements to achieve each purpose

Purpose	Requirements
Measure the health of local catchment	Set of attributes/indicators that represent the health of the catchment Sampling design that adequately represents the catchment
Provide input into sub-catchment management planning and enable groups to practice adaptive management	Study design (sufficient number of sites) that facilitates planning
Identify options for remedial action	Study design that enables prioritisation
Monitor and evaluate the effectiveness of their on-ground projects	Study design that targets on-ground projects
identify early warning signals of environmental problems	Study design with sufficient samples to identify problems; sufficient long term monitoring to be able to notice a departure from 'normal'
Measure trends in the condition of the natural resources in their catchment over time	Long term monitoring

Indicators of catchment health and how does CHIP compare

There are many features of the system that make up 'catchment health' and there is a broad range of attributes or indicators chosen to represent river and catchment health. The indicator chosen will be dependent upon the definitions of catchment and river health and how the information is to be used (Bunn et al. 2010). Most have undergone a scientific and pragmatic process of selection. Many use attributes of water quality as the central attribute that represents catchment health and most have little focus on catchment attributes other than riparian vegetation assessments.

CHIP uses:

4. Water (water quality);
5. Riparian (algae, macroinvertebrates, frogs, riparian vegetation, instream condition); and
6. Land (land-use, ground cover, soil quality/structure, weeds)

Catchment health assessment and reporting should be clearly linked to identified values and objectives. Without agreed objectives, it is difficult to justify public investment in monitoring and to implement effective management actions (Bunn et al. 2010; Norris and Thoms 1999). The CHIP has an agreed definition of catchment health and has a recommended suite of indicators that are considered to represent catchment health. The focus is broader than the rivers of the catchment with indicators representing instream, riparian areas and land characteristics. The CHIP is well framed for reporting on catchment health.

Catchment /river health monitoring/assessment designs and recommendations for CHIP

Programs established to monitor/assess catchment health use a suite of indicators measured across the catchment and report at either a catchment or reach based scale. The sampling design is an important consideration in establishing catchment health programs. Popular assessment of catchment health methods include sub-catchment assessments (South East Queensland Ecological Monitoring Program – Sheldon et al. 2012), end of catchment assessment (e.g. Sustainable Rivers Audit – Davies et al 2010) and reach based assessments (e.g. Index of Stream Condition – Ladson et al. 1999, Tasmanian River Condition Assessment – DPIPWE 2012) (Figure 18).

There are numerous challenges in the sampling design used to report on catchment health. For example, sub-catchment assessments may be dependent upon the number of sites within the sub-catchment (i.e. a single site within a sub-catchment may not represent the whole sub-catchment). Furthermore, end of catchment assessments may be confounded if there is a stressor at the downstream end of the catchment and the upper parts of the catchment are in pristine condition.

Reach-based assessments allow reporting at a finer scale and are not dependent on multiple points of assessment to obtain a true picture of health for a site. The challenge is that often catchment based reporting is required for communication purposes. Also a challenge, is determining what length of stream is represented by a single point.

The CHIP focuses on sub-catchment health assessment based on the results of sites located within the sub-catchment. However, one site within a sub-catchment may not give an indication of sub-catchment health. Based on the requirements outlined in Table 4, and the current study design (where there are many sites in a sub-catchment), CHIP only provides a measure of the health of the local catchment, early warning of a possible problem where there is a long term data set and provides a measure of trends through time (i.e. a baseline data set).

We suggest that it would be more appropriate have a reach based assessment for areas where data are available within a sub catchment and class other reaches as “no assessment made”. Reaches can be defined in a number of ways (see later text). This would avoid assessments of sub-catchment health where there is only one site in a catchment and also avoid combining and average data from sites which are not physically similar to give an overall sub-catchment assessment which is currently done for the CHIP. This can produce results bias towards some sites in a catchment with no indication of variability within a sub-catchment.

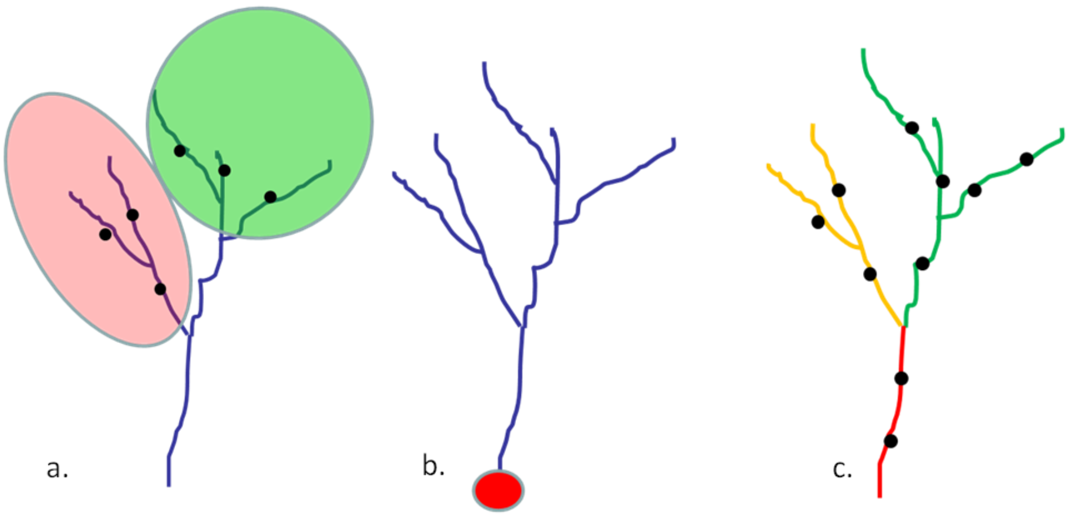


Figure 18. Popular ways of measuring catchment/river health (a) sub-catchment; (b) end of catchment (c) reach based with different ratings for each reach shown by colours. Dots represent sample sites

Water quality data is the most frequent CHIP assessment because the data are easily collected by volunteers. The water quality CHIP data provides a valuable baseline dataset for sites throughout the ACT. However, data collected for the CHIP can only inform change compared with the baseline data set. For management prioritisation and impact assessment within a catchment a Before After Control Impact design is needed. Having control sites will allow confidence in concluding that changes at test sites are the result of human impact. Control sites should be upstream of the impact or management intervention being assessed.

The CHIP does provide an opportunity to assess catchment health in the ACT and to engage the community in the assessment. Using a reach based assessment may provide a better study design to fulfil the purposes of the CHIP (Table 4). Using a reach based-assessment will allow for assessments of impacts within a catchment and be more relevant to community regarding the health of locations with their catchments, allow assessment of on ground projects and provide a baseline data set to provide early warning signals for changes in catchment health. The results of the assessment could then be used in ACT State of the Environment reports to contribute to an assessment of catchment health. Given the different assessment timelines for different aspects of the CHIP, different indicators can only be reported when they have been measured. Reaches with no sites should be marked as not assessed. The location of assessment reaches could be defined based on priority areas for assessment where catchment management activities are taking place.

An example of our proposed reach assessment for the CHIP is shown in Figure 19. The example shows an assessment of the influence of tributary flowing from a degraded reach into a less disturbed reach.

Reaches should be defined based on similar physical habitat characteristics (e.g. changes in landuse, channel character). They can be delineated in different ways:

1. Expert opinion: using local experts to define reaches with similar physical characteristics or water quality behaviour. This could also allow reaches to be defined on the basis of activities in the catchment such as reaches where catchment remediation works are taking place.
2. Catchment area increases: based on mapping data in which a new reach is defined when catchment area increases by a predefined amount (e.g. doubles). This is based on the assumption that stream character will change as discharge increases and a doubling of discharge (assuming a strong correlation between discharge and catchment area) is set as a threshold for a new reach. This approach is similar to that used by the National Land and Water Resources Audit (Norris et al. 2001).
3. Tributary inputs: similar to the increase in catchment area, a new reach can be defined when tributaries of similar magnitude (defined by stream order) combine.
4. Mapped stream characteristics: using stream attributes such as substrate character, geology, landuse and water quality to identify reaches of similar character.

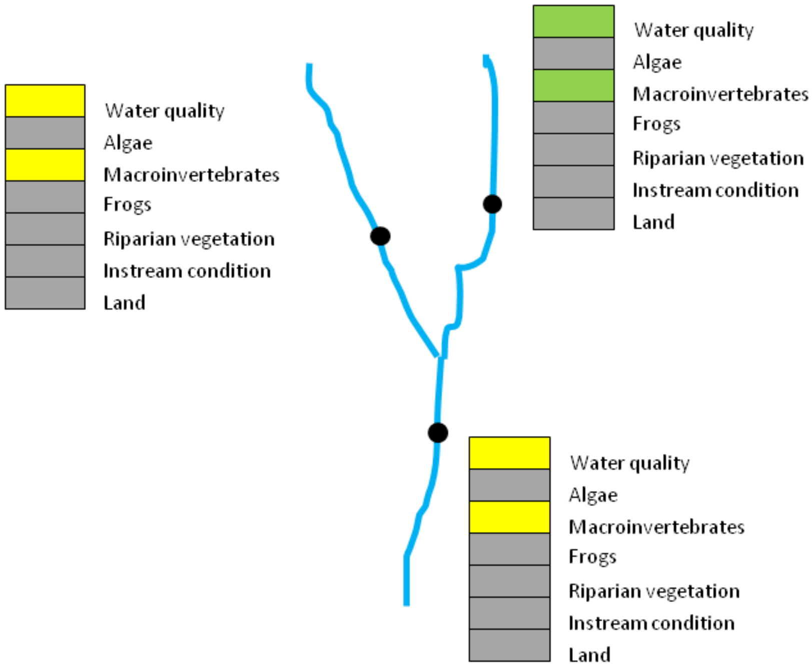


Figure 19. An example of a reach based CHIP assessment for an assessment upstream and downstream of a tributary confluence. Green = “good” assessment; Yellow = “moderate assessment” Grey = “not assessed”. Black dots are sample sites representative of the reach.

Sampling and scoring method review and recommendations

An advantage of the CHIP scoring method is that it provides an easily calculated assessment of catchment health that provides a baseline assessment for catchment health. In Table 5 we review the CHIP sampling and scoring methods. Other issues with the CHIP that cover several indicators are:

- The riparian zone is defined as any land which adjoins, directly influences or is influenced by a body of water (Boulton and Brock 1999). Currently, the set of indicators representing Riparian condition encompasses both biological and physical indicators and instream indicators. While the indicators chosen and the riparian condition may be highly correlated, the majority of indicators are more indicative of in-stream characteristics. The riparian group should just include riparian vegetation as an indicator. For instance, conspicuous algae, macroinvertebrates and frogs could be incorporated in an aquatic life group similar to the ISC. While instream condition should be incorporated into an indicator for channel physical condition There would be value in considering the use of control or sentinel sites to evaluate changes in biological character that may be caused by climate conditions compared with land management to assist in identifying potential problems or evaluating long term trends.
- Desktop land measures are reliant on the data being available and updated every 5 years. This is unlikely to be the case because a lot of this data is not updated that regularly.

- Land measures – there is need for an evaluation of what constitutes a healthy landscape within a catchment – and relating it to the processes that are expected and therefore define the measures. This is the weakest part of the assessment. The measures used are quite different from those used for the riparian and instream areas, which focus on measures of quality, but also measures of diversity and abundance. For example, a pine forest has 100% tree cover, would this be considered healthy? Is a blue gum plantation healthy? Monocultures typically do not provide a healthy catchment. We suggest revision to this measure.
- Assessment categories are assigned as Excellent through to Degraded. It is not clear how these categories have been defined and if they are based on specific objectives. For example, it is not clear if the excellent category is based on what is expected for minimally disturbed conditions. This is the case for most indicators in the CHIP. Ambiguous definitions will lead to variable data as a result of different interpretations by recorders and not actually related to catchment health. Given this, in manuals for volunteers there is a need for clear definition of categories and exact instructions for measurement.

Table 5. Evaluation of CHIP indicators

Water	**Frequency**	**Scoring**	**Evaluation**
Water quality attributes (pH, EC, DO, turbidity, phosphorus, nitrate)	Monthly (typically)	Scoring system based on national standards (presumably ANZECC); Victorian guidelines and some from the Hudson River scheme with separate guidelines for urban and rural streams. The mode of the monthly values are calculated for each attribute and then assigned a score. Water score is the summation of individual attribute scores.	While many of the values presented in the scoring table for water quality are reasonable, this would benefit from updating to align with ACT water quality guidelines It is not clear if both measurements of DO are to be included in the total score and it is recommended that only one be included to avoid weighting DO measurements more heavily than other attributes.
Riparian			
Conspicuous Algae (based on form and % cover)	Monthly	Scoring based on abundance and a rating given to the type of algae present	Multiple forms of algae at a single site not currently handled and it is generally assumed that the more algae, the more degraded the condition. These are probably reasonable assumptions at present, but there would be some value in considering the use of reference or sentinel sites to evaluate changes in algal composition/abundance that may be caused by climate conditions in comparison with land management.
Macroinvertebrates (edge habitats only)	Autumn/Spring	SIGNAL2 and taxonomic richness	SIGNAL scores and taxonomic richness at order level are the practical level for volunteer assessments. However, a limitation of the SIGNAL method is that it does not account for macroinvertebrates expected at a site (i.e. a site may have naturally low taxonomic richness).

Frogs	Annually	Scoring based on diversity and abundance. No weighting given to sensitive species but purely a measure of diversity and abundance – with the assumption that greater diversity and greater numbers of individuals is good.	There is no account of what macroinvertebrates are expected to occur at a site. For example, some locations may naturally have low taxonomic richness. Using the current assessment approach naturally low diversity sites would receive a poor rating
Riparian condition	Annually	Rapid Appraisal of Riparian Condition (RARC)	Established and tested method which seems appropriate
In-stream condition	Annually	Habscore	There needs to be a sedimentation component in the Habscore to assess instream condition/habitat. For example the % of fine sediment covering the stream bed could be broken into categories such as 0-10%, 10-25%, 25-50%, 50-75% and >75% fine sediment cover.
Land			
% weed cover,	Biannually	done as a visual estimate in original scheme	Useful
% bare soil	Biannually	visual estimate in original scheme	Useful
soil pH	Biannually	done with meter or paper (no detail)	Useful
soil EC	Biannually	done with meter (no detail) slaking and dispersion, done by observation (no detail)	Useful
area of catchment	Every 5 years	No scoring suggested	Not an indicator of health
% urban area	Every 5 years	No scoring suggested	This is an observation that is collected to support assessments of catchment health. It is not an indicator.

% tree cover	Every 5 years	No scoring suggested	Useful provided there are separate scoring systems for urban/rural areas
Area of forest with stands >50 ha	Every 5 years	No scoring suggested	Depends on the size of your catchment or subcatchment as to the value of this as a health measure, better with some measure of connectivity (distance to nearest forest stand of >50ha?)
% bare soil	Every 5 years	No scoring suggested	Useful but need to differentiate from the measure given above
Area of slope >5° on agricultural land	Every 5 years	No scoring suggested	This is an observation that is collected to support assessments of catchment health. It is not an indicator.
Length of riparian vegetation vs total length of creek,	Every 5 years	No scoring suggested	Useful
Length of roads vs total catchment area	Every 5 years	No scoring suggested	This is an observation that is collected to support assessments of catchment health. It is not an indicator.
Number of times a road crosses a stream	Every 5 years	No scoring suggested	This is an observation that is collected to support assessments of catchment health. It is not an indicator.

ACT Government and Waterwatch Workshop:CHIP review

Currently the CHIP is not used in Government compliance reporting and is only used for Waterwatch assessment reports written by catchment groups that are passed on and filed for future reference if required by ACT Government. The CHIP has the potential to provide catchment health reporting score cards that could be used in Government reporting. Giving a whole catchment score based on one site is not appropriate and for catchment management purposes using reach based reporting may be more appropriate to remove the bias of using a small number of sites to assess overall catchment health.

The CHIP provides an important education program for the community and engages the community in assessing the health of catchment. State of the Environment reporting was identified as a future opportunity to use CHIP data to assess the health of ACT catchments using the reach based approach we have proposed.

References

Allan, J. D. 2004. Landscapes and riverscapes: The influence of land use on stream ecosystems. Annual Review of Ecology Evolution and Systematics **35**:257-284.

Boulton, A., Brock, M. 1999 Australian Freshwater Ecology, processes and management. Gleneagles Publishing. South Australia.

Bunn, S.E., Abal, E.G., Smith, M.J., Choy, S.C., Fellows, C.S., Harch, B.D., Kennard, M.J., and Sheldon, F. 2010. Integration of science and monitoring of river ecosystem health to guide investments in catchment protection and rehabilitation. *Freshwater Biology* **55**: 223-40.

Davies, P.E. and Harris, J and Hillman, T, and Walker, K, 2010, 'The Sustainable Rivers Audit: assessing river ecosystem health in the Murray-Darling Basin, Australia.*, Marine and Freshwater Research* **61:**764-777.

Environment Protection Regulations SL2005-38. Environment Protection regulation 2005 made under the Environment Protection ACT (1997). Australian Capital Territory Government.

Hynes, H. B. N. 1975. The stream and it's valley. Verhandlungen der Internationale Vereiningung für theoretische und angewandte Limnologie **19**:1-15.

Ladson, A. R., White, L. J., Doolan, J. A., Finlayson, B. L., Hart, B. T., Lake, P. S., and Tilleard , J. W.. 1999. Development and testing of an Index of Stream Condition for waterway management in Australia. Freshwater Biology **41**:453-468.

DPIPWE. 2012. Tasmanian River Condition Index – Reference manual. http://www.dpipwe.tas.gov.au/internnsf/WebPages/LBUN-4YG9G9?open

Murrumbidgee CMA. 2012. Upper Murrumbidgee Actions for Clean Water Plan. State of New South Wales 2012.

Norris, R. H. and M. C. Thoms. 1999. What is river health? Freshwater Biology **41**:197-209.

Norris, R. H., Prosser, I., Young, B., Liston, P., Bauer, N., Davies, N., Dyer, F., Linke, S., and Thoms, M.. 2001. The Assessment of River Conditions (ARC): An audit of the ecological condition of Australian Rivers. Final Report submitted to the National Land and Water Resources Audit Office, Cooperative Research Centre for Freshwater Ecology and CSIRO Land and Water, Canberra.

Sheldon, F., Peterson, E. E., Boone, E. L., Sippel S., Bunn, S. E., and Harch, B. D.. 2012. Identifying the spatial scale of land use that most strongly influences overall river ecosystem health score. Ecological Applications **22**:2188-2203.

Simpson, J.C. and Norris, R.H.. 2000. Biological assessment of river quality: development of AUSRIVAS models and outputs. Pages 125-142 *in* J.F. Wright, D.W. Sutcliffe, and M.T. Furse (eds). Assessing the biological quality of fresh waters; RIVPACS and other techniques. Freshwater Biological Association, Ambleside, Cumbria, U.K.

Walker, J. And Reuter, D.J. 1996. Indicators of catchment health. A Technical Perspective. CSIRO Publishing, Collingwood

Appendix 1

Matching government and Waterwatch river water quality sampling sites

Government site number	Waterwatch site number	Matching sampling times
HOS100	CGH100	1
HOS300	CGH300	1
MOL407	CMM100	91
MUR207	CMM150	131
MUR200	CMM200	223
MUR209	CTM250	88
MUR778	CTM310	46
MUR142	CTM400	23
PAD010	CTP450	15
TID050	CTT050	2
TID070	CTT070	3
TUG058	CTT100	131
GIN006	GIN002	3
GIN194	GIN005	27
GIN347	GIN007	5
GIN064	GIN011	30
GIN302	GIN020	2
GIN064	GIN024	30
GIN237	GIN040	1
COT112	MCC050	1
CON450	MCC200	22
MOL601	MOL295	4
MOL428	MOL401	3
MUR200	MUR200	223
QUE090	QUE495	8
COT111	SCR100	16
GUD902	TGC100	2
GIB017	TGC200	3
GIB018	TGC300	1
YAR416	YAR400	4