Water pollution discharge impact assessments

Technical note – consideration, modelling and assessment of mixing zones

1. Introduction

This technical note has been prepared to help industry and practitioners when considering a mixing zone as part of a Water pollution discharge impact assessment in NSW.

When the NSW Water Quality Objectives (WQOs) of the receiving waters cannot be met at the discharge point, there is a risk associated with the discharge. In such a case, you can consider the effects of initial mixing. If the EPA permits a discharge of a quality that does not meet the NSW Water Quality Objectives at the discharge point, this implies that mixing is being used to mitigate impacts through the actions of momentum, buoyancy and turbulence.

EPA policy is that the NSW Water Quality Objectives should be met at the edge of the area where this initial near-field mixing takes place.

When licensing a discharge to waters, the EPA can consider the mitigating effects of near-field mixing driven by momentum, buoyancy and turbulence within a mixing zone. This does not include passive dilution, buoyant spreading motion, or other processes that take place in the far-field beyond the area of initial mixing.

The effects of near-field mixing can only be considered when all practical and reasonable measures to prevent, control, abate or mitigate pollution have first been exhausted and there is still a potential risk to receiving waters.

General guidance on how to conduct a water pollution discharge impact assessment is provided on the EPA website at Water pollution discharge impact assessments. This technical note expands on the mixing zone component of that guidance.

1.1. Legislative context

The *Protection of the Environment Operations Act 1997* (POEO Act) provides the statutory framework for managing water pollution in NSW. The main ways that the EPA regulates water pollution include environment protection licences and environment protection notices. Section 45 of the POEO Act sets out the matters the EPA must consider when exercising licensing functions. The use of a mixing zone assessment may inform consideration of these matters.

NSW Environment Protection Authority. ISBN 978 1 923328 59 4 | EPA 2026P4679 | July 2026

1.2. Purpose of this technical note

Policy related to mixing zones for point-source discharges can vary between states and territories. The purpose of this technical note is to outline NSW EPA expectations when mixing is considered as part of a water pollution discharge impact assessment. National guidance on mixing zones is provided in the *Australian and New Zealand Guidelines for Fresh and Marine Water Quality* (ANZG, 2018 and ANZECC & ARMCANZ, 2000).

This technical note:

- supports a consistent approach to conducting mixing zone assessments in NSW
- provides technical information on key concepts that are relevant to mixing zones
- outlines the EPA's general expectations and factors that will be considered when reviewing a proposal for a mixing zone
- provides examples of mixing zone assessments
- identifies resources that provide further information and guidance.

1.3. How the EPA will use this document

The EPA will use this technical note to inform consideration of applications for, or variation to, a licence that includes a discharge to waters where the use of a mixing zone is proposed.

1.4. Limitations

The guidance in this document relates only to the NSW EPA's expectations regarding mixing zone assessments conducted as part of a water pollution discharge impact assessment. A proponent undertaking water-related activities could have other obligations that are not regulated by the EPA – for example, requirements from a consent authority or other water regulator.

This technical note should not be used as an exhaustive list of requirements for conducting a mixing zone assessment. Rather, it should be used by a suitably qualified and experienced person as a guide to key concepts, techniques and EPA policies and practices when conducting an assessment.

1.5. Disclaimer

The EPA has compiled this technical note in good faith, exercising all due care and attention. No representation is made about the accuracy, completeness, or suitability of the information in this publication for any particular purposes. The EPA shall not be liable for any damage which may occur to any person or organisation taking action or not on the basis of this publication. Readers should seek appropriate advice when applying the information to their specific needs. This technical note may be subject to revision without notice and readers should ensure they are using the latest version.

Further disclaimer and copyright information is available on the EPA website.

2. Mixing processes and mixing zones

Point-source discharges mix with receiving waters through two key processes:

- **near-field mixing** – where dilution is driven by the discharge conditions, including the actions of momentum, buoyancy and turbulence
- **far-field mixing** – where initial discharge-driven momentum is lost and further dilution is driven by the receiving environment, including buoyant spreading motion and passive diffusion.

A mixing zone should reflect the area around a discharge where initial near-field mixing takes place and some NSW Water Quality Objectives might not always be fully protected.

The EPA's policy is that only initial mixing is considered for the purposes of assessing the impacts of water pollution and the NSW Water Quality Objectives should be met at the edge of the area where initial near-field mixing takes place.

For the purposes of a water pollution discharge impact assessment, all calculations should be carried out relative to the mixing process, not a pre-designated area.

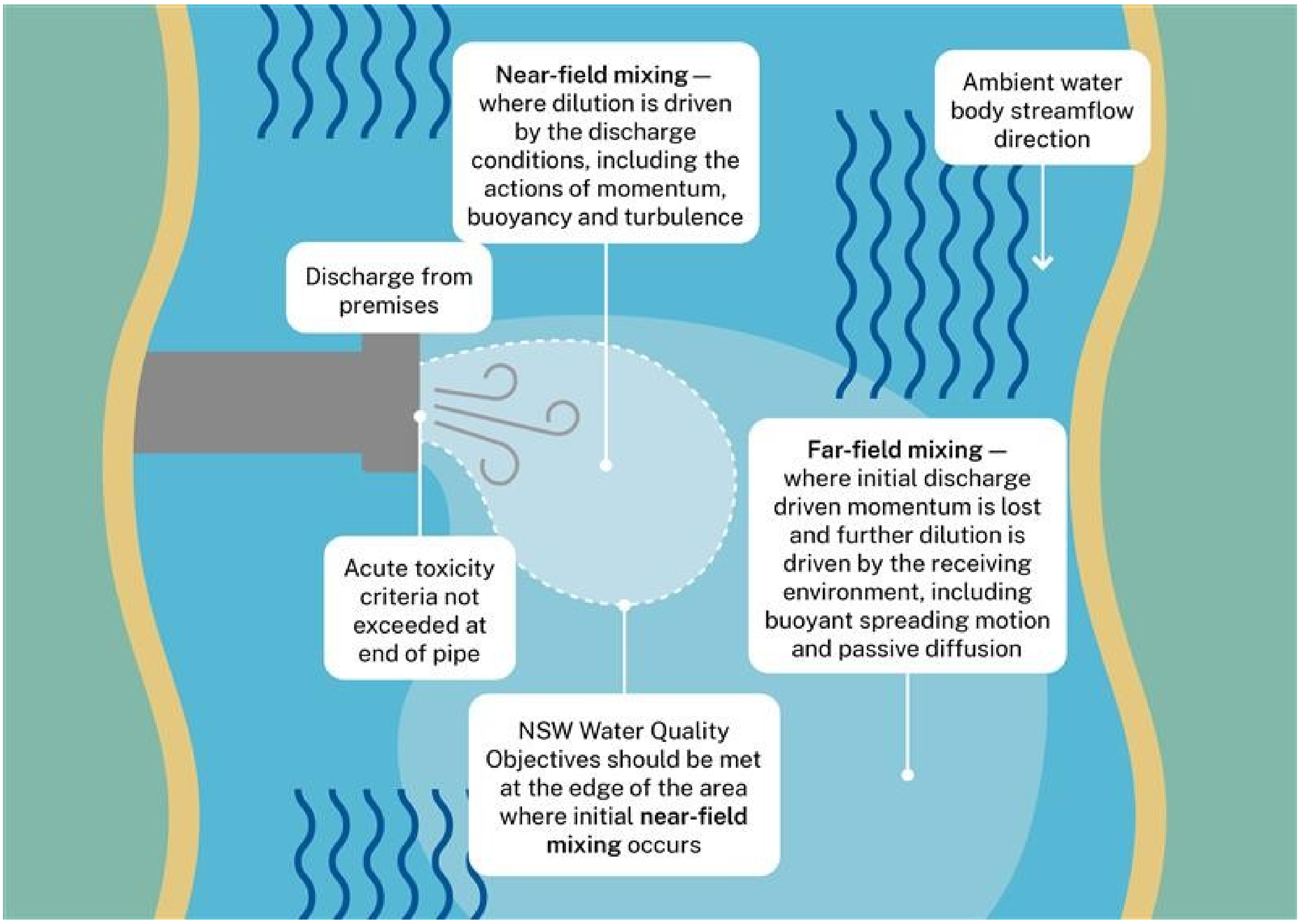

Figure 1 Key features of a point-source discharge

3. Steps in assessing initial mixing and identifying the mixing zone

The following figure outlines the key steps to be considered when conducting an assessment of initial mixing and identifying the mixing zone. These are explained further in the following sections.

Some further steps may be required to demonstrate that the water quality objectives of the receiving waters will be met at the edge of the area where initial near-field mixing takes place. This requirement will depend on the level of risk posed by the discharge and site-specific circumstances, and should be determined in consultation with the EPA.

Consider whether a mixing zone is appropriate

↓

Conducting a mixing zone assessment
Discharge characteristics
Receiving water characteristics
Environmental values
Predicted water quality

↓

Modelling a mixing zone
Model aims, objectives and scope
Selecting a suitable modelling approach and design specifications
Calibration, verification and model performance
Model scenarios
Model results

↓

Monitoring programs

Figure 2 Steps in assessing initial mixing and identifying the mixing zone

3.1. Consider whether a mixing zone is appropriate

When should mixing processes and mixing zones be assessed?

Sometimes a proposed discharge may not meet the NSW Water Quality Objectives at the point of discharge. This may even be after all practical measures to avoid, minimise or mitigate pollution have been exhausted. For such cases it may be possible to show that the extent of impact is limited to the area where initial near-field mixing takes place and the NSW Water Quality Objectives are protected beyond. In these cases, you can carry out an assessment of mixing processes and the zone in which near-field mixing takes place.

The EPA will only consider the use of a mixing zone under certain circumstances. These are where you have considered and implemented both:

- all practical measures to avoid a discharge to waters
- all practical options to minimise impacts if a discharge cannot be avoided.

When is the use of a mixing zone not appropriate?

There are various circumstances where mixing zones are not appropriate. The EPA is unlikely to consider a mixing zone proposal that includes:

- pollutants known to bioaccumulate (e.g. mercury, per- and polyfluoroalkyl substances (PFAS), some polycyclic aromatic hydrocarbons (PAHs), etc.)
- significant irreversible harm within the mixing zone, including objectionable bottom deposits (e.g. unacceptable concentrations of suspended solids)
- pollutants at concentrations that cause acute toxicity to fish or other aquatic life (acute toxicity information is typically available with published guideline values)
- odours that would adversely affect the use of the surrounding environment
- visible floating foam, oils, grease, scum, litter or other objectionable matter
- discolouration of the surface of the mixing zone that could adversely affect the use of the surrounding environment
- pollutant concentrations that may stop migration of aquatic organisms. The size of the mixing zone must also be considered
- substances in concentrations that result in undesirable aquatic life or the dominance of nuisance species (e.g. nutrients contributing to algal blooms).

Further information on circumstances where a mixing zone would not be appropriate is provided in ANZECC & ARMCANZ (2000) Volume 2, Appendix 1.

3.2. Conducting a mixing zone assessment

A mixing zone assessment can be used to determine whether potential risks are likely to be mitigated by initial near-field mixing. The guiding principles when considering a discharge and assessing a mixing zone are as follows.

- Consider and, if appropriate, implement all practical engineering options to optimise mixing processes and minimise the size of the mixing zone.
- Aim to remove mixing zones over time as improved treatment measures become available, other mitigation measures become feasible (e.g. managing excess water via reuse rather than discharge), or new risks (e.g. emerging contaminants) are identified.
- The mixing zone should not interfere with the uses of the receiving waters or aquatic life.
- The shape of the mixing zone should be a simple configuration that is easy to locate in the body of water and doesn't impinge on biologically important areas.
- Avoid shore-hugging plumes.
- Any potential impacts within mixing zones should be reversible.

Mixing zone assessments can vary in their level of detail and complexity. The level of detail should reflect the complexity of the discharge conditions and be in line with the potential risk to the environment. The EPA website has guidance on the appropriate level of assessment when conducting a water pollution discharge impact assessment.

In all cases, you should design and locate the outfall to optimise the discharge characteristics that minimise impacts on receiving waters or avoid them completely.

A proposal to discharge to receiving waters using a mixing zone should include at a minimum:

- discharge water characteristics, including the quality and rate of discharge and the range of variability over time
- characteristics of the receiving waters, including physical (e.g. depth, flows, tides), chemical and biological characteristics
- the NSW Water Quality Objectives for the receiving waters
- the predicted water quality in the receiving waterway during discharges, under conditions that range from typical to worst-case. The proposal should demonstrate that the relevant guideline values and ranges will be achieved at the edge of the area where near-field mixing takes place.

These points are discussed further below.

Discharge characteristics

Discharge characteristics include those of the effluent (e.g. effluent quality and flux) and those related to the physical design and location of the discharge point. Effluent quality and discharge rates can vary significantly between industries and over time. For example:

- Discharges from a sediment basin may typically include pollutants that cause turbidity or high or low pH, and other pollutants specific to the area of disturbance. Discharge rates would depend heavily on rain events but would also be influenced by other factors such as water reuse and evaporation.

- Treated wastewater discharges from a small industrial site may contain a limited number of pollutants, have relatively low discharge rates, and have their timing determined by site operations.
- Sewage treatment plant discharges would have a range of pollutants, including those associated with sewage and trade waste. Discharge rates from sewage treatment plants can be complex, and typically vary with both the time of day and how much rain has fallen recently. Seasonal fluctuations may also be relevant for sewage treatment plants in holiday locations.
- Groundwater treatment plant discharges from a tunnelling project may contain a range of pollutants, with discharge rates that are relatively constant but influenced to some degree by rain.

The physical and chemical characteristics of the discharge can also affect mixing dynamics: for example, temperature and salinity affect buoyancy.

Discharge velocity and near-field mixing are also influenced by the physical characteristics of the discharge point, including:

- number of port(s)
- port location, including with respect to the water column
- port size and shape
- port orientation.

Receiving water characteristics

Understanding the characteristics of the receiving waters is crucial in conducting a mixing zone assessment and likely to be useful when designing a discharge point. Many of these characteristics should also be considered for simpler water pollution discharge impact assessments. Key factors to consider when characterising receiving waters include the following:

- **Physical properties** – these could include bathymetry, flow rates and density. For larger and deeper rivers, estuaries or the ocean, spatially dependent data (e.g. velocity fields) should also be considered.
- **Ambient water quality** – characterisation of ambient water quality should include analysis of all pollutants of potential concern and relevant chemical indicators over a range of likely conditions. This could include characterising the temporal and spatial variability of all relevant pollutants and chemical indicators within the receiving waters at a frequency and intensity proportional to the risks they pose.
- **Biological characteristics** – can be determined by biological surveys, particularly if there are sensitive receptors such as threatened species.

Environmental values

The environmental values of the receiving waters should be used to determine which analytes are relevant for the assessment and which water quality criteria should be used. Guidance on how to consider the environmental values of water can be found on the EPA website under Water pollution discharge impact assessments.

Predicted water quality

Predicting water quality in receiving waters is generally done through some degree of modelling depending on the level of assessment required.

The output of a mixing zone model would often include a distribution of potential pollutant concentrations at a particular point (e.g. at the edge of the area where initial near-field mixing takes place) or a probability that the environmental values (NSW WQOs) are met at that point. This output should inform the assessment and decision on whether the discharge poses an acceptable risk to the environment.

Note that predictive errors are often high (e.g. plus or minus 50%). Model sensitivity testing and validation/verification may be necessary to test and refine a model. This is discussed further below.

3.3. Modelling a mixing zone

The type and extent of modelling required to consider the use of a mixing zone should be appropriate for the level of risk to receiving waters. This includes the nature of the receiving environment, the environmental values of the receiving waters, and the pollutants being discharged.

The level of detail included in a mixing zone model could range from

- a simple, qualitative or semi-quantitative dilution study based on the site and waterway catchment area

  to

- a detailed modelling study incorporating comprehensive data over a wide range of conditions. An interdisciplinary team of scientists and modellers could be needed to carry out such a study.

A simple model may also be used as a screening exercise to determine whether a more complex model is warranted.

Model aims, objectives and scope

The aims, objectives and scope of the modelling should be clearly defined, including a description of the chosen methodology that outlines how those aims will be achieved. This should include the stakeholders and their expectations and the parameters of interest.

Selecting a suitable modelling approach and design specifications

There is a range of models and methodologies available for mixing zone assessments. Dedicated modelling software is typically used for more complex scenarios. Simpler models can be created using simple calculations, spreadsheets or general statistical software.

CORMIX and PLUMES2.0, supported by the United States Environmental Protection Agency, are examples of models that have been effectively used to model mixing zones. Various other proprietary alternatives are also available. Each model will have strengths and weaknesses, requiring its limitations to be considered and acknowledged/reported in the assessment.

The EPA is an outcome-focused regulator and does not prescribe models or methodologies for modelling mixing zones.

The following factors should be considered when selecting a suitable model.

Appropriateness of the modelling platform

The modelling platform should be able to represent the critical hydrodynamic processes and port/diffuser designs in the study area. Some modelling platforms are designed for specific use cases or only consider select hydrodynamic processes. A mixing zone assessment with a modelling component submitted to the EPA should include adequate discussion on why a particular platform has been selected and if its use is valid for the use case, or why certain processes can be disregarded.

Model complexity

The complexity of the model should be appropriate for the amount of data available (or that will be acquired) and the potential risks to receiving waters. To be fit for purpose, the model must take into account conservation of mass, momentum, buoyancy and entrainment, at minimum. Generally, the simplest model that achieves the assessment objectives will be the most effective.

Assumptions

Users should understand any assumptions made in formulating the model design and setup and interpret the results in this context. A mixing zone assessment with a modelling component submitted to the EPA should clearly explain all assumptions in the model design and setup, such as simplification of diffuser design or assumption of zero background flows in low-flow environments. The operating limits of the model should also be outlined.

Validation and publication

Publicly available models should have good validation and publication records. If a model hasn't been published it is unlikely to have been peer reviewed, and the EPA would be unlikely to consider the associated mixing zone assessment.

Calibration, verification and model performance

When modelling a mixing zone, the performance of the model should be assessed to inform whether it can be relied upon and to what extent. Assessment of model performance could include consideration of data requirements, model performance indicators and model sensitivity analysis. The EPA may request calibration, verification and model performance information, especially if the discharge is high-risk or the model is complex.

Data requirements

Mixing zone models usually require data for calibration and verification. Exceptions to this may include simple dilution studies. Data requirements vary between models and generally depend on the complexity of the model, the variability of the system to be modelled over the spatial and temporal range of interest, and the model performance criteria. The errors associated with the field measurements should be identified and presented with the field data.

Model performance indicators

In designing or selecting a mixing zone model, the required performance of the model must be understood and defined to ensure the model is fit for purpose. Performance requirements should reflect the overall model aims and objectives.

Performance is typically assessed through a comparison of modelled values with corresponding observations. For simple models, a visual or semi-quantitative assessment of performance may be adequate. For complex models, statistical methods such as correlation would generally be necessary.

Commonly used performance indicators include the coefficient of determination (R^2), mean absolute error, mean squared error, root mean squared error and index of agreement (*d*). The performance of publicly available models is generally based on the Nash–Sutcliffe coefficient of model efficiency, percentage bias and normalised root mean squared error (Moriasi et. al., 2007). Performance indicators can be shown for both validation and calibration.

An appropriate performance indicator(s) and desired value (or range of values) should be selected according to the aims and objectives of the model, and be appropriately justified and agreed to by the EPA if included in a mixing zone assessment. While some default parameters are often suitable, certain applications of publicly available models require more strict criteria. Note that modelling criteria are negatively sensitive to outlier data.

Model sensitivity analysis

Model performance depends on several parameters that are best guesses based on field datasets. These parameters can often significantly change the outcome of the modelling. For example, the entrainment rate set in the model is generally constant. However, different entrainment rates will produce different mixing zone dimensions. Furthermore, some models consider only simple entrainment dynamics while others can consider more complex ones. A sensitivity analysis supports a better understanding of any variance in the modelling.

A mixing zone assessment that includes modelling should include a sensitivity study. This can be the baseline scenario being tested for a range of realistic values of parameters (for example, entrainment rates).

Model scenarios

A mixing zone model and assessment should cover a range of likely scenarios, including:

- the range of variations in the discharge quality and quantity

- the relevant range of environmental conditions in the waterway (e.g. variations due to tides, background current flows, seasonal temperatures and storm events).

The scenarios should describe a set of worst-case conditions (from an environmental perspective) as well as typical or average conditions. The frequency of each of these scenarios should also be calculated.

Accordingly, assessment of model performance should also cover a range of modelled scenarios. The scenarios' limits can be broader than calibration limits but should not exceed them significantly.

Ensemble modelling

Depending on the variance of the environmental conditions and the modelling platform capabilities, it is often beneficial to create scenarios so that ensemble modelling can be done. Here the possible variances in the key environmental conditions are modelled separately and statistical outputs (such as average or median) are used to project the mixing zone.

Where ensemble modelling is conducted, the objectives and results of the modelling should be presented and discussed in the mixing zone assessment.

It is also possible to create ensembles using different modelling platforms to show that the solutions are converging to similar solutions.

Future or climate change projections

Depending on the location and duration of a discharge, a model may need to take into account changes projected to occur in the future. For example, sea-level rise will inundate nearshore areas, so mixing zone dimensions will be different for discharges close to shore.

Model results

The results of a mixing zone modelling exercise should inform two things. The first is whether the proposed discharge is consistent with the mixing zone guiding principles. The second is whether the environmental values will (or are likely to) be protected at the edge of the area where near-field mixing takes place or at another location. This is often expressed as an estimated probability. Results should be interpreted with caution and in the context of the model aims and objectives, assumptions made, and model performance.

The following data should be clearly presented:

- background concentrations
- adopted guideline values (e.g. ANZG 2018) and exceedances
- identification of protected areas and sensitive receptors, and their proximity to the proposed discharge(s)
- modelled outputs at the edge of the area where near-field mixing takes place (for water quality parameters of interest)
- dilution ratios

- centreline dilution (in certain cases)
- dimensions of the proposed mixing zone.

The data presented can extend beyond this for specific use cases and is best discussed with stakeholders during the initial consultation periods.

3.4. Monitoring programs

If a mixing zone is permitted, the EPA is likely to require ongoing monitoring to verify the predictions of the assessment or measure any changes to discharge conditions over time. A key component is to gather monitoring data under different receiving water and discharge conditions where possible.

Requirements of a monitoring program could include:

- monitoring of a discharge's physical characteristics (e.g. discharge rates or near-field mixing extent)
- water quality monitoring at the discharge point, at the edge of the near-field mixing zone, or at another pre-determined location. Monitoring could be done at the surface and/or at multiple depths to capture any variability.
- sampling to cover the expected spatial extent of the plume so interpolated spatial mapping can be produced using the dataset
- maintaining a flow meter (e.g. an acoustic doppler current profiler) at the site to record background flows
- benthic sediment assessments
- assessment and reporting of the monitoring data at a frequency appropriate to the risk.

Mixing zone monitoring would typically be undertaken as part of a wider monitoring program associated with the discharge. In this case, it is important to recognise the purpose of different monitoring locations.

Mixing zone monitoring should assess whether the NSW Water Quality Objectives are met at the edge of the area where initial near-field mixing occurs, not at the discharge point. Monitoring at the discharge point would have other uses including, for example, assessing compliance with a discharge limit.

Monitoring programs and their requirements are informed by risk and must therefore be developed on a case-by-case basis. Monitoring requirements may also need to be updated as more data or information becomes available, and updates may include changes to monitoring locations, frequency or analytes tested.

4. Further information and resources

ANZECC & ARMCANZ, 2000. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Environment and Conservation Council & Agriculture and Resource Management Council of Australia and New Zealand.

ANZG, 2018. Australian and New Zealand Guidelines for Fresh and Marine Water Quality. Australian and New Zealand Governments and Australian state and territory governments, Canberra ACT, Australia.

Moriasi, D.N., Arnold, J.G., Van Liew, M.W., Bingner, R.L., Harmel, R.D. and Veith, T.L., 2007. Model evaluation guidelines for systematic quantification of accuracy in watershed simulations. *Transactions of the ASABE*, *50*(3), pp.885–900.

NSW EPA, 2026. Water pollution discharge impact assessments. NSW Environment Protection Authority. https://www.epa.nsw.gov.au/Your-environment/Water/managing-water-pollution-in-nsw/environment-protection-licensing/Water-pollution-discharge-assessments.

Appendix A – Mixing zone assessment examples

These examples are generic and have been included to show how the guidance in this technical note can be applied. They are simplified and don't cover every issue or complexity that may arise in real situations. A mixing zone assessment is only one part of a water pollution discharge impact assessment, and licensing decisions will take other relevant factors into account, consistent with s 45 of the POEO Act.

Discharges not appropriate for mixing zone analysis

Example 1 – Sediments

A major road upgrade has begun, regulated under an environment protection licence for road construction. The project is significantly disturbing the ground, and a series of sediment basins has been installed; these discharge to a nearby creek through a single discharge point.

The project is in a metropolitan area. The project footprint is long and narrow, and there is limited space for the sediment basins. The contractor is experiencing challenges with meeting the NSW Water Quality Objectives for turbidity. Practical mitigation measures – such as water reuse and further treatment – have not been considered.

The use of a mixing zone to manage suspended sediments in the discharge is not appropriate because all practical and reasonable measures to avoid and minimise impacts have not been considered and the discharge would probably form objectionable deposits.

Example 2 – Bioaccumulating pollutants

A resource recovery facility accepts a range of waste streams under an environment protection licence. A portion of the site is uncovered, and stormwater run-off from this area drains to a stormwater detention basin before being discharged off site. The stormwater basin is effective in reducing sediment concentrations to trivial levels; however, recent water quality testing has detected elevated concentrations of benzo(a)pyrene (BaP).

The use of a mixing zone to manage BaP concentrations in the discharge is not appropriate as this pollutant is known to bioaccumulate.

Circumstances where use of a mixing zone is appropriate

Example 3 – Simple dilution study

A resource recovery facility accepts a range of waste streams under an environment protection licence. A portion of the site is uncovered, and stormwater run-off from this area drains to a stormwater detention basin via a vegetated swale before being discharged off site. The vegetated swale and stormwater basin are effective in reducing sediment concentrations to trivial levels; however, recent water quality testing has detected elevated concentrations of nickel.

The facility has limited space available and all practical measures to minimise pollution have already been considered and implemented. Nickel concentrations measured at the discharge point occasionally exceed the adopted guideline value of 11 µg/L but are always below published concentrations known to be acutely toxic. Given this, the licensee has included a simple mixing zone assessment as part of a water pollution discharge impact assessment.

Excess stormwater is discharged from the site into an open, concrete-lined stormwater drain which captures run-off from a larger catchment and conveys it to a creek that is afforded a slightly to moderately disturbed level of protection consistent with NSW Government policy. Given the narrow and elongated nature of the stormwater drain, it was assumed that site discharges and run-off from the greater catchment are well mixed before reaching the creek.

A limited sampling exercise was conducted to inform the assessment, which included sampling from the discharge point and the stormwater drain (upgradient and downgradient of the discharge point) during high- and low-flow conditions. The highest nickel concentration measured at the discharge was 13 µg/L (representing a potential worst-case scenario), and nickel was not detected upstream of the discharge (with a limit of reporting of 1 µg/L), so 1 µg/L was adopted as a conservative estimate.

The catchment area for the stormwater basin is approximately one hectare (ha), and the total catchment area reporting to the stormwater drain is approximately six ha (i.e. five ha excluding the stormwater basin sub-catchment).

A simple dilution study was chosen for the assessment because:

- it was considered suitable to capture the relatively simple nature of the discharge
- there can be issues with application of mixing zone models in bounded systems such as narrow and/or shallow receiving waters.

Nickel concentrations entering the creek were estimated as follows:

$$\text{Concentration}_{\text{(estimate)}} = \frac{\boldsymbol{Concentration_1\ x\ Area_1 + Concentration_2\ x\ Area_2}}{\boldsymbol{Area_1 + Area_2}}$$

$$\text{Concentration}_{\text{(estimate)}} = \frac{\boldsymbol{13\,\frac{\mu g}{L}\ x\ 1\ ha + 1\,\frac{\mu g}{L}\ x\ 5\ ha}}{\boldsymbol{1\ ha + 5\ ha}}$$

$$\text{Concentration}_{\text{(estimate)}} = 3\ \mu g/L$$

Note: This calculation assumes uniform rainfall across the catchment and uniform time taken for run-off to reach the drain. This may not be suitable for some assessments.

Based on this calculation, it was estimated that water entering the creek would have a nickel concentration of 3 µg/L. Sampling downstream of the discharge measured concentrations of 2 µg/L. The difference between the estimated and measured results was likely to be related to natural variation, conservative use of sampling results in the calculation, or inaccurate assumptions.

Comparing the estimated and measured calculations with the adopted guideline value, it was concluded that the discharge was unlikely to pose a risk to the receiving creek.

Example 4 – Modelling study

An industrial facility operates adjacent to an estuary, and typical operations involve intake and discharge of estuary water for cooling. Cooling water is isolated from site operations and pollutants of potential concern are limited to antifoulant additives and thermal pollution. Preliminary discharge characterisation shows that antifoulant additive concentrations are below guideline values, but it is not always feasible to reduce the discharge temperature to within the adopted guideline value range.

Given the expected complexity of the discharge mixing dynamics, a third-party mixing zone model was used to model water temperature in the receiving waters.

The following factors were considered in the mixing zone assessment:

- **Discharge characteristics**: Water is discharged at a maximum rate of 10 L per second, through a single horizontal (0° angle) port of 0.25 m diameter. The port extends into the estuary (10 m) where the depth of the receiving water immediately adjacent to the outlet is 2 m and the pipe is positioned in the middle of the water column (i.e. 1 m depth).
- **Receiving water characteristics**: The discharge point is located near a beach within a tidal estuary. The beach is offset from the nearby river and the low currents at the discharge point were measured. The beach is not typically used for swimming, but primary contact has been considered, and an oyster farm is located approximately 500 m away.
- **Environmental values**: The environmental values of the receiving waters were determined with reference to the NSW Water Quality Objectives and are aquatic ecosystems, recreational water and aesthetics, and aquatic foods. The estuary's environmental values with guideline values for temperature are aquatic ecosystems (between 20^{th}–80^{th} percentile of expected natural range), primary contact recreation (15–35°C) and aquatic foods (<2°C change over one hour).
- **Predicted water quality**: Discharges were not expected to exceed 35°C, so recreation was expected to be protected at the discharge point. Based on the results of the mixing zone model, the guideline values for aquatic ecosystems and aquatic foods were predicted to be met within the area where near-field mixing takes place (10 m and 20 m from the discharge point, respectively) with 95% confidence. Further modelling predicted these distances would be reduced to 5 m and 10 m with the installation of a diffuser.

Based on the results of the mixing zone assessment, it was concluded that the discharge was unlikely to pose an unacceptable risk of thermal pollution outside the area where near-field mixing will take place. Monitoring was conducted at variable depths and distances from the discharge point and results were consistent with the model. To improve mixing, a diffuser was later installed at the discharge point and over time monitoring requirements were reduced to only include the discharge point.