Design of Assessment of Site Contamination Investigations – NSW[1]

For assessment of site contamination (ASC) investigations, the *National Environment Protection (Assessment of Site Contamination) Measure* (ASC NEPM 2013) lists the design components as:
– establishing the objectives of the investigation;
– development of a conceptual site model (CSM) and identification of data gaps;
– development of the data quality objectives (DQOs); and
– design of a sampling strategy and optimisation of a sampling, analysis and quality plan (SAQP)[2].

This technical note reviews the ASC investigation 'design tools', that is CSMs, DQOs and SAQPs, and provides notes and references to assist in their application (see Page 6). The ASC process, described as an environmental data life-cycle (EDLC) by the USEPA, is illustrated in Figure 1.

Regulatory basis

Under Section 105 of the New South Wales *Contaminated Land Management (CLM) Act* 1997, the EPA may approve guidelines for any purpose connected with the objects of the Act. The ASC NEPM (2013) is an approved statutory guideline, which must be considered by the EPA, accredited site auditors, contaminated land consultants, and those responsible for land contamination with a duty to notify the EPA.

State Environmental Planning Policy No 55 – Remediation of Land states that all remediation work must, amongst others, be carried out in accordance with the guidelines in force under CLM Act. The *Guidelines for the NSW Site Auditor Scheme* (EPA 2017) describe that:

> *A systematic planning process must be used by consultants for defining the objectives of all site assessment and remediation programs and to develop sampling and validation plans for the collection and evaluation of representative data to achieve those objectives.*

In fulfilling these requirements, it is noteworthy that the ASC NEPM (2013) describes that "the sub-optimal performance of many remediation systems can be traced back to the failure to undertake adequate site characterisation and to fully integrate the information gained into the CSM". Adequate site characterisation is underpinned by the use of these design tools.

Project objectives

While overall project objectives are usually broad statements, such as "to make the site suitable" or "to respond to a management order", these can be broken down into a series of distinct decisions that need to be made. The design components of the ASC generally seek to answer these distinct decisions through investigations. Given that to achieve any overall project objectives, numerous decisions are required to be made, both the overall project objectives and the distinct decisions need to be considered and documented. The need to resolve numerous decisions arises as ASC projects generally address multiple contaminants, multiple media, and multiple potential receptors, often over multiple investigations, with multiple potential solutions for each decision.

The distinct decisions required should be identified through the development and refinement of CSMs. This logically requires the overall project objectives to be established; at the very least, the proposed land uses and whether the site's use is to be subject to long-term management with active control systems or passive control systems, should be specified. Changes to the overall project objectives, based on investigation results or modification of the proposed development, will generally change or modify the decisions required.

Process outputs

START

Systematic planning and design components

CSM ⟷ DQOs ⟷ Sampling design

Study or Investigation Design

DQIs ⟷ SAQP ⟷ SOPs

MQOs   Methods

Plans, QA procedures, specifications

Conduct study/ investigation ⟷ TQM reviews

Field, analytical, and QC data

Quality review

Data verification/ data validation

QA reporting

Validated data and QA/QC reporting

Data analysis and interpretation

Updated and refined CSM

Compare output data and information with design components

Robust ASC conclusions

NO ⟵ Problem resolved? ⟶ YES

Begin at start for further investigations

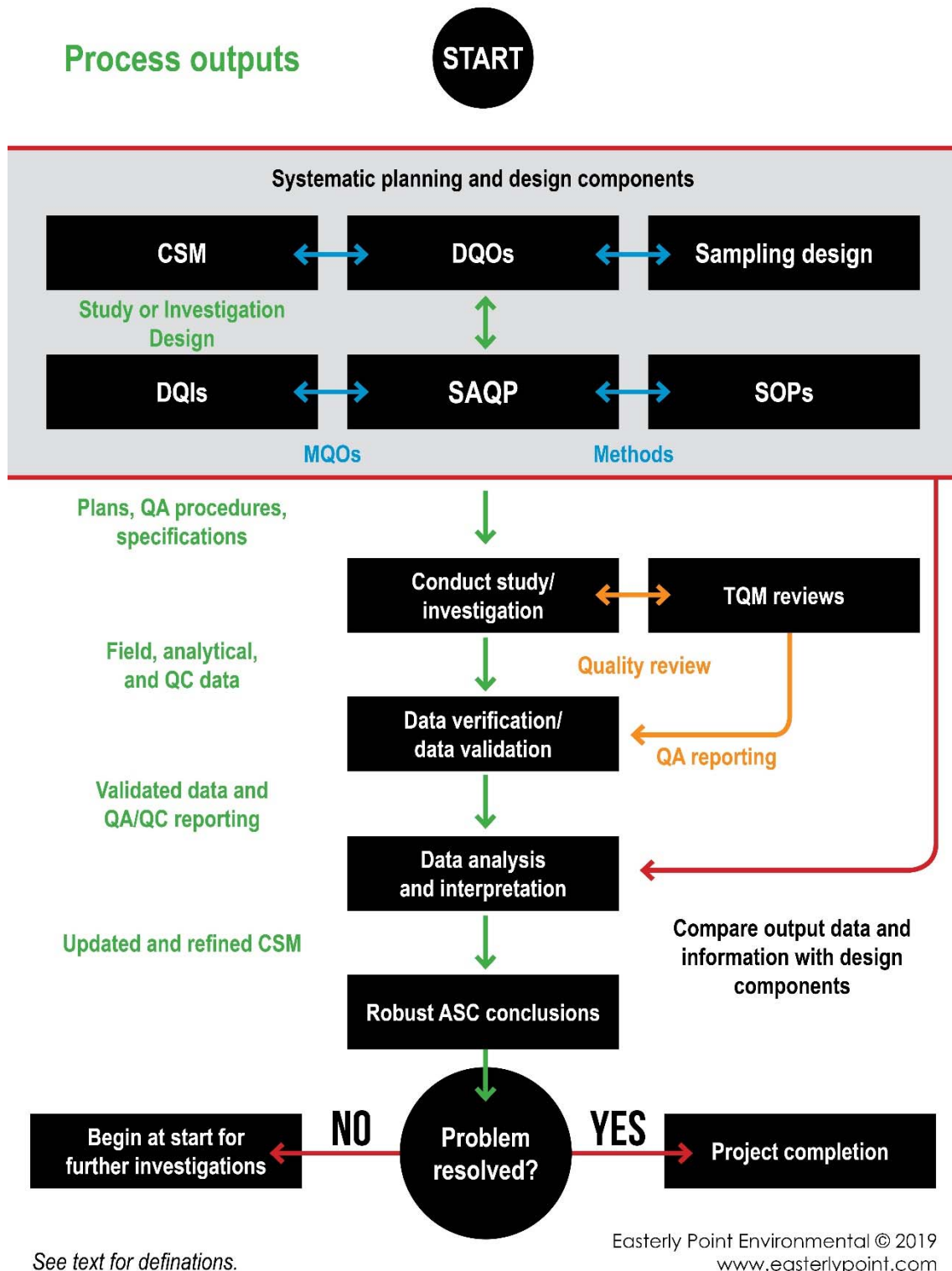Project completion

See text for definations.

Figure 1: Environmental data life-cycle for ASC investigations

CSMs

A CSM provides a four-dimensional overview[3] of the contamination at a site, highlighting the sources, receptors and exposure pathways between the sources and receptors over time. CSMs should highlight uncertainties and data gaps in relation to the contamination and all potential exposure pathways on and off the site, and should be updated iteratively throughout the investigations as existing data gaps are closed or as new data gaps emerge.

CSMs should be presented using text, tables, plans, diagrams and cross-sections, as required[4], and should consider and specify:
– how representative the available data are likely to be;
– the potential sources of variability and uncertainty; and
– how important the identified gaps are to the objectives and reliability of the site assessment.

A CSM should be developed prior to each investigation as part of the development of the DQOs and SAQP, and the CSM should be iteratively updated as part of the data analysis and interpretation, as shown in Figure 1. Simple sites can often be resolved with only a few such iterations, whereas more complex sites may require many more iterative cycles.

USEPA (2006) stresses that "It is important to identify theories and assumptions underlying CSMs to ensure adequate transparency", and the ASC NEPM (2013) describes that:

> In developing the CSM, the assessor needs to distinguish between variability and uncertainty. Variability arises from true heterogeneity in the environment such as lateral variations in soil properties or lithology or changes in contaminant levels over time and space. Uncertainty represents lack of knowledge about factors, such as contaminant levels (which may be reduced with additional investigation).

Specific information relating to the development of CSMs can be found in the ASC NEPM (2013), Clements et al. (2009), which includes an example of a semi-quantitative assessment tool, and NT EPA (2013). These include examples of CSMs and further references.

DQOs

The seven-step DQOs process, as summarised in Figure 2, was developed by the USEPA as a method for systematic planning. It is based on formal hypothesis testing, such as t-tests or upper confidence limits (UCLs), and the associated statistical framework, with the DQOs simply representing a formalisation by the USEPA of a systematic investigation design method[5]. The statistical design and control of sampling errors both occur within the DQOs process and as part of the sampling design, and these are integrated in the SAQP, along with the data quality indicators (DQIs), measurement quality objectives (MQOs) and standard operating procedures (SOPs), as shown in Figure 1. The later components address the quality assurance and quality control (QA/QC) aspects of the EDLC process (as part of total quality management (TQM))[6], and importantly, these should not be interpreted as the desired outcomes of the DQOs process.

Options are included in the DQOs process for the type of problem to be addressed, based on the intended use of the data to be collected. The two primary types of intended use are classified as *decision making* and *estimation*. Decision making is broadly defined as making a choice between two alternative conditions, such as determining if site data are less than health investigation levels (HILs) or health screening levels (HSLs). Estimation problems are those for which the intended use of the estimate is not directly associated with a well-defined decision, at least at that time. Examples include determining ambient background concentrations (ABCs) for site soils and determining background groundwater or surfacewater quality; which site data may subsequently be compared to as part of resolving a decision problem.
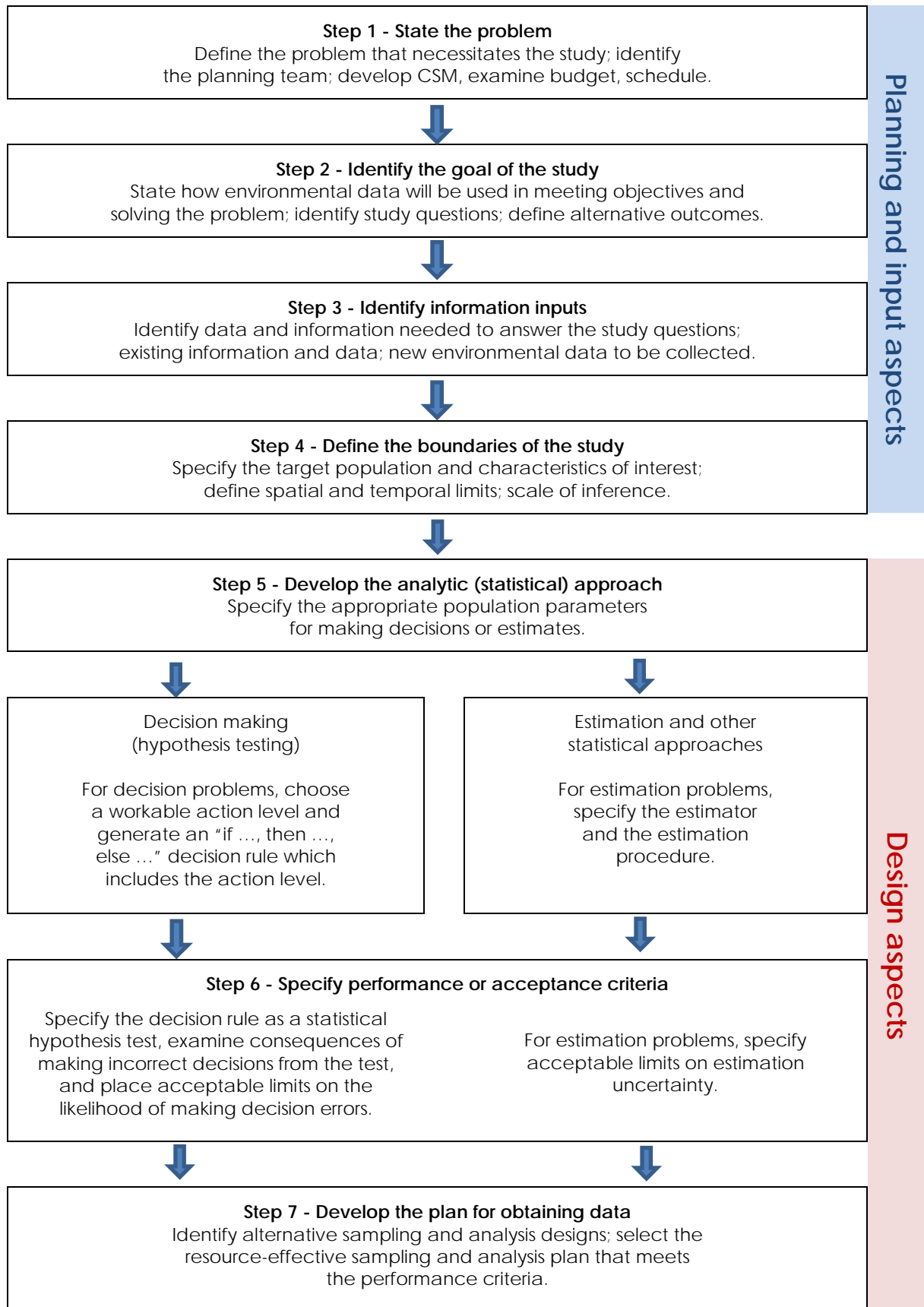
Step 1 - State the problem
Define the problem that necessitates the study; identify
the planning team; develop CSM, examine budget, schedule.

Step 2 - Identify the goal of the study
State how environmental data will be used in meeting objectives and
solving the problem; identify study questions; define alternative outcomes.

Step 3 - Identify information inputs
Identify data and information needed to answer the study questions;
existing information and data; new environmental data to be collected.

Step 4 - Define the boundaries of the study
Specify the target population and characteristics of interest;
define spatial and temporal limits; scale of inference.

Step 5 - Develop the analytic (statistical) approach
Specify the appropriate population parameters
for making decisions or estimates.

Decision making
(hypothesis testing)

For decision problems, choose
a workable action level and
generate an "if …, then …,
else …" decision rule which
includes the action level.

Estimation and other
statistical approaches

For estimation problems,
specify the estimator
and the estimation
procedure.

Step 6 - Specify performance or acceptance criteria

Specify the decision rule as a statistical
hypothesis test, examine consequences of
making incorrect decisions from the test,
and place acceptable limits on the
likelihood of making decision errors.

For estimation problems, specify
acceptable limits on estimation
uncertainty.

Step 7 - Develop the plan for obtaining data
Identify alternative sampling and analysis designs; select the
resource-effective sampling and analysis plan that meets
the performance criteria.

Planning and input aspects

Design aspects

Figure 2: Overview of the USEPA DQOs process
Modified from USEPA (2006)

For complex problems, such as multiple contaminant types and a number of impacted media, more than one decision is generally required, or estimates of multiple parameters may need to be combined. And these multiple decisions or estimates may combine or impact on each other in resolving the problems. The DQOs process includes, in addition to CSMs, recommendations for the use of flow charts, logic diagrams, influence diagrams and the like, to illustrate, document and manage these problems. For addressing multiple but specific technical questions, the use of modules is recommended, grouped by logical categories depending on the magnitude of the problem. For example, contaminant types, media, or decision areas, or some workable combination of these.

The planning and input aspects of the DQOs process are summarised in Figure 2, and are described partially in the ASC NEPM (2013)[7] and in detail in USEPA (2006). The design aspects of the DQOs process are developed in Steps 5 to 7, as shown in Figure 2. While these can be developed in various ways, aspects of a common decision problem are shown as an example:

- Step 5 – as resolution of decision problems is based on hypothesis testing, it is necessary to develop a statistical framework. To constructing a theoretical "If ..., then ..., else ..." decision rule related to an action level, a relevant population parameter is needed, such as the 95% UCL of the arithmetic mean ($\bar{x}$), along with a suitable action level, such as a HIL. As part of this step, the sampling and analysis methods should be confirmed as appropriate, including that the limits of reporting (LORs) are lower than the action levels.

- Step 6 – the statistical framework is established in this step, including the quantitative criteria. These are specifically referred to as the DQOs within the USEPA process, and are either *performance criteria* for new environmental data to be collected or *acceptance criteria* for evaluating the adequacy of existing data to be used. Where existing data and information does not meet the acceptance criteria, the data may need to be classified as estimates, and new information and data may need to be obtained, subject to specified performance criteria.

  For decision problems, the DQOs typically include tolerable limits on the probability or chance (risk) of the collected data resulting in an incorrect decision being made. An example is the specification of confidence levels; commonly as α at 95% and β at 80%.

- Step 7 – a resource-effective, investigation sampling and analysis design is developed to generate data that satisfies the decision performance criteria, as well as other requirements specified in the preceding steps of the DQOs. Generally, an iterative process is used between Step 6 and Step 7, to assess and refine the design parameters selected against the project objectives, distinct decisions and site constraints. The output of this step is the sampling and analysis design that is documented in the SAQP.

  This step includes the development of alternative data collection designs, to assess which best limits the total study error to tolerable levels to satisfy the decision performance criteria. As part of this, the likely distribution of the data should also be considered, as this may impact on the statistical design and the numbers of samples required. For most field investigations, a probabilistic sampling approach is necessary to provide a scientific basis for extrapolating the results from samples to the entire site or decision area. USEPA (2000) describes that "By combining an effective probabilistic data collection design with a statistical hypothesis test, the decision maker will be able to optimize resources such as funding, personnel, and time while still meeting DQOs".

SAQPs

The ASC NEPM (2013) describes that a well-developed SAQP "has a critical role in ensuring that the data collected is representative and provides a robust basis for site assessment decisions". The CSM and DQOs outputs should be documented in the SAQP, along with clearly articulated project objectives and the decision statements that are to be resolved by the investigation.

The ASC NEPM (2013) summarises the information that should be included, and notes that the scope and level of detail contained in SAQPs will vary according to the site-specific circumstances and the stage of the investigation.

Where standard methods are used, standard operating procedures (SOPs) should be included, and any variations or modifications to SOPs should be clearly documented; including changes to standard LORs. The ASC NEPM (2013) also notes that flexibility in SAQPs is advisable, so that changes may be made as required by site conditions during the course of the investigations. This should include documentation of the methods for analysing and interpreting field data where dynamic or reactive sampling and analysis is to be used. In developing SAQPs, it should also be recognised that a weight of evidence[8] approach is required in the ASC.

Site auditors

The *Guidelines for the NSW Site Auditor Scheme* (EPA 2017) describe that:

> It is imperative that a site auditor is engaged as early in the site assessment and remediation process as possible. Early communication between the landowner or developer, consultant and site auditor improves the efficiency of the audit process by ensuring all environmental issues have been addressed to the satisfaction of the auditor, in an appropriate manner and in accordance with guidelines made or approved by the EPA.

This also describes that "DQOs must be adopted for all assessment and remediation programs and the process must be commenced before any investigative works begin on the project". As part of the conducting of site audits, site auditors are required to check that consultants have properly addressed and adopted DQOs, and that well-developed SAQPs have been prepared.

Nevertheless, it should be recognised that the site auditor role does not equate to "approval", in any regulatory or legal sense, of the design components or investigation reports. Contaminated land consultants should consider site auditor comments in finalising investigation designs and reports, while recognising that review of technical guidance and the design of ASC investigations are the responsibility of the contaminated land consultant under the contaminated land framework and the CLM Act.

<div align="center">✧ ✧ ✧ ✧</div>

This Technical Note should be cited as:

Salmon M.C. (2019) *Design of Assessment of Site Contamination Investigations – NSW*, Easterly Point Environmental, Byron Bay NSW.

Notes

2. "Sampling, analysis and quality plan" is used rather than "sampling and analysis quality plan", as it emphasizes that all three components are required to be addressed and documented, rather than simply the proposed "quality" of the sampling and analysis.

3. Three spatial dimensions (X, Y and Z) and time, as contaminants migrate and conditions change.

4. Practitioners should recognize that if the site cannot be drawn, then it is not sufficiently understood.

5. For comparison, see Provost (1984), who describes that sampling design needs to consider: clear statement of the study objectives; description of the study population; characteristics of interest; methods of measurement; degree of precision required*; and design of study, including determination of the number and type of samples to be collected. Provost L.P. (1984) Statistical Methods in Environmental Sampling, in Schweitzer G. E. and Santolucito J. A. (Eds.) *Environmental Sampling for Hazardous Wastes*.

   * Used in the context of statistical precision, with for example, Provost describing that "The use of confidence intervals is one way to state the required precision".

6. Whereas the ASC NEPM describes that the DQOs process is used to define "the type, quantity and quality of data needed", USEPA's 2015 ProUCL Technical Guide, in discussing hypotheses testing approaches, highlights that "good quality data" relates to representative data. That is, the data set is sufficiently representative of the population under study; which in this context relates to field variability, with measurement variability addressed elsewhere in the EDLC process.

7. For example, preliminary estimation of the variability of the target media, such as standard deviation, should also be specified in Step 4, as this relates to the number of samples required to support the decision with sufficient confidence.

8. Weight of evidence describes the process to collect, analyse and evaluate a combination of different qualitative, semi-quantitative and quantitative lines of evidence to make an overall assessment of contamination. Applying a weight of evidence process incorporates judgements about the quality, quantity, relevance and congruence of the data contained in the different lines of evidence (ANZG 2018); all of which need to be synthesised into robust ASC conclusions.

References

Australian and New Zealand Governments (ANZG) (2018) *Australian and New Zealand Guidelines for Fresh and Marine Water Quality*.

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National Environment Protection Council (NEPC) (2013) *National Environment Protection (Assessment of Site Contamination) Measure 1999,* including *Amendment Measure 2013 (No. 1)* (ASC NEPM), *Schedule B2: Guideline on Site Characterisation*.

Northern Territory Environment Protection Authority (NT EPA) (2013) *Guidelines on Conceptual Site Models*.

United States Environmental Protection Agency (USEPA) (2006) *Guidance on Systematic Planning Using the Data Quality Objectives Process, EPA QA/G-4*, (Ref. EPA/240/B-06/001).

USEPA (2000) *Data Quality Objectives Process for Hazardous Waste Site Investigations, EPA QA/G-4HW*, (Ref. EPA/600/R-00/007).