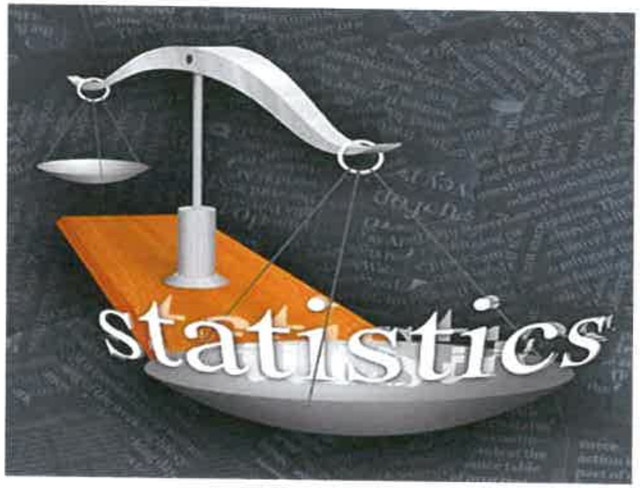
TABLED AT HEARING

Application: Lyttelton Port Co - Channel Deepening

Date: 3rd May 2017



Summary of Evidence

Prof. David Fox

Environmetrics Australia

LPC Channel Deepening Project
Consent Hearing, May 1-9, 2017

Summary of Evidence – Prof. David Fox

Academic qualifications

- BAppSci
- MAppSci (statistics)
- PhD (statistics)

Professional Societies

- Fellow Royal Statistical Society
- Member American Statistical Association
- Chartered Statistician (RSS London)
- Professional Statistician (ASA USA)
- Chartered Scientist (Science Council UK)

Awards

- Recipient of Edwards Deming Award (USA)
- Recipient of CSIRO Chairman's Gold Medal (Aus)

R&D

- 45 publications in refereed journals
- 6 book chapters

Employment

- 30+ years universities in Australia; USA; UK
- 15 years Senior research management CSIRO (Aus)
- 10+ years company Director

Relevant Experience

- Co-author of ANZECC/ARMCANZ Water Quality Guidelines (2000; 2016)
- Director, Adelaide Coastal Waters Study (1999-2006)
- Director, Effluent Management Study (Melb. Water, 1998-2006)
- Consultant statistician Port of Melbourne Corporation Channel Deepening Project (2006-2007)
- Consultant statistician Gladstone Ports Corporation Western Basin Dredging Project (2009-2014)
- Member, Dredge Technical Reference Committee (GPC) (2010-2014)

My work

Two reports:

1. *Statistical Considerations Associated with the Establishment of Turbidity Triggers* - Appendix 19 to the Applications (*Statistical Report*).
2. *Recommended data processing and Trigger-Value Methods for the LCP CDP* - Appendix 20 to the Applications (*Recommendations Report*).

- Further technical updates to m-IFD method as per pre-circulated evidence
- Focus on statistical methodology for compliance (tier-three trigger level) and advice for trigger values for internal management (tiers two and three trigger levels) using SMART data from Vision Environment

Outline

1. Statistical QA/QC
   - Smoothing
   - Imputation

2. Trigger Values
   - Rationale
   - Best practice
   - Conceptual development
   - Strengths and weaknesses

3. The IFD Approach
   - Rationale
   - Precedents
   - Conceptual development
   - Strengths and weaknesses

4. The m-IFD Approach
   - Overview
   - Implementation

5. Recommendations & Conclusions

Statistical QA/QC

Smoothing or Filtering

- Filtering is a common method of reducing 'noise' and improving the quality of a signal or output



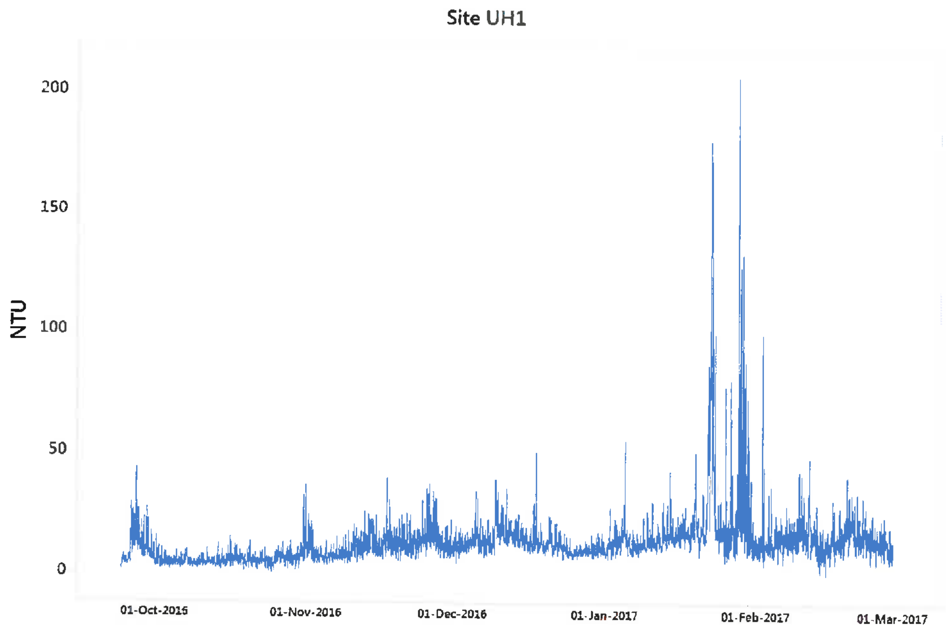


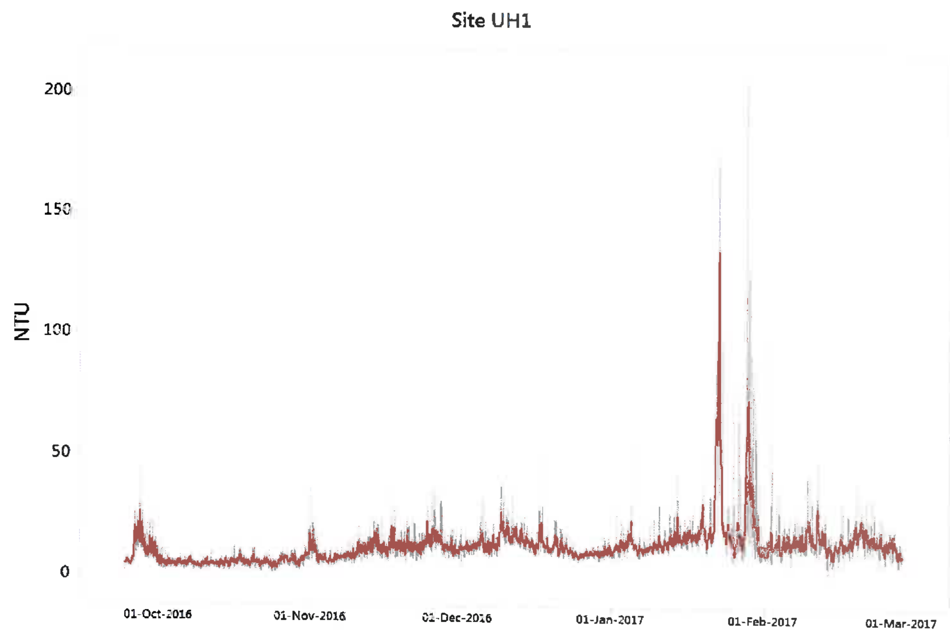

Statistical QA/QC

Smoothing or Filtering

- 'Raw' turbidity signal is very noisy

We can filter a little



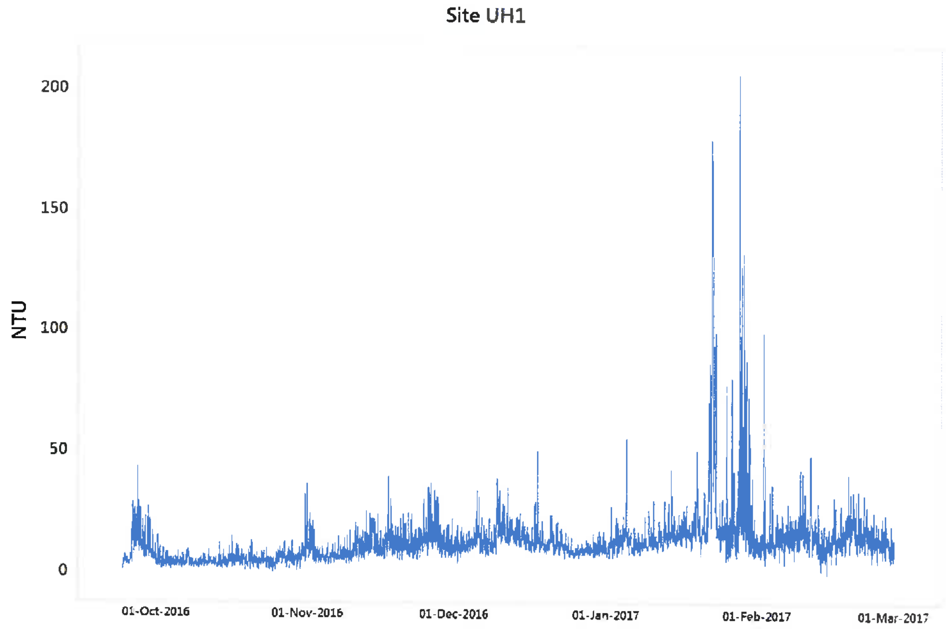


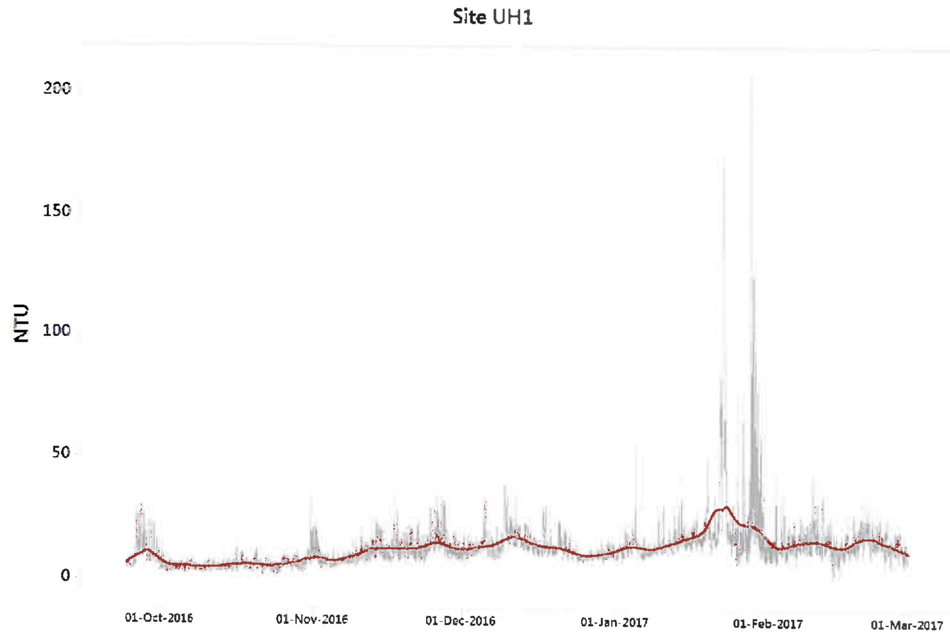
Statistical QA/QC

Smoothing or Filtering

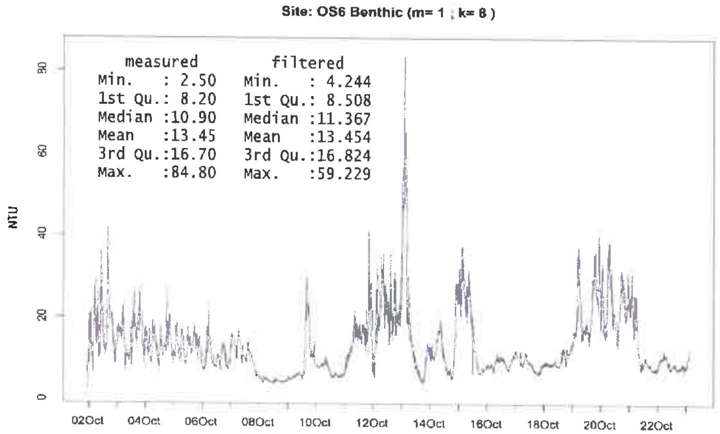
- ‘Raw’ turbidity signal is very noisy

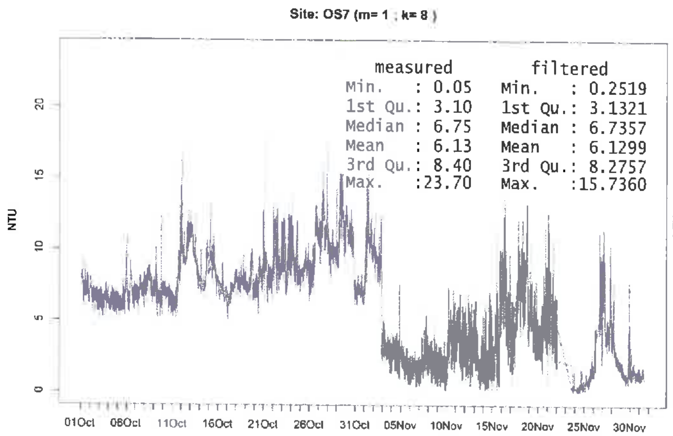
. . . or we can filter a lot

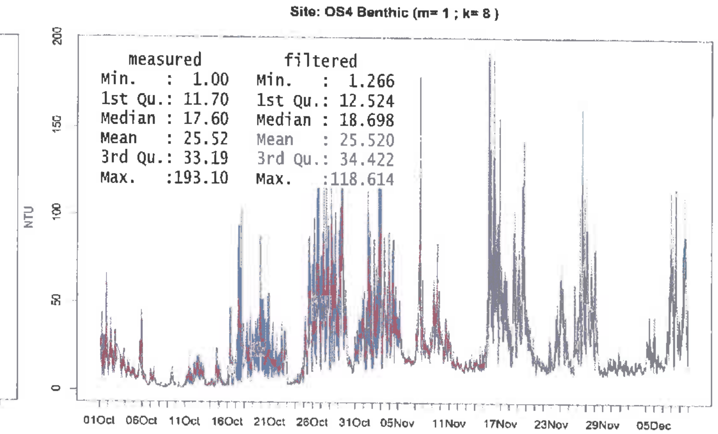


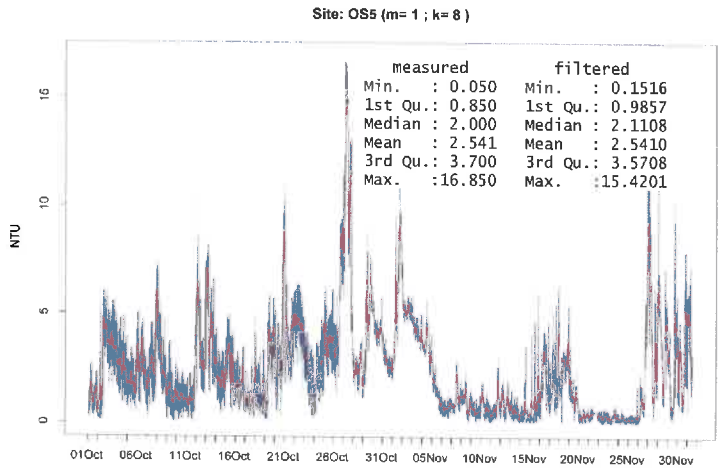


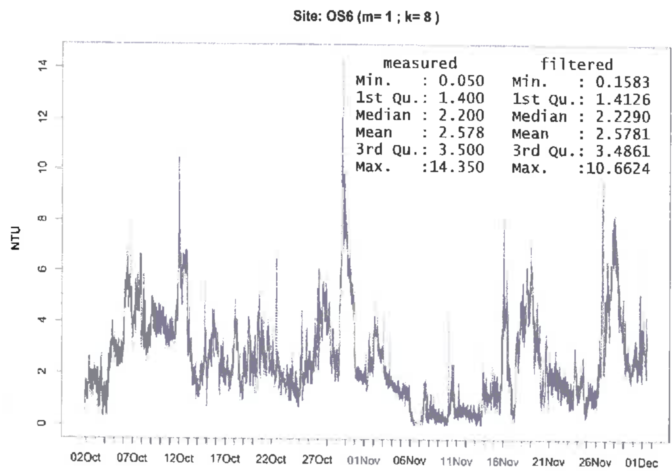
Statistical QA/QC

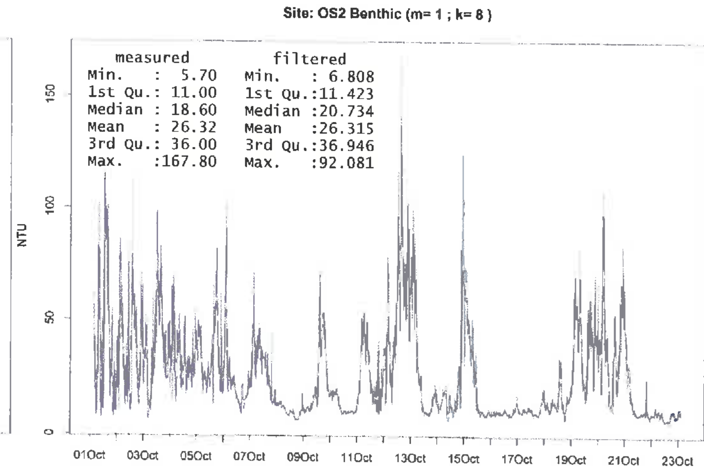




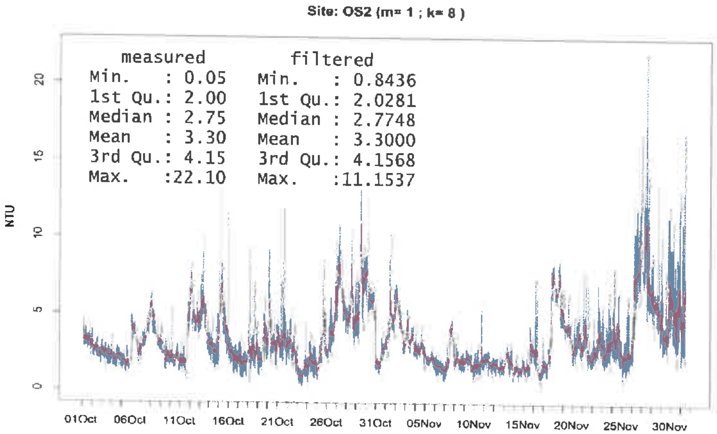


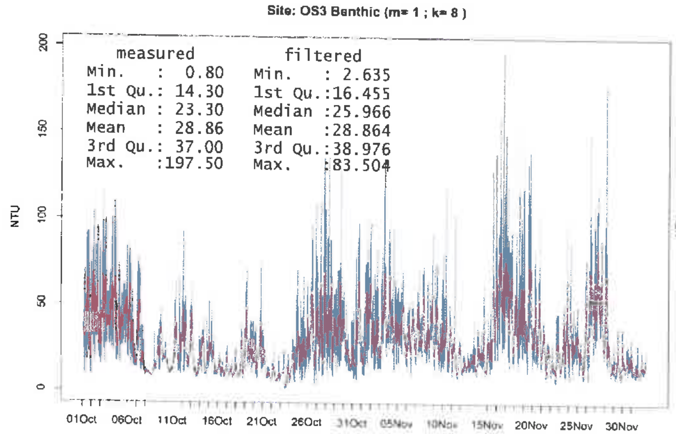


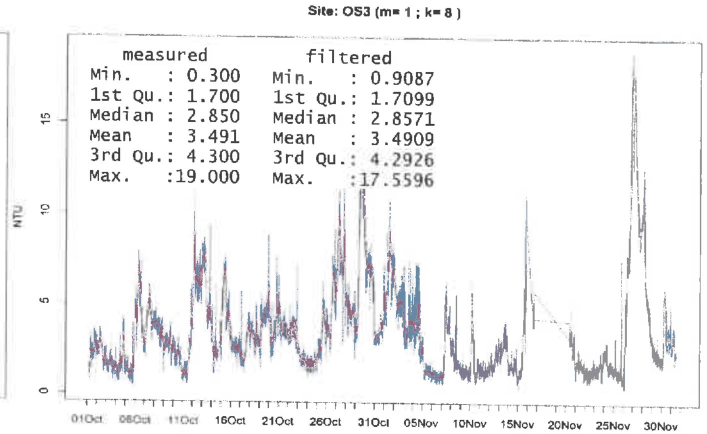


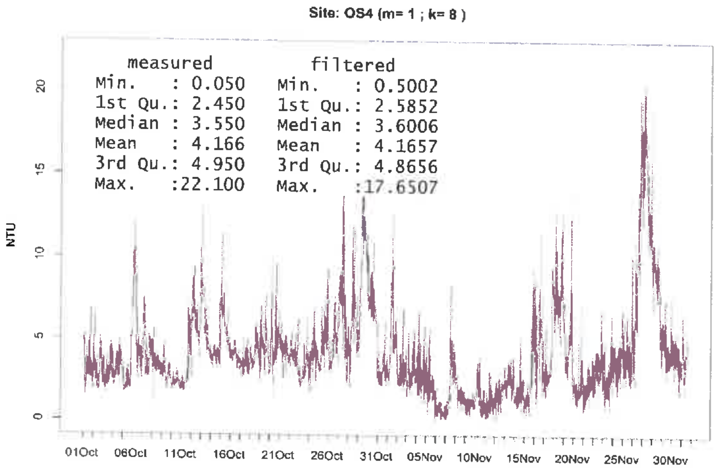


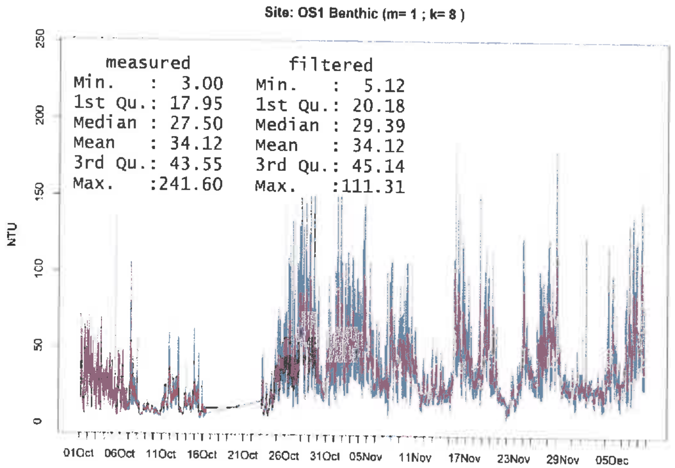
Statistical QA/QC

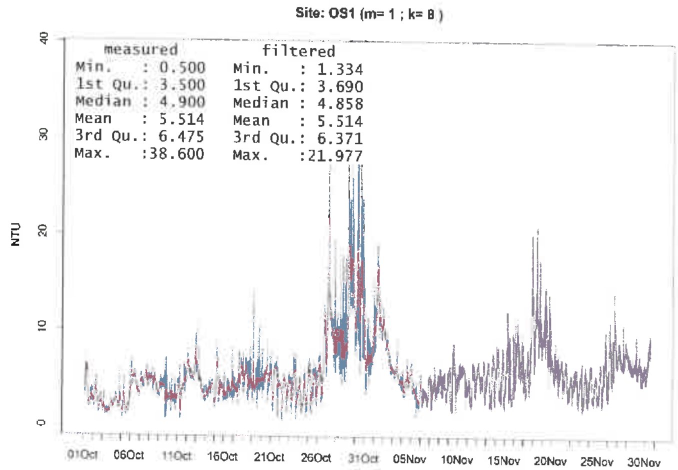




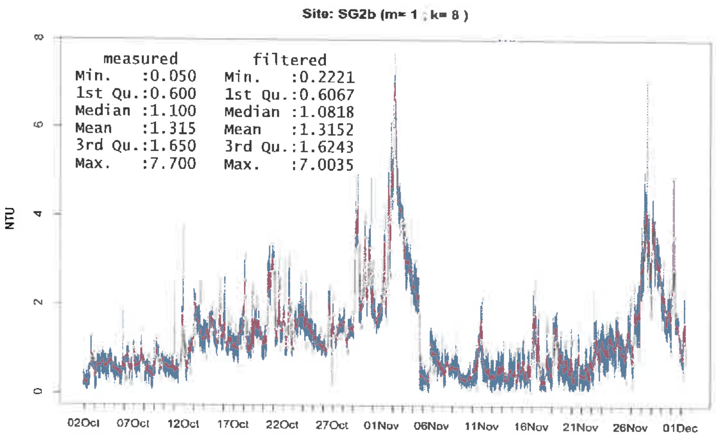


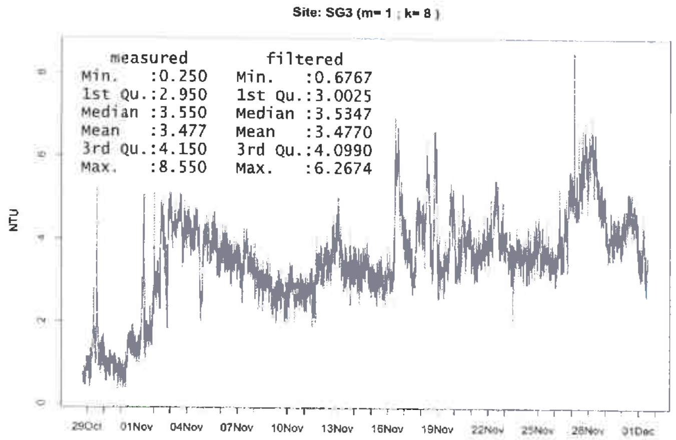


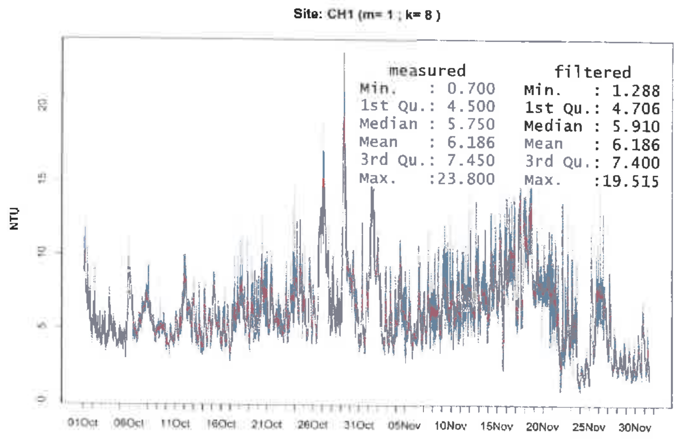


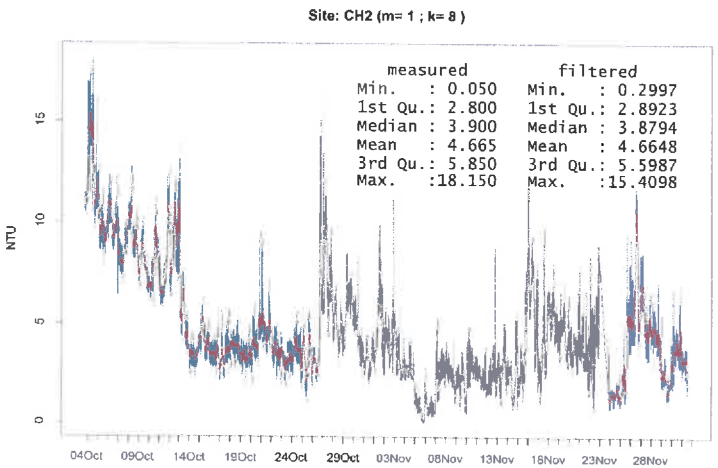


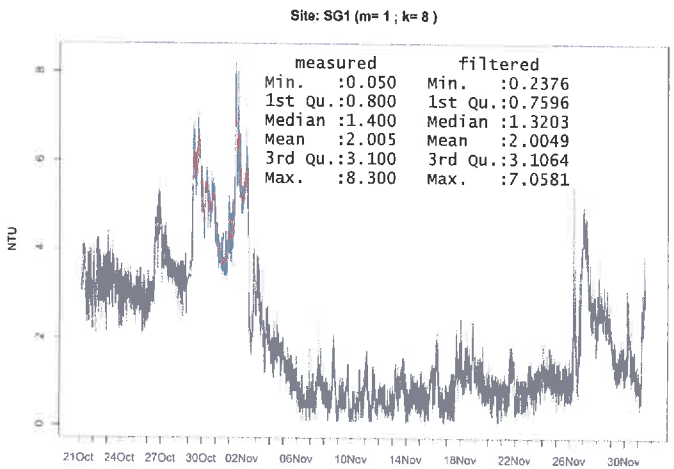
Statistical QA/QC

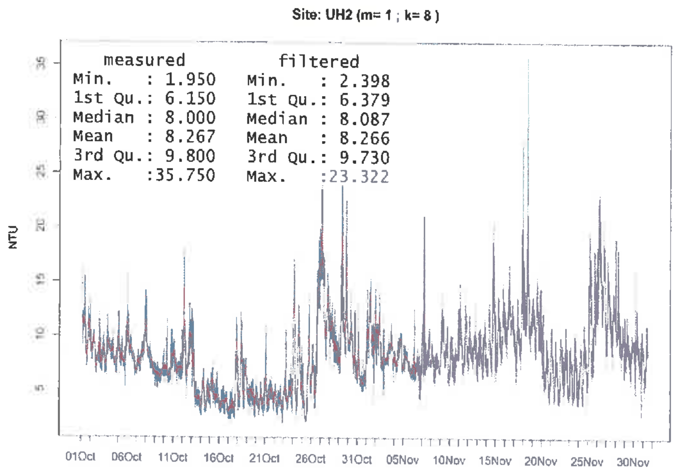




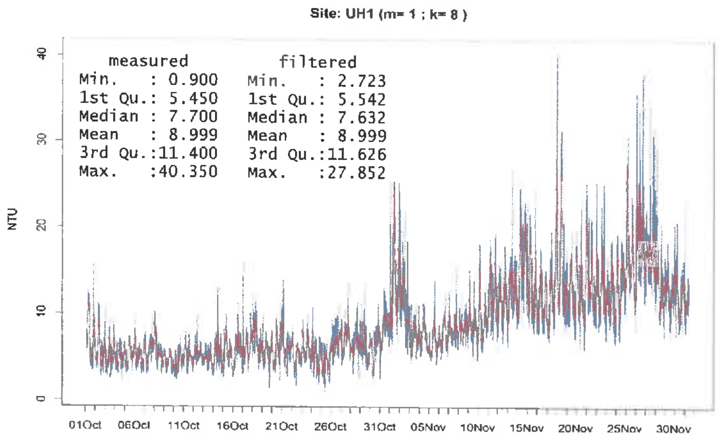


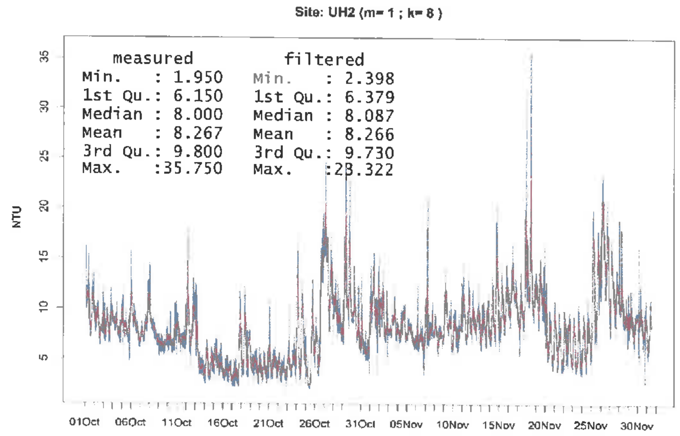






Statistical QA/QC





Recommendation

- Use of the Kolmogorov-Zurbenko (KZ) filter using 4 iterations over 2 hour averaging window

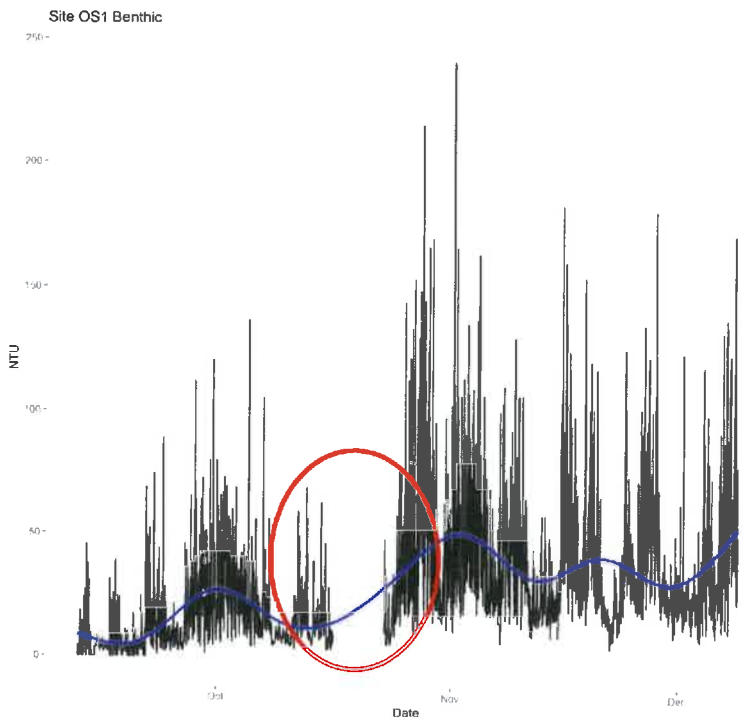
Statistical QA/QC

Data Imputation

- Gaps in the recorded turbidity signal are to be expected

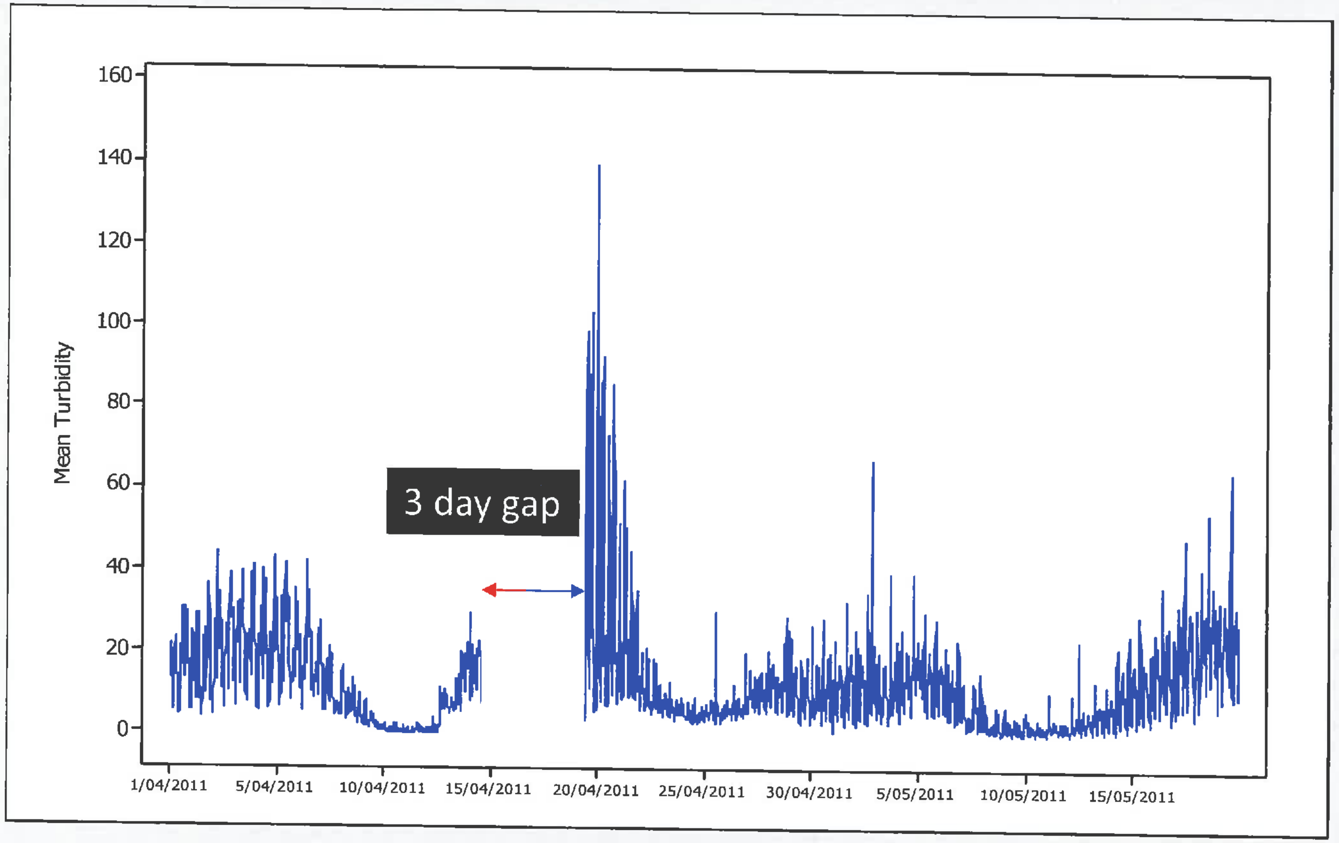
EXAMPLE

2 ½ months data from OS1 benthic logger (September – December)

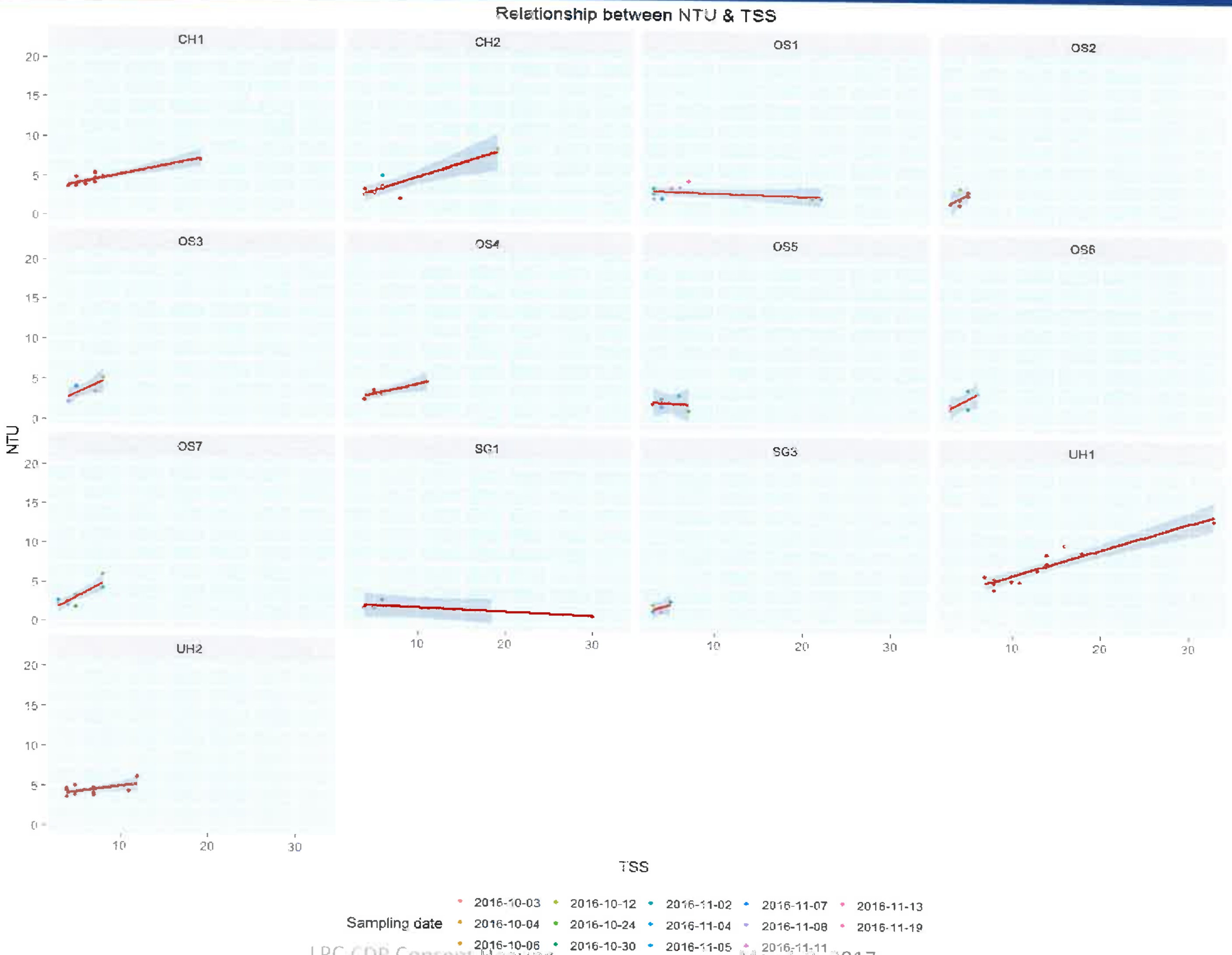


Statistical QA/QC

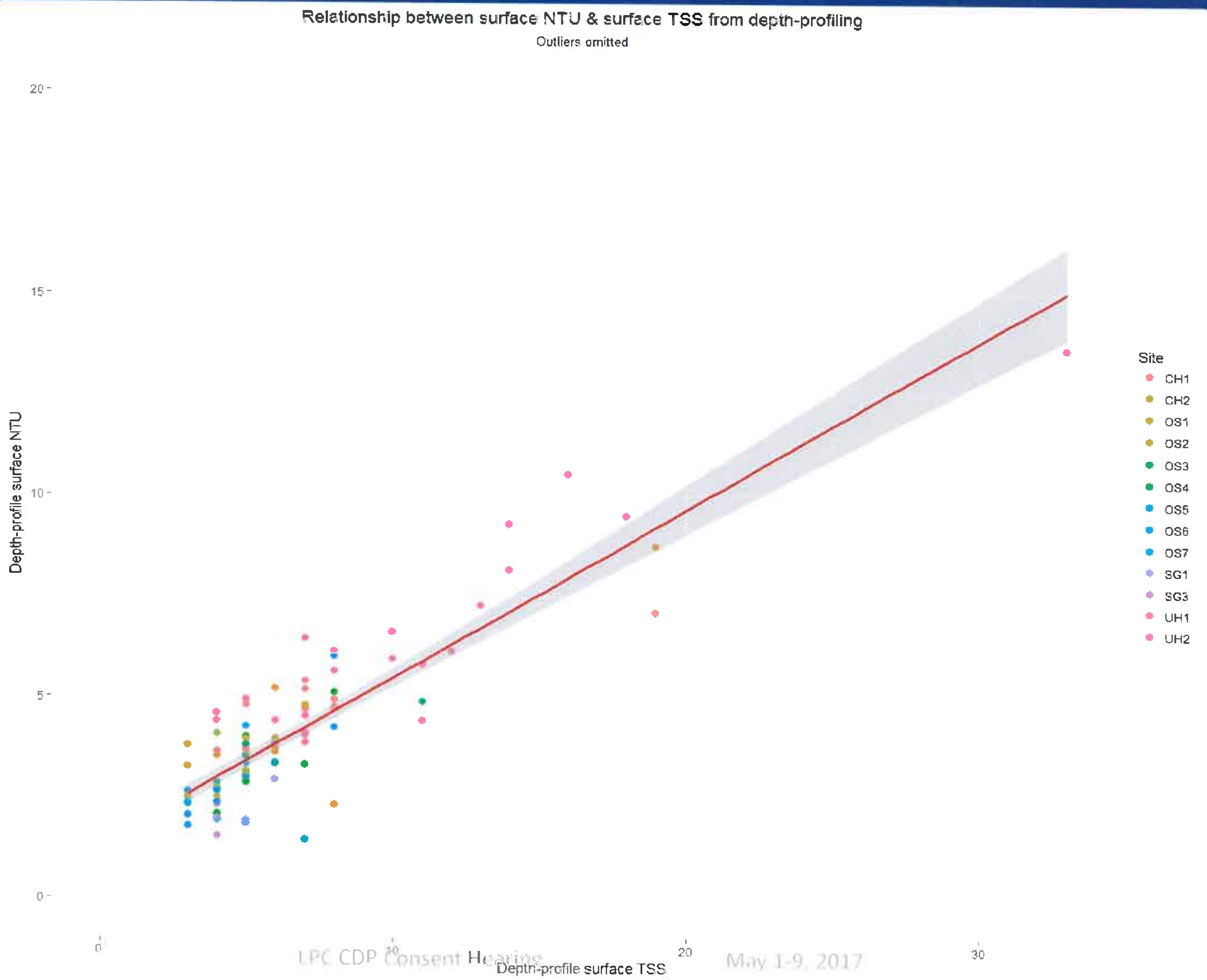
Data Imputation - *example from Gladstone Port Project*



TSS-NTU relationships



TSS-NTU relationship



Trigger Values – 'Regulatory' framework

NATIONAL WATER QUALITY MANAGEMENT STRATEGY

PAPER No. 4

Australian and New Zealand Guidelines for Fresh and Marine Water Quality

Volume 1

The Guidelines

(Chapters 1–7)

October 2000

Australian and New Zealand Environment and Conservation Council

Agriculture and Resource Management Council of Australia and New Zealand

www.csiro.au

CSIRO

Technical Rationale for Changes to the Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants

G.E. Batley, R.A. van Dam, M.St.J. Warne, J.C. Chapman, D.R. Fox, C.W. Hickey and J.L. Stauber

June 2014, updated January, 2017

Prepared for the Council of Australian Government's Standing Council on Environment and Water (SCEW)

Department of Science, Information Technology and Innovation

Revised Method for Deriving Australian and New Zealand Water Quality Guideline Values for Toxicants

Prepared for the Council of Australian Government's Standing Council on Environment and Water (SCEW)

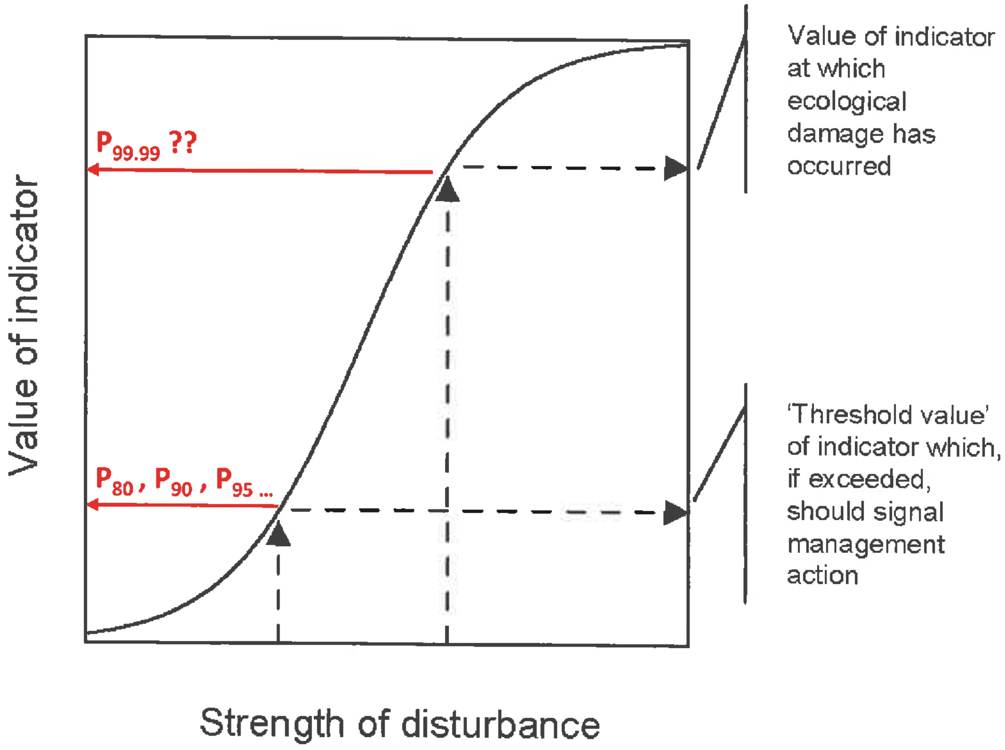
MStJ Warne, GE Batley, RA van Dam, JC Chapman, DR Fox, CW Hickey and JL Stauber

August 2015 – Updated January 2017

Great state. Great opportunity.

Trigger Values

Conceptual Basis



Adapted from ANZECC Guidelines (2000)

Trigger Values

Best Practice

The ANZECC Guidelines are a definitive source of information

However

- They are only *guidelines.* Trigger values in the guidelines are best regarded as *defaults* in the absence of better information

Chapter 3 — Aquatic ecosystems

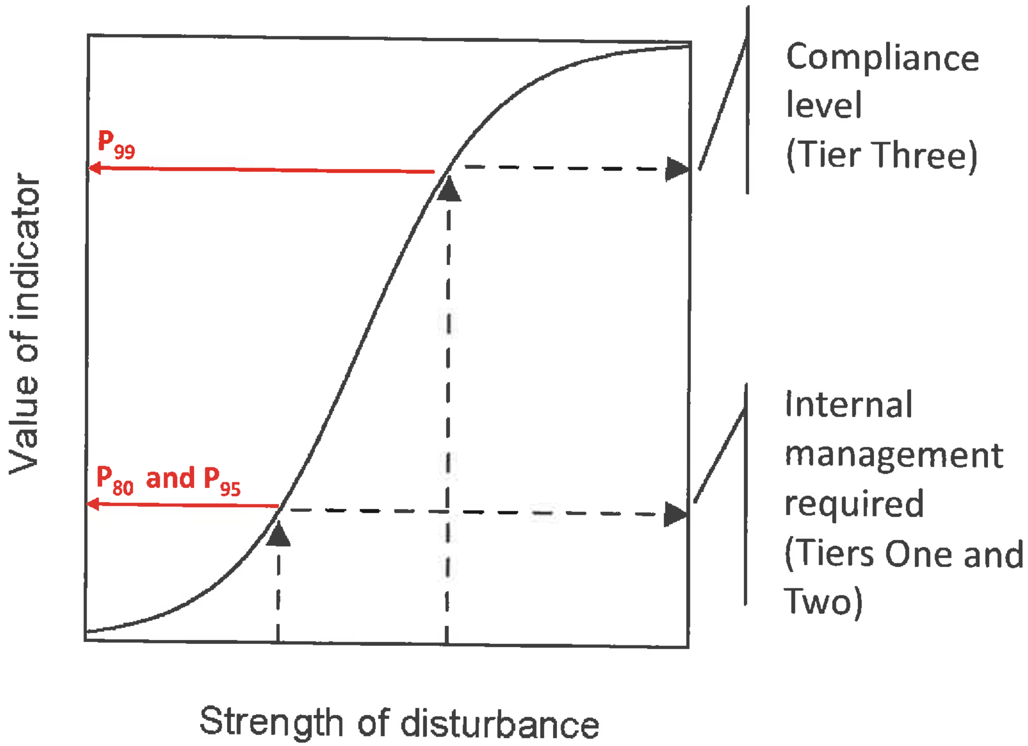
Table 3.3.11 Default trigger values for water clarity (lower limit) and turbidity (upper limit) indicative of unmodified or slightly disturbed ecosystems in New Zealand

Ecosystem types	Upland rivers[a b]		Lowland rivers	
	Clarity (m^{-1})[c d]	Turbidity (NTU)[c d]	Clarity (m^{-1})	Turbidity (NTU)
	0.6	4.1	0.8	5.6

- The Guidelines encourage site-specific investigations to inform development of monitoring programs

Trigger Values

LPC CDP is consistent with ANZECC Guidelines



Adapted from ANZECC Guidelines (2000)

Trigger Values

Standard Practice

- Recent large-scale capital dredging programs in Australia have embraced the concepts of *intensity, frequency,* and *duration* (of turbidity exceedances)

    → the IFD approach

- Adapted from unpublished work of McArthur et al. (2002)
- Shown to be flawed (so *standard practice* ≠ *best practice*)
- *Modified* IFD approach proposed for LPC CDP corrects the flaw and re-establishes equality in the equation above.

    → the *m*-IFD approach

The m-IFD Approach

Rationale

- Need simple tool or mechanism to **<u>alert</u>** us to elevated turbidity → trigger-value
- <u>Operationally</u> – ***<u>when</u>*** to initiate a compliance response:
  - as soon as a trigger is tripped ✕
    - → high rate of false positives
    - → environment resilient to episodic events of short-duration
  - after some period of time in a tripped state → how long?
  - after a certain number of trip incidences reached → how many?
  - some combination of the above – how?

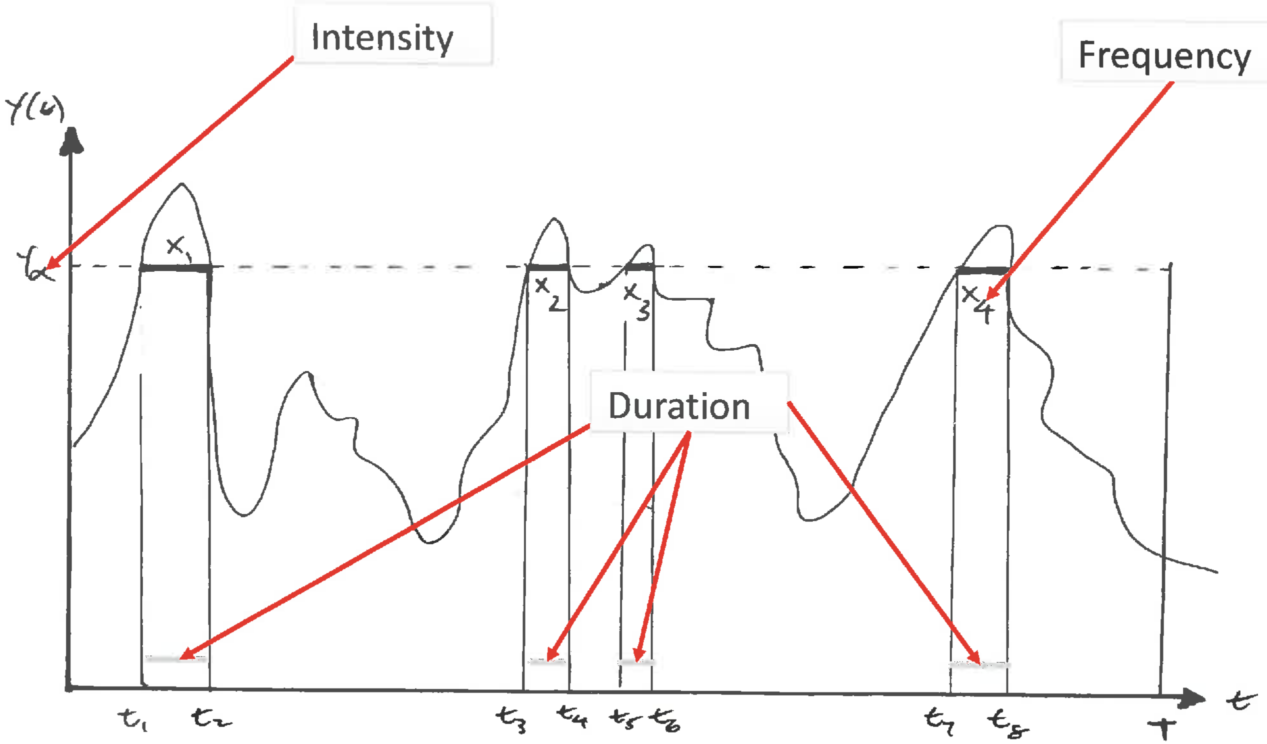
IFD-based Approaches

Precedents

- Rio Tinto – Cape Lambert, Western Australia (2 million m^3)
- North West Shelf, Western Australia
  - Wheatstone 25 million m^3
  - Gorgon 8 million m^3
- Inpex – Darwin (16.9 million m^3)
- Gladstone Port Corporation – Queensland (20 million m^3)

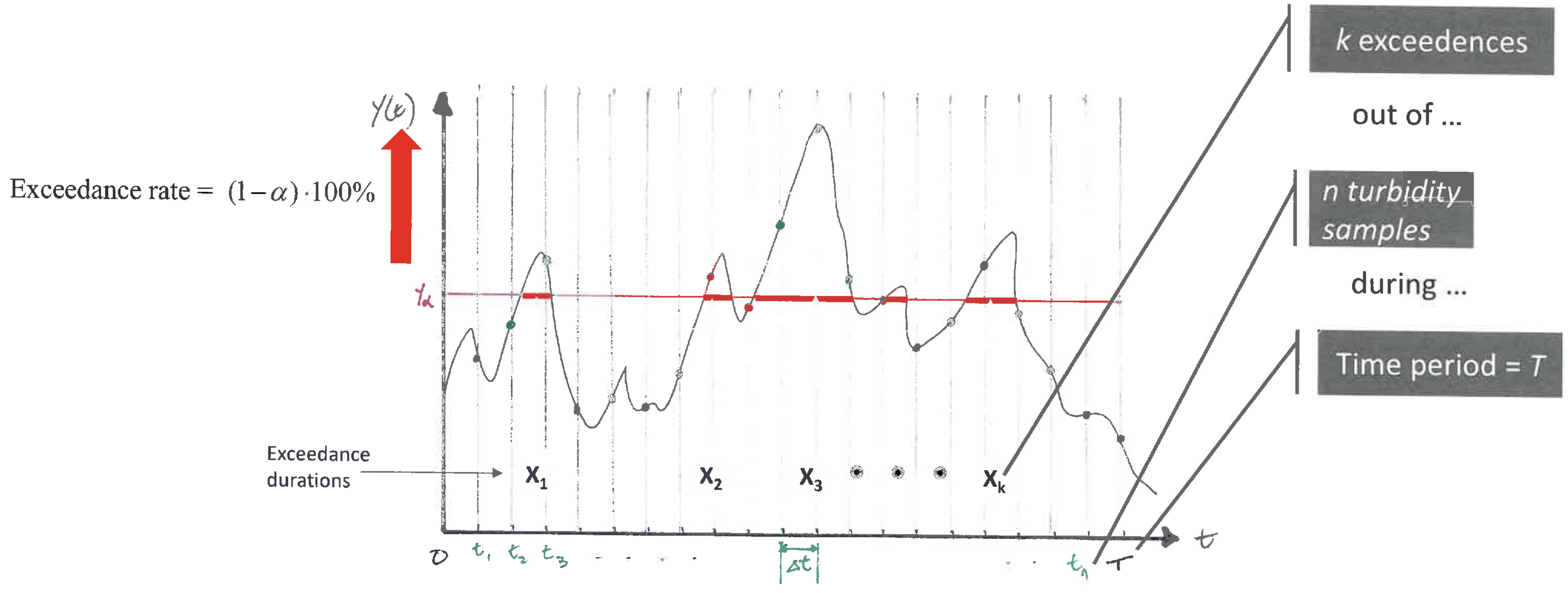
The IFD Approach

Conceptual Development



The m-IFD Approach

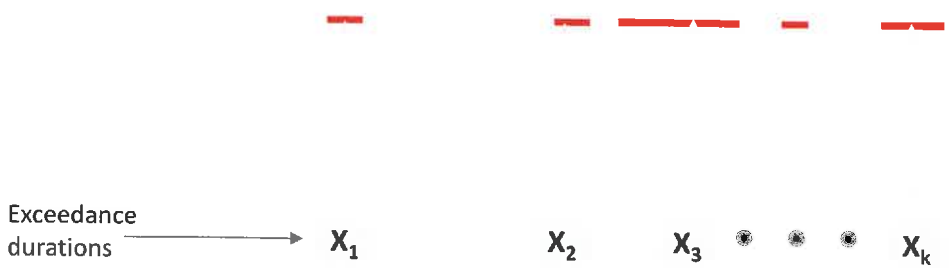
Conceptual Development



The m-IFD Approach

The important bits

Exceedance rate = $(1-\alpha)\cdot 100\%$



k exceedences

out of …

n turbidity samples

during …

Time period = *T*

The m-IFD Approach

1. Discrete sampling exceedance rate

$$\text{Exceedance rate} = (1-\alpha)\cdot 100\% = \frac{k}{n}$$

k exceedences

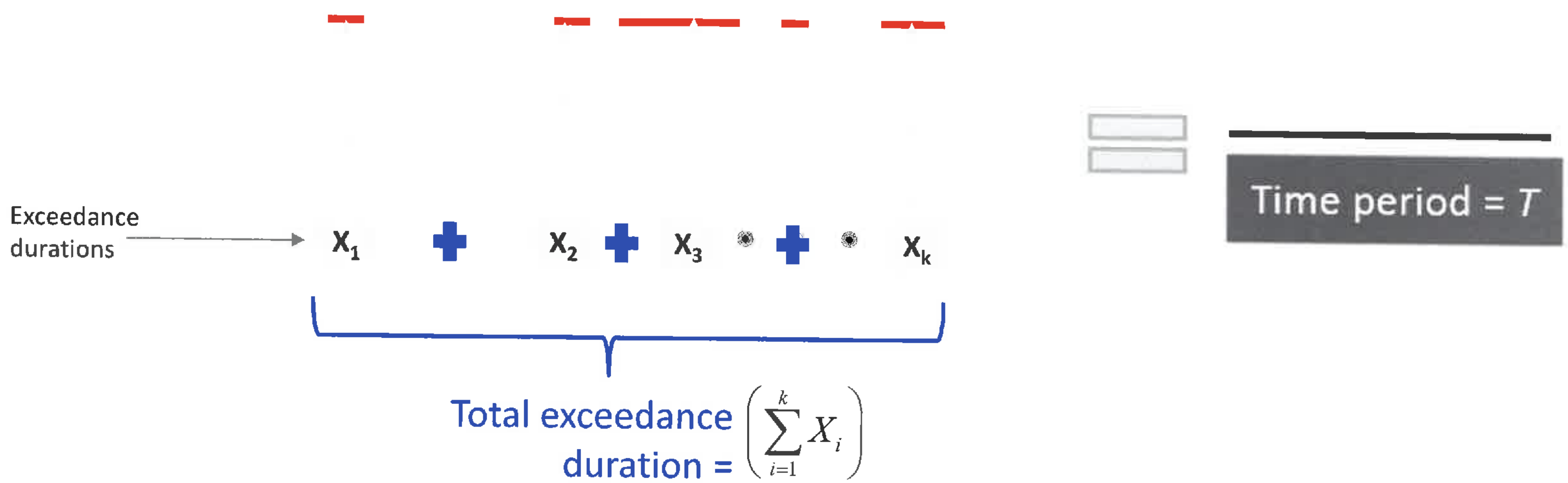
out of …

n turbidity samples

The m-IFD Approach

2. Time-based exceedance rate

$$\text{Exceedance rate} = (1-\alpha)\cdot 100\%$$



The m-IFD Approach

1. Discrete sampling exceedance rate

Exceedance rate = $(1-\alpha)\cdot 100\%$

$$\frac{k}{n}$$

k exceedences

out of ...

n turbidity samples

2. Time-based exceedance rate

Exceedance rate = $(1-\alpha)\cdot 100\%$

$$\frac{\text{Total duration } \left(\sum_{i=1}^{k} X_i\right)}{\text{Time period} = T}$$

Same thing!

Proportion of time spent in exceedance state

=

Fraction of samples exceeding trigger

The m-IFD Approach

Proportion of time spent in exceedance state

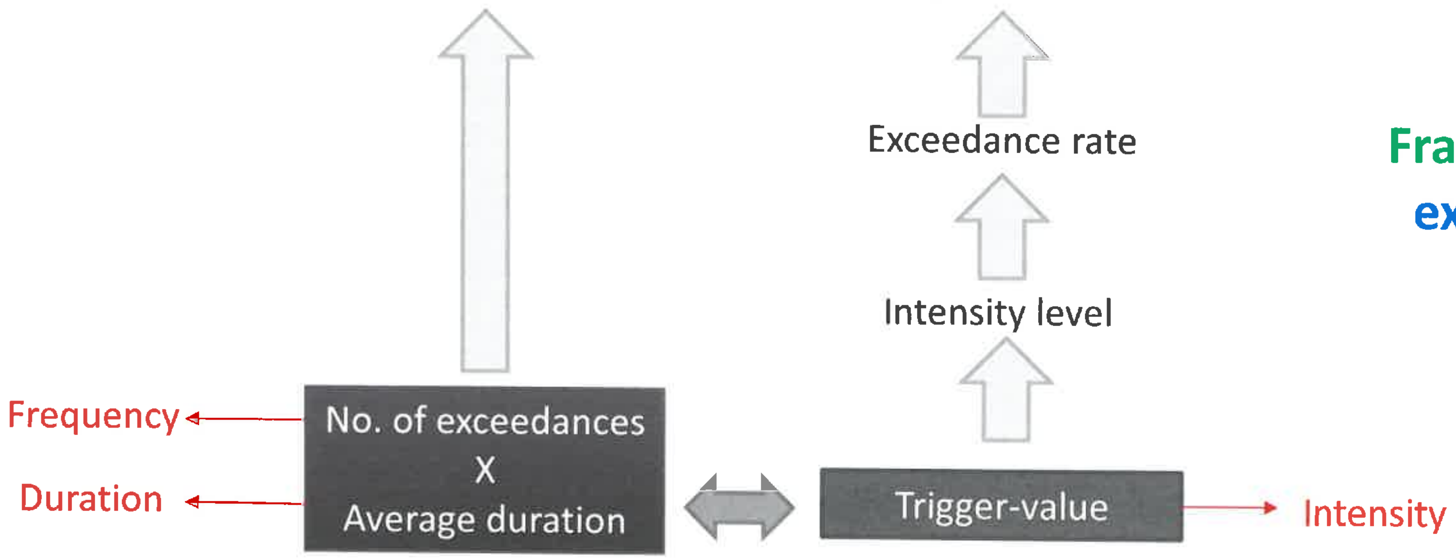
=

Fraction of samples exceeding trigger

The m-IFD Approach

All-important result :

Proportion of time = Fraction of samples

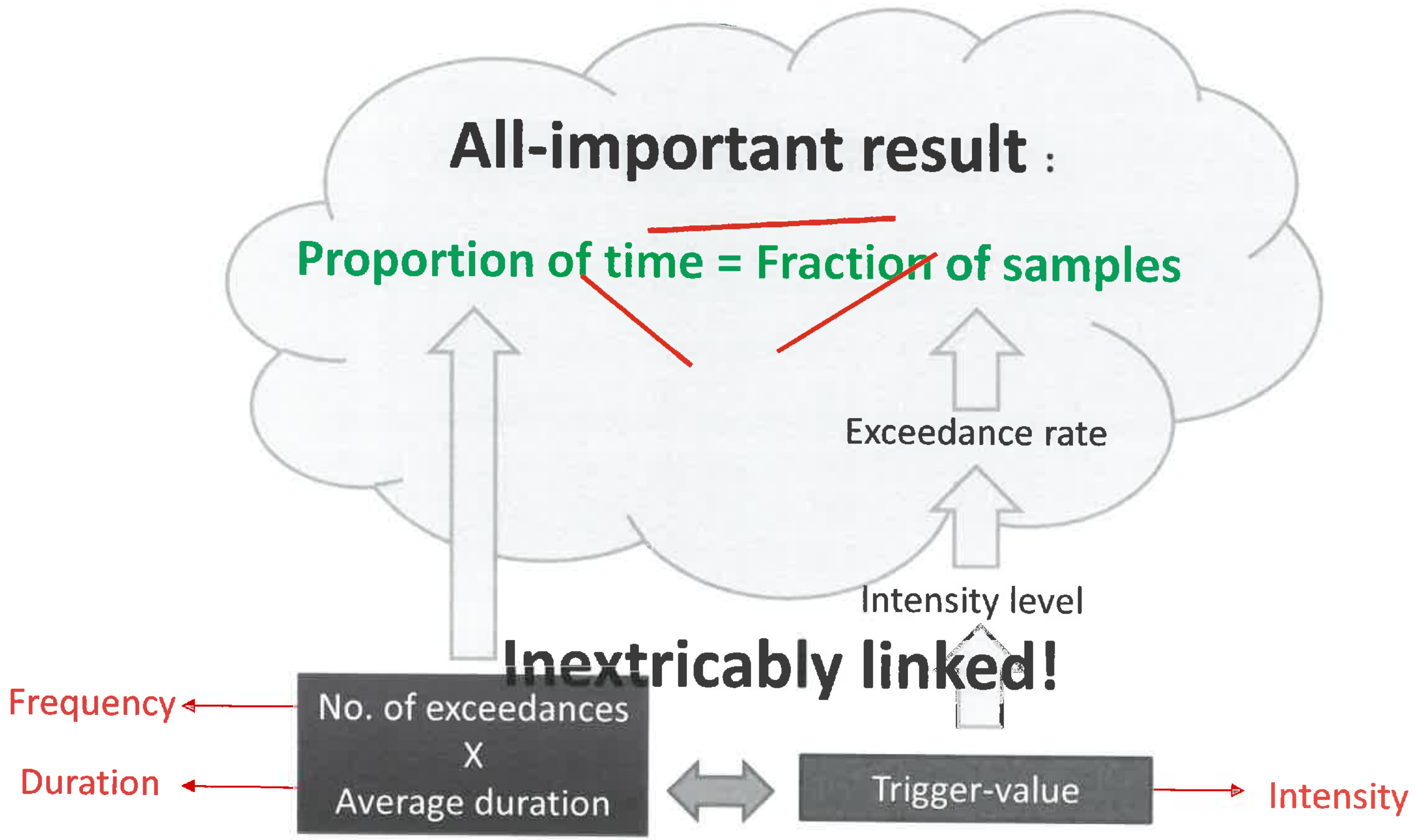


Proportion of time spent in exceedance state

=

Fraction of samples exceeding trigger

The m-IFD Approach



The m-IFD Approach

- Each turbidity signal has its own IFD 'fingerprint'.

  → different turbidity time-series have different {IFD} descriptors

- 2 series having the same {IFD} descriptors are (for our purposes) statistically equivalent

  → IFD-Equivalence 'Theorem': (my terminology)

$$\{IFD\}_{series1} = \{IFD\}_{series2}$$

$$\Rightarrow \quad Series1 \equiv Series2$$

The m-IFD Approach

Use of Background + Modelled turbidity

My position

To maintain the integrity of the IFD method, it is critical that the mechanics of the m-IFD approach be underpinned by an analysis of empirical background data PLUS predicted additional turbidity due to dredging.

Why?

- A future turbidity signal that honours an IFD scheme derived from an analysis of baseline data has *intensity-frequency-duration* components that are equivalent to the baseline turbidity signal. This means the turbidity signal during dredging would be the same as the baseline turbidity signal.
- Therefore under this scheme there can be no change of the background signal → no dredging

The m-IFD Approach

Use of Background + Modelled turbidity

Rationale

i. Dredging (temporarily) increases turbidity and that increase has been quantified as part of the modelling by MetOcean Solutions;

ii. Approval of the project gives license to (i);

iii. The monitored turbidity signal during dredging cannot honour a relationship between I,F and D that was derived from background turbidity alone

iv. The I, F, and D components of turbidity exceedances need to be adjusted to capture the characteristics of the *modified* turbidity signal. Limits can then be placed on these components which:

   a) acknowledge the link between I – F – D components ; and

   b) ensure that more extreme turbidity events during dredging are within the limits of what has been predicted.

The m-IFD Approach

Implementation

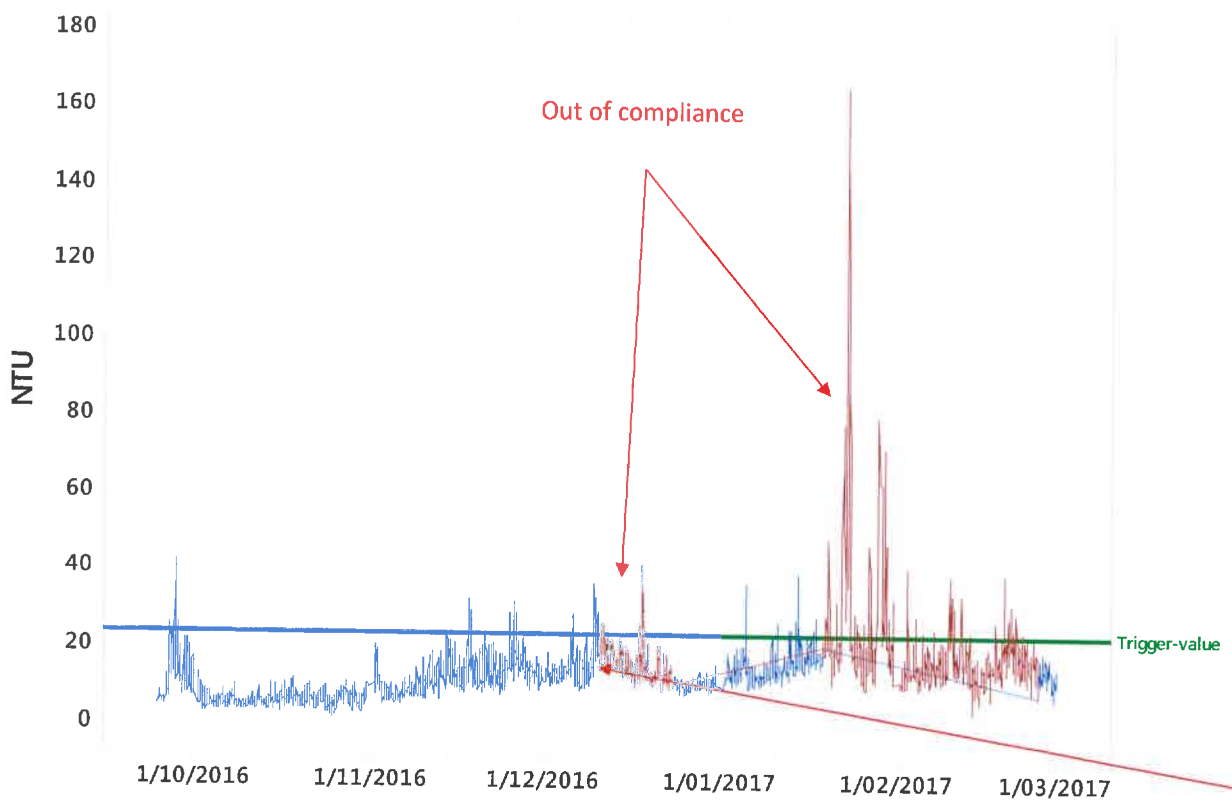
Simple 2-step process:

1. For a chosen intensity level $(1-\alpha)$ determine the intensity trigger $Y_{1-\alpha}$;
2. For a fixed monitoring interval $[0,T]$ set a limit on the *cumulative* exceedance time equal to $\alpha \cdot T$

- A compliance response is required when the limit in 2 above has been (or is about to be) exceeded;
- I suggest using *T = 30 days (moving window)*

The m-IFD Approach

Ease of use – Graphical + Spreadsheet



date	Exceedance time	ramaining exceedance time
15/11/2016	0	16
16/11/2016	0	16
17/11/2016	3	13
18/11/2016	2	11
19/11/2016	0	11
20/11/2016	1	10
21/11/2016	0	10
22/11/2016	0	10
23/11/2016	0	10
24/11/2016	0	10
25/11/2016	3	7
26/11/2016	3	4
27/11/2016	0	4
28/11/2016	0	5
29/11/2016	0	5
30/11/2016	0	5
1/12/2016	0	8
2/12/2016	0	10
3/12/2016	0	10
4/12/2016	0	11
5/12/2016	0	11
6/12/2016	2	9
7/12/2016	0	9
8/12/2016	0	9
9/12/2016	0	12
10/12/2016	10	5
11/12/2016	5	0
12/12/2016	0	0

Questions?

Contact: Prof. David R. Fox
Email david.fox@environmetrics.net.au