LPC hearing
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Memorandum

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Clarification of Issues Raised during Consent Application Hearing

David R. Fox,
PhD.,C.Stat.,P.Stat.,C.Sci.

During the recent hearing associated with LPC's dredging consent application, several issues discussed in my Evidence and previously circulated reports were raised. These related to:

1. Control sites
2. KZ Filter – frequency components
3. Adding modelled dredge turbidity to baseline data
4. Length of assessment window

Although I believe these matters have been adequately addressed either in the aforementioned reports and/or in person at the hearing, it is evident that doubts continue to be raised.

The purpose of this memorandum is to provide a definitive response to issues 1-4 above.

1. The use of 'control' sites

The suggestion that the monitoring program incorporate some 'control' sites has been made by Dr. Leslie Bolton-Ritchie and Mr. Dougal Greer. The use of 'control' sites is central to sampling strategies that are collectively referred to as before-after-control-impact or BACI designs. As noted in my Evidence:

> *"contemporary water quality monitoring programs have moved away from these types of assessment. This is mainly due to: (i) environmental data invariably (and usually seriously) violates many of the underlying assumptions required for the legitimate use of these methods; (ii) even when the assumptions are substantially met, the outcome is often a prosaic statement that the 'control' and 'test' sites are different; (iii) these designs do not provide quantification of trends in space and time; and (iv) they are inefficient in terms of resource allocation".*

Notwithstanding these technical drawbacks, there is a more fundamental issue that the proponents of 'control' sites have overlooked and that concerns the core objective of monitoring during dredging.

The Consent Application seeks to (temporarily) increase the ambient or 'background' turbidity levels of receiving waters impacted by dredging activities. Thus, the primary objective of monitoring during dredging is to ensure that the degree to which background turbidity is elevated lies within the envelope of model predictions. The monitoring sites have been carefully chosen to provide an early-warning mechanism -<u>not</u> to conclude that "the monitoring site is different to the control site". The use of a control sites within a BACI framework limits us to such prosaic statements of a self-evidentiary fact.

2. Frequency-response of the K-Z Filter

Again, this is another technical, almost academic consideration that is of intrinsic interest to mathematicians and statisticians but has little relevance to the environmental monitoring program and the ecosystem components it seeks to protect.

The K-Z filtering strategy recommended both in my report and at the Consent Hearing provided clear evidence that the impact on the raw turbidity signal was minimal. The filter performs precisely as intended: it dampens rapid fluctuations as well as attenuating transient extreme values. Summary statistics have been presented for every monitoring location which clearly demonstrate that the key features of the turbidity signal are preserved by the recommended filtering process.

What is essentially being asked of LPC is to undertake a spectral analysis of the proposed K-Z filter to fully understand its characteristics in terms of its frequency response. This type of analysis is summarised thus:

> *"Signals are converted from time or space domain to the frequency domain usually through the Fourier transform. The Fourier transform converts the signal information to a magnitude and phase component of each frequency. Often the Fourier transform is converted to the power spectrum, which is the magnitude of each frequency component squared. The most common purpose for analysis of signals in the frequency domain is analysis of signal properties. The engineer can study the spectrum <u>to determine which frequencies are present in the input signal and which are missing</u>".*
>
> *Source:* https://en.wikipedia.org/wiki/Digital_signal_processing
> Accessed: May 11, 2017 (emphasis added).

This can be done, but the question needs to be asked "why" and "will it help"? I concede that different ecosystem components may respond differently to different *modes* of impact. Environmental scientists talk of "press" and "pulse" disturbances. A press disturbance is once that is sustained over an extended duration while a pulse disturbance is a short-duration event. Beyond this dichotomy, I am unaware of spectral analysis being used in these contexts.

Unless one can identify specific ecosystem components that are to be protected together with a complete understanding of their physiological responses to press and pulse events and anything in between, then the frequency analysis of the K-Z filter is entirely academic and only serves to distract us from our real endeavour.

3. The method by which modelled turbidity from dredging is added to baseline data.

This is a reasonable request as my original report did not provide any detail nor was it discussed during my presentation at the Consent Hearing. Accordingly, my report dated 16 September 2016 has been updated and now includes a section titled *"Assimilation of Modelled TSS data and Baseline Monitoring Data"*.

4. Length of assessment window

Again, requests for further details on the implementation of Tier 3 compliance triggering and related issues regarding the length of the moving assessment 'window' and its overall performance have been addressed in the May 11, 2017 revision to my original report dated 16 September 2016.

I will not repeat those details here except to note that in recent discussions with Mr. Dougal Greer, he claimed that, as proposed, the Tier 3 trigger method will necessitate a management response 50% of the time. Mr. Greer supplied me with a copy of Matlab code[1] he used to generate synthetic data and explore the properties of the Tier 3 trigger mechanism.

At one level, Mr. Greer makes a legitimate point: the use of smaller sub-sets of data to assess compliance status has associated with it an extra source of variation that was not captured by the original Tier 3 construct. Unfortunately, the way in which Mr. Greer constructed his synthetic data neglected a crucial characteristic of real turbidity data – that is a high level of *autocorrelation*. Autocorrelation is a numerical measure of how strongly a quantity (which is typically distributed over time) is correlated with itself: it ranges in magnitude from 0 (no correlation) to 1 (perfectly correlated).

The plot in Figure 1 is the actual empirical autocorrelation function for site UH1 using baseline data collected between September 24, 2016 and February 28, 2017. The horizontal axis is a 'lag' variable – it represents the number of time spacings separating NTU readings. It is evident from this figure that turbidity readings separated by a day are reasonably strongly correlated (coefficient of approx. 0.5). Moderate levels of correlation among turbidity readings persist even between values recorded a week apart.

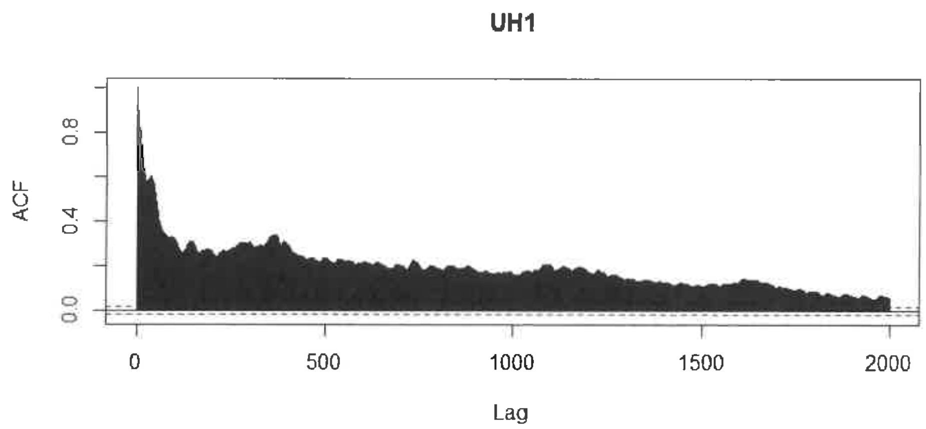

Figure 1. Empirical autocorrelation function of baseline turbidity data at UH1.

In contrast, Figure 2 shows the type of autocorrelation function associated with synthetic data which assumes individual readings are independent of each other – as was the case in Mr. Greer's simulations. The upshot of this oversight is that results and claims based on Mr. Greer's synthetic

[1] Matlab is a high-end mathematical and statistical computing software system

data are at best unreliable and at worst simply wrong. Further analysis and detail is provided in the May 11 revision to my September 16, 2016 report.

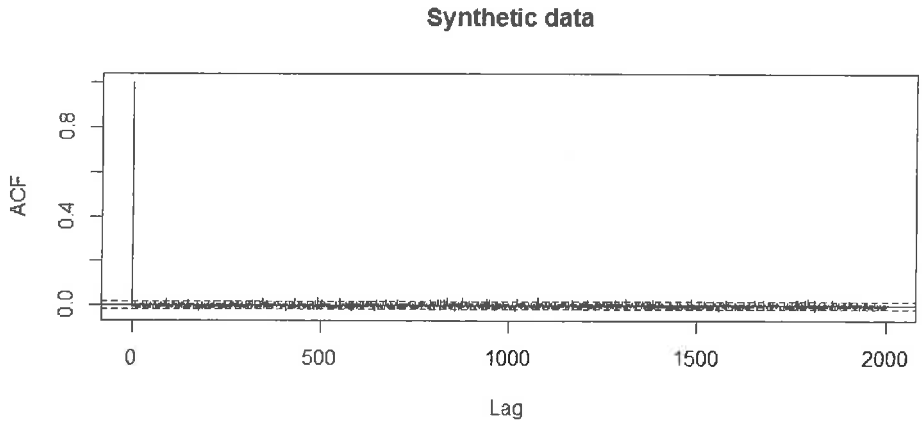

Figure 2. Autocorrelation function for randomly generated turbidity data.

REFERENCE

Fox, D.R. 2016. Statistical considerations associated with the establishment of turbidity triggers: Candidate methodologies for large-scale dredging projects. Environmetrics Australia Technical Report, 16 September 2016. *Revised 11 May, 2017.*

Prof. David R. Fox
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