

Contaminated Land Technical Practice Guideline TPG7

Design of Assessment of Site Contamination Investigations

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 in Queensland. The ASC process, described as an environmental data life-cycle (EDLC) by the USEPA, is illustrated in Figure 1.

Regulatory basis

Under Section 389(2)(iv) of the Queensland *Environmental Protection (EP) Act* 1994, contaminated land investigation documents (CLIDs) must include a statement regarding the extent to which the assessment of the land is in accordance with the ASC NEPM (2013). Module 6 of the Auditor Handbook (DES 2019) states that anyone preparing or auditing a CLID “must also use the contaminated land NEPM as an authoritative guide”, and that:

The people preparing or auditing the contaminated land investigation document are responsible for ensuring that the contaminated land NEPM is applied as necessary.

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 an environmental evaluation notice”, 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 is to remain on the land registers with management, or is to be removed from the land registers, 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.

CSMs

A CSM provides a four-dimensional overview³ 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.

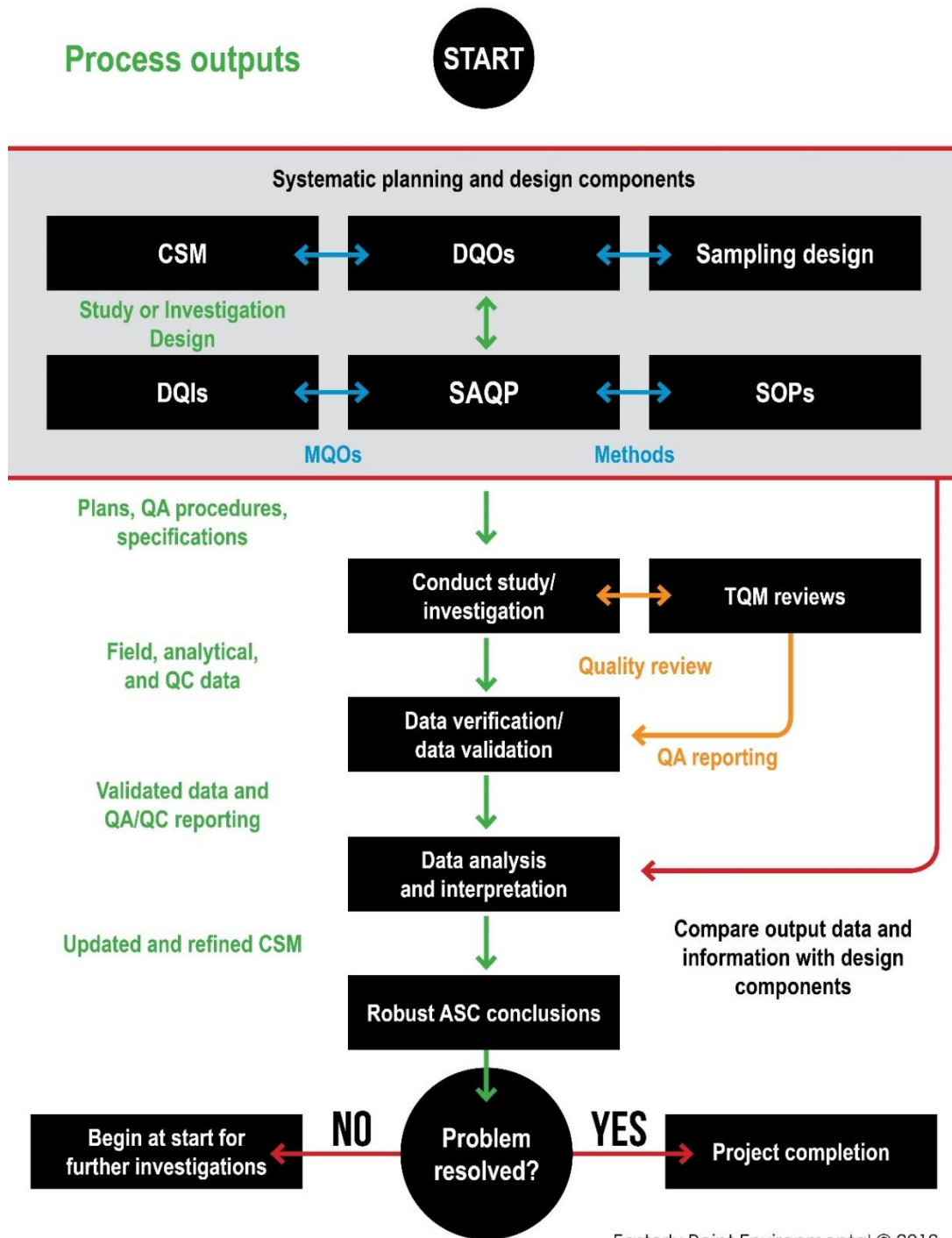


Figure 1: Environmental data life-cycle for ASC investigations

CSMs should be presented using text, tables, plans, diagrams and cross-sections, as required⁴, 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 method⁵. 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.

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.

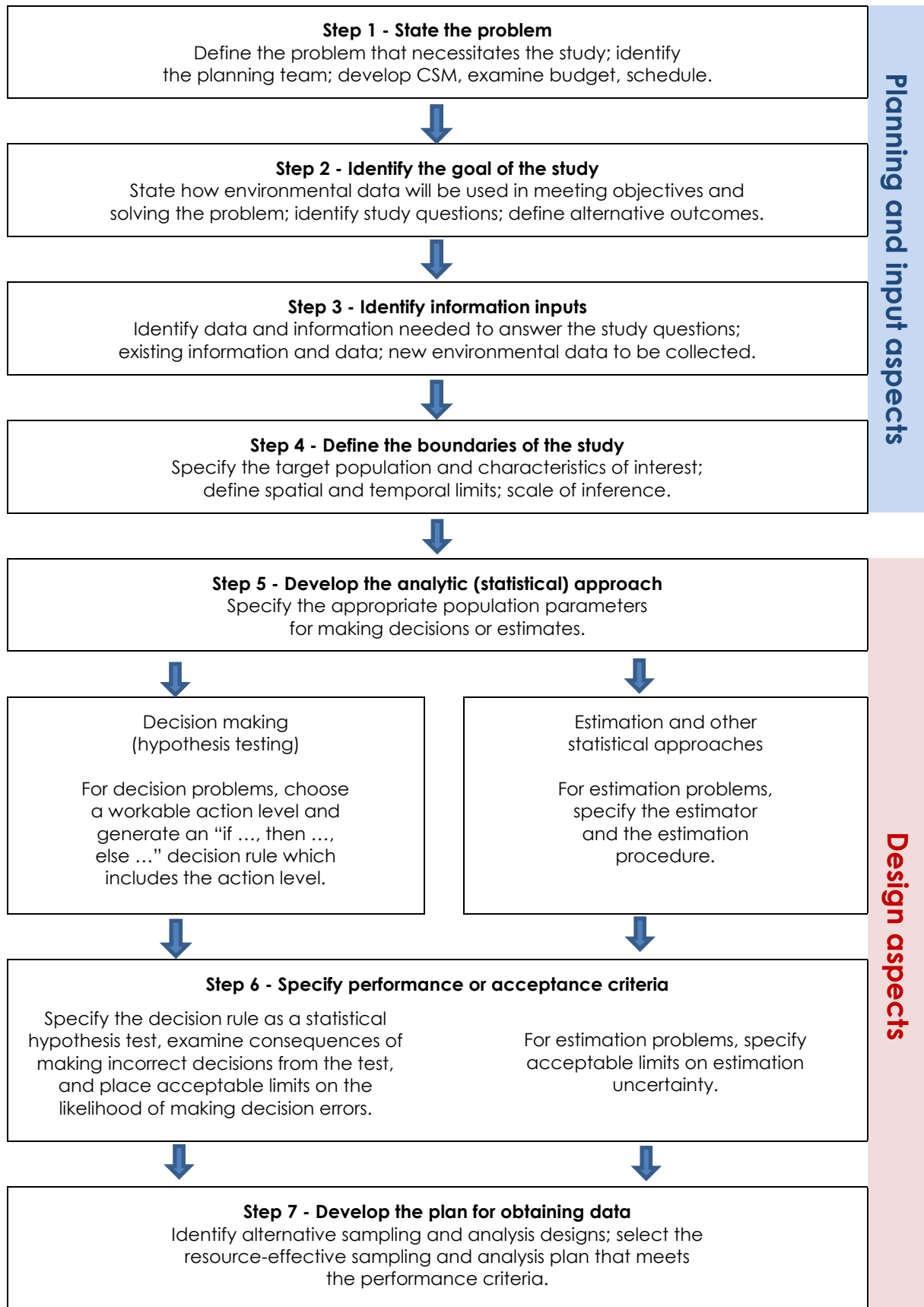


Figure 2: Overview of the USEPA DQOs process
Modified from USEPA (2006)

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 evidence⁸ approach is required in the ASC.

Contaminated land auditors (CLAs)

Module 5 of the Auditor Handbook (DES 2018) describes that “The auditor must be engaged at the earliest possible stage of the site investigations”, and that auditors should review the site investigations as they progress. The most efficient approach is for auditors to review the design components of investigations prior to implementation.

Nevertheless, it should be recognised that the CLA role does not equate to “approval”, in any regulatory or legal sense, of the design components or investigation reports. Suitably qualified persons (SQPs) should consider CLA comments in finalising the investigation design and reports, while recognising that review of technical guidance and the design of ASC investigations are the responsibility of the lead SQP under the contaminated land framework and the EP Act.



This Technical Note should be cited as:

Salmon M.C. (2020) *Design of Assessment of Site Contamination Investigations*, ACLCA Queensland - Contaminated Land Technical Practice Guideline TPG 7.

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

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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).

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