Wastewater Treatment Planning Guidelines

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1.0	2/07/2021	Norbert Schaeper	New Document

Wastewater Treatment Planning Guidelines

1. Wastewater Treatment Planning Guidelines

1.1 Purpose of the Wastewater Treatment Planning Guidelines

The purpose of the guidelines is to promote consistent and efficient planning of wastewater treatment assets across Sydney Water. The use of this document will:

- Facilitate delivery of innovative, sustainable and valued wastewater treatment services to our customers;
- Contribute to a liveable city while meeting, growth, environmental, public health and regulatory drivers;
- Incorporate lowest life cycle cost and acceptable risk in treatment planning;
- Ensure robust and prudent decisions, placing customers front of mind.

The guidelines are intended to support the Planning Framework by providing treatment specific guidance for:

- **Formulating a Basis of Planning** | defining a holistic project scope and product outcomes; linking scope and outcomes to servicing objectives and project drivers; identifying treatment inputs and design boundaries; and methods for data analysis and inputs generation.
- **Developing a servicing solution** | plant assessment; configuration of overall treatment plant; sizing of treatment units and equipment; identifying critical parameters, common interactions and constraints; estimating project cost, treatment risk, and investment timelines.
- **Discrete planning activities** | activities which may not easily align with the Framework process map.

1.2 Development of the Wastewater Treatment Planning Guidelines

The guidelines were formulated by an integrated team which comprised of a development team and an inputs team. The development team facilitated workshops, called Working Group Sessions, where the input team would provide references, inputs, and experiences to be written into the guidelines. The development team would then independently develop the guidelines. After which, the outcomes would be presented to the integrated team at subsequent workshops for further refinement or approval. This approach is shown in Figure 1-1.

The purpose of this methodology was to promote universal buy in from the integrated team and to develop a Wastewater Treatment Guidelines document that is constructed from collective experiences, rather than individual perspectives. It is suggested that future amendments and guidelines are developed with a similar approach.

The guidelines have been developed with the expectation that they will be maintained, modified and updated based on future learnings and end-user requirements.

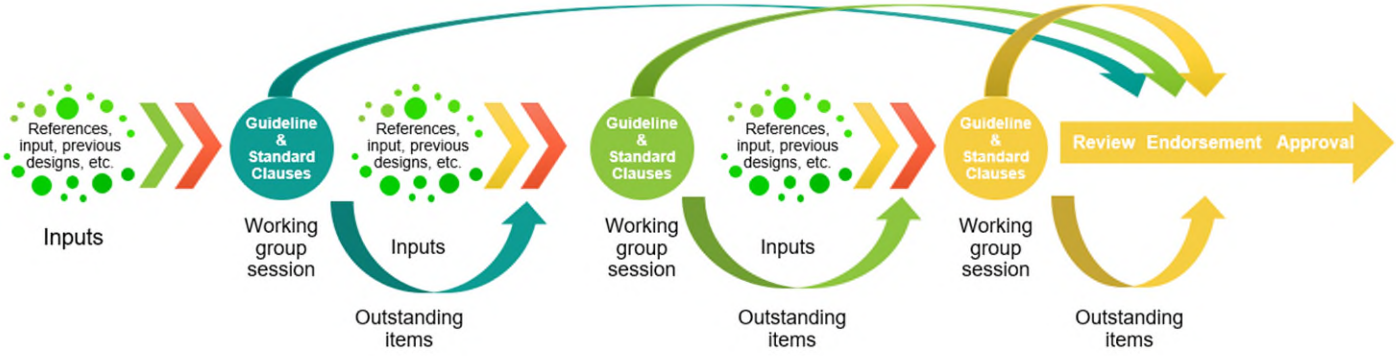


Figure 1-1 Methodology for the development of the Wastewater Treatment Asset Guidelines

1.3 Application of the Wastewater Treatment Planning Guidelines

1.3.1 Overview of the Planning Framework

Planning tasks are activities which define a project need, scope, solution options, and preferred solution concept, prior to continuation of the project into a delivery or 'build' cycle of detailed design and construction. The Planning Framework, shown in Figure 1-2 below, exists to standardise these planning activities to align to corporate objectives, strategy, planning workflow, activity and role function, and artefact creation and management.

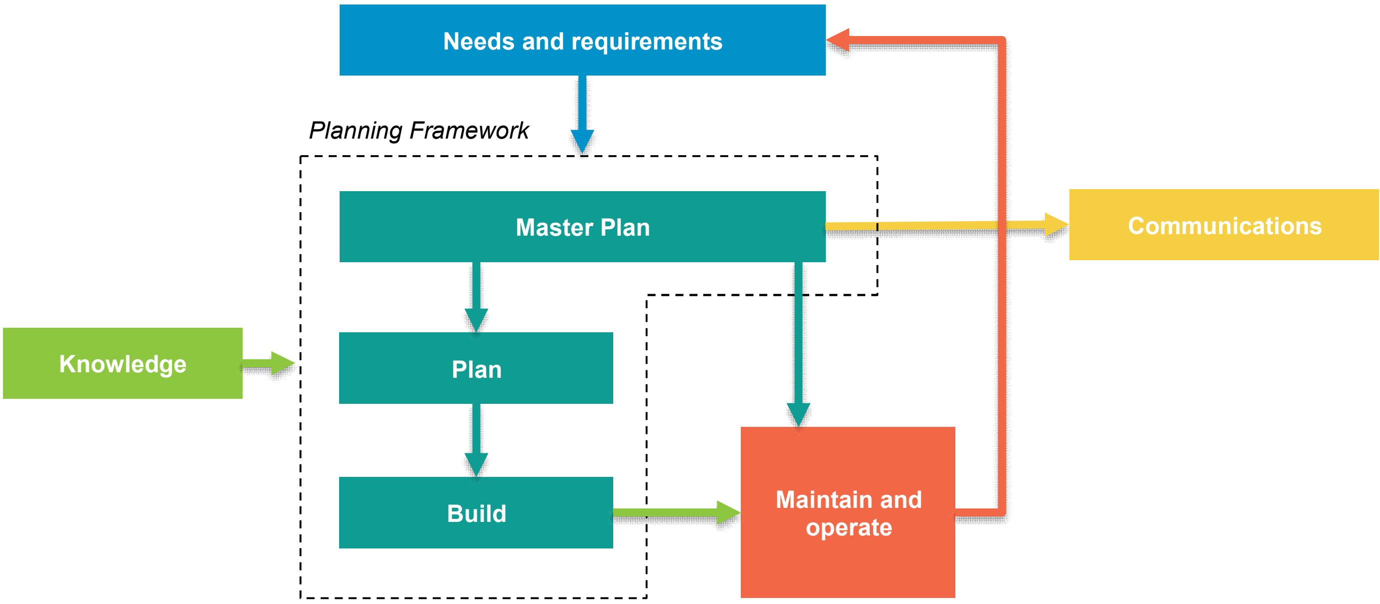


Figure 1-2 Planning Process and the extent of the Planning Framework

The Planning Framework is designed to provide one common framework that describes how we plan and build assets. The intent of Planning Framework is to enable a step change in how Sydney Water performs its strategy, planning, design and construction activities, by:

- Ensuring alignment of investments and plans with the corporate strategy and plan and Lifestream, clearly demonstrating line of sight to corporate objectives and priorities and alignment with the Asset Management System requirements.
- Mapping the planning process to the value chain to improve the flow of work through the planning lifecycle.
- Defining the stratum levels of strategic (master) and integrated planning required to ensure we effectively achieve product and service outcomes.
- Embedding customer insight and engagement approaches into our strategy development, planning and investment decisions to move us from an inside out and asset focus (engineering) to an outside-in (customer) and outcome mind-set.
- Establish an economic approach to options assessment to ensure that environmental and social benefits are adequately considered during decision making.
- Clarify roles and accountabilities throughout the planning framework, providing a consistent process for working across internal teams, with external stakeholders and customers.

The process map of the Planning Framework is presented in Figure 1-3. The process emphasises aligning product and asset level outcomes with strategic objectives, now and into the future.

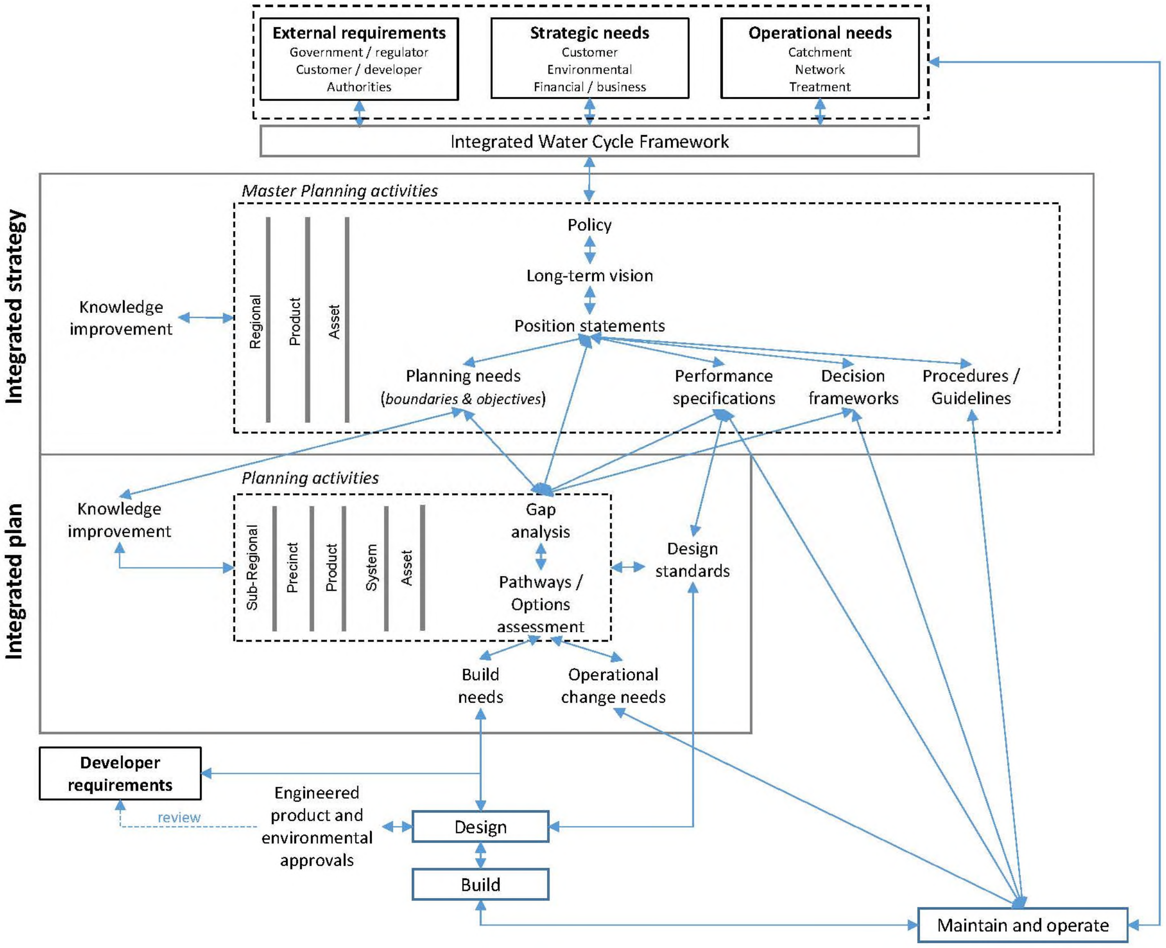


Figure 1-3 The Planning Framework

1.3.2 Application of Guidelines within the Planning Framework

The Wastewater Treatment Planning Guidelines is the first document of Sydney Water's Wastewater Treatment Asset Guidelines and Standards series. The series consists of three tiers of specification:

1. **Wastewater Treatment Planning Guidelines** | guidelines for planning wastewater treatment assets at Sydney Water with the intent of facilitating efficient and robust asset planning
2. **Process Technology Selection and Sizing Guidelines** | guidelines for the selection of treatment train technologies, configurations and unit sizing
3. **Asset Standards** | detailed design standards for discrete process units and treatment trains for use with the relevant Sydney Water material and equipment standards (existing)

The Guidelines provide typical treatment train configuration and process variables which can be used to facilitate high-level project scoping and budget formulation. However, this is are not intended to replace detailed design methodologies, site-specific variables which should more prevalent as asset planning progresses towards asset delivery. This generally should occur during options assessment, with concept design based firmly on site-specific variables and configurations as required for the project outcomes.

The Wastewater Treatment Planning Guidelines shall be used in conjunction with the Planning Framework and adopted wholly for planning activities related to wastewater treatment at Sydney Water. The Guidelines support the Planning Framework by providing guidance for the planning tasks that are specific to wastewater treatment assets and treatment processes.

1.4 Structure of the Wastewater Treatment Planning Guidelines

The Wastewater Treatment Planning Guidelines have been structured into discrete sections for referencing and application. A summary of the document sections is provided below.

1. **Wastewater Treatment Planning Guidelines** | purpose and development of guidelines and location of guidelines within the planning framework
2. **Identification and Alignment of Project Drivers** | formulation and alignment of project drivers to servicing objectives as well as ensuring a wholistic and systemic approach is adopted in planning projects
3. **Formulating a Basis of Planning** | methodology and references for defining planning inputs, variables, and product outcomes
4. **Treatment Plant Configuration Guidelines** | principles for treatment train configuration as well as heuristic flow path and sizing criteria to facilitate high level planning activities and budget forming exercises, heuristic values intended to be superseded by more detailed methodologies and site-specific requirements and variables
5. **Assessment of Cost, Time** and Risk | standard considerations for cost estimating, assessment and investment profiling, as well as defining wastewater treatment risk assessment
6. **Discrete Planning Activities** | methodologies and considerations for discrete wastewater treatment planning activities which as extraordinary to the asset creation cycle
7. **Definitions** | list of key definitions and abbreviations
8. **Governance** | governance record, change history and contact information for queries and change requests
9. **Appendices**

2. Identification and Alignment of Project Drivers

2.1 Project drivers

Notionally, project drivers are the reason planning, and ultimately investment, in assets occur. 'Driver' is a broad term but in wastewater treatment it is typically a need relating to growth, product quality or regulation, and operation requirements. There can be multiple project drivers in a project and project drivers can span multiple treatment products. Examples of project drivers are listed below:

- **Increasing catchment growth** | forecast growth will result in greater flows and loads to a treatment facility
- **Unreliable equipment** | a mechanical unit keeps failing resulting high maintenance call out costs, repeat investment and/or product impacts
- **Discharge effluent quality requirements change** | more stringent EPL requirements result in the need for higher level of treatment
- **Corporate objective to reduce reliance on grid power** | need for more efficient mechanical units and potentially look to capture more chemical energy from sewage

Project drivers need to link directly to servicing objectives which include obligations to the customers serviced and the environment. In the planning process, these objectives are translated to project outcomes through the planning needs, performance specifications, decision frameworks and procedures/guidelines.

2.2 Servicing objectives

Servicing objectives are typically presented as position statements based on policy and strategy directives pertaining to economic, environmental and social outcomes. Specific to wastewater treatment, servicing objectives start with public health, ecological health and amenity of receiving waters. Secondary to this, servicing objectives may be linked to industry, corporate, regional, sub-regional, or site and product specific outcomes.

2.2.1 Where to find servicing objectives

Servicing objectives are defined in several references.

Policy and strategy documentation capture high level servicing objectives which set the direction of servicing, and the regulations which Sydney Water follows, examples include *Corporate Strategy and Plan, Environmental Policy, Recycled Water Management Policy.*

There also exists external regulations which overlay internal policies and strategies, examples include *Environmental Protection Licences*, and product specific guidelines such as for recycled water and biosolids.

Relevant for planning are asset strategies, product strategies and planning artefacts, such as masterplans, regional masterplans. These artefacts synthesise and prioritise the project drivers and objectives based on regional or asset specific contexts. Where these plans exist, they provide a key reference for initial consideration of a facility or region's servicing objectives.

The next level is growth servicing and facility plans (e.g. System Blueprints). These identify short and long-term investment strategies to address facility specific drivers – which inherently link back to policy and strategy documents and higher-level planning artefacts.

A summary of artefacts which are commonly referenced when defining the servicing objectives for wastewater treatment is provided in Table 2-1. External links to these documents has been provided and are accessible as of October 2019.

Table 2-1 Servicing objective references

Group	Document Title	Description	Link [1]
Policy documents	Corporate Strategy and Plan	Corporate strategies and plans outlining the commitments and priorities to reach strategic and business objectives.	Link
	Environmental Policy	Policy covering all aspects of the business in relation to environmental policies and commitments	Link
	Recycled Water Management Policy	Policy for strategic intent of improving recycled water management and development of recycled water resources	Link
Asset strategy documents	Wastewater Treatment Asset Masterplan	Vision, direction, strategies and investment program for wastewater treatment and water recycling plant assets (AMQ0113)	Link
	Asset Management System	Asset management policy and objectives	Link
	Asset Reliability Masterplan	Asset Reliability Master Plan Implementation Roadmap 2018	Link
Product strategy documents	Product Servicing Strategies	General documents for Product Servicing Strategies	Link
	Waterways Masterplan	Masterplan for wastewater and stormwater services	Link
	Bioresources Masterplan	Masterplan for biosolids, grit, screenings, water sludge, storm water material and others	Link
	Energy Masterplan	Masterplan for use and generation of energy	Link
	Water Masterplan	Masterplan for water sources and supply	Link
Regional and Precinct Servicing Strategy	Regional Servicing Strategies	General documents for Regional Servicing Strategies	Link
	Western Sydney Regional Masterplan	Masterplan for water and wastewater services for Western Sydney	Link
	Precinct Servicing Strategies and Masterplans	Water and wastewater servicing strategies and masterplans for precincts	Link
Regulation and external policies	Sydney Water Act	Act to establish a State owned corporation for water services	Link
	Operating Licence	Sets requirements for water, wastewater, recycled water and stormwater services	Link
	Environmental Protection Licences	The EPA has issued Environment Protection Licenses for all Sewage Systems under the control of Sydney Water.	Link
	NSW EPA Biosolids Guidelines for Beneficial Application	Requirements for the beneficial use and disposal of biosolids to land in NSW	Link
	Recycled Water Guidelines	Common documents and reports for recycled water management and specifications	Link
	Other Industry Standards	Sydney Water access link to Standards Online platform	Link
System Plans and PCAs	System Blueprints and Process Capability Assessments	System Blueprints and Process Capability Assessments for wastewater treatment plants	Link

Group	Document Title	Description	Link [1]
Growth servicing investment plans	2018 Wastewater Treatment Growth Servicing Investment Plan report	Growth Servicing Investment Plants for wastewater treatment plants	Link
	2013 Growth Servicing Strategy reports	Growth Servicing Strategy Reports for wastewater treatment plants	Link
[1] External links available as of October 2019			

2.2.2 Future servicing objective changes

Servicing objectives are dynamic and change in response to corporate drivers and environmental issues. Known or expected future changes should be identified and considered during the planning exercise.

If the exact nature and timing of change in servicing objectives is not known, sensitivity analysis should be conducted to estimate the impact on planning outcomes.

Examples of potential future servicing objective changes, which can form new project drivers, may include:

- **Product specification changes** | discharge effluent nutrient load limit changes; minimum biosolids stabilisation grade for beneficial reuse; change in product destination.
- **New servicing options** | food and beverage waste, or other biodegradable waste streams may be disposed of at wastewater treatment plants with anaerobic digestion.
- **Climate change impact** | requirements to manage greenhouse gas emissions from treatment processes; or increased effluent pumping needs due to future sea level rises.

Future servicing objective changes should be considered throughout the asset lifecycle.

2.3 Alignment of project outcomes with servicing objectives

Projects are often initiated from a single identified need such as identified gap in asset capability, asset reliability or due to a change in servicing objectives. To avoid planning delays, cost blowouts, and suboptimal asset or servicing outcomes, the initial identified project outcome(s) should be reviewed in a holistic manner and the project outcomes aligned with the relevant servicing objectives.

2.3.1 Holistic assessment of project outcomes

The initial need statement for a project shall be reviewed within the current planning iteration to ensure that:

- All associated gaps/needs have been identified, including consideration of upstream and downstream process unit capabilities
- Demand profiles are representative of the current experienced demand and future demand has been considered for the next 30 to 40 year horizon, with particular attention paid to interim horizons related to asset life
- There hasn't been a change in product performance requirements or other servicing requirements since the need was initial identified
- Climate change impacts or drought cycle haven't resulted in a change in strategic approach or site variables

Example: Holistic project outcomes

It has been identified by reliability engineers that the thickening and dewatering centrifuges at a treatment plant are at end of design life and are becoming less reliable.

A project has been initiated to do a like for like renewal of the centrifuges, with an expected asset life of 15 years. The plant is known for odorous sludge.

Current project outcome: like for like replacement of thickening and dewatering centrifuges

Holistic review of needs could identify other needs and change the project outcomes:

- Impact of solids management to the wastewater network.
- Impact of solids management on ability to provide recycled water and meet the EPL in the liquid stream
- There may be a high growth demand resulting in a like for like replacement not having sufficient capacity to process sludge in the new centrifuges lifespan
- Sludge odour may be enhanced by certain screw conveyors, changing dewatered cake conveyors to belt conveyors and modifying the configuration could reduce sludge cake odours The digesters may have a low solids retention time which is causing high odour potential and poor cake dewaterability, this will deteriorate further with increasing growth demands – introducing recuperative thickening would enhance SRT
- Current centrifuge loading rates may be resulting in poor centrate quality and inducing high load returns to the liquid stream processes – larger units or different thickening and/or dewatering technologies may be required
- Biosolids stabilisation for beneficial reuse now requires Grade A sludge instead of Grade B stabilised sludge – THP is to introduced and alternate project exists to design a new biosolids processing train at the plant
- Or, the biosolids stabilisation grade requirements mean that there has been a change in servicing strategy to stop biosolids processing and out loading at the site in favour of transferring all sludge streams to an adjacent centralised facility in the next two years

Consideration of the any of the above items would result in a significant shift in the project outcomes. This may be from an upsizing of the units selected, to a complete abandonment of the project and a management plan developed to maintain the existing units over an interim period while an alternative processing train is delivered.

Clear identification of project outcomes is critical to proper scoping of the project and tracking the evolution of scope through the planning and delivery cycle. Where there are additions or revisions made to the initial project outcomes, the variations shall be noted. The following shall be noted:

- Change in project outcomes and identified reasons for change
- Impact on project scope and anticipated impact on total project cost
- Where additional scope is identified as required: risk assessment of not adopting additional scope items

2.3.2 Alignment with servicing objectives

Project outcomes shall be aligned to and prioritised based on the identified servicing objectives.

This shall be facilitated by:

- Considering applicable current and expected future servicing objectives during the holistic review of project outcomes
- Identifying any competing outcomes and prioritising them based on the servicing outcomes
- Revising the prioritisation and alignment of outcomes during and after the current planning project

3. Formulating a Basis of Planning

3.1 Purpose of the Basis of Planning

The Basis of Planning document contains planning and design criteria, growth, flow, load, demand forecast for current and future planning horizons, and key assumptions adopted for the planning activity. It is the key reference document to ensure that project outcomes are achieved from project initiation to design and asset delivery.

The Basis of Planning must include the following seven key components, namely:

- ***Servicing Objectives and Project Outcomes*** | the purpose, drivers, and outcomes of the project and their alignment or link to the corporate strategy and policies, product masterplans, and servicing objectives.
- ***Project Information*** | information related to the project such as project drivers, preceding planning artefacts, concurrent or future projects, and any project information or assumptions that can affect project outcomes.
- ***Scope Boundary*** | an agreement of the time, processes, and tangible or non-tangible boundaries of the project.
- ***Inputs Basis*** | the input flow and load conditions that the asset must service to achieve the project outcomes.
- ***Asset/Facility Basis*** | the condition, configuration, and site characteristics of the asset which affect its ability to operate under the defined input conditions.
- ***Products Basis*** | the product outcomes that must be achieved by the asset under the input and asset conditions defined in the Asset/Facility Basis.
- ***Planning Horizon and Future Considerations*** | the future changes in the inputs, asset/facility, and products basis which affect the ability of the asset to achieve the project outcomes.

A summary of the components of the basis of planning and their interrelationships is provided in Figure 3-1.

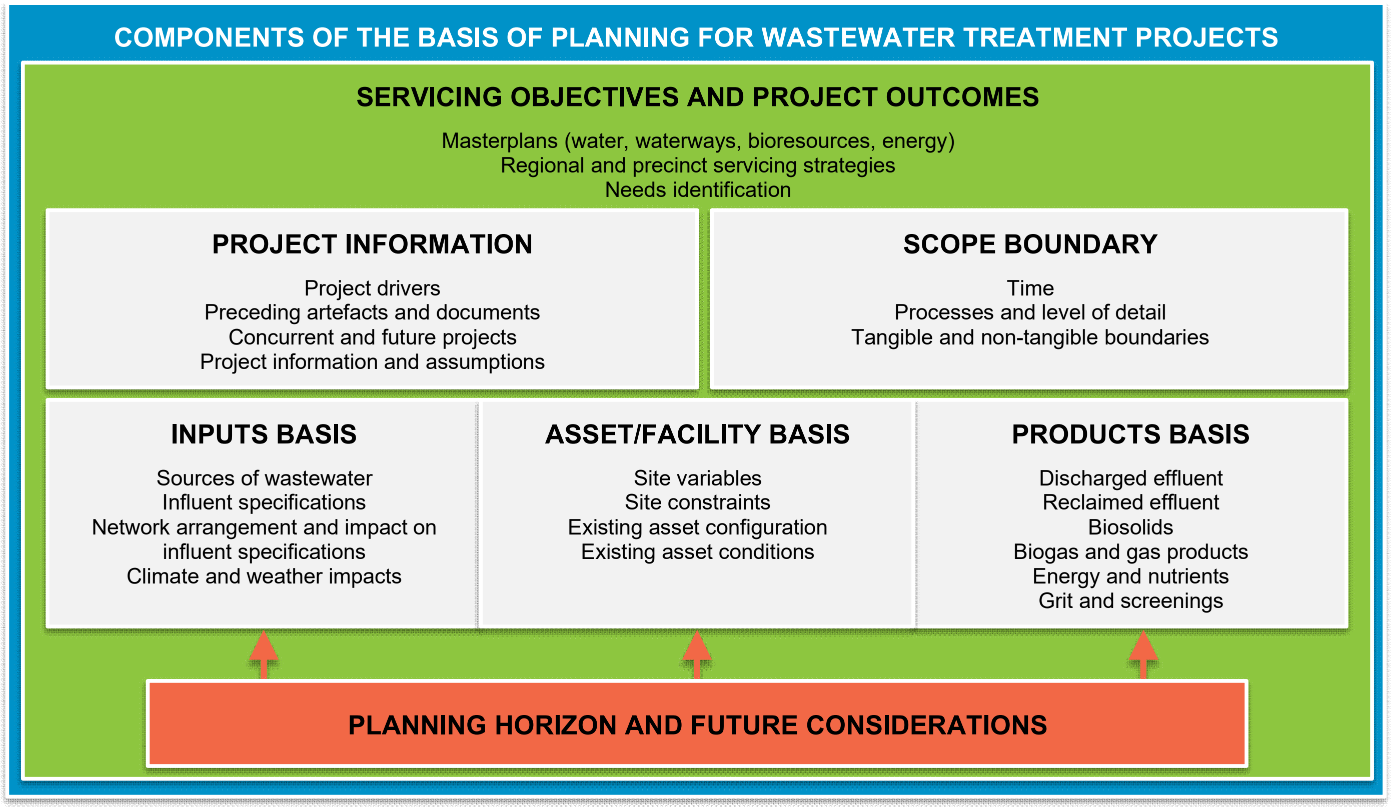
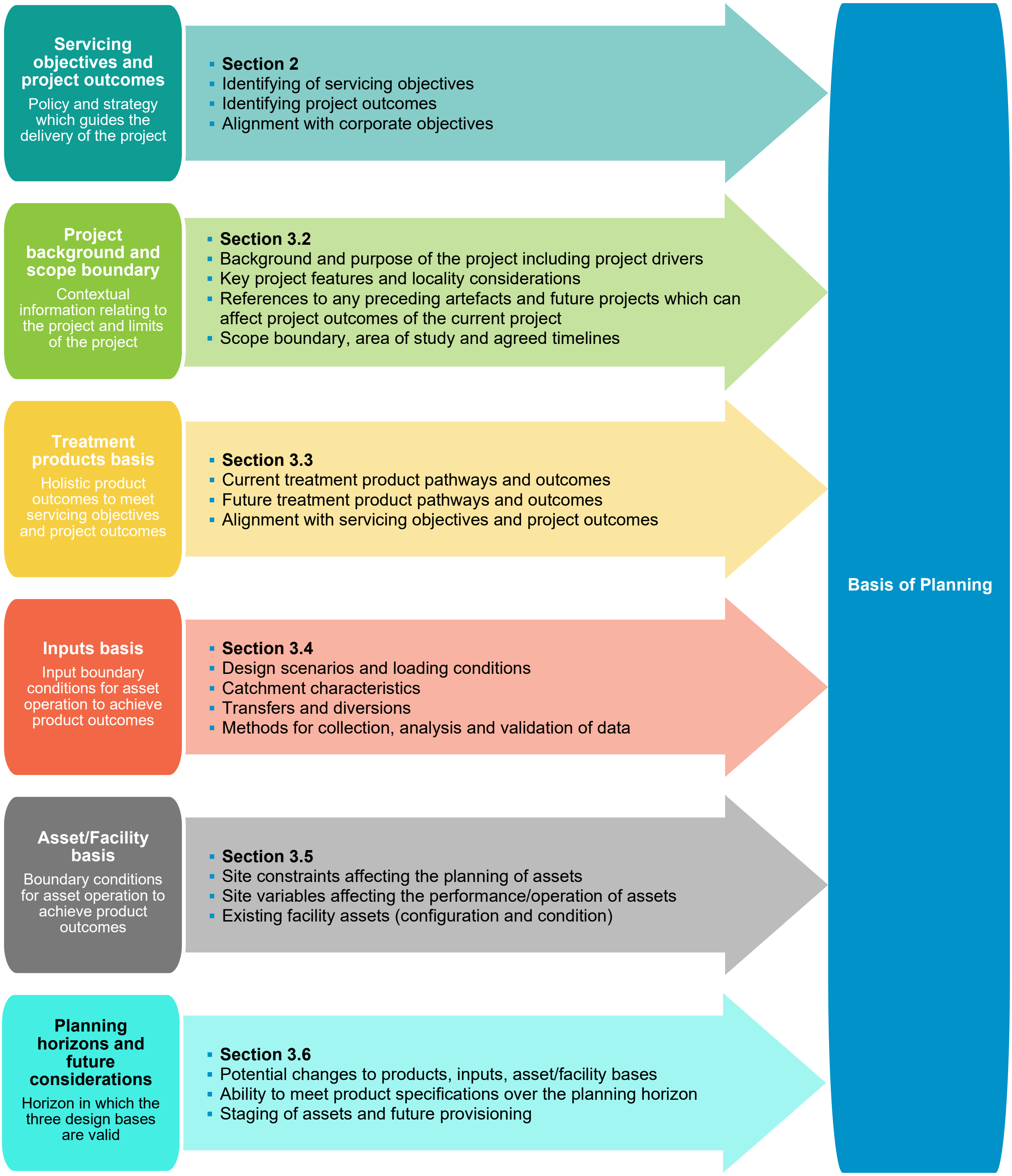


Figure 3-1 Components of the Basis of planning and their interrelationships

3.1.1 General approach for formulation of the Basis of Planning

A general approach for the development of the Basis of Planning is shown in Figure 3-2.



Servicing objectives and project outcomes

Policy and strategy which guides the delivery of the project

- **Section 2**
- Identifying of servicing objectives
- Identifying project outcomes
- Alignment with corporate objectives

Project background and scope boundary

Contextual information relating to the project and limits of the project

- **Section 3.2**
- Background and purpose of the project including project drivers
- Key project features and locality considerations
- References to any preceding artefacts and future projects which can affect project outcomes of the current project
- Scope boundary, area of study and agreed timelines

Treatment products basis

Holistic product outcomes to meet servicing objectives and project outcomes

- **Section 3.3**
- Current treatment product pathways and outcomes
- Future treatment product pathways and outcomes
- Alignment with servicing objectives and project outcomes

Inputs basis

Input boundary conditions for asset operation to achieve product outcomes

- **Section 3.4**
- Design scenarios and loading conditions
- Catchment characteristics
- Transfers and diversions
- Methods for collection, analysis and validation of data

Asset/Facility basis

Boundary conditions for asset operation to achieve product outcomes

- **Section 3.5**
- Site constraints affecting the planning of assets
- Site variables affecting the performance/operation of assets
- Existing facility assets (configuration and condition)

Planning horizons and future considerations

Horizon in which the three design bases are valid

- **Section 3.6**
- Potential changes to products, inputs, asset/facility bases
- Ability to meet product specifications over the planning horizon
- Staging of assets and future provisioning

Basis of Planning

Figure 3-2 General approach for the development of the Basis of Planning

3.1.2 Application of the Basis of Planning

A Basis of Planning document should be developed prior to or during needs assessment. During the life-cycle of a project, project activities may require multiple Basis documents to be developed. These documents will typically increase in detail as project outcomes become more defined. It is therefore natural for the Basis of Planning document to evolve into a Basis of Design or form the foundational chapters in a Concept or Detailed Design Report. Conversely, for higher-level planning activities, the key components of the Basis of Planning can be included but in lower detail, focusing on broader project outcomes and servicing strategies.

Note that a template exists for the Basis of Planning (Link), however, this template covers all water services. A Basis of Planning template has been developed specifically for treatment assets, refer to Appendices. This template should be used as a starting point for developing a project-specific Basis of Planning document.

Table 3-1 illustrates the transition of detail, of the components, from needs assessment to detailed design. The critical stages of a project lifecycle are shown with the number of icons representing the indicative level of detail.

Table 3-1 Application of the Basis of Planning at various project stages

Section	Key components	Needs Assessment	Options Assessment	Concept Design	Detailed Design
Servicing Objectives and Project Outcomes	Servicing objectives of the asset/facility	✓✓✓	✓✓	✓	
	Alignment with masterplans	✓✓✓	✓✓		
Project Background and scope boundary	Project background	✓✓✓	✓✓✓	✓	✓
	Reference documents / artefacts	✓✓✓	✓		
	Scope boundary	✓✓✓	✓✓✓	✓✓	✓
Products Basis	Treatment product pathways	✓✓✓	✓✓	✓	
	Treatment product outcomes	✓✓	✓✓✓	✓✓✓	✓
	Detailed product specifications	✓	✓✓	✓✓	✓✓✓
Inputs Basis	Project area (i.e. understanding of the site, network and catchment)	✓✓	✓✓✓	✓✓	✓
	Input flow and load scenarios	✓✓	✓✓	✓✓✓	✓✓✓
	Input data collection and analysis	✓✓	✓✓✓	✓✓✓	✓
Asset/Facility Basis	Site variables and constraints	✓✓	✓✓✓	✓✓✓	✓✓✓
	Existing asset configuration, capacity and condition	✓✓✓	✓✓✓	✓✓✓	✓✓✓
Planning Horizons and Future Considerations	Assessing planning horizons and future considerations	✓✓	✓✓✓	✓✓	✓

✓ Low effort or detail
✓✓ Medium effort or detail
✓✓✓ High effort or detail

3.2 Project information and scope boundary

It is important that the Basis of Planning captures the background of project to the required level of detail to ensure that the integrity and continuity of servicing objectives and project outcomes are maintained during the service lifecycle of the developed assets or facility. As a minimum, include the following information:

- Type of project that is undertaken and the need/reason for the project (drivers), typical examples include:
    - Amplification, upgrade, or new asset/facility to service growth or change in product outcome requirements
    - Renewal of asset/facility due to end-of-life
    - Reliability upgrade to improve service availability
    - Facility upgrade to meet new product or operating standards
    - Technology investigation or demonstration
- Key features of the project and locality such as:
    - Locality or region of the asset or facility
    - Project stakeholders (internal or external)
    - Critical project milestones suitable for the level of planning
- Reference to past, current and future projects directly related to the project or project area that can affect the outcome of the project, examples include:
    - Water and non-water related projects at the locality or regional level (e.g. transfers or diversions, regional or precinct servicing strategies, trade waste plans)
    - Existing or planned upgrades or changes at the site (e.g. new processes, amplifications, renewals)
    - Network artefacts and planning projects, include consideration of network masterplans
- Scope boundary should be included and must clearly define the tangible and non-tangible boundaries of the project, examples include:
    - Project timelines and milestones
    - Interface points and boundaries of treatment processes and assets
    - Level of detail in project methodologies/activities (e.g. cost estimation accuracy, process design accuracy)

3.3 Treatment product outcomes

3.3.1 Treatment product pathways and products

A wastewater treatment facility is designed to impart mechanical or chemical energy into wastewater to remove organic and inorganic pollutants through physical, chemical and biological processes. After treatment, the treated effluent is discharged to the environment or treated further for reuse (onsite, third pipe, purified recycled water, agriculture etc).

During the treatment process, by-products are generated and released in solid, liquid, or gaseous pathways. The by-products that have valuable quantities of energy or nutrients, and that can be captured effectively, are collected and processed further for beneficial purposes (e.g. biogas for cogeneration to provide heat and electricity). Conversely, the by-products with insufficient energy or nutrients (e.g. grit and screenings) are generally treated further and disposed where possible.

A graphical summary of the treatment product pathways, and the types of treatment products under each pathway, is shown in Figure 3-3. Note that this graphical summary represents a typical arrangement for tertiary level treatment (i.e. pre-treatment, primary, secondary, tertiary and biosolids treatment). Not all treatment facilities will undertake all the represented steps and/or produce all the identified products and by-products as shown. Further, there may be other treatment pathways or products not shown below.

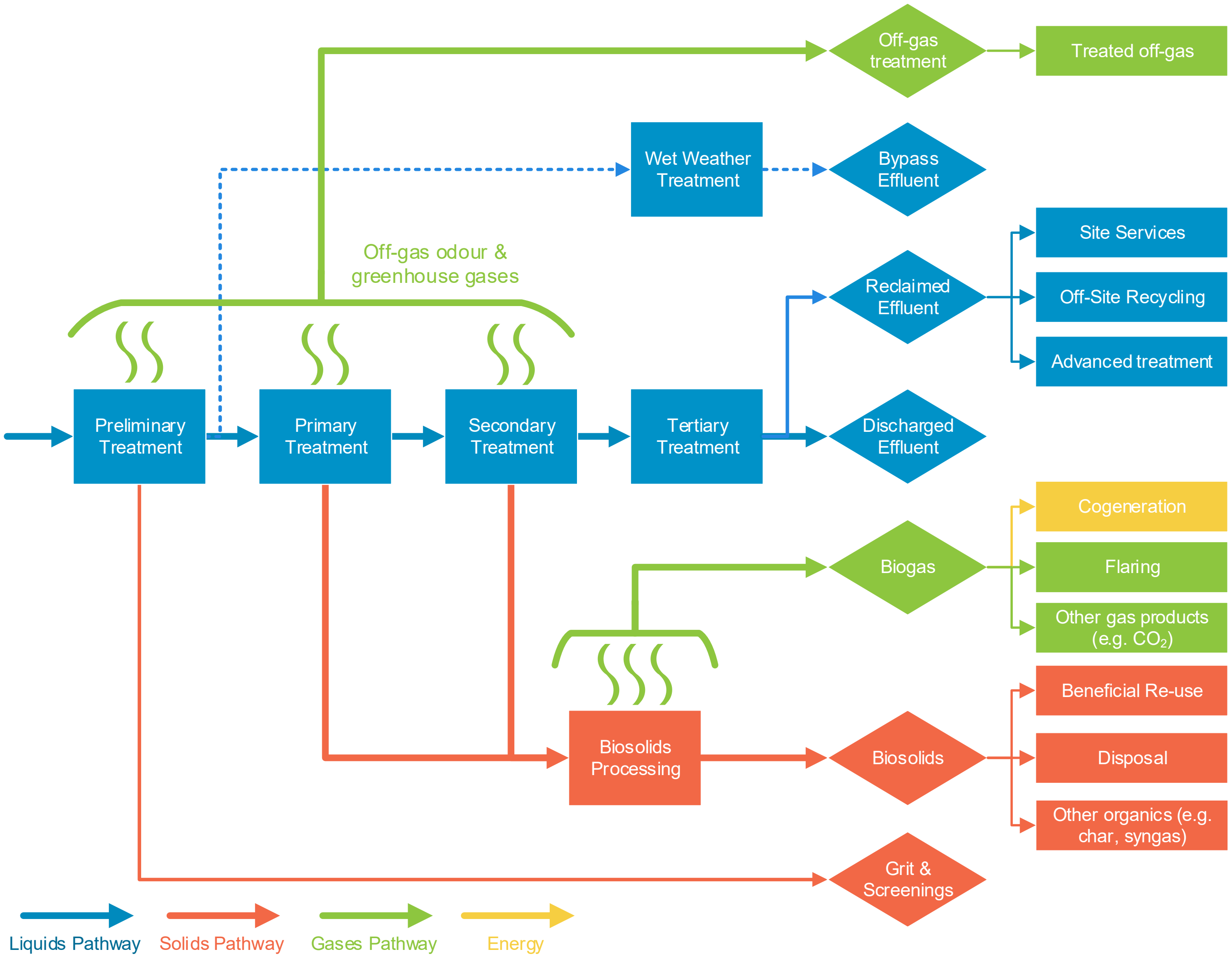


Figure 3-3 Treatment product pathways and types of treatment products

3.3.2 General approach for developing treatment product outcomes

When developing product outcomes, the following general sequence can be used to ensure robust and holistic product outcomes are developed:

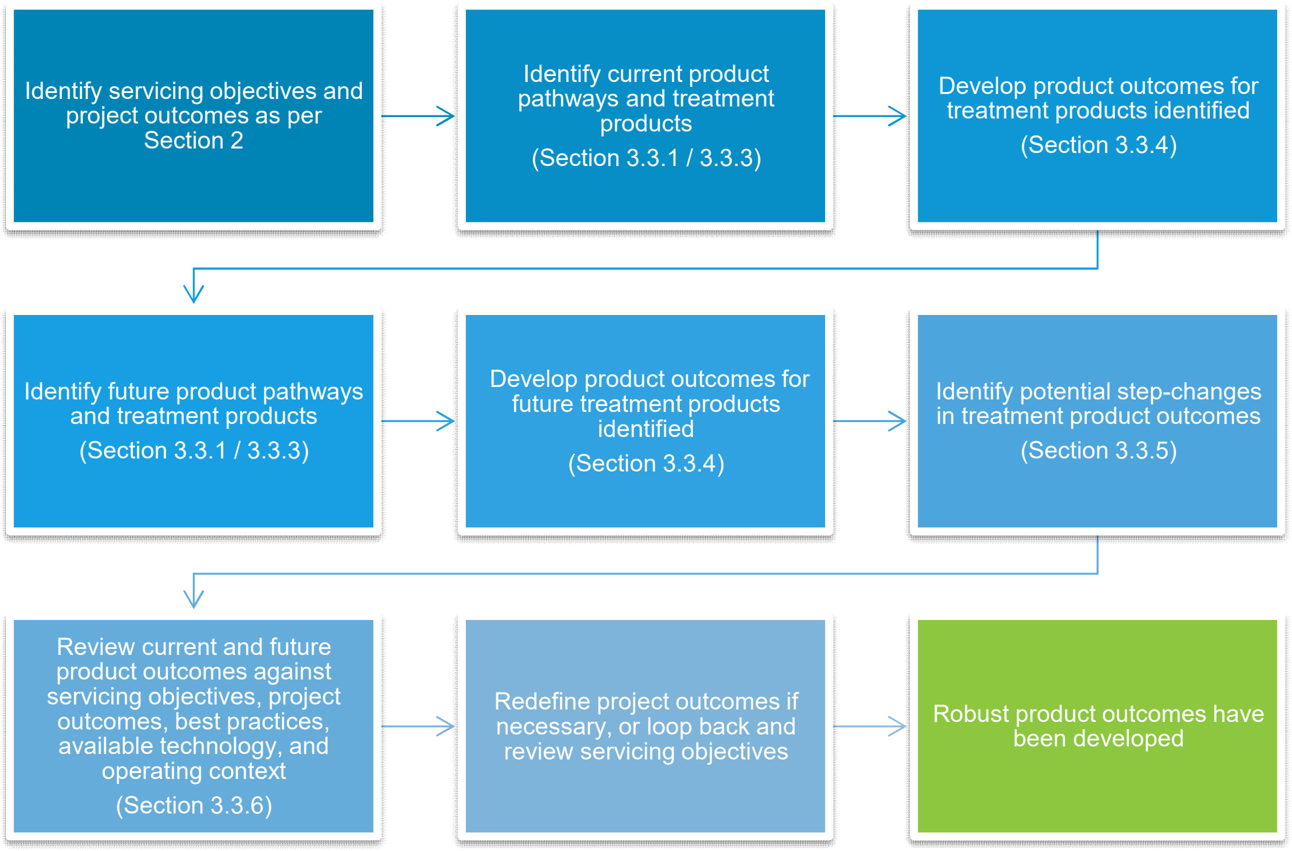


Figure 3-4 Activity sequence for identification of treatment products and product outcomes

3.3.3 Identify current and future treatment products

Future changes to the treatment configuration or level of treatment can create new treatment product pathways and hence new treatment products. Alternatively, the changes may result in removal of pathways or product. Examples of this include the scenarios in Table 3-2.

Table 3-2 Examples of changes to types of treatment product

Scenario	Treatment Product Affected
Conversion of a raw wastewater system to a settled wastewater system by means of installing primary treatment	Primary sludge will be generated resulting in changes to the biosolids treatment process and by-products of the biosolids treatment include biogas, biosolids
Change in the screening and grit removal system	Change in screening and grit product characteristics and quantities
Change in the biosolids treatment process such as conversion of aerobic digesters to anaerobic digesters	Change in biosolids characteristics and generation of biogas
Installation of reclaimed effluent systems	Change in discharged effluent product volumes and generation of reclaimed effluent product

3.3.4 Develop treatment product outcomes

3.3.4.1 Effluent product outcomes

Effluent product outcomes are directly defined by the nature of the effluent discharge and/or any end use applications of the effluent.

For effluent which are disposed of by environmental discharge (i.e. to a river or the ocean), the product objectives are founded on protecting the receiving environment. Product specifications for discharge effluent are defined for both concentration performance and total annual discharge load. The required performance will be determined by the sensitivity of the receiving waterway to contamination for example discharge to an inland tributary compared to a deep ocean outfall.

Likewise, the end use(s) of reclaimed effluent will determine the required product outcomes. Reuse applications are varied, and the application will determine the quantity and quality required.

3.3.4.1.1 Discharge effluent product outcomes

The product outcomes for discharge effluent are stipulated in an Environmental Impact Statement (EIS) and/or an existing plant's Environmental Protection Licence (EPL). The EPL is issued and regulated by the Environmental Protection Agency (EPA), with performance against the product specifications reported to the EPA.

Each treatment facility with a dry weather discharge has its own EPL. There are a number of facilities which provide dry and/or wet weather treatment and then discharge to another facility – the performance of these facilities come under the discharge facility EPL as a system EPL. The EPA has the statutory authority to change/revise the EPL and thus the latest EPL should always be utilised.

The latest EPL for each treatment facility can be found here: Link

Discharge effluent outcomes are typically prescribed in the EPL through the following criteria:

- Maximum total daily volume
- Quality criteria – concentration values for key pollutants, typically 50th and 90th percentile values
- Annual load limits – total annual discharge mass limit for key pollutants

All effluent streams are volume monitored. Plant effluent streams are typically quality monitored as a combined stream. In some instances, wet weather plant bypass streams do not have dedicated quality monitoring. Similarly, storm wastewater treatment plants which operate only in high flow wet weather events are typically not quality monitored due to the unpredictable nature of their operation. Unmonitored effluent streams have standardised emission factors applied to them, with nominated quality parameter values for wet and dry weather "overflows". The standard quality parameters applied to unmonitored plant bypass streams are summarised in Table 3-3.

Table 3-3 Emission factors for wet and dry weather overflows

Analyte	Carbonaceous Biological Oxygen Demand	Oil & Grease	Total Suspended Solids	Total Nitrogen	Total Phosphorous
Emission factor for wet weather overflow (mg/L)	40	18	80	13	1.9
Emission factor for dry weather overflow (mg/L)	204	39	250	52	11

Annual discharge effluent loads are key compliance parameters in the EPL's. Discharge loads are reported annually to the EPA for compliance purposes. In recent times, emphasis has shifted towards more stringent load limits.

The total discharge effluent load from a plant is defined as the combined loads from all the discrete discharge effluent streams – typically this is just the main, periodically monitored combined plant effluent stream, but there can be multiple other discharge effluent streams included a plant bypass stream.

For the purposes of reporting against the EPL, annual discharge effluent load calculations should be done as per the methodology described in the procedure ***Reporting of STS Loads and Fee*** (BMIS: MP0012).

The annual discharge load from any discharge point is derived by the following (as adapted from MP0012):

Annual discharge load calculation for reporting against EPL:

$$\boldsymbol{L_{a,total} = L_{a,1} + L_{a,2} + \ldots + L_{a,n}}$$

$$\boldsymbol{L_{a,n} = C_{fw,n} \times V_{a,n}}$$

Where:

$L_{a,n}$ = annual load of analyte discharged at point 'n' (kg)

V_a = total annual discharged volume from point 'n' (ML)

C_{fw} = flow weighted average concentration (mg/L) at point 'n', such that

$$\boldsymbol{C_{fw} = \frac{\sum[C_1V_1 + C_2V_2 + \ldots + C_nV_n]}{\sum[V_1 + V_2 + \ldots + V_n]}}$$

Where:

C_n = measured concentration of analyte on sample day 'n' for quality monitored streams, or the applicable emission factor for an unmonitored bypass stream (mg/L)

V_n = discharged volume on sample day 'n' (ML)

The above methodology is applicable to reported historic performance, however it is highly complex to estimate future performance using this methodology. This is due to the variable performance which is experienced under different events, as well as the probabilistic nature of sampling and weather events. For planning purposes, annual load limit performance can be estimated using simplified methodology in the first instance.

Annual discharge load estimate methodology 1:

Applicable when no significant change in configuration or level of treatment is expected.

$$L_a = F_{WW} \times (C_{median} \times ADWF \times 365)$$

Where:

L_a = annual load of analyte discharged (kg)

ADWF = average dry weather flow (ML/d)

C_{median} = median concentration (mg/L) at main discharge point (i.e. not bypass)

F_{WW} = wet weather load factor – typically between 1.05 and 1.20

Note on F_{WW}...

F_{WW} can be estimated by reviewing plant performance data. It is recommended that at least five years of effluent data and licence load reporting data should be examined to ensure a range of 'wet' and 'dry' years accounted for. F_{WW} can be estimated based on determining the average wet weather factor over past years such that:

$$F_{WW} = \left(\frac{L_{reported,y1}}{C_{median,y1} \times ADWF_{y1}} + \frac{L_{reported,y2}}{C_{median,y2} \times ADWF_{y2}} + \ldots + \frac{L_{reported,yn}}{C_{median,yn} \times ADWF_{yn}}\right) / (365 \times n)$$

Annual discharge load estimate methodology 2:

Applicable when change in configuration or level of treatment is expected, or for new treatment plants with no historic performance data for reference.

$$L_a = L_{a,dry} + L_{a,wet}$$

Where:

L_a = annual load of analyte discharged (kg)

$L_{a,dry}$ = annual load of analyte discharged in dry weather conditions (kg)

$L_{a,wet}$ = annual load of analyte discharged from bypass streams (kg)

$$L_{a,dry} = C_{dry} \times V_{a,dry}$$

$$L_{a,wet} = C_{wet} \times V_{a,wet}$$

Where:

C_{dry} = annual load of analyte discharged in dry weather conditions (kg)

$V_{a,dry}$ = estimated annual dry weather discharge volume (i.e. sum of daily volumes less <3xADWF or similar, prorated for growth as required)

C_{wet} = wet weather bypassed concentration (emission factors may be used in lieu of measured values)

$V_{a,dry}$ = estimated annual wet weather bypassed volume (i.e. sum of daily volume component >3xADWF or similar, prorated for growth as required)

3.3.4.1.2 Recycled water (reclaimed effluent) product outcomes

Recycled water can be utilised for site service water or for off-site re-use. The recycled water product outcomes are driven by the end-use requirements:

- For recycled water, refer to the Australian Guidelines for Water Recycling (Link).
- For industrial purposes, engage with the industrial businesses that requires the effluent.
- For on-site service water requirements, refer to the equipment supplier for the required product standard.

When developing the Basis of Planning for the reclaimed effluent, the following information must be included:

- Product outcomes or scheme-specific water quality parameters required for the reclaimed effluent
- Management of ‘off-spec’ reclaimed effluent such as return streams or discharge with treated effluent
- Management of risks and impact if the demand for reclaimed effluent decreases or is removed, including any demand projections
- Scheme-specific recycled water management plans such as monitoring and reporting requirements, risk assessments etc.

When developing the plant configuration to achieve recycled water product outcomes, consider the log removal value (LRV) of the overall treatment train and its measurements against recycled water guidelines. The LRV is proven once the system is installed. However, LRV’s based on external references can be used to estimate the LRV capabilities of the selected treatment train before it is installed. Further details are provided in Section 4.5.11.

IPART has a framework for pricing considerations for recycled water, refer to Section 5.2 for further details.

3.3.4.2 Biosolids product outcomes

3.3.4.2.1 Biosolids product outcomes

Biosolids are the residual organic product from the treatment of wastewater sludges (primary sludge, waste activated sludge and tertiary sludge). The primary end use of Sydney Water’s biosolids are land application in broad acre agriculture, forestry or mine site rehabilitation and composting. The value of biosolids is a function of its constituents namely: nutrients, organic content, trace matter and water, which can improve the land on which it is applied.

Biosolids must be stored, treated, processed, classified, transported and disposed in accordance with the *NSW Biosolids Guidelines,* or as otherwise approved in writing by the EPA. The biosolids product outcomes as per the *NSW Biosolids Guidelines* (Link) aim to promote sustainable use of biosolids under the following principles:

- Protection of public and environmental health depends on implementing a preventive risk management approach.
- Application of preventive measures and requirements for use of biosolids should be commensurate with the intended uses.
- Application of multiple barrier approach to ensure sufficient barriers to protect safe biosolids-use should any single barrier fail.

3.3.4.2.2 Sydney Water defined outcomes and strategies

Further to the regulated guidelines, Sydney Water has a defined *Biosolids Solids Strategy* which assigns a biosolids quality score (BQS) to the biosolids produced based on odour potential and consistency (refer to Bioresources Masterplan 2018 (Link) for the history of the development of this strategy). The scores are ranked from 1 to 4, with 1 being the best quality product in terms of odour and stickiness and 4 being the worst. Based on the BQA score, the Biosolids Solids Strategy gives guidance on the management and disposal of the biosolids to ensure that the product is correctly matched to end-use requirements and market demands.

The Biosolids Strategy should be used to select an appropriate biosolids product outcome (i.e. BQS). However, when doing so, the following must be considered:

- The BQS model uses site variables such as conveyer length, SRT and dewatering technology to estimate the BQS of a sludge. It does this by using empirical relationships between historic qualitative sludge scores and historic site conditions.
- Based on the above, the BQS model is therefore a quantitative scoring model which uses model parameters determined from ***qualitative assessments*** by operations staff and contractors.
- The qualitative assessment includes scoring for odour potential (sniff test), biosolids consistency (visual check), and other factors that can impact on community acceptance – these parameters are ***site-sensitive***
- Site-sensitivity is based on a weighting that includes distance to nearest occupied dwelling, nearest residential zone, previous odour complaints and community culture
- The BQS score is indicative only and the model BQS may be superseded by onsite qualitative assessments, the latter should always precedence due to site-sensitivity.

In addition to the above qualitative requirements, there is a concentration threshold of 15% dry solids (or total solids residual) on the transporting of dewatered biosolids. Biosolids with TSR content less than this threshold may not be able to be out loaded due to the risk of loss of containment from the transporting truck during transfer.

3.3.4.3 Biogas and off-gas outcomes

3.3.4.3.1 Biogas

Biogas is product of anaerobic digestion, with a combustible component in the form of methane gas. This makes it a useful resource for heating applications (i.e. digester heating) and also for cogeneration to create electricity. Currently, Biogas that is excess to heating demand or engine capacity is flared in a waste gas burner to mitigate any environmental impact of its release. Looking forward, new projects should consider the relative value of gas storage or gas purification for supply to the grid as alternatives to conventional cogeneration.

The biogas product outcomes are developed in accordance to the process requirements, e.g. cogeneration. The application of cogeneration is driven by the Energy Master Plan (Link) which sets the goals for energy recovery and energy efficiency for Sydney Water assets and facilities. This will affect the requirements for biogas production and the configuration of the biosolids processing and cogeneration.

3.3.4.3.2 Off-gas odours and greenhouse gases

Off-gases are gaseous products released from treatment processes and products. Historic and current focus is predominately focused on the odour and corrosion causing potential of these gases, and safety aspects to them. It is expected that more emphasis will be placed on off-gases moving forward, especially relating to greenhouse gas emissions.

The product outcomes for off-gas odours should be developed in accordance to the type of off-gas, availability of ventilation systems, odour contours and wind flow characteristics at the facility. Furthermore, the product outcomes should also be linked to the risk of odour complaints, e.g. facilities in close proximity to the local community.

For the products basis, the level of detail for the off-gas product outcome will depend on the level of planning and type of project. Higher levels of planning should include the approach for the management of the off-gas odours, whereas detailed planning, should include detailed product outcomes.

The product outcomes for greenhouse gases should be developed in accordance with Sydney Water’s Environment Plan and/or Greenhouse Gas targets.

3.3.4.4 Grit and screenings product outcomes

The product outcomes for grit and screenings should be developed in accordance to the following criteria:

- Expected capture rates at the facility rate and type of grit and screening technology
- Handling and disposal processes for the grit and screenings (to improve ease of storage and removal)
- Separate out loading and storage facilities for grit and screenings
- Out loaded screening total solids residue (TSR, i.e. dryness) of >35%
- Out loaded grit TSR of >90%
- Both products should be well washed to removal organic compounds (reduced odour potential)

Some recycling markets exist for grit products. Further product specifications may apply to these opportunities.

3.3.4.5 Other product outcomes

Other product outcomes should be developed in accordance to regulatory bodies, guidelines, and/or end-use requirements.

3.3.5 Identify potential step-changes in treatment product outcomes

Product outcomes can evolve over time due to changes in corporate or regulatory positions. It is important that current and future product outcomes are identified and developed holistically as they have a strong influence on plant configuration, site layout and technology selection.

The identification of step-changes in the treatment product outcomes is an extension of the identification of current and future treatment products activity. Under this scenario, the type of treatment products remains the same; however, their respective product specifications are changed due to different end-use or regulatory requirements.

It is important to consider any known or expected future product outcome requirements, future positions on servicing objectives and asset-level changes at the treatment facility as these can result in step-changes to product outcomes.

Table 3-4 Examples of changes to treatment product outcomes

Example scenario	Treatment Product Affected
Changes to EPL, EIS, Waterway Guidelines, concentration limits, load limits	Discharged effluent product
Changes to end use of reclaimed effluent, recycled water guidelines, water supply and load diversion schemes, storage and supply networks.	Reclaimed effluent product
Changes to Biosolids Guidelines (EPA), SW biosolids strategy end use type, side stream nutrient load considerations	Biosolids product Biogas product
Changes to off gas strategies or legislations, e.g. greenhouse gas emissions	Off gas product

3.3.6 Review of treatment product outcomes against project outcomes

3.3.6.1 Alignment with project outcomes with servicing objectives and corporate strategies

The product outcomes should align with the servicing objectives and project outcomes. This is to ensure that the objectives of *Protection of Public Health, Protection of the Environment, Corporate objectives, and Regional Servicing Objectives* are thoroughly achieved.

When developing the Basis of Planning, it is important to review the project outcomes against servicing objectives and corporate strategies. Conflicting objectives will result in tension between product pathways. A common example is the specification for a high-quality effluent product but a low energy treatment system.

The following activities can be used to review project outcomes:

- Ensure project objectives are clear and that their hierarchy is understood; for example: product quality objectives are prioritised before energy efficiency is optimised to meet that product outcome.
- Check that that scope of work is fully covered and that all the product pathways are considered.
- At the facility level, consider all upstream and downstream processes of the treatment asset/facility as changes to one product pathway can affect others.

3.3.6.2 Alignment with best practices and available treatment technology

Product outcomes should be aligned with industry best practices and available treatment technology. This is to ensure that the product outcomes are achievable in practice, i.e. product outcomes should not exceed the abilities of current treatment technologies. However, this should not prejudice the quality of product outcomes as demand for higher-quality product outcomes is effective in driving technology, research and development.

This alignment should also extend to sampling and monitoring systems in which the product outcomes are quantitated, particularly for emerging contaminants or difficult to measure contaminants.

The following recommendations can be utilised to ensure this alignment:

- Conduct literature reviews and examine case studies before specifying technologies and product outcomes
- Engage with technology suppliers or involve technology suppliers to understand the achievable product outcomes
- Engage with laboratories and suppliers for monitoring systems to understand the limits of measurement

3.3.6.3 Alignment with design scenarios and locality considerations

Product outcomes should be aligned with an understanding of:

- design scenarios and load conditions,
- site variables and constraints, and
- approaches to plant configuration.

These variables are usually considered in more detail as projects progress into detailed planning stages. Understanding of these variables will greatly assist in the formulation of the planning approaches such as performance monitoring plans, scope of work and analysis.

Any concerns relating to the feasibility of achieving prescribed product outcomes should be addressed at the earliest possible moment.

3.3.7 Checklist for treatment product outcomes

Table 3-5 Checklist for treatment product outcomes

Checklist	
Treatment product pathways and treatment products	Current treatment pathways and products have been identified
	Future treatment pathways and products have been identified
	For the above, assess the risk and sensitivity of any future changes
Product Outcomes	Effluent product outcomes have been developed in line with EPL and/or end-use guidelines
	Biosolids product outcomes have been developed in line with EPA Biosolids Guidelines
	Biogas product outcomes have been developed in line with Energy Master Plan, if anaerobic process
	Grit and screenings and other products have been developed in line with their respective regulations, guidelines, and end-use requirements
	Product outcomes align with customer expectations and or customer representatives
Potential step-changes	Future step-changes in regulations, guidelines, and end-use requirements have been identified
	Future step-changes have been considered when developing the product outcomes
	Changes to product outcomes align with customer expectations and or customer representatives
Alignment of product outcomes with project outcomes	Product outcomes align with strategic drivers, servicing objectives and project outcomes
	Competing product outcomes have been identified and prioritised according the strategic objectives and project outcomes
	Product outcomes can be achieved considering the current best practices and available treatment technologies
	Product outcomes can be achieved considering the design scenarios, load conditions, and locality considerations
General	Products Basis has been developed and the following have been included:
	• List or process flow diagram showing product pathways and treatment products (current and future)
	• General approach or reference documents utilised for the development of the product outcomes
	• Details of any conflicting product outcomes and the reasoning for the tension
	• Details of how conflicting product outcomes are managed or prioritised with respect to each other and the servicing objectives and project outcomes

3.4 Inputs identification and analysis

3.4.1 General approach for inputs identification and analysis

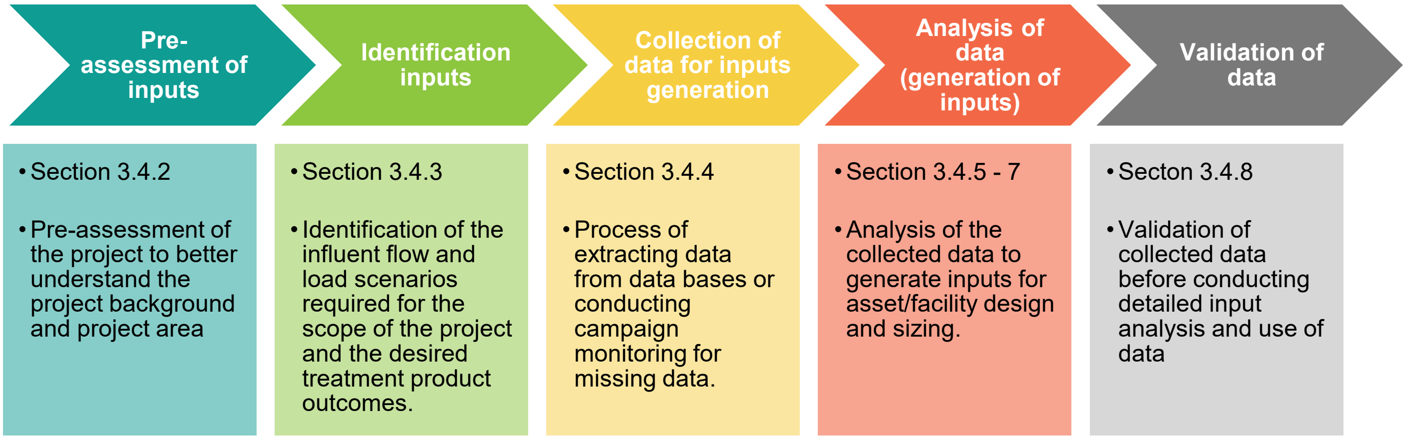
For wastewater treatment assets, these inputs can be categorised into two distinct categories:

i) “***Influent Specifications***” refers to the flow and composition of the influent wastewater as determined by the nature and size of the catchment and network system. Influent specifications are critical for planning and design of treatment assets and have a plant-wide impact on the design and operation of process units.

ii) ***“Plant Process Data”*** refers to the flow and composition of treatment products, generated by a process unit, to be utilised as input for planning/design of the plant or another process unit. Examples include primary and secondary sludge flows, biosolids volume, biogas flow, water quality of effluent and return streams etc.

A key difference between influent specifications and plant process data is that the measurement of the latter is a consequence of the influent specifications, process operation parameters and site variables. Influent specifications, in most cases, is not affected by the plant process data.

For both categories of inputs, it is suggested to follow the approach shown below for holistic identification, collection, validation and analysis of the data to generate a robust set of inputs for project related activities,



- Section 3.4.2
- Pre-assessment of the project to better understand the project background and project area

- Section 3.4.3
- Identification of the influent flow and load scenarios required for the scope of the project and the desired treatment product outcomes.

- Section 3.4.4
- Process of extracting data from data bases or conducting campaign monitoring for missing data.

- Section 3.4.5 - 7
- Analysis of the collected data to generate inputs for asset/facility design and sizing.

- Secton 3.4.8
- Validation of collected data before conducting detailed input analysis and use of data

Figure 3-5 Methodology of inputs identification and analysis

3.4.1.1 Flow data collection and analysis

A general methodology for the collection and analysis of flow data is provided in Figure 3-6

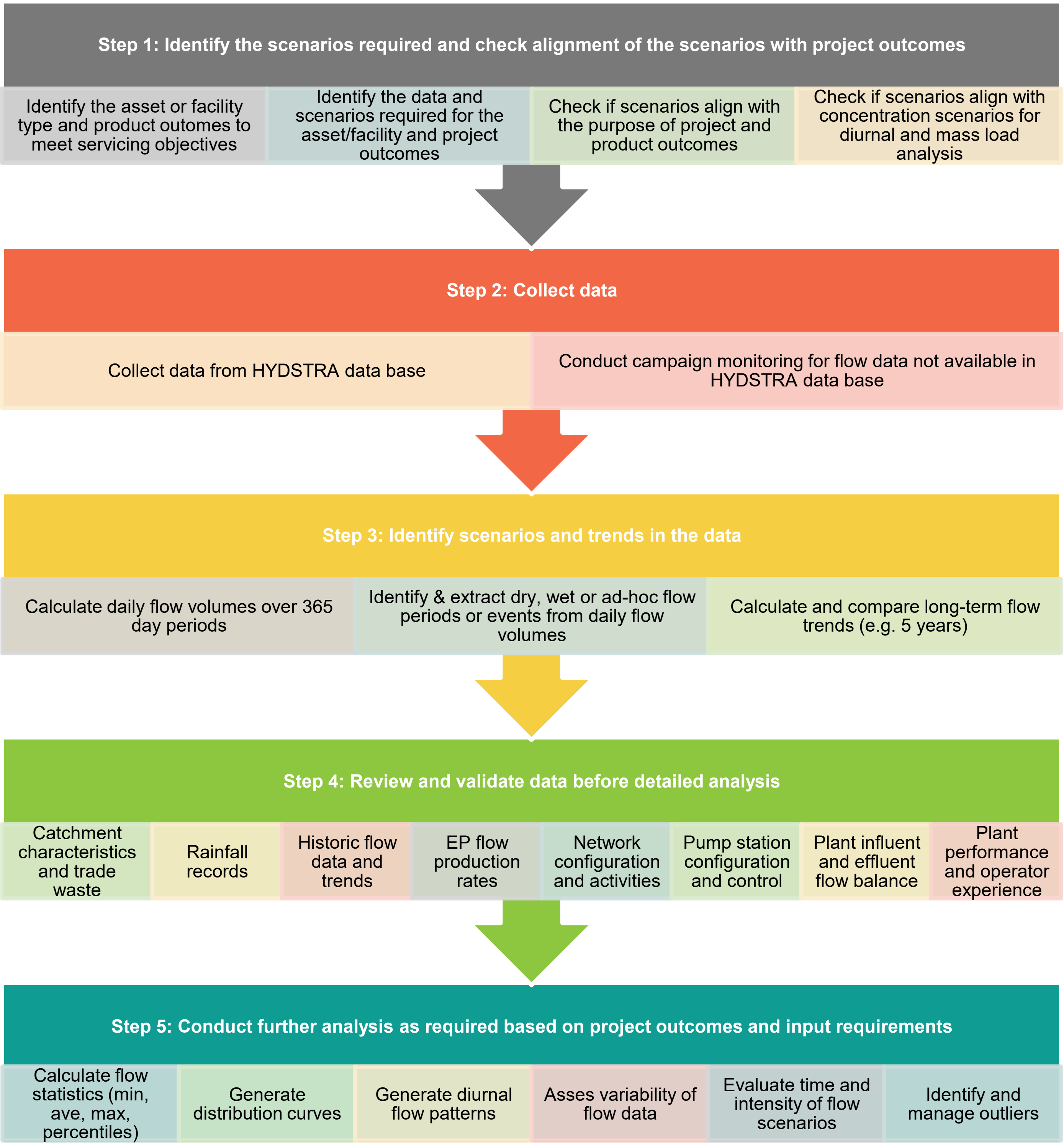


Figure 3-6 Methodology for flow data collection and analysis

3.4.1.2 Concentration and load data collection and analysis

A general methodology for the collection and analysis of concentration and load data is provided in Figure 3-7.

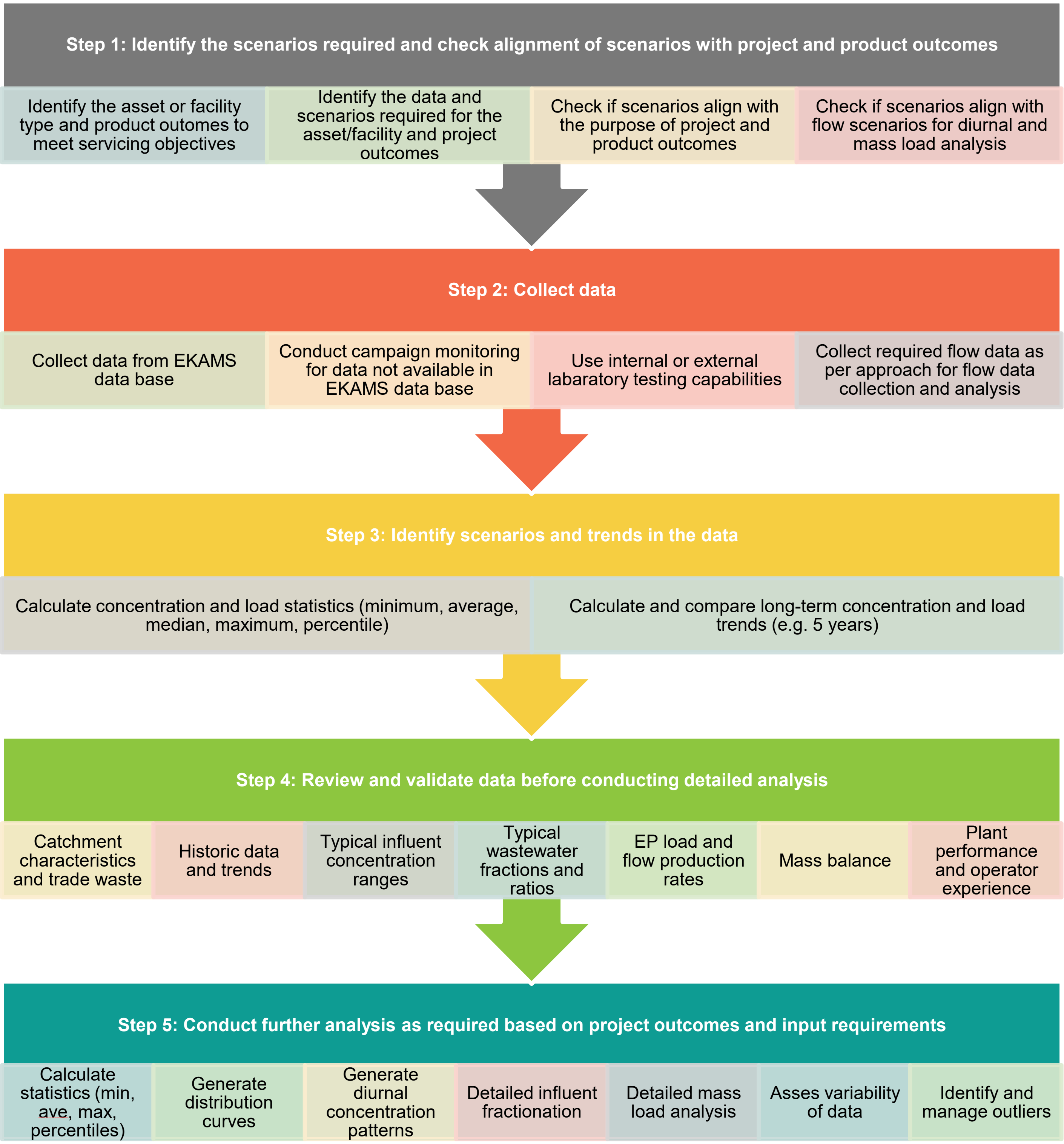


Figure 3-7 Methodology for concentration data collection and analysis

3.4.2 Pre-assessment of inputs

A clear alignment of the treatment inputs with the project methodology should be demonstrated before conducting any data collection or analysis activities. This is to ensure that the project methodology is not prejudiced to fail.

The following list of pre-assessment and initialisation activities can be included as part of the identification and analysis of inputs process.

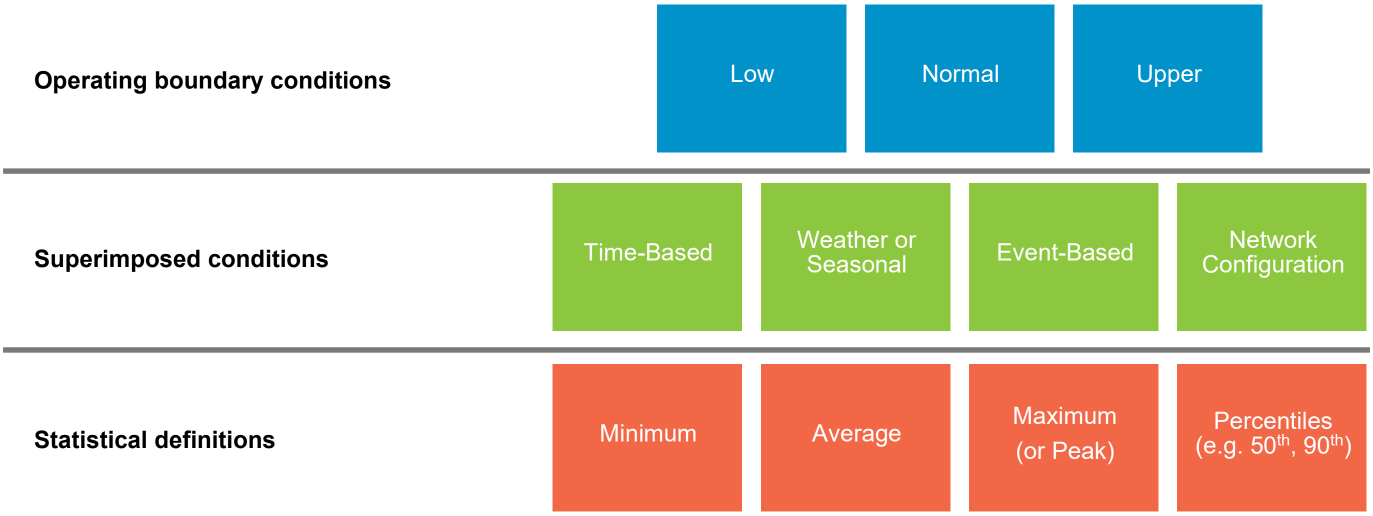
- Understanding of the project background and project area through:
  - Literature reviews
  - Site investigations, e.g. site visits, engagement with the operations team,
- Review of planning artefacts such as:
  - *Growth Servicing Investment Plans* (GSIPs)
  - *Process Capability Assessments* (PCAs)
  - network related planning artefacts
  - process specific assessments and investigations
  - past design reports and drawings
- Pre-identification of wastewater sources including review and referencing of:
  - catchment portioning of flow
  - trade waste data base
  - wastewater or sludge transfers
  - network related flows
- Identify proposed investigations and assessments required in project and then catalogue data needs before being data collection – data needs should consider range of analytes, duration of monitoring, frequency of sampling, and resolution of data. If process modelling is to be undertaken, key input variables including inter and intra process unit calibration point should be collected with resolution fit for modelling type (i.e. steady state vs dynamic).
- Further to the above, include pre-identification of flow and load scenarios required for the calculation methodologies. This will improve the efficiency of the data collection and reduce the repeat of data collection activities. It is noted that initial data reviews may themselves trigger further investigation as the planner or engineer identify certain previously unidentified factors.
- Early engagement of project stakeholders, internal or external to Sydney Water to provide any inputs to the Basis of Planning, example: plant operators.
- For any monitoring requirements, consider the lead times required for the engagement of external stakeholders and monitoring and testing services. Further details are provided in Section 3.4.4.5.

3.4.3 Identification of input scenarios

3.4.3.1 Input scenarios matrix

The methodology for the identification of the influent flow and load scenarios shall involve assessing the permutations of the operating boundary conditions of the treatment asset, superimposed flow and load conditions due to network or climate events, and statistical outputs of the influent data.

A matrix illustrating the permutations is shown in Figure 3-8.



Operating boundary conditions	Low	Normal	Upper	
Superimposed conditions	Time-Based	Weather or Seasonal	Event-Based	Network Configuration
Statistical definitions	Minimum	Average	Maximum (or Peak)	Percentiles (e.g. 50th, 90th)

Figure 3-8 Scenario identifications matrix

3.4.3.2 Operating boundary conditions

The influent flow and load scenarios will depend on the scope of the project and the required product outcomes of the treatment asset. In most cases, there are three flow and load boundary conditions to be considered for planning or design activities. These three are:

1. **Low** flow or load for when the treatment asset operates at its lowest operating boundary condition
2. **Normal** flow or load for when the asset operates at its typical operating boundary condition
3. **Upper** flow or load for when the asset operates at its highest operating boundary condition, typically the maximum or 90th percentile flow or load

The three boundary conditions are typically aligned to the operational range of the treatment asset or system and can be used to size infrastructure and process requirements.

Once the boundary conditions relevant to the treatment asset(s) or system have been identified, the flow or load scenarios assigned to the boundary conditions should be quantified based on either statistical outputs of the influent data or imposed operating conditions. The latter can be due to required operating modes or imposed from upstream processes – such as flow range limitations to secondary reactors at settled sewage plants or flow to recycled water assets.

For certain process units or systems, a greater emphasis is placed on specific types of analytes and load scenarios. Therefore, when collecting and analysing flow and concentration data, with the purpose of generating an input mass load or influent fractionation, a pre-understanding of the scope of work and process area is required. Examples of such considerations are presented in Table 3-6.

Table 3-6 Examples of flow and load scenarios for process units

Process Area	Flow	Load	Example of Scenarios
Preliminary Treatment	Maximum	N/A	Peak hydraulic flow rate for sizing of screening and grit removal
Primary Treatment	Average, Maximum	COD, TSS	Peak hydraulic flow rate for sizing primary treatment tanks Average dry weather COD and TSS load for primary sludge load to biosolids processing multiplied by peak week or peak month factor
Secondary Treatment	Average, Maximum	COD, TN, TP, TSS	Peak dry weather COD, TP and TN load under high and low temperature conditions for bioreactor design Peak hydraulic flow rate and corresponding bioreactor concentration for solids-liquid separation system design Average dry weather COD and TSS load for WAS load to biosolids processing under low temperature conditions
Tertiary Treatment	Maximum	COD, TN, TP, TSS	Peak hydraulic flow rate for sizing of tertiary treatment
Biosolids Treatment	Average, Maximum	COD, TSS	Peak week or peak month primary sludge load generated by primary treatment under average dry weather conditions Average WAS load generated by secondary treatment under low temperature conditions Note: impact of available plant operating hours on unit capacity sizing

3.4.3.3 Superimposed conditions

Superimposed conditions refer to conditions in the treatment system which create the lower, normal, and upper boundary conditions. There are four categories to consider:

- Time-based factors where flow or load conditions change over time, a notable example is weekday vs weekend diurnal flows and loads.
- Weather and seasonal trends where flow and load conditions change according to weather or season. For example, high flows during rainfall events or transient/holiday flows.
- Event-based factors where flow or load conditions change due to discrete events occurring in either the catchment or at the facility level.
- Network events where flow or load conditions change according to network operations.

It is important to consider these superimposed conditions, as low, normal, and peak **flow** scenarios may not necessarily coincide with the low, normal, and peak **load** scenarios. For example, the peak load to a treatment plant may occur during a holiday event whereas the peak flow may occur during wet weather scenario. Likewise, in instances of trade waste loading events or inter system transfers, load and flow patterns may not align. Moreover, when assessing historic data trends, any of the above events can be a reason for uncommon peaks or troughs in data records.

Some examples of the superimposed conditions which should be considered when determining the low, normal, and peak flow/load scenarios, are listed below:

Table 3-7 Superimposed network and climate conditions for planning of wastewater treatment assets

Superimposed Conditions	Definition	Examples of Superimposed Conditions	
Time-based conditions	A flow or load condition that is dependent on the timing of the event	Weekday	Weekday occurrence, Monday to Friday (See Figure 3-16 for example)
		Weekend	Weekend occurrence, Saturday to Sunday
		Sustained	A flow or load conditions that is sustained for a set period
		Growth / Deferral	Impact of growth or deferral on the design scenario, i.e. future loading conditions. Can also include change in loading conditions due to project delivery timelines.
Weather and seasonal conditions	A flow or load condition that is affected by the climate conditions in the network	Dry weather	Period at which the rainfall occurring in the catchment does not result in significant stormwater infiltration, typically minimum 2-week period in which there is no rainfall. It is the base flows in the network as generated by network customers. Dry weather flows are also called base flows and are typically representative of the flows generated by the customers within the wastewater catchment. However, there may be minor infiltration flows due to leakages in the system.
		Wet weather	Period at which the rainfall occurring in the catchment results in significant stormwater infiltration and hence an increase in base flows, typically >10mm on single day. The increase in flow is typically due to stormwater infiltration due to leakages in the network or backflows from overflow points. Examples of leakages include at manholes, pipe joints, or defective pipes. Influent load is not expected to increase during wet weather conditions, however, plants may observe an “slug loads” due to the flushing effect of the network. Example 1 and Figure 3-9 illustrates the impact on diurnal flows due to dry and wet weather conditions.
		Seasonal Temperature	Period at which the wastewater exhibits an increase or decrease in the average water temperature due to seasonal impacts in the catchment.
		Abnormal	Special weather or climate conditions affecting the network that are not considered abnormal for example drought or water shortage conditions.
Event-based conditions	Event-based impacts which occur in the network or at the plant	Ad-hoc events	An irregular occurrence resulting in temporary increase or decrease in flow or load, e.g. unplanned network transfer, network maintenance, chemical dosing or flushing of network.
		Recurring events	A regular occurrence resulting in temporary increase of decrease in flow or load, e.g. a school holiday, peak tourism season, septage tank discharge.
		Change in servicing availability	A change in servicing availability resulting in induced flow or load conditions at the plant or on other plants, for example changes in the availability of the number of duty equipment or processes.
Network configuration and planning conditions	A flow or load condition created by the configuration of	Gravity vs pumped network	Gravity flow and pressurised flow networks have different flow patterns. Gravity flow networks generally have a smoother flow curve whereas pumped networks are affected by the configuration and control of the pump stations.

Superimposed Conditions	Definition	Examples of Superimposed Conditions	
	the network including network activities and planning		Configuration and control of the pump station includes the number of pumps in the network and the control of the pumps. Example 2 and Figure 3-10 below is a case study example of pumped network impacts.
		Network activities	Network activities can affect the flow and wastewater characteristics. Examples of network activities include flushing and maintenance, chemical dosing (for odour and corrosion control).
		Network planning	Future network choices such as decentralized treatment, diversions, and new connections

Example 1:

Wastewater flows in the network vary significantly depending on the time of day and rainfall conditions. During dry weather conditions wastewater flows are produced based on wastewater generated from various customers in the wastewater catchment. During wet weather conditions, the where there is rainfall in the wastewater catchment, the network experiences infiltration due to leak points. This results in higher wastewater flows during rainfall periods, correlating with the intensity and length of the rainfall. The higher wastewater flow will also result in dilution of the wastewater concentration. The influent load to the treatment plant is largely be unchanged, although there may be "slug" loads due to the high flow rates causing a network flushing effect.

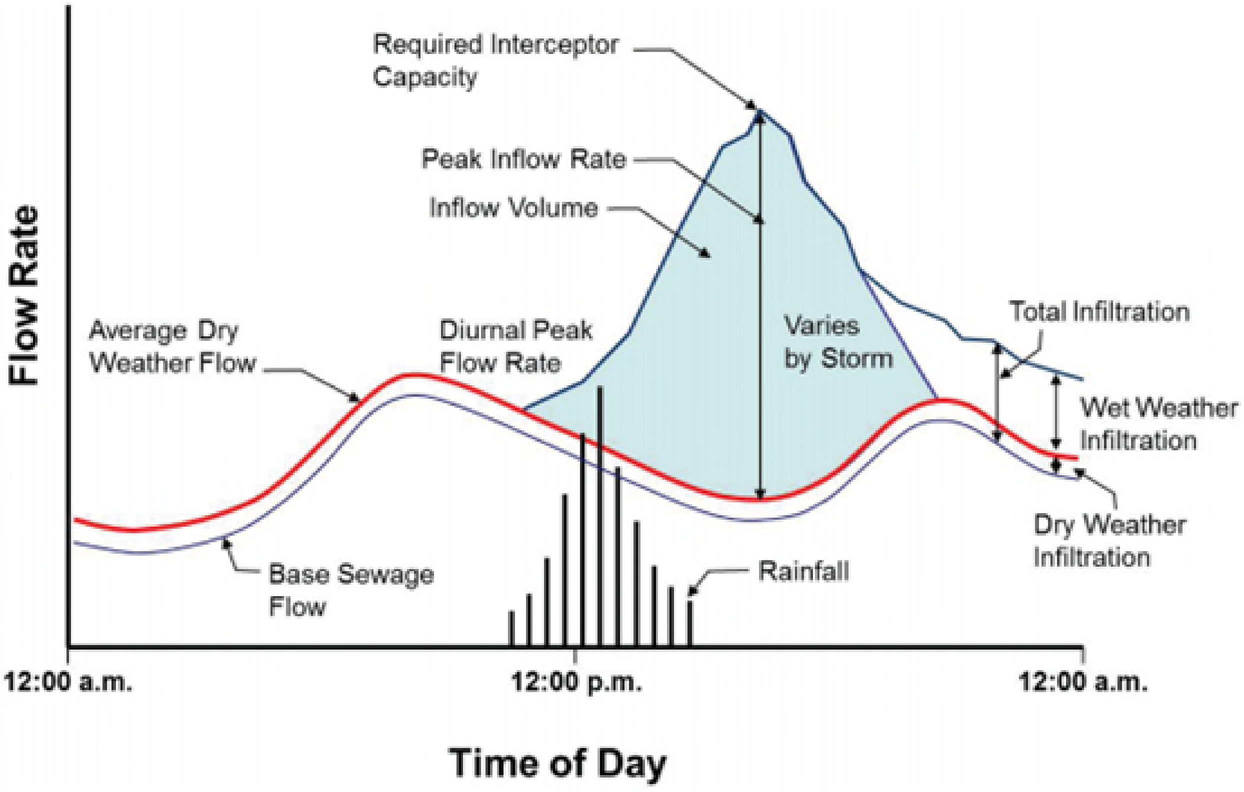


Figure 3-9 Impact of wet weather of wastewater diurnal pattern

Source: B&V Project No. 187976, 2015 WASTEWATER COLLECTION SYSTEM MASTER PLAN

Example 2:

Network design such as pumped versus gravity flow design, and pump station sizing and control philosophy. This is important as the arrangement and control of pump stations can lead to inaccuracies in flow and concentration data collection and hence misinterpretation of data. An example as shown in Figure 3-10, shows three influent pump stations with different pump timing which needs to be considered when developing an influent monitoring plan.

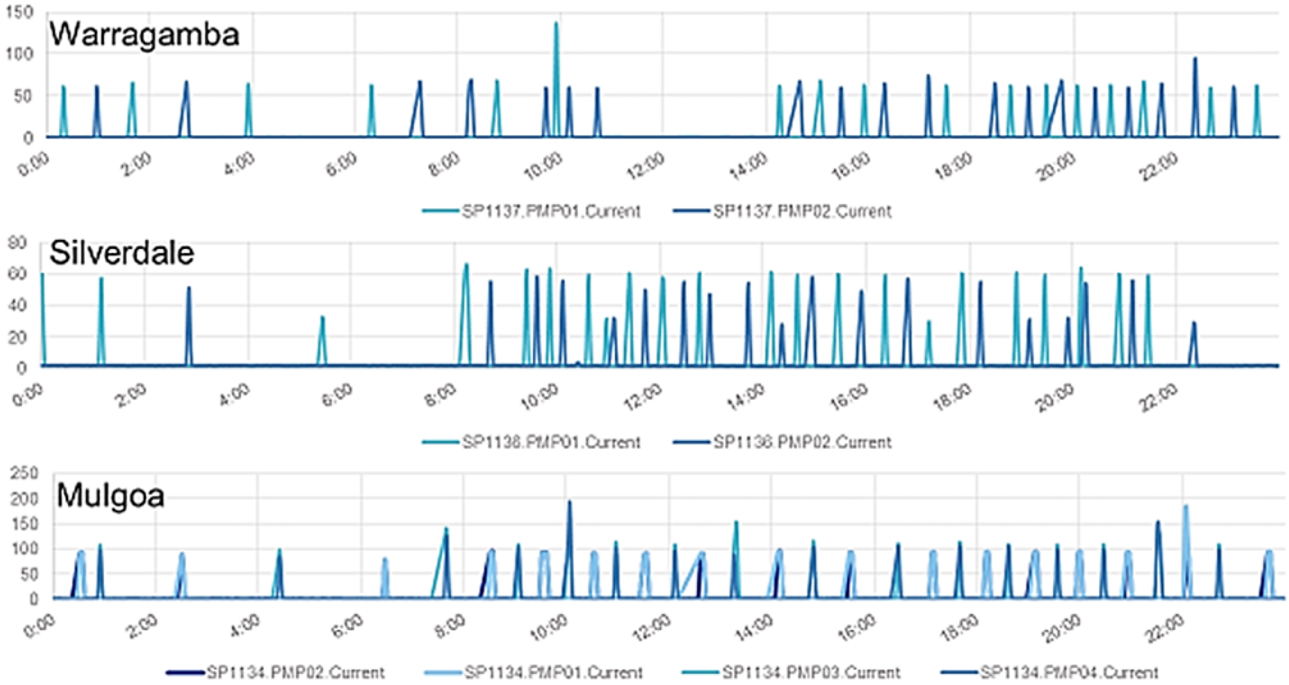


Figure 3-10 Example of network impact of influent flow

3.4.3.4 Alignment of input scenarios with project outcomes

It is important that the input scenarios for flow, load, or plant outputs align with project outcomes. For example, if the product outcome requires 90th percentile compliance then a 90th percentile input condition should be included as an input scenario.

Furthermore, it is important that the type of input data is suitable for the identified project methodology. For example, statistical averages and percentile distributions of input load is more relevant for the assessment of biological treatment systems as to the performance of these processes are driven load rather than flow. Whereas peak flow data is more relevant for hydraulically limiting systems, such as grit removal and screening equipment.

It is therefore important that the level of effort in input data collection aligns with project outcomes and the scope of work. A general procedure for ensuring this alignment is provided in Figure 3-11 and examples of data requirements for specific types of projects are provided in Table 3-8.

Likewise, the use of historical data versus modelled forecast inputs should be considered based on project scope and objective. Review of existing facility demands and short-term future considerations may be well based in recent measured input data, whereas future plant inputs should reference modelled forecast input data – this particularly applies to influent flows and flow profiles.3

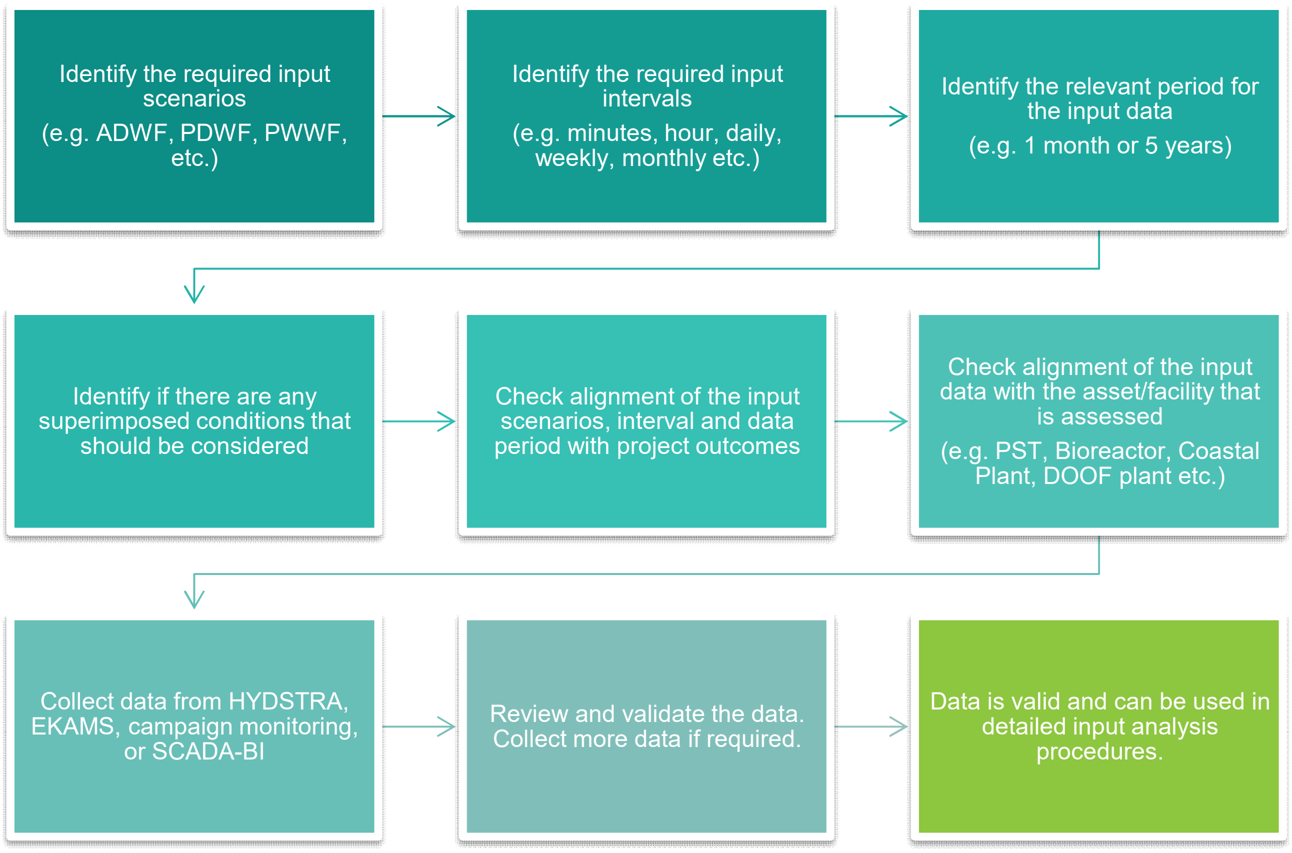


Figure 3-11 Activity sequence for the identification of inputs

Table 3-8 Examples of data requirements for specific types of projects

Examples	Data requirements
Aeration equipment upgrade	Extensive influent and bioreactor data are needed to determine minimum, average, and peak oxygen demand. • Influent COD, TN, Ammonia concentrations (full characterisation including distribution and diurnal profile, and projected concentration in relation to EP generation rates) • Influent flow rate (as per influent concentrations, but with a focus on ADWF and PDWF) • Bioreactor MLSS, waste volume and mass (for SRT calculations) • Water temperature • Local site data (humidity, air temperature, elevation etc.)
Biosolids upgrade	Extensive solids data is required to determine minimum, average, and peak solids demand • Primary and waste activated sludge flows and mass rates • Sludge characteristics (e.g. VSS:TSS) • Peak factors (may require assessment of liquid stream to determine future sludge generation rates)
Growth assessment for development of a long-term servicing strategy	Influent data will focus on analytes which have a significant impact on treatment capacity, rather than full characterisation. However, internal plant data will be required. • Influent COD, TN, TP concentrations (distribution only) • Influent flow rate (distribution only, but including PWWF)

3.4.4 Input data collection

3.4.4.1 General considerations for data collection

When collecting data from HYDSTRA, EKAMS, campaign monitoring, or SCADA-BI, consideration must be given to the location of the sampling, the instrument or technology used for the sampling, the type of sampling method for manual sampling, and the monitoring interval. Further details regarding are provided in Appendix 2.

3.4.4.2 HYDSTRA flow data

The HYDSTRA data base contains the flow data captured from flow measurement devices located at the various Sydney Water sites. The data base allows different permutations of interval and period for extraction of data.

In most cases, the following methodology is provided as a starting point for extraction of the data:

- Total daily flow (i.e. total daily flow) should be used to identify flow scenarios, weather conditions, seasonal trends, and ad-hoc or recurring flow events.
- The period for daily flow extraction will be project dependant (e.g. monthly or yearly).
- Total minute flow (or another suitable small interval) should be used to identify diurnal trends including weekday and weekend variations.

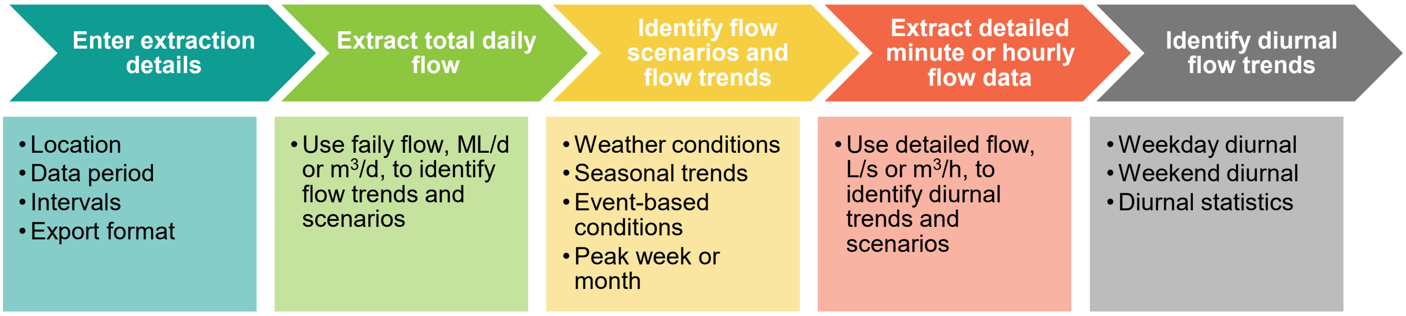


Figure 3-12 General approach for the extraction of flow data from HYDSTRA

3.4.4.3 EKAMS concentration data

The EKAMS data base contains the concentration data captured from the monitoring stations located at the various Sydney Water sites. When extracting the data consider the frequency and type of the data.

As of July 2018, influent monitoring is conducted every six days at Sydney Water's dry weather wastewater treatment plants. A reduced suite is analysed every six days and once a month a comprehensive suite is undertaken.

Best attempts have been made to ensure plant returns and "double counting" are excluded from EKAMS concentration data; however, a number of WWTPs and WRPs do not have pristine data sets. EKAMS data should always be reviewed and validated before used in planning. Methodologies for review and validation are provided in Section 3.4.8.

3.4.4.4 SCADA-BI (plant monitoring data)

SCADA-BI should be used to extract plant monitoring data. The general approach for the data extraction is provided in Figure 3-13. Plant monitoring data can be used to in planning or design projects that involve existing treatment assets.

It is also suitable for use in planning or design of new treatment assets, typically as a reference for specification of operational performance for similar or duplication of assets. However, when doing so, it is important to consider the asset's operating context, performance outputs can only be mimicked if the operating context is holistically similar. Examples of the types of plant monitoring data and the key operating contexts to considered when utilising the data is provided below in Table 3-9.

Figure 3-13 General approach for the extraction of plant monitoring data from SCADA-BI

Table 3-9 Typical plant monitoring outputs, considerations, and application of plant output data

Plant monitoring outputs	Example of plant monitoring data	Example applications of plant monitoring data	Considerations when assessing data (i.e. factors affecting data)
Raw wastewater data	• Raw wastewater concentrations • Raw wastewater flow rates	• Assessing total influent load to the plant • Calculating primary treatment efficiency and removal rates • Assessing catchment wastewater flow and composition trends	Presence of catchment transfers Current observations/trends in catchment generation behaviour Typical EP production rates
Settled wastewater data (primary effluent)	• Settled wastewater concentrations • Settled wastewater flow rates	• Assessing total influent load to the secondary treatment process • Calculating primary treatment efficiency and removal rates	Impact of HRT and primary treatment efficiency Composition of wastewater and impact on primary treatment efficiency
Primary sludge data	• Sludge concentrations • Sludge flow rates	• Calculating sludge load to biosolids processing	Impact of settling tank HRT and sludge production
Bioreactor performance data	• Dissolved oxygen • MLSS concentration • pH	• Calibrating process models, e.g. sludge yield • Assessing bioreactor performance	Impact of bioreactor operating parameters on performance (e.g. DO set-point, SRT, temperature)
Waste activated sludge data	• Sludge concentrations • Sludge flow rates	• Calculating sludge load to biosolids processing	Impact of bioreactor operating parameters on sludge production (e.g. SRT, temperature)
Biosolids processing data	• Digester feed concentration • Digester MLSS • Dewatering process outputs • Biogas production • Biosolids production	• Calibrating process modes, e.g. sludge and gas yield • Assessing biosolids processing performance • Assessing mechanical equipment performance	Impact of biosolids processing operating parameters on performance (e.g. HRT, SRT)
Return streams data	• Return streams flow rates	• Assessing mechanical equipment performance	Impact of equipment efficiency on return streams quality

3.4.4.5 Campaign monitoring

3.4.4.5.1 Purpose of campaign monitoring

Campaign monitoring can be conducted for data that does not exist in HYDSTRA, EKAMS or SCADA BI. This will involve the temporary installation of a flow meter, autosampler, manually collected grabs sample, or monitoring instrumentation.

Campaign monitoring can be conducted for internal plant streams and the approaches and guidelines provided in this section are suitable for internal streams.

There are two key considerations when conducting campaign monitoring that should be considered before conducting the campaign monitoring:

- Consider the level of effort in the campaign monitoring aligns with the project scope of work, the identified flow and load scenarios, and the required treatment product outcomes.
- Consider the time and location of the campaign monitoring to ensure alignment of the data with the required inputs for the project outcomes and methodologies.

Campaign monitoring can be an expensive exercise depending on the scope and duration of monitoring required. Effort should be invested in the formulation of the monitoring plan to ensure that value money is achieved – the collected data should add value to the planning or design activity. At the same time, where data is insufficient for a Planner/Engineer to hold an informed analytical position, it is the role of the Planner/Engineer to advocate for additional monitoring. While a monitoring campaign may typically cost between $20k to $50k, the decisions made on the information gained may have implications of significance a hundred or a thousand-fold the investment of the campaign.

3.4.4.5.2 Setup procedure for campaign monitoring

Sydney Water has dedicated monitoring, sample collection and analysis departments. These departments conduct monitoring for all of Sydney Water's operation. When composing a monitoring campaign, the following steps are recommended:

- Compose draft sampling plan including list of sample sites, type of sample (composite or grab), frequency and duration of samples, and analyte list for each sample site
- Contact Analysis & Reporting – fill out a request form and discuss timing and cost of monitoring campaign; if possible, **notify at least two to three months before required start date of monitoring**
- Meet with FS&T onsite – before finalising monitoring plan meet with FS&T and a plant operator onsite to do a walkthrough of the monitoring plan to confirm sample collection location, need for additional autosamplers, discuss any OHS concerns, discuss flow of concentration of any monitored streams due to operational changes through the day, and confirm sample location is representative of intended sampled stream
- Confirm budget with project manager
- Confirm sample plan and dates with Analysis and Reporting
- Analyte prioritisation and wet weather protocol – confirm wet weather procedure with FS&T and provide them with analyte priority list for limited volume samples
- Access data – data is typically accessed through a BI report set up by A&R, confirm with them a time of request the exact reporting method and who requires access
- Report monitoring data set – it is important to include monitoring campaign dataset in any artefacts created to ensure future access to the raw data for verification or future planning applications. Data sets can also be distributed to relevant stakeholders (e.g. plant operators).

3.4.4.6 Network models

For new treatment plants or plants with feed catchments with forecast changes to operating philosophy or with moderate to high rates of growth, it is recommended to source flow data (daily volumes and diurnal profiles) from network models. The modelled outputs will provide estimated flow profiles based on assumed rates or infiltration, pumping station configurations, customer types and distribution, and adopted sewerage technology. Future changes in network characteristics are predicted in the models, whereas current influent flow data will only convey the current catchment properties and will not be a good representation of the future catchment.

3.4.4.7 Reporting and management of input data and analysis outputs

When developing the Basis of Planning, raw data, inputs, and outputs must be presented in a consistent format with standardised symbols and units. This section provides guidelines on the best practise for reporting of the data, inputs, and outputs.

- Raw data refers to data that has not been structurally altered, i.e. all data points remain intact in their original format. Any editing or calculations utilising the raw data should not be done in the original raw data file.
- After collecting raw data, it is important that the data is stored and disseminated appropriately to relevant stakeholders. This is particularly important for data collected under campaign monitoring as this data is not often captured into EKAMS and thus the knowledge remains within the project group.
- Proper dissemination is to ensure that the gathered data is not restricted to only the project group as the data can be relevant for wider stakeholders.
- Raw data should include the important tagging information such as:
  - Location of recording station
  - Date and time of data points (*hh:mm*, *dd-mmm-yyyy*)
  - Any sampling notes which can adversely affect the use of the data
  - A schematic of the sampling location or method should be provided if it cannot be clearly explained or if there is possibility of confusion in knowledge transfer; for example, an unconventional location or method.
- For analyte data it is important to also include the following information:
  - Type of data (EKAMS or Campaign Monitoring)
  - Type of sample (time-based composite, flow-weighted composite, grab sample)
  - Laboratory testing methods (if applicable)

3.4.5 Influent flow analysis

3.4.5.1 Key definitions

Key influent definitions for plant influent flow typically employed in the planning and design of wastewater treatment facilities include:

- Diurnal flow profile
- Average dry weather flow
- Median flow
- Peak dry weather flow
- Peak wet weather flow
- Minimum dry weather flow

- Ranked flow distribution

3.4.5.2 Diurnal flow profile

Diurnal flow analysis is the process in which the diurnal pattern of the flow is determined. The aim is to generate a set of diurnal graphs illustrating the variation of the flow during a single day.

Diurnal flow profiling should be conducted as part of influent analysis of all wastewater treatment plant upgrades involving the liquid stream.

Influent diurnal flow profiling may not be required for the assessment or design of some solids stream processes depending on the process unit configurations and technologies.

The general approach to diurnal analysis is shown in Figure 3-14.

Figure 3-14 Alignment of flow and concentration data collection with mass load analysis

3.4.5.2.1 Important diurnal scenarios

There are various diurnal scenarios which can be generated. These are detailed further below:

- Weekday diurnal (Monday to Friday)
- Weekend diurnal (Saturday and Sunday)
- Wet weather diurnal (e.g. during peak months)
- Ad-hoc diurnals (e.g. holiday months or catchment specific events)

3.4.5.2.2 Selection of diurnal scenarios for design or planning

As per the concentration and flow scenarios, the correct diurnal scenario must be selected in line with the expected project outcomes and the type process unit or asset that is assessed. Consider the following application of diurnals for design or planning:

- Weekday or weekend diurnal for aeration assessment
- Wet weather diurnal for hydraulic or secondary settling assessment

3.4.5.2.3 Methodology for dry weather influent diurnal profiling

Consideration should be given to the application of the flow profile. For forecasting flow profiles for catchments with moderate to high growth; changing system configurations; or for new treatment facilities, profiles should be sourced from network models.

For review of demand profiles are existing facilities at present or in the future after a period of minimal catchment change (i.e. low growth and no system reconfigurations), the following methodology should be adopted.

- Identify dry weather influent flow periods of relevance (i.e. ADWF periods or key seasonal event periods)
- Source low interval duration flow data – average influent flow data with a data point interval of 1 min up to 1 hour should be source from HYDSTRA
- Generate daily average flow profiles – generate separate profiles for weekdays and weekend days, examine for any trends

- If using source data interval of less than 1 hour: create hourly or half hourly average data point for a representative smoothed profile (see Figure 3-16)

It is important to use a representative average diurnal pattern for flow. Generating a diurnal pattern with data from single day can lead to inaccuracies in design. It is suggested to generate the diurnal pattern using the averages of the induvial time intervals across multiple days of data, i.e. the 11AM value is the average value recorded at 11AM from multiple days.

Examples of the data point generation (Table 3-10), discrete daily diurnal flow profiles (Figure 3-15), and average day of the week profiles (Figure 3-16).

Table 3-10 Diurnal analysis methodology

Time	Day 1	Day 2	Day N	Average Diurnal
0	D_1T_0	D_2T_0	D_NT_0	$\sum[D_1T_0 + \cdots + D_NT_0]/N$
1	D_1T_1	D_2T_1	D_NT_1	$\sum[D_1T_1 + \cdots + D_NT_0]/N$
2	D_1T_2	D_2T_2	D_NT_2	$\sum[D_1T_2 + \cdots + D_NT_0]/N$
H	D_1T_H	D_2T_H	D_NT_H	$\sum[D_1T_H + \cdots + D_NT_H]/N$
22	D_1T_{22}	D_2T_{22}	D_NT_{22}	$\sum[D_1T_{22} + \cdots + D_NT_{22}]/N$
23	D_1T_{23}	D_2T_{23}	D_NT_{23}	$\sum[D_1T_{23} + \cdots + D_NT_{23}]/N$
Total	$\sum[D_1T_0 + \cdots + D_1T_{23}]/24$	$\sum[D_1T_0 + \cdots + D_1T_{23}]/24$	$\sum[D_NT_0 + \cdots + D_NT_{23}]/24$	

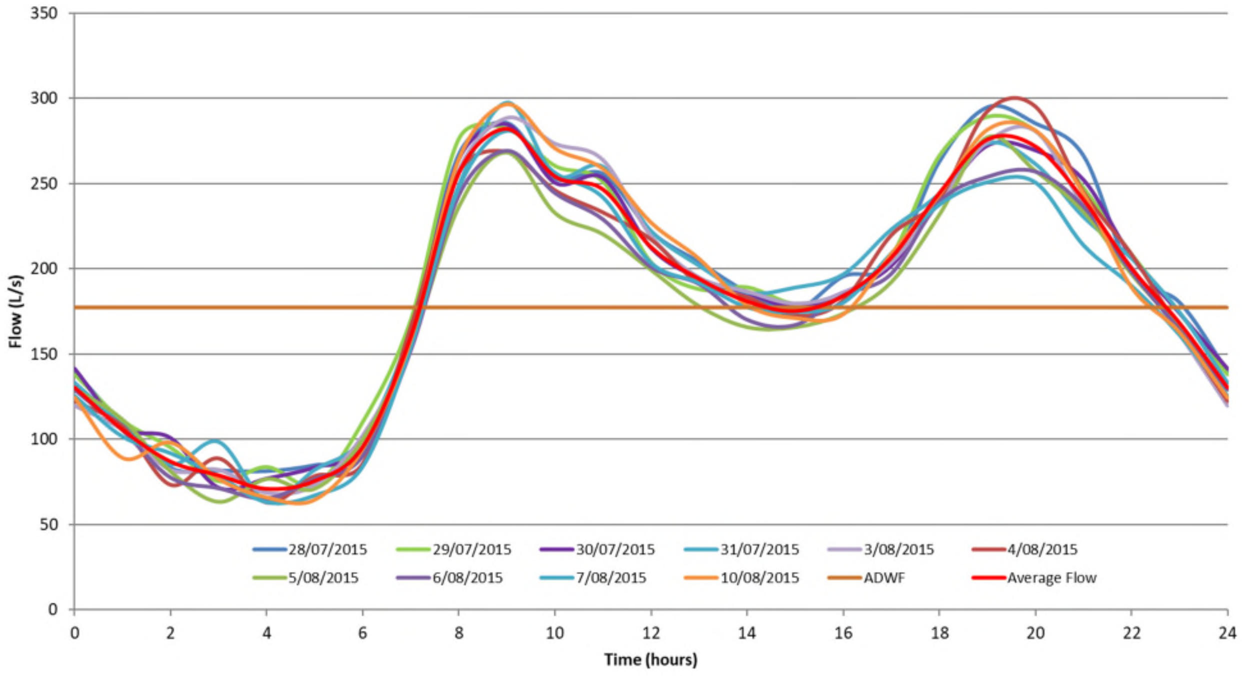


Figure 3-15 Example of a diurnal pattern for flow showing a representative average diurnal

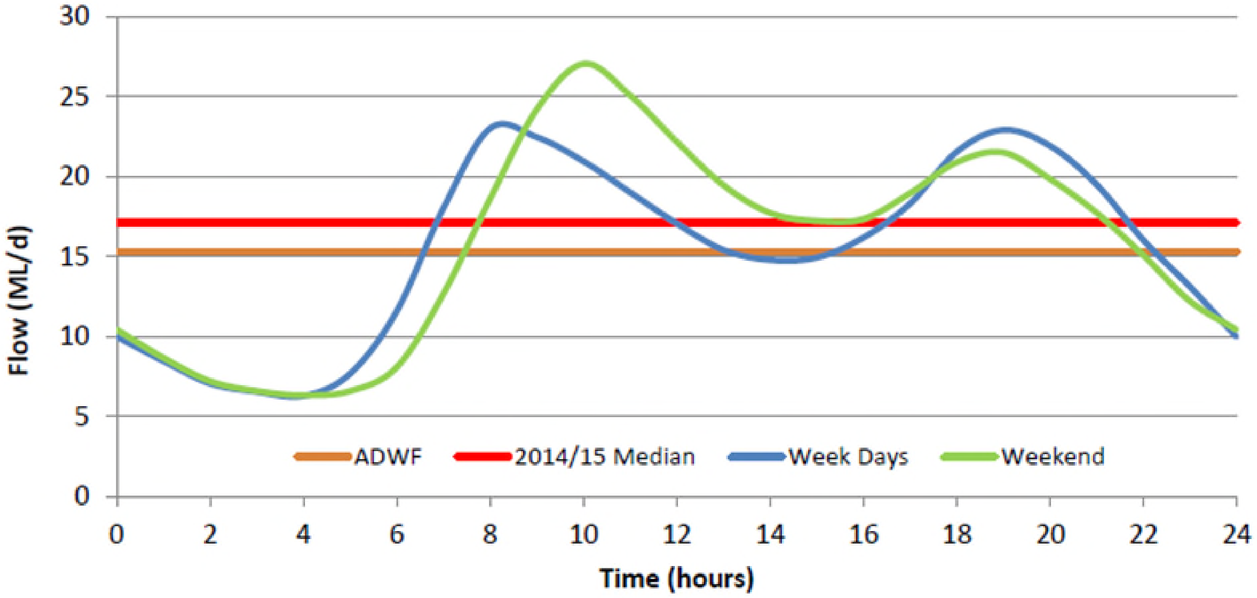


Figure 3-16 Example of a weekday and weekend flow scenario

3.4.5.2.4 Additional requirements for pumped influents

For pumped influent flows, it is recommended that a high resolution (i.e. short interval data set such as 1-minute data interval) be analysed due to the potential for rapid and significant variations in influent flow rates. This is network specific and is see in particular with large feed sewage pumping station with pump cut-in/cut-out as well as pump duty changes.

This can have significant impact on preliminary and primary process unit performance, as well as automated control functions. Figure 3-17 shows an influent stream from Shellharbour WWTP plant with significant flow variability – this impacted on screenings capture as well downstream process units include RAS control and WAS wasting. Figure 3-18 is from Penrith WRP which receives influent from eight pump stations and a periodically charged gravity main.

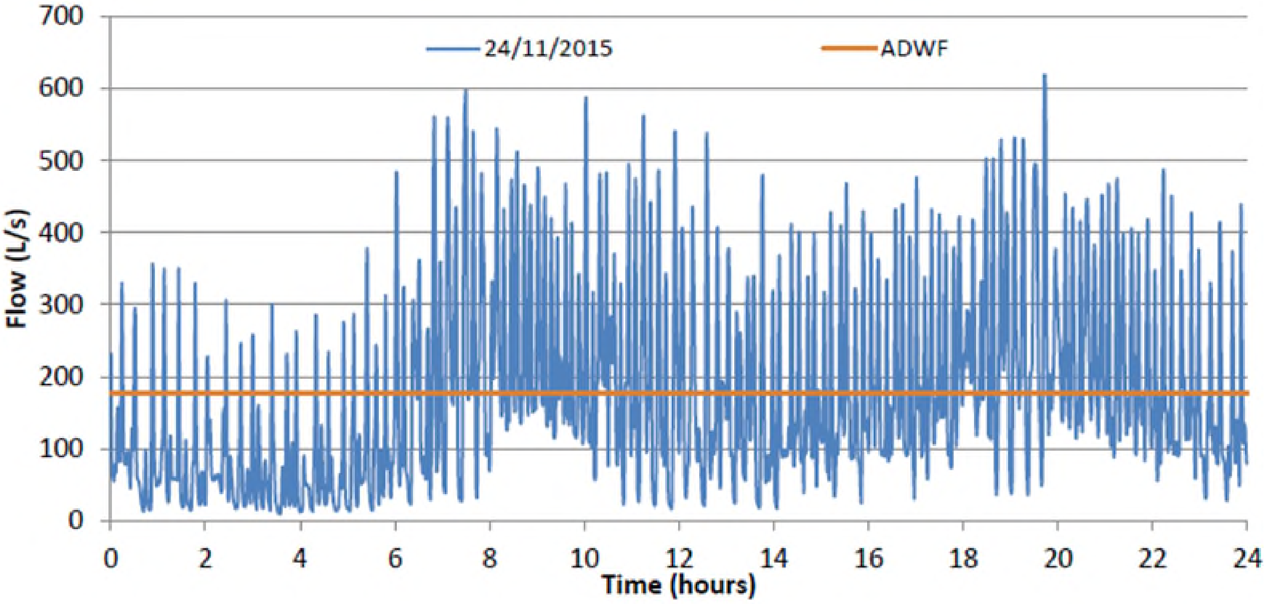


Figure 3-17 One-minute average data interval influent flow data for a discrete calendar day demonstrating high variability

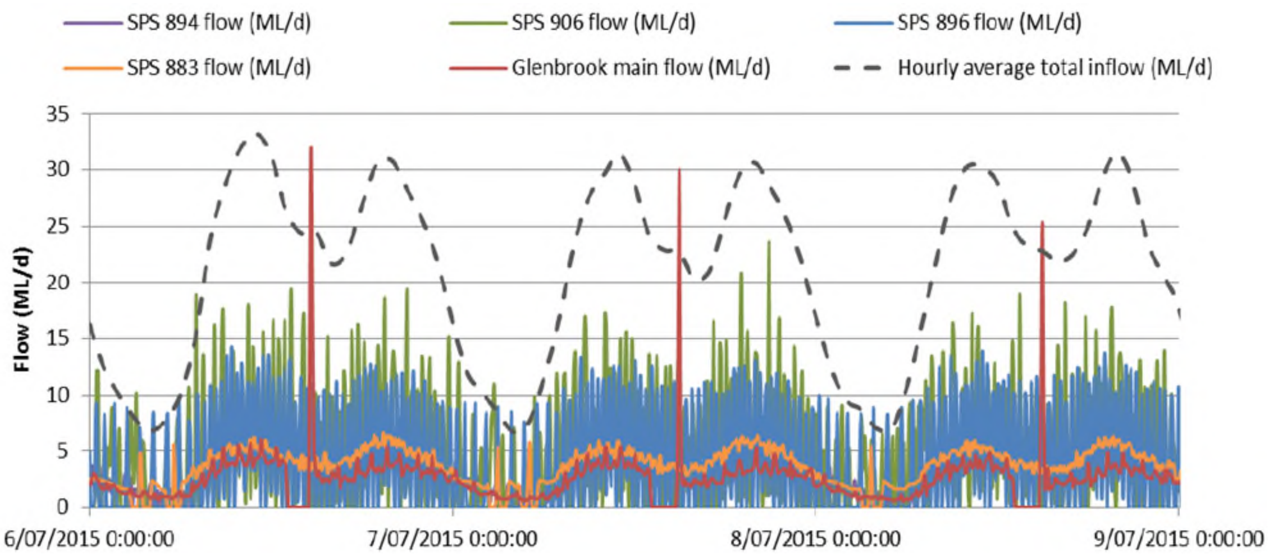


Figure 3-18 5-minute average influent flow data of composite influent showing variability based on originating catchment

3.4.5.3 Ranked distribution

Ranked flow distribution analysis is valuable in the determination of flow variability across a data period (typically annual basis) and the effect of rainfall on influent volumes. Ranked flow distributions can be produced for multiple years with a different distribution for each year and/or a single distribution for a number of years.

The methodology for ranked flow distribution is as follows:

- Source total daily influent volumes for period of interest – at least 12 months
- For multiple distributions, separate data into years or an alternative clearly defined period
- Sort each data set from lowest to highest and calculate each value's percentile rank using the PERCENTRANK function in Excel
- Plot the daily volumes on the y-axis and the percentile rank on the x-axis
- Note that the above ranked flow distribution can also be applied to concentration and load data

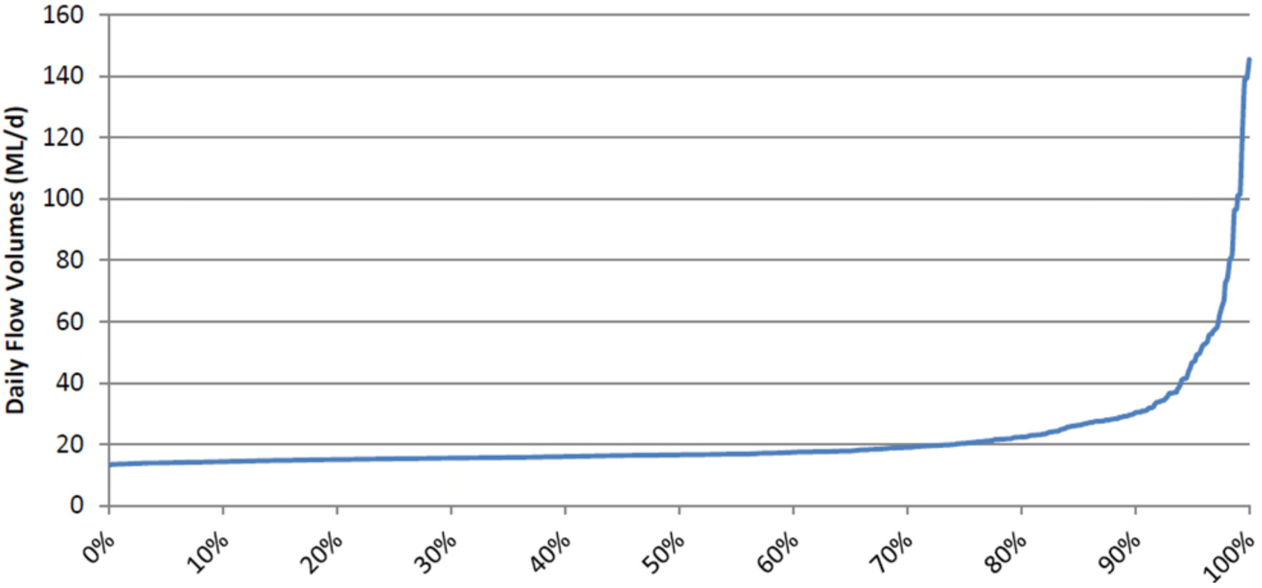


Figure 3-19 Example output graph from ranked flow distribution

3.4.5.4 Average dry weather flow

Average dry weather flow is a key design input variable for new facilities, and key capacity parameter for existing facilities.

Average dry weather flow should be assessed only in the periods in which influent flow volumes are impacted on by rainfall, this is typically a minimum 2-week period in which there is no rainfall. However, the configuration of the network may affect this period (e.g. short/small gravity networks will have short “no rainfall” period). These periods can be identified graphically by plotting the daily flow volumes over an extended period, as shown in Figure 3-20.

Event-based conditions should not be used in calculation of average dry weather flow and load. Examples of event-based flows include the following:

- Holiday period resulting in population influx (e.g. school holiday)
- Temporary flow diversion due to changes in servicing availability at the facility level
- Temporary flow diversion due to network maintenance or construction
- Network flushing or maintenance

When sourcing ADWF values from other sources (i.e. network modelling or flow projections), be sure to confirm the method that was adopted to calculate the ADWF value.

Wet weather duration, frequency and intensity, combined with catchment characteristics will determine the length of time before rain induced ingress ceases. 2-weeks has previously been adopted as a guideline, but this could be adjusted to account for the configuration and size of the sewer network.

Median flow values can be less than ADWF values – the differential will vary between catchments and years, and is typically driven by wet weather and seasonal loading patterns

The application of average or median is case dependent. However, in general, the average usually provides better measurement of central tendency when the sample size is large and does not include outliers.

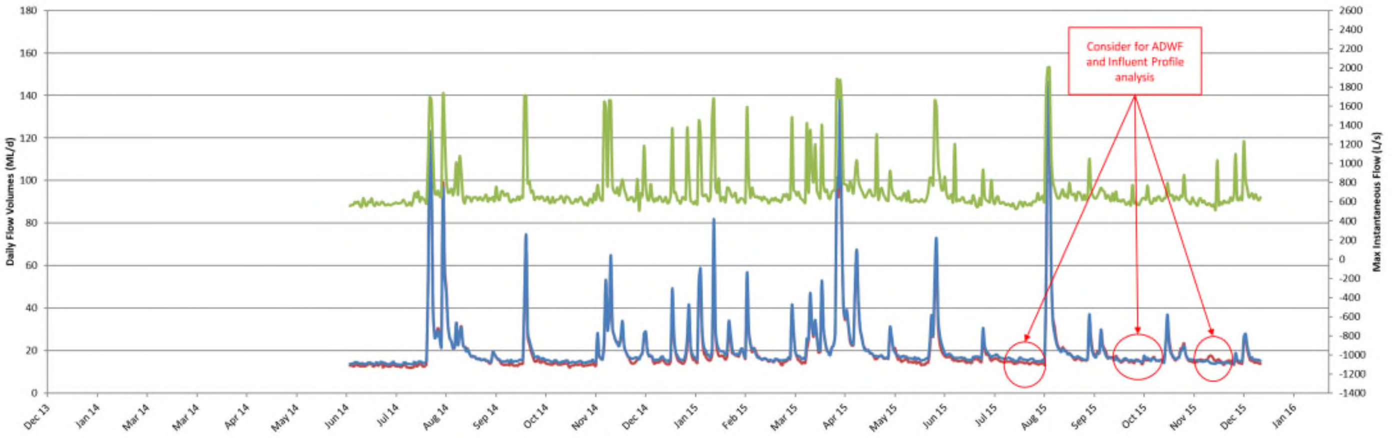


Figure 3-20 Graphical identification of average dry weather flow

3.4.5.5 Median flow

Median flow is indicative of the most often experienced flow, analysed and reported in total daily volume in ML/d.

Statistically it is the 50th percentile of the influent flow dataset. In non-statistical terms it should be considered the daily volume that the plant most often experienced.

It is recommended that an extended (i.e. annual) dataset be adopted to ensure that seasonal and other catchment variability is included in assessment of median flow.

Median flow is useful, similarly as ADWF, for influent flow demand tracking and projections. Median flow is also useful for quick influent load checks as it is statistically more aligned to the measured influent concentrations than ADWF.

Median flow should be greater than ADWF for influent flow values, unless assessing a very short dataset period. The ratio of median flow to ADWF will vary year to year based on the magnitude and frequency of wet weather flow events. Due to this median flow is not suitable for the tracking of baseline flow variations between periods, such as population growth from year to year, instead ADWF should be assessed for this.

3.4.5.6 Peak dry weather flow

Peak dry weather flow (PDWF) is the maximum flow rate occurring during dry weather conditions. The PDWF can be expressed as a peak factor of the ADWF (e.g. PDWF = 2×ADWF); however, it is typically presented in L/s or m^3/h.

The peak dry weather flow shall be calculated considering both the following factors:

- Dry weather diurnal peak – the diurnal flow peak value or ratio to ADWF equivalent
- Dry weather total daily flows peak periods – such as day of the week or peak periods such as holidays

Peak dry weather flow to ADWF ratio will vary depending on catchment size, type and network configuration. Peak dry weather flow is a key variable for determining the capacity of secondary and tertiary process units and the required flows that is to be treated through these units. Typical ratios of PDWF to ADWF range from 1.5 to 3 but may lay outside of this range.

The peak dry weather flow is the maximum flow rate occurring during dry weather conditions. The PDWF can be expressed as a peak factor of the ADWF (e.g. PDWF = 2×ADWF); however, it is typically presented in L/s or m^3/h.

Note that the for secondary treatment systems, a bypass safety factor of 1.2 is applied to the PDWF for hydraulic sizing of process units (i.e. design PDWF = 1.2×PDWF = 1.2×PF×ADWF). This safety factor is to prevent triggering oof dry weather flow bypass events when the influent flow is equal to the PDWF.

3.4.5.7 Peak wet weather flow

The peak wet weather flow (PWWF) is the maximum flow rate occurring during wet weather conditions. It can be expressed as a peak factor of the ADWF (e.g. 6xADWF). It is typically the maximum instantaneous flow rate in L/s during the data period.

The peak wet weather load is the maximum hourly or daily load occurring during wet weather conditions.

Key notes for peak wet weather flow:

- The PWWF shall be checked for obvious outliers, and the adopted maximum instantaneous value shall have extended for a significant duration – sensor data issues related to things such as floating debris are more likely to occur in high flow events.
- Wet weather is defined as the 3-day period after a significant rainfall event occurs in the catchment. A significant rainfall event is an event in which the total rainfall equals or exceeds 10mm. Some systems may exhibit an extended period of increased flow due to high infiltration inflow in the catchment.
- PWWF may not coincide directly with rainfall timing due to delays/storage in the network, its configuration and/or pump control.

3.4.5.8 Minimum dry weather flow

The minimum dry weather flow (MDWF) is the lowest flow rate occurring during dry weather conditions. It be expressed as a turn down ratio or multiple of the ADWF (e.g. 0.3xADWF).

MDWF is important in hydraulic and process unit design as it represents lowest expected flow rate through a facility. Process design should also consider the MDWF at different catchment growth phases. For example, a treatment plant is typically designed and built to service a future demand and as such the experienced flow and loads at commissioning may be significantly lower than the ultimate design demand. It is important to assess the required unit turn down of each process unit including the expected MDWF at the initiation of plant operations.

3.4.5.9 Equivalent population definition for flow

Equivalent population definition for flow is used to define and also forecast influent flow demand to a facility. Influent flow is comprised of:

- Residential flow – wastewater from domestic sources
- Non-residential flow – wastewater from non-domestic sources included identified trade waste customers
- Base flow – additional flows in the network resulting from infiltration inflow or direct ingress

Existing Sydney Water facilities typically experience catchment wastewater production rates lower than their design wastewater generation rates. Current EP wastewater generation is typically in the range of 180 L/EP/d to 200 L/EP/d. Small scale catchments with low pressure systems are typically lower, with EP production rates in the range of 100 L/EP/d to 140 L/EP/d. For existing sites, EP definition of existing flows is somewhat redundant, however it is a useful verification assessment both the influent flow data, but also the catchment proportioning and classification.

EP flow definition is predominately applied for the forecasting of future additional inflows.

3.4.5.10 Influent flow forecasting

As per the network guidelines, the following shall be adopted when forecasting future additional catchment flows:

- Domestic sources – wastewater generation rate of 150 L/EP/d shall be adopted for future additional domestic flows
- Non-residential sources – wastewater generation rate of 150 L/EP/d, where 5 jobs = 1 EP

In addition to the above, it is recommended that a sensitive analysis is undertaken for the following two scenarios:

- Future wastewater generation rate of 180 L/EP/d
- EP to job ratio greater than 1:5 be tested – this may be through simulating one or more future additional major trade water customers with EP to job ratios in the range of 30:1 to 50:1

3.4.6 Influent composition analysis

Typical influent wastewater composition can be used for planning or design projects in the absence of influent wastewater data (as surrogate inputs) or for the validations of influent wastewater data. **Refer to Section 3.4.7.3 for the methodologies on how to use the typical compositions for validation of data.**

It is recommended that the typical influent wastewater compositions are updated regularly and are aligned with periodic process capabilities assessments (PCA’s), servicing planning projects (GSIPs), or any known or observed catchment changes due to climate or regulatory conditions (e.g. drought).

3.4.6.1 Notes on influent monitoring database

Influent concentration is monitored on a regular basis at all Sydney Water wastewater treatment plants. Influent monitoring data is sourced through EKAMS or Monitoring BI. In general, the following monitoring regimes were adopted for the EKAMS dataset:

- Prior to July 2018: full analyte suite once per month – 24-hour composite with hourly grab frequency
- Post July 2018: full analyte suite once per month and reduced analyte suite every six days (with effluent monitoring) – 24-hour composite with 20-minute grab frequency

Monitoring points at treatment plants may have had or still have contaminated influent monitoring points. Influent monitoring point contamination is typically due to return streams from:

- Filter backwash foul water – typically diluting effect

- Sludge thickening or dewatering returns – increased concentrations, especially organics and particulates (all sites), as well as ammonia (anaerobic digestion sites)
- Flow balancing/equalisation return flows – variable impact depending on concentration profile and equalisation philosophy
- Storm pond returns – typically diluting effect

In addition to influent monitoring point contamination, a treatment site may not be directly applicable and first require additional analysis. For example: Malabar WWTP and Wollongong WRP both have multiple and separately quality monitored influent streams.

Campaign based diurnal composite monitoring or online instrument-based monitoring is highly recommended on influent streams on high concentration influents, or where diurnal loading is suspected (i.e. due to trade waste or interplant transfers).

3.4.6.2 Influent concentration statistics

The following key statistics should be assessed and reported for each influent dataset:

- Mean: average of the dataset points, typically lower in than median concentration in residential catchments due to wet weather; may higher than median concentration for certain analytes in trade waste impacted influents
- Median: should be adopted as the indicative concentration of an influent stream; if less than the mean concentration then adopt the mean value instead
- Standard deviation
- Data point count: low data counts should be manually examined point by point to check for influencing factors such as wet weather
- Minimum: typically, due to wet weather – consider removing wet weather data points prior to further analysis
- Maximum: typically due to peak loading events as resulting from return streams, interplant transfers, network dosing and/or trade waste discharges

Before conducting statistical analysis, reported values below the detectable limit of the analysis technique should be modified to be half the detection limit value. For example, if an analyte has detection limit of 2 mg/L, the data points of "<2" shall be replaced with a "1".

3.4.6.3 Flow weighted average concentration

Flow weighted average concentration is the calculated average concentration as related to influent load. Flow weighted average concentration is a more accurate indication of influent concentration as it relates to influent loading. Flow weight average concentration is applicable for daily loads, as well diurnal loading. It is calculated as per the following:

$$\boldsymbol{C_{fw}} = \frac{\sum[\boldsymbol{C_1 V_1} + \boldsymbol{C_2 V_2} + \ldots + \boldsymbol{C_n V_n}]}{\sum[\boldsymbol{V_1} + \boldsymbol{V_2} + \ldots + \boldsymbol{V_n}]}$$

Where:

C_n = *measured concentration of analyte on sample 'n' for quality monitored influent streams (mg/L)*

V_n = *influent volume for sample interval 'n' (ML)*

Flow weighted average concentration is most applicable to load calculations, but can also be compared to the median or average concentration to assess deviation related to flow.

3.4.6.4 Diurnal concentration profiling

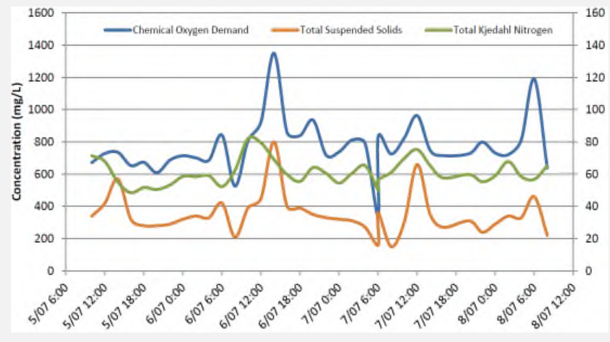
Diurnal concentration profiling is useful to identify catchment loading events and peak loading potential on process units. Concentration profiling can be achieved in several ways, yielding different data resolution and analyte spread. Notionally they are:

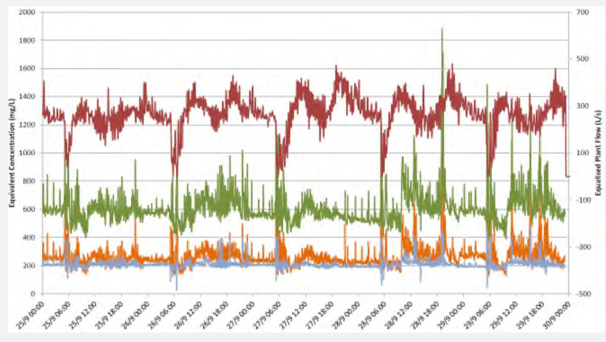
- Diurnal autosampler composite monitoring and lab analysis: two-hour average concentration profile
- Online instrument monitoring: high resolution trends for single or multiple analytes depending on instrumentation

Table 3-11 Summary of diurnal concentration monitoring techniques

	Autosampler Collected - Laboratory Analysed Monitoring	Online Instrument Monitoring
Description	• Autosampler for collection of samples • Typically, two-hour composite with 15-20 min grab frequency • Samples collected daily from autosampler and autosampler reloaded for next run • Collected samples are analysed in laboratory • Results accessed through Monitoring BI report generally a week after analysis	• Online instrument is used to take continuous or high frequency readings of monitored stream • Multiple probes/analysers may be used • Output data is instantaneous recorded and available for analysis for online system with remote uplink or hardwired connection, otherwise downloaded periodically at site
Set up requirements	• Autosampler at sample point • Serviced daily for duration of monitoring • Test list prioritisation recommended in the event of low sample volumes	• Identify of appropriate analyser • Work with instrument specialist to setup monitoring including calibration and maintenance requirements • Calibration sampling and lab analysis may be required • Ongoing unit
Data resolution	• Two-hour average data point • Due to interval in grab sample collection, may miss sampling discrete streams such as in pumped influent systems	• High resolution – typically in the minutes • Can be trended with instantaneous flow trends for load calculations and/or identification of load sources
Analyte range	• Total number analytes able to be tested in each sample is limited due to reduced sample volumes (approximately 5-6 analytes depending on required test) • Choice of analytes not limited by methodology	• Limited depending on analysers employed • Analysers may use proxy indicators to infer concentration measurement for wider application
Applications	• Initial profiling in campaign monitoring • Initial investigations into plant loading • Less suitable for pumped influents (especially with multiple feeding SPSs) • Expensive for extended periods due to servicing and laboratory costs	• Use for high resolution application • Trade waste investigations and ongoing customer management • Efficient for long term applications • Can be interfaced with SCADA for operator visibility and automated plant control • For broad investigations a multi analyte instrument such as a UV-Visual Spectrograph is useful, however once key analytes of interest are identified, these expensive units may be replaced with single analyte probes for long term monitoring

Example outputs





3.4.6.5 Typical concentration ranges

The typical concentration ranges are presented in Table 3-12. These were based on observed data ranges at existing Sydney Water catchments and are provided for guidance in verify influent datasets and identify catchment type and risk profile. The values in the tables apply to 24-hour composite samples. Diurnal values may be more volatile.

Table 3-12 Typical influent concentrations

Analytes	Symbol / Acronym	Units	Domestic low strength	Domestic with light trade waste	Domestic with high trade waste
Trade Waste EP$_{COD}$ Component	-	%EP	**0 – 5%**	**5 - 15%**	**> 15%**
Chemical oxygen demand	COD	mgCOD/L	<500	500 – 700	>800
Biological Oxygen Demand (5-day)	BOD_5	mgBOD_5/L	<200	200 – 350	>300
Total Kjeldahl Nitrogen	TKN	mgN/L	<45	40 – 65	50 – 90
Ammonia	NH_3	mgN/L	<40	35 – 50	40 – 80
Nitrates and Nitrites [1]	NO_x	mgN/L	<1	<1	<1
Non-biodegradable soluble TKN [2]	nbsTKN	mgN/L	1	1	1
Total Phosphorous	TP	mgP/L	8 – 12	8 – 12	8 – 12
Total Suspended Solids	TSS	mgTSS/L	<250	220 – 350	>300
Volatile Suspended Solids	VSS	mgVSS/L	<230	200 – 330	>250

1. Nitrate concentrations in influent flows typically non-existent across Sydney Water plants, should be confirmed with monitoring especially in trade waste catchments or in catchments which dose calcium nitrate for hydrogen sulphide control.
2. Non-biodegradable TKN in the order of 1.0 mgN/L observed – not typically monitored and should be confirmed with campaign based monitoring especially where low TN effluent concentrations are required.

3.4.6.6 Influent fractions and ratios

Influent fractionation involves the subdivision of wastewater analytes into sub-parts. This composition will have an impact on process performance such as sludge mass and biogas production, aeration demands, and effluent quality. Therefore, correct fractionation is important for accurate process design and asset sizing.

It is important that correct level of fractionation is identified for the project. A full and accurate fractionation requires time and effort in data collection and analysis. The latter can involve the use of propriety process modelling/simulation software or tools, which in turn require the use of calibrated process models to generate accurate predictions.

Full fractionation is generally conducted for concept and detailed design of process units. For higher-level planning projects, such as a needs assessment, detailed fractionation may not be required, and the important influent concentrations can suffice.

Figure 3-21 Alignment of inputs and methodology

The fractionation approach should be based on current wastewater modelling practices. The format of the outputs from the fractionation process have been streamlined to be used in process modelling software.

3.4.6.6.1 Typical wastewater fractions and ratios

Typical wastewater fractions and ratios as observed at Sydney Water are summarised in Table 3-13. This table can be utilised for data validation but should not replace measured values. The interrelationships between concentration analytes, typically presented as fractions or ratios, can also be utilised to assess if the concentration data is valid.

Table 3-13 Typical influent wastewater fractions and ratios observed at Sydney Water treatment plants

Wastewater analyte ratios	Symbol	Units	Raw Wastewater	Settled Wastewater
COD to cBOD ratio	-	gCOD/gcBOD	2.4 to 3.1 (unadjusted) 2.0 to 2.6 (TCMP adjusted)	
TN to COD ratio (see Figure 3-22)	-	gTN/gCOD	0.070 to 0.120	0.120 to 0.150
TP to COD ratio (see Figure 3-23)	-	gTP/gCOD	0.010 to 0.020	0.020 to 0.030
Ammonia to TKN ratio (see Figure 3-24)	Fna	gN/TN	0.66 to 0.80	0.80 to 0.90
VSS to TSS ratio (see Figure 3-25)	Fvt	gVSS/gTSS	0.80 to 0.98	0.70 to 0.80
Wastewater fractions	**Symbol**	**Units**	**Raw Wastewater**	**Settled Wastewater**
Slowly biodegradable (particulate) COD fraction of total COD	Fbp	gCOD/gCOD	0.35 to 0.52	0.40 to 0.50
Readily biodegradable (soluble) COD fraction of total COD	Fbs	gCOD/gCOD	0.14 to 0.20	0.20 to 0.25
Volatile fatty acids fraction of readily biodegradable COD	Fac	gCOD/gCOD	0.10 to 0.20	0.12 to 0.20
Unbiodegradable soluble COD fraction of total COD	Fus	gCOD/gCOD	0.04 to 0.05	0.06 to 0.08
Unbiodegradable particulate COD fraction of total COD	Fup	gCOD/gCOD	0.18 to 0.20	0.10 to 0.12

Note: values are indicative only – specification shall be verified for each influent stream based on monitoring data. If no influent data, find representative reference catchment (i.e. with or without more trade waste and/or network dosing)

3.4.6.6.2 COD to cBOD

There is high variability in BOD due to the nature of the measurement. COD is best used for process modelling activities; however, the carbonaceous BOD (cBOD) and COD:cBOD ratio can be used to cross-check influent data and calibrate process models. When doing so, it is important to note that the BOD test method and the nitrifier inhibiter utilised for test will affect the cBOD measurement. There are two types of inhibitors ATU and TCMP.

- When ATU is utilised as an inhibitor: measured cBOD should be divided by 0.87 to obtain the uninhibited cBOD
- When TCMP is utilised as an inhibitor: measured cBOD should be divided by 0.84 to obtain the uninhibited cBOD

3.4.6.6.3 TN to COD ratio

TN:COD should be between 0.07 to 0.12. Note that this is the normal operating range for TN removal in conventional activated sludge systems.

A higher ratio indicates an elevated presence of trade waste or non-conforming catchment characteristics which may require more advanced liquid stream treatment technologies. An example of non-conforming catchment characteristics is Brooklyn.

3.4.6.6.4 TP to COD ratio

TP:COD should be between 0.010 to 0.20. At lower range, plants optimised for TN removal (e.g. MLE, IDAL) can produce good effluent TP concentrations meaning lower chemical dosing for TP polishing. However, at the upper range, BNR secondary treatment systems (e.g. UCT, Bardenpho) may be required.

As per TN:COD, a higher ratio indicates an elevated presence of trade waste or non-conforming catchment characteristics, which may require more advanced liquid stream treatment technologies.

3.4.6.6.5 Ammonia to TN ratio

65% to 75% of the influent nitrogen is in ammonia form. The balance is organic nitrogen bound to soluble or particulate organics. A ratio that is towards the upper end, or higher, is an indication of elevated levels of trade waste.

3.4.6.6.6 VSS to TSS ratio

VSS:TSS should be between 0.88 to 0.92. A lower influent VSS:TSS indicates elevated presence of inorganic suspended solids (ISS) such as grit and sand.

3.4.6.6.7 Effluent COD to influent COD ratio

The f_{us} fraction should be approximately 0.040 to 0.050 as a portion of the influent COD is unbiodegradable soluble. If the measured f_{us} fraction is outside of this range, conduct further analysis/investigation of the influent and effluent data.

3.4.6.6.8 Non-biodegradable soluble TKN ratio

Nominated as ‘soluble unbiodegradable TKN’ or ‘Fnus’ in BioWin, non-biodegradable soluble TKN (nbsTKN) ratio should be determined based on the measured influent nbsTKN concentration to total TKN. For preliminary investigations, a value of 1 mgN/L nbsTKN may be adopted. It is recommended that this be confirmed with campaign based monitoring especially for facilities looking to achieve low effluent total nitrogen concentrations.

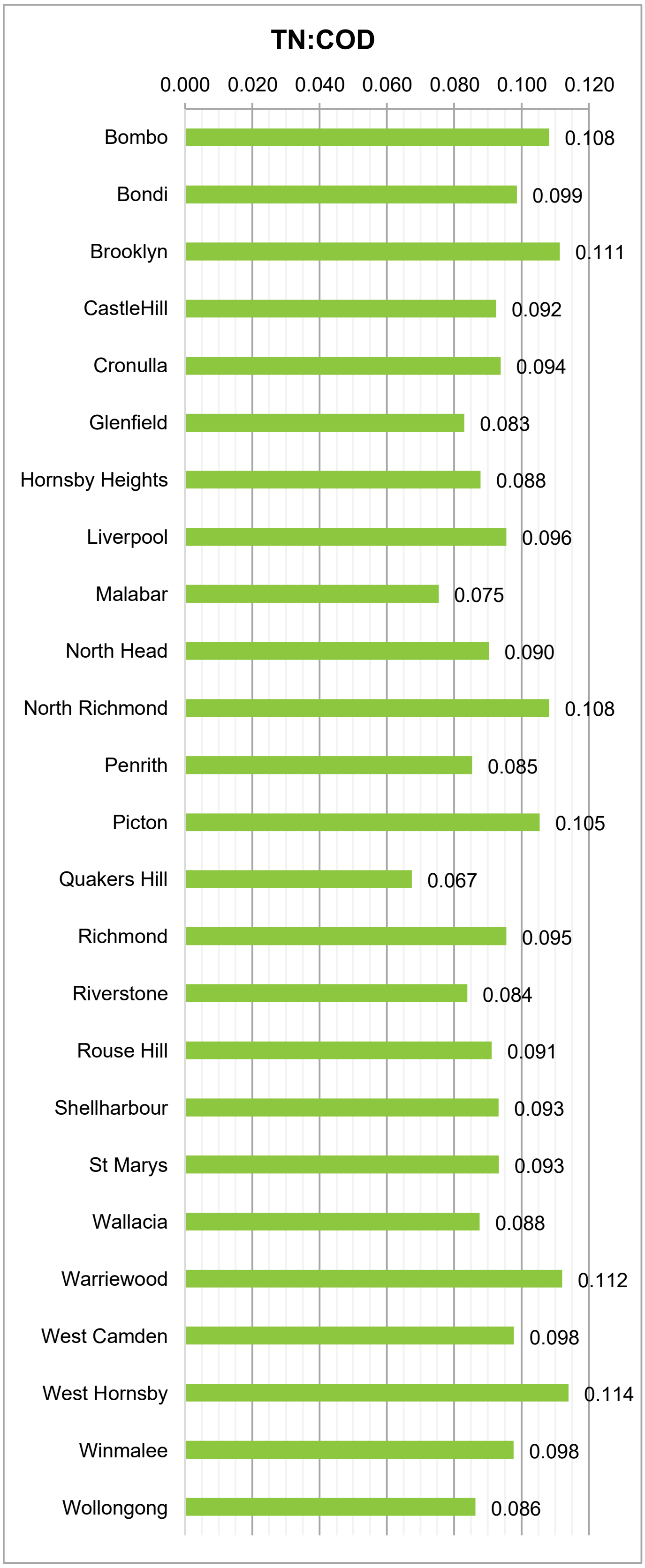


Figure 3-22 **Observed average TN:COD ranges (2015-2017 data)**

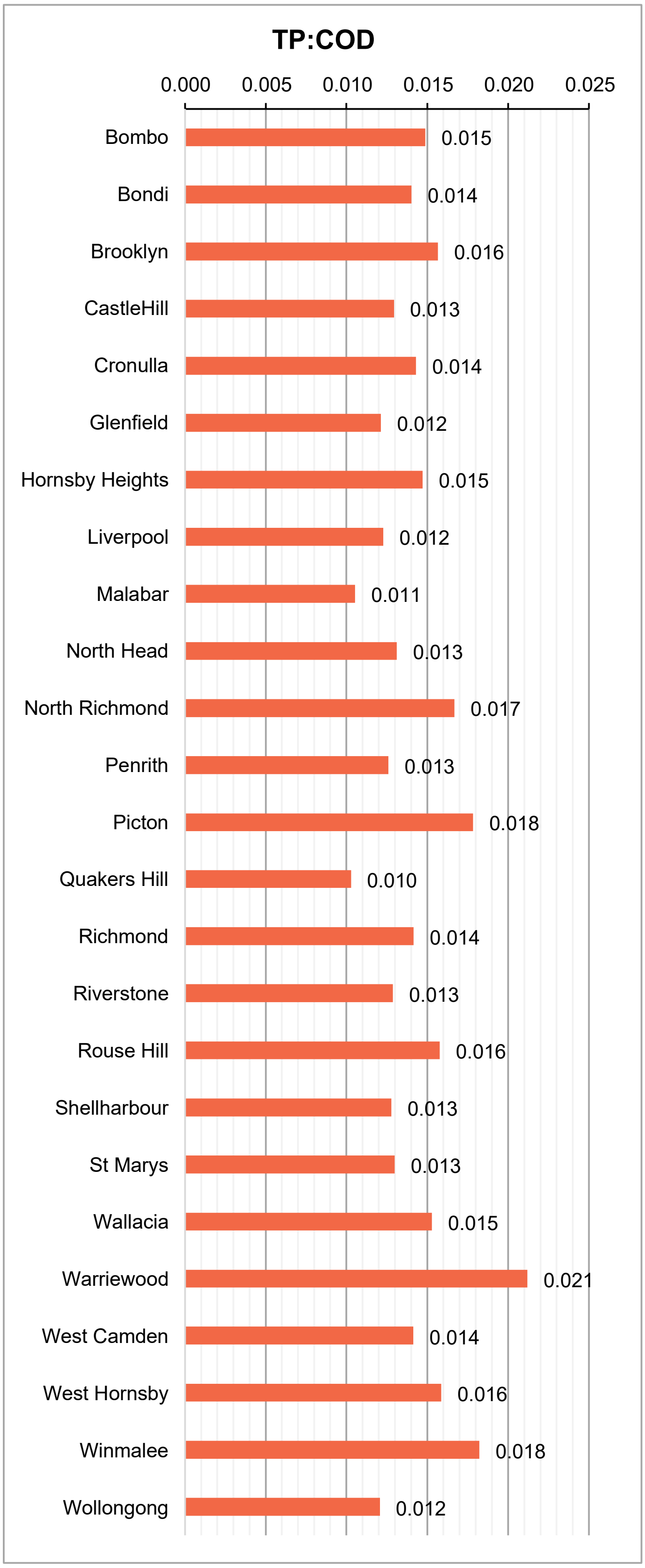


Figure 3-23 **Observed average TP:COD ranges (2015-2017 data)**

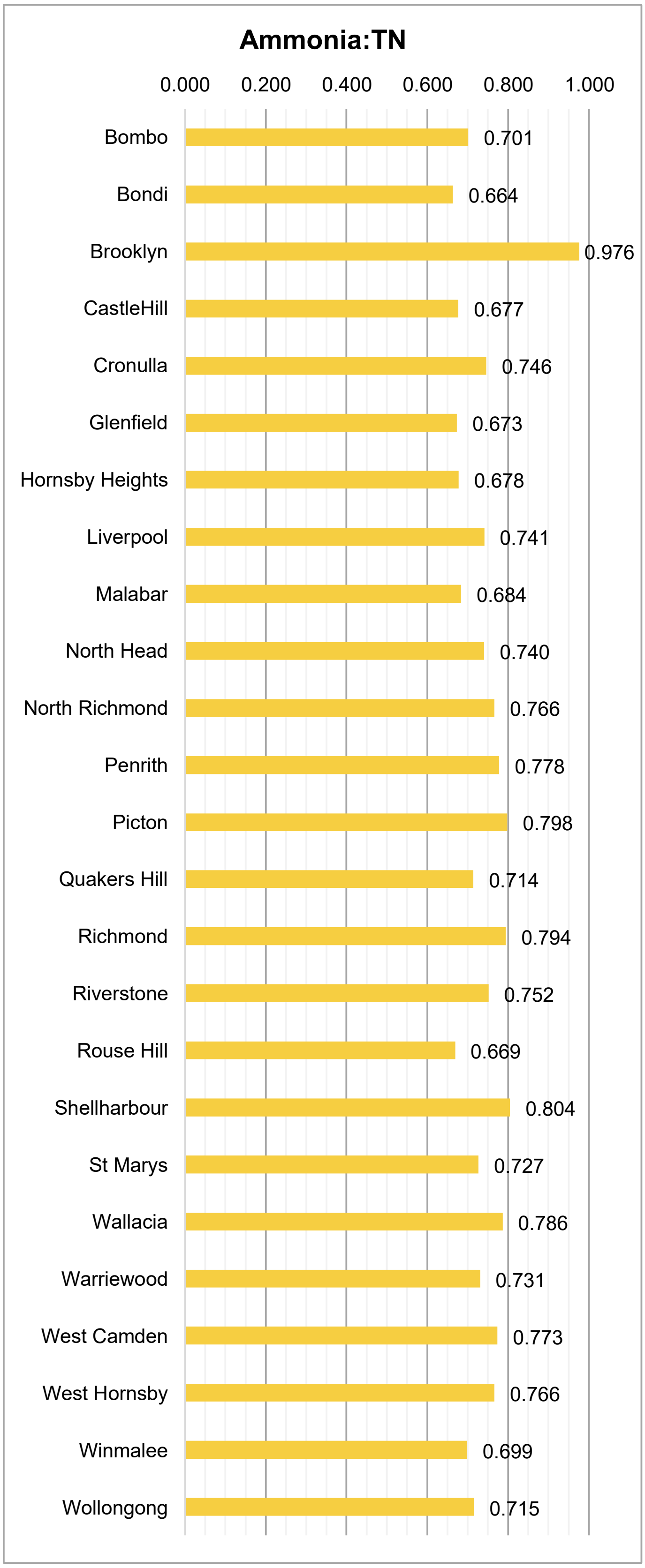


Figure 3-24 Observed average Ammonia:TN ranges (2015-2017 data)

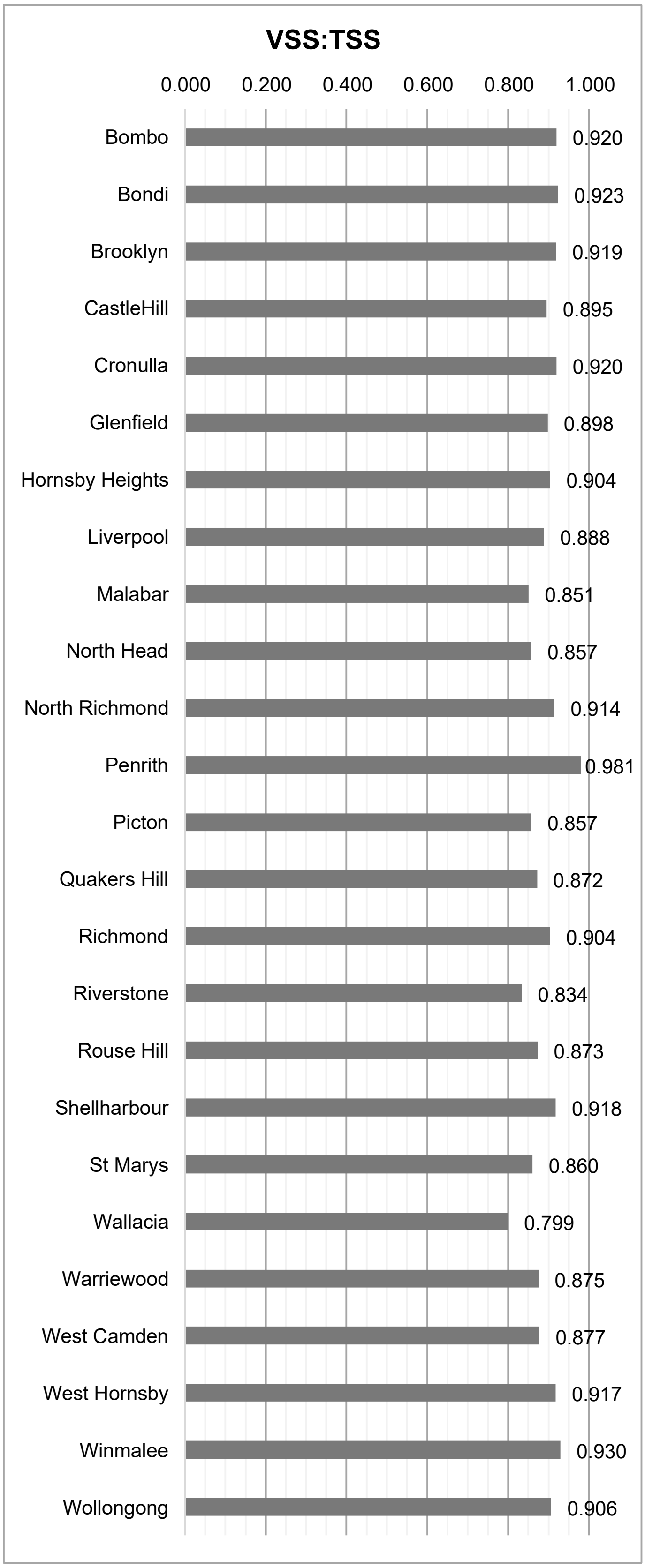


Figure 3-25 Observed average VSS:TSS ranges (2015-2017 data)

3.4.6.6.9 Validation of influent fractionation

If the outputs from fractionation defines a value outside the typical range, additional steps shall be undertaken to validate specification

The following methods can be used to validate the fractionation outputs:

- Use process model to check mass balance (i.e. BioWin mass balance and calibration)
- Cross-check the f_{up} vs digester performance – a high f_{up} value will lead to lower biogas production
- Cross-check the f_{us} and filtered effluent COD – a high f_{us} value will lead to high filtered effluent COD
- Sensitivity of product outcomes to fractionation parameters, including risk assessment of future changes in influent composition and fractions (e.g. change in rbCOD due to change in trade waste quantity or composition)
- Identification of cause through re-assessment of influent concentration data, catchment understanding, site investigations etc.

3.4.6.6.10 Reporting of fractionation outputs

The fractionation outputs should be reported in a logical and consistent format. It is suggested that the outputs are presented in either table or graphical forms as shown in Appendix 2.

3.4.7 Influent load analysis

Mass load is a product of volume (flow for influent) and concentration. Therefore, the analysis of the mass load should only be conducted after analysis and validation of the influent flow and concentration data, although it is noted that this may be an iterative process involving plant mass balance.

Furthermore, as per the collection of flow and concentration data, an appropriate level of effort should be given to identify the mass load scenarios required to meet the product outcomes, and hence the project outcomes. This will help determine the most appropriate method of analysis.

A general approach to ensure alignment of data collection and mass load analysis is provided in Figure 3-26.

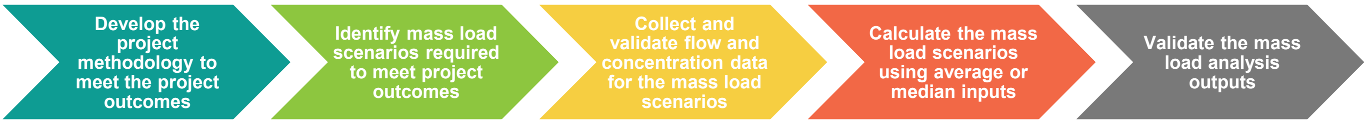


Figure 3-26 Alignment of flow and concentration data collection with mass load analysis

3.4.7.1 Assessment of current influent loads

There are several ways of analysing the influent load. The method should be selected based on the available data and the intent of the analysis outputs.

For a quick high-level average load check, the load can be analysed by undertaking separate analysis of flow and concentration, and then multiplying the selected function of concentration by the selected function of flow. For example, the product of the median concentration and median flow for a defined data period. This is often useful for quick, high-level load calculations to cross-check input data. However, it does not account for flow weighting of the concentration and may therefore over or under estimate influent loading.

For most load analyses, discrete load event analysis is recommended. The load for each monitored day is calculate by multiplying the concentration measured on that day by the total volume measured on that day. This forms a new dataset for the analysis period, with discrete load events as data points, on which further statistical and scenario-based analysis can be conducted. The is the most representative method for load analysis and profiling. This method can also be applied to shorter data intervals such as diurnal profiles.

An example of a discrete load analysis procedure is shown below.

1. **Calculate discrete load event masses |** multiply measured analyte concentration by the measured influent volume for each monitored interval (i.e. typically daily but may be hourly for diurnal).
2. **Plot analyte masses and review trends |** this allows patterns to be observed and high/low outliers to be easily identified.
3. **Assess outliers |** where outliers are identified, assess their validity: outliers can be due to sampling errors, or isolated network events, e.g. trade waste, sewer disconnection. Mass sensitivity should be conducted if trade waste suspected. Remove outlier data point if deemed invalid.
4. **Identify average load, peak loads and load patterns |** for long-term load analysis identify periods of load variability such as weekdays, weekends and holiday periods. Quantify load peaking factors associated with long term peaks and quantify diurnal load peaks.

3.4.7.2 Load peaking factors

A peak factor can be applied to the average mass load for the design of certain process units or assets. Plant loads are affected by catchment events; examples of typical events leading to major variability in loads are provide in Table 3-14.

Note that peak loading to a process unit is typically driven by influent loading patterns but may also be a function of process unit configuration, control philosophy and availability. An example is the biosolids processing which requires units to be sized for peak week or peak month mass loads, and for a select SRT and number of equipment out-of-service. Further details on process unit demand peaking factors are given in Section 4.5.

Table 3-14 Load peaking factors

Source/Scenario	Description	Diurnal effect	Daily effect
Trade waste	Loading (typically organics and solids) from large single source or clusters of multiple customers.	Different customers have different loading patterns and slug loading due to trade waste is often observed – observed high diurnal peak loads are observed.	Day of the week loading patterns may be observed – for example business does not operate on a weekend. The may be observed period of shutdown such as at Christmas/New Year.
Network dosing	Mass loading related typically to metal salt additions for odour and corrosion control.	Varies depending on dosing control logic.	Observed significant increases in mass loading rates during summer months when odour and corrosion potential is high. Should be separated assessed especially for solids stream processes.
Network operations	Network operational controls and functions can induce load peaks and troughs. For example: gravity main charging (Glenbrook gravity main), large pump station configuration, modulating penstocks for network equalisations, storm storages (North Side Storage tunnel).	Can result in significant diurnal loading impacts as observed with the daily Glenbrook main charging at Penrith WRP. Any existing network loading modulation may result in underestimated normal diurnal variations – as such existing system should be identified and understood (i.e. Mt Kuring-gai modulating penstock at Hornsby Heights WWTP).	Large storages returning flow (and load) after a wet weather events is the typical impact. This may be a purely network events, or may be a sludge stream load in the case of post wet weather storm treatment plant operations, such as those observed at Bellambi and Port Kembla plants loading to Wollongong WRP following wet weather initiation.
Network size	Catchment size (area and EP loads) can determine the variability of influent loading.	Small networks have lower times of concentration resulting in more	Small catchments will be more prone to variability (weekly or seasonal) as they have less

	Also, catchment size will determine sensitivity to discrete load events and sources.	pronounced load and flow variability. Conversely, large networks (Malabar, North Head) have long times of concentrations and therefore a lower degree of peaking.	baseline load relative to the event or single source load variations. Vice versa for very large catchments.
Holidays	Changes in holiday loading due to catchment type and location. Loading profiles may change due different usages.	Aside from the previously noted potential for trade waste customer to be offline in holiday periods, catchment loading profile and magnitude may change due to changes in people's routines and activities.	Holiday destination catchments will experience an increase in daily loading rates during peak holiday periods. The size and location of the catchment will determine when this may be observed. For example, Brooklyn WWTP is a very small catchment that sees major loading increases on weekends as well as extended periods in December and January.
Transient populations	Catchments may experience a significant temporary relocation of population (and associated loads) during certain periods. This is typically observed with the daily movement of people for work into and out of central business districts.	Typically observed in small outlaying catchments with high rates of transience. Significant difference between week day and weekend day diurnal profile typically observed. Peaks may be more pronounced.	Weekend day loads typically higher in transient population catchments. Holiday periods may be higher on average compared to 'normal periods'.

3.4.7.3 Equivalent Population definitions for load

A standardised load definition for Equivalent Population (EP) exists for Sydney Water catchments based on mass production rates for key analytes. Refer to the "*Standardised Loads for the Determination of Equivalent Population"* technical memorandum for the development of the standardised load definition: The adopted EP production rates are as follows:

- COD: 110 gCOD/EP/d
- TSS: 60 gTSS/EP/d
- TKN: 12 gTKN/EP/d
- TP: 2 gTP/EP/d

The standard was developed to allow for improved assessment of influent load, direct comparison of influent loads between catchments, and for direct comparisons between influent load and asset capacity.

The standard is applied by dividing the mass load by the relevant standardised production rate as per the following equation:

$$Equivalent\ Population\ (EP) = \frac{Measured\ Daily\ Mass\ Load\ (kg/d)}{EP\ Allowance\ (g/EP/d)}$$

3.4.7.3.1 Non-residential loads

Non-residential loads are defined as loads not generated by a solely residential source. Non-residential loads are typically provided in the source data as a fraction of total ADWF for a catchment. Non-residential sources may be identified from either customer information, the trade waste register, or plot zoning designation.

Previous load calculation methodology for non-residential sources determined the EP load in the non-residential flow proportion by dividing the allocated flow by 150 L/EP/d. This previous method assumed that non-residential flows contained pollutants are domestic concentrations – it is typical that non-residential sources produce wastewater of higher concentration (and thus load) than domestic sources. In the case of catchments with industrial trade waste customers, influent concentrations can be significantly increased due to high non-residential load contribution.

Non-residential loads shall be analysed by cross referencing Sydney Water's trade waste database for the relevant catchment. This allows for known high concentration flows to be accounted for by directly calculating EP based on the measured (or allocated) trade waste masses for the trade waste (TW) flow proportions, and then applying domestic concentrations for the residual non-residential flow proportion. The equation for the calculation of the non-residential loads is as follows:

$$Non - residential\ EP_{COD} = \frac{Measured\ TW\ Load}{110\ gCOD/EP/d} + \frac{Assigned\ Total\ Non\ Res\ Flow - Measured\ TW\ Flow}{150\ L/EP/d}$$

The determination of non-residential EP in the current catchment is important for the determination of the Trade Waste Load Factor (see Section 3.4.7.4).

3.4.7.3.2 Communicating EP load

The standard nominates four key load indicators. When assessed, four numbers are defined for the influent load. While useful and meaningful for demand profiling and asset capacity assessment, four numbers are not concise enough for clear communication of demand or capacity for most end users.

The following should be adopted when communicating load:

- Quantify the mass load equivalent for each key analyte and nominate as EP_{COD}, EP_{TSS}, EP_{TN}, EP_{TP}
- Use EP_{COD} as the primary load (and capacity) indicator when summarising
- Refer to EP_{TSS}, EP_{TN}, EP_{TP} only as relevant – for example if a load indicator other than COD will lead to exceedance of asset capacity, state the relevant indicator value

3.4.7.4 Forecasting future influent load

For residential sources, future additional populations were defined as contributing one equivalent population (EP) worth of load per person across the key analytes.

For non-residential sources, as future additional non-residential loads were supplied in terms of flow (ML/d), a multiplier should be applied to future allocated non-residential flows to better approximate future non-residential loads.

Combined, the total future plant load at any future horizon shall be defined as:

$$Future\ EP = Current\ EP + Additional\ Res\ Pop + (Additional\ Non\ Res\ Flow \times TW\ Load\ Factor)$$

The trade waste (TW) load factor is defined as the load to flow ratio for the current catchment's non-residential wastewater sources, such that:

$$TW\ Load\ Factor = \left(\frac{TW\ Load}{Mass\ g/EP/d} + \frac{Non\ Res\ Flow - TW\ Flow}{150\ L/EP/d}\right)/Non\ Res\ Flow$$

Applying the trade waste load factor from the current catchment to the future non-residential flows allocated assumes that the current catchment's non-residential characteristics won't changes. It is noted that in small to medium sized catchments, the addition of a medium or large industrial trade waste customer would significantly vary the realised loading compared to the forecast loading – sensitivity scenarios should be developed to assess the impact of these high single load sources on future asset planning.

3.4.8 Validation of input data

Validation of data involves the use of discrete procedures to verify if collected data accurately represents the observations at the measurement site. Validation will assist in identifying outlier or periods of inaccurate measurement and is necessary to ensure that input data is guaranteed for fitness, accuracy, and consistency before being utilised for detailed project activities. An activity sequence to validate input data is provided in Figure 3-27.

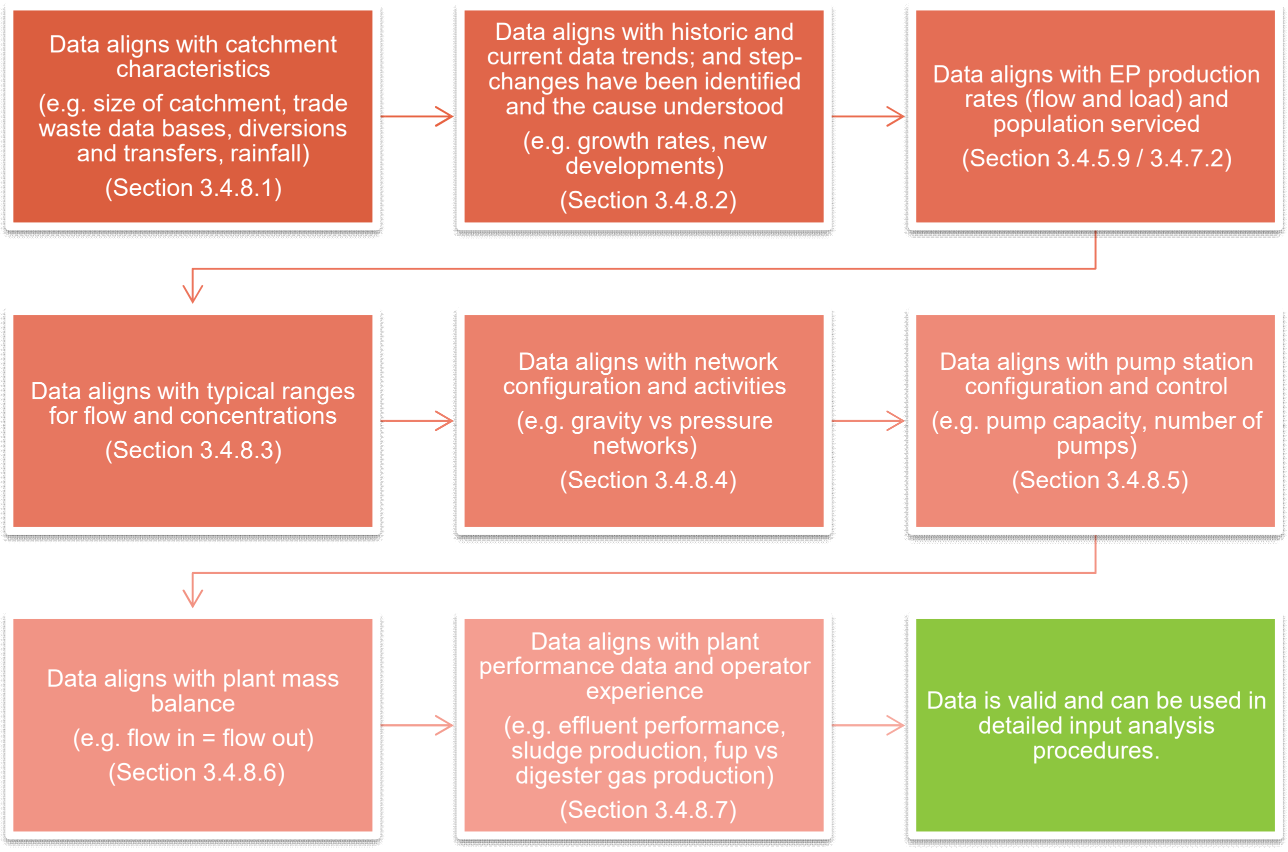


Figure 3-27 Activity sequence for the validation of input data

3.4.8.1 Catchment characteristics

For influent data, check if the data aligns with the sources of the wastewater in the catchment and the catchment characteristics, for example:

- Volume and type of trade waste in the catchment
- Presence of wastewater or sludge transfers
- Septage discharge
- Chemical dosing in the network
- Water consumption patterns
- Rainfall records

Further considerations should be given to the location of influent monitoring station and whether plant return streams will have an impact.

Rainfall occurring in the wastewater catchment results in stormwater infiltration into the network. Influent flow data can be overlaid with rainfall occurrences in the catchment to identify and validate the high inflow days.

3.4.8.2 Historic data and current trends including identifying of step-changes

Compare averages, medians, and other statistical outputs to historic data and current data trends. This can be done for influent, effluent, and internal plant streams. Generally, the following trends should be observed in the data:

- Flow data will trend upwards during periods of sustained population growth and urban development; and downwards during periods of decreased water consumption due to water restrictions.
- Concentration data should not vary with population growth or urban development. However, concentration trends will be affected trade waste and water consumption.
- Load trends should not be affected by water consumption patterns.
- Internal plant streams and effluent can show poorer product outcomes during periods of higher loading stress; for example, when equipment is out-of-service or when a facility is undergoing a large upgrade.
- Consider abnormal variations or outliers as this can be an indication of poor sampling or data collection; for example, influent oil and grease at Bondi WWTP which shows lower concentration measurements than in the effluent.

When assessing trends, it is important to identify any step-changes. This can easily be done by plotting measurement vs time graphs for the relevant analytes. The cause for step-changes should be assessed and this can involve engaging with plant operators or network planners as they could know the reason for the step-changes.

An example includes the effluent O&G concentration at Bondi WWTP, as shown in Figure 3-28, which showed step-changes due to various plant activities (e.g. change in polymer type, installation of new centrifuges, change in glycerol dosing etc.). Other causes could be the addition of new trade waste customers or change in catchment characteristics.

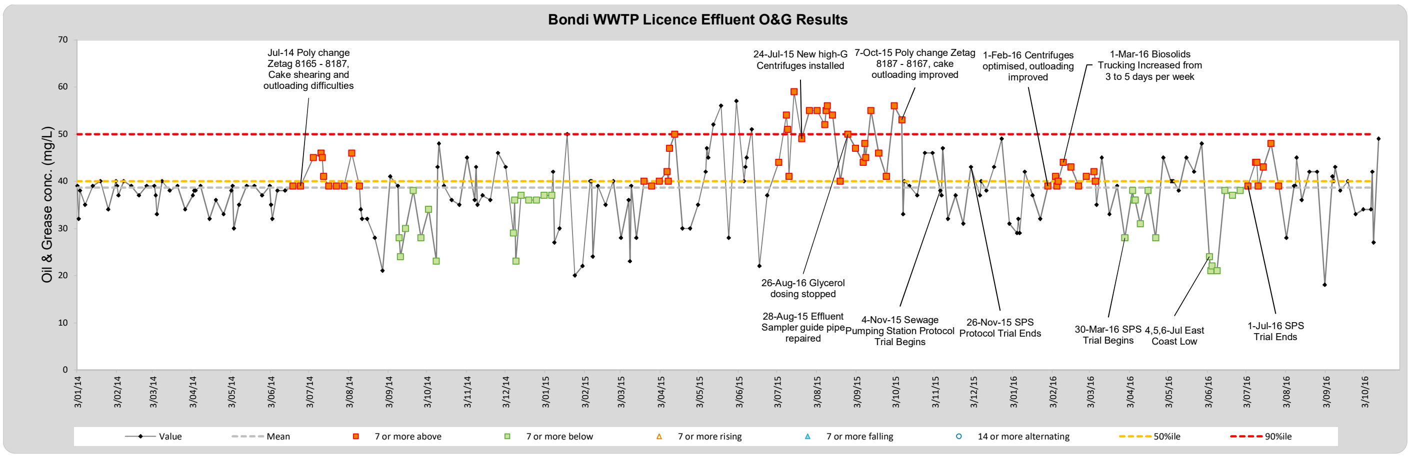


Figure 3-28 Bondi effluent O&G concentration step changes due to plant activities

3.4.8.3 Typical wastewater concentration ranges

The concentration data can be validated against with the typical concentration ranges for the catchment, and the expected volume of trade waste. This is particularly useful for new treatment plants servicing regions that are not yet fully developed, a similar catchment can be used for surrogate influent concentrations. Refer to Table 3-12 for the typical wastewater concentration ranges.

3.4.8.4 Network configuration and maintenance activities

The network specification and maintenance activities should be included in the flow validation process. These aspects include the following:

- **Network hydraulic capacity** | influent flow data should not exceed the hydraulic capacity of the influent sewer (channel or pipeline)
- **Network maintenance** | the influent flow data should be consistent with the immediate upstream network maintenance activities, for example flushing, shutoff, bypasses etc.
- **Network assets** | the influent flow trends will be affected by network storage and overflow management/abatement and thus flow trends should align the management and operation of these network assets

3.4.8.5 Pump station configuration and control

The immediate influent pump station has an impact on the influent flow and load profile to the plant. Validation of the data against the influent pump station relates to an assessment of the pump capacity and the pump control.

- **Influent pump station capacity** | influent data points should not exceed the capacity of the influent pump station
- **Influent pump station control** | hourly trends of the flow data should be consistent with the control philosophy of the influent pump station

The above can be done graphically, as shown in the example figure below in which the diurnal flow pattern is overlaid against flow rates at the influent pump stations.

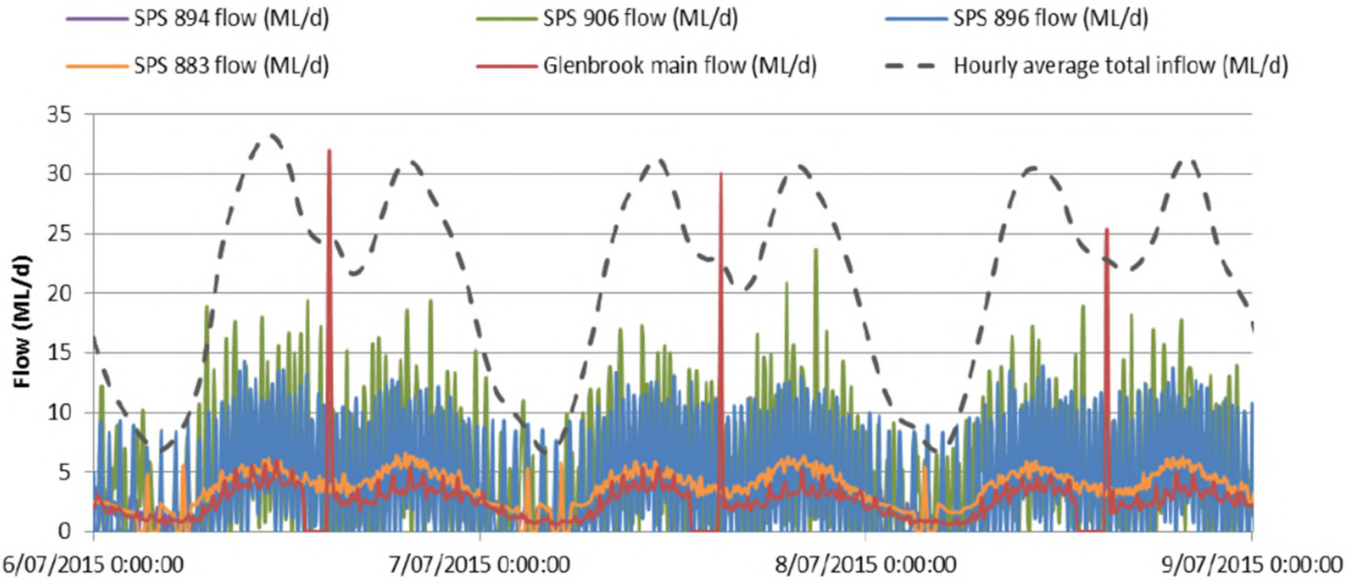


Figure 3-29 Example of diurnal flow data validation with influent pump stations and control philosophies

3.4.8.6 Flow and mass balancing

The influent flow data can be validated against the effluent flow data by comparing the daily influent volume with the effluent flow volume. The treatment system must maintain a flow balance; however, consideration should be given to non-effluent discharge routes such as evaporation and service water demands. In general, the variation between the daily influent and effluent flow volume should not exceed 10%. If influent flows trend below plant effluent flows, calibration issues should be suspected and investigated.

3.4.8.7 Plant performance and operator experiences

Check the data against the performance of the plant and/or the plant operator’s experience. It is suggested to engage with the operator to better understand the current performance of the asset or facility. This activity can be conducted as part of the pre-assessment stage.

3.4.9 Checklist for inputs identification and analysis

Table 3-15 Checklist for inputs identification and analysis

Checklist	
Pre-assessment	Understanding of the project area has been obtained
	Appropriate site investigations or literature reviews have been conducted to fill missing information
	Inputs or data for project activities have been pre-identified
	Stakeholders have been engaged to provide any inputs to the Basis of Planning
Flow and load scenarios	Operating boundary conditions for the asset/facility have been identified
	Flow and load scenarios align with the operating boundary conditions
	Superimposed conditions and/or special conditions have been considered as part of the operating boundary conditions and flow/load scenarios
Data collection from databases	Flow data has been extracted from HYDSTRA (with appropriate data resolution and period)
	Concentration data has been extracted from EKAMS
Campaign monitoring	HYDSTRA, EKAMS, and SCADA-BI have been thoroughly assessed for the required data
	If data does not exist, then monitoring plan has been developed detailing monitoring requirements (timeframe, sampling locations, number of samples, cost etc.)
Data validation	Flow, concentration, and load data have been validated using validation procedures (section 3.4.8)
Data analysis and inputs generation	Diurnal profiles have been generated and the diurnal profile scenarios align with project outcomes
	Influent composition (concentrations and fractionation) has been conducted and the composition scenarios align with project outcomes
	Fractionation has been conducted to the level of detail required for project activities
	Mass load analysis has been conducted and the loading scenarios align with project outcomes
	Sensitivity checks have been conducted for diurnal, concentration, load and fractionation analysis
Reporting and management **(particularly for from campaign monitoring data)**	Data is stored correctly, and can is easily accessible for future projects
	Data is captured and referenced in planning artefacts
	Data is disseminated to relevant stakeholders

3.5 Asset/Facility considerations

This section provides the guidelines for developing the asset/facility basis for the basis of planning and includes the guidelines for the development of process flow diagrams (existing or new), and the site variables and constraints that should be considered for planning of assets/facilities.

The purpose of this section is to provide prompts for variables and constraints that can affect project outcomes, particularly for project outcomes which include costing exercises.

3.5.1 Existing asset performance data

Where planning or design is occurring at an existing operating facility, site specific data shall be collected and analysed for use in the planning exercise. Data may include process unit operating setpoints and configuration, performance data, and plant product data.

3.5.1.1 Asset performance data sources

Performance data for treatment plants are Sydney Water can be sourced from the following databases:

- **SCADA BI |** Process Data Management System reports which captures daily plant laboratory results and daily average online instrument output results (i.e. DO probes and flow meters) for all monitored process units and streams
- **Plant SCADA |** real time and historic high-resolution output trends of all online probes, flow meters, valve positions, programmed control setpoints, pump and blower run speeds, and more
- **EKAMS |** reportable product stream monitoring results, may include recycled water and biosolids data in addition to plant influent and effluent data
- **Residuals Management Database |** grit and screenings production data, as well biosolids quality and quantity data
- **Campaign Monitoring |** tailored discrete monitoring datasets may exist for the site in past artefacts, generally conducted for PCA's

Needs for additional monitoring to supplement the existing datasets should be assessed based on project data needs and the existing dataset resolution and quality. Commonly conducted additional monitoring includes:

- Intra and inter process unit grab samples, especially return streams
- Diurnal liquid stream monitoring (influent and effluent)
- DO monitoring for secondary reactors and secondary effluent streams
- IDAL and SBR DO and decant ammonia profiling

3.5.1.2 Asset performance data analysis

The exact analysis required will vary depending on the process unit and the stream assessed. In general however, the following procedure is recommended when analysis plant data:

1. Compile daily value datasets – access data from all available sources and conduct initial review and analysis
2. Plot data points for key variables – plotting trends is very useful to observe process unit variability
3. Identify trends of note – focus on causational links and operational step changes related to asset availability or operating set point changes
4. Identify units requiring high resolution data and seek data from plant SCADA or other – use long term daily data to identify periods of interest and then extract high resolution data for the limited periods
5. Review datasets for data gaps – do you have the necessary data to inform the project, collect more as required

3.5.2 Site variables

When assessing site suitability for proposed new treatment assets or upgrades at existing facilities, the following factors should be considered:

- Topology profile of the wastewater catchment and treatment plant
- Pumping costs associated with wider system – 'sewer to discharge point' type system view?
- Process impacts – plant hydraulic profile, ambient pressure

3.5.2.1 Site altitude

Table 3-16 List of site altitude for Sydney Water treatment plants

Plant	Hub / Catchment	Site Altitude (msl)
Bombo	Illawarra	7
Bondi	Bondi	58 (above ground)
Brooklyn	Lower Hawkesbury	8
Castle Hill	North West Hub	65
Cronulla	Georges River	22
Glenfield	Malabar System	21
Hornsby Heights	Lower Hawkesbury	101
Liverpool	Malabar System	5
Malabar	Malabar System	17
North Head	North Head	62 (above ground)
North Richmond	Richmond Hub	23
Penrith	Blue Mountains	28
Picton	Camden Wollondilly	212
Quakers Hill	Wianamatta Hub	26
Richmond	Richmond Hub	19
Riverstone	North West Hub	32
Rouse Hill	North West Hub	49
Shellharbour	Illawarra	3
St Marys	Wianamatta Hub	22
Wallacia	Camden Wollondilly	145
Warriewood	Lower Hawkesbury	5

West Camden	Camden Wollondilly	80
West Hornsby	Lower Hawkesbury	73
Winmalee	Blue Mountains	221
Wollongong	Illawarra	4

3.5.2.2 Temperature (water)

The minimum, average, and maximum temperatures should be considered for the design or treatment assets/facilities (where suitable), for example for blower aeration systems and biological reactions (refer to Table).

The following temperatures should be utilised as a standard for planning activities - supersede with site-specific data where relevant. However, not that the minimum and maximum temperature values are typical values used in process models which have been calibrated and validated at these temperatures.

Table 3-17 Typical range of water temperatures

Criteria	Water Temperature
Minimum influent water temperature	14°C (typical minimum value used in process model)
Average influent water temperature	18°C (site-specific)
Maximum influent water temperature	22°C (typical minimum value used in process model)
Aeration zone temperature increase (for diffused air systems)	+2 to 4°C

Note: temperatures will vary from site to site, confirm using sewage monitoring data.

Table 3-18 Temperature scenario and unit sizing

Process Area / Unit	Temperature scenario and typical application in unit sizing		
	Minimum	Average	Maximum
Primary treatment	N/A	Average sludge yield	N/A
Bioreactor volume	Maximum sludge yield (highest WAS generation) Calculation of minimum SRT for nitrification	Average sludge yield	Minimum sludge yield (lowest WAS generation)
Aeration demand	Minimum aeration demand	Average aeration demand	Maximum aeration demand
Secondary settling	Maximum solids load to settling tank as linked to bioreactor sludge yield	N/A	N/A
Aerobic / Anaerobic digestion	Maximum solids load to digesters as linked to bioreactor sludge yield	N/A	Maximum aeration demand for aerobic systems
Biosolids processing	Maximum solids load to processing units as linked to bioreactor sludge yield	N/A	N/A

3.5.3 Site constraints

3.5.3.1 Overview of site constraints

An overview of the site constraints that should be considered during planning is shown in Figure 3-30. Further details regarding categories are provided in the subsection below.

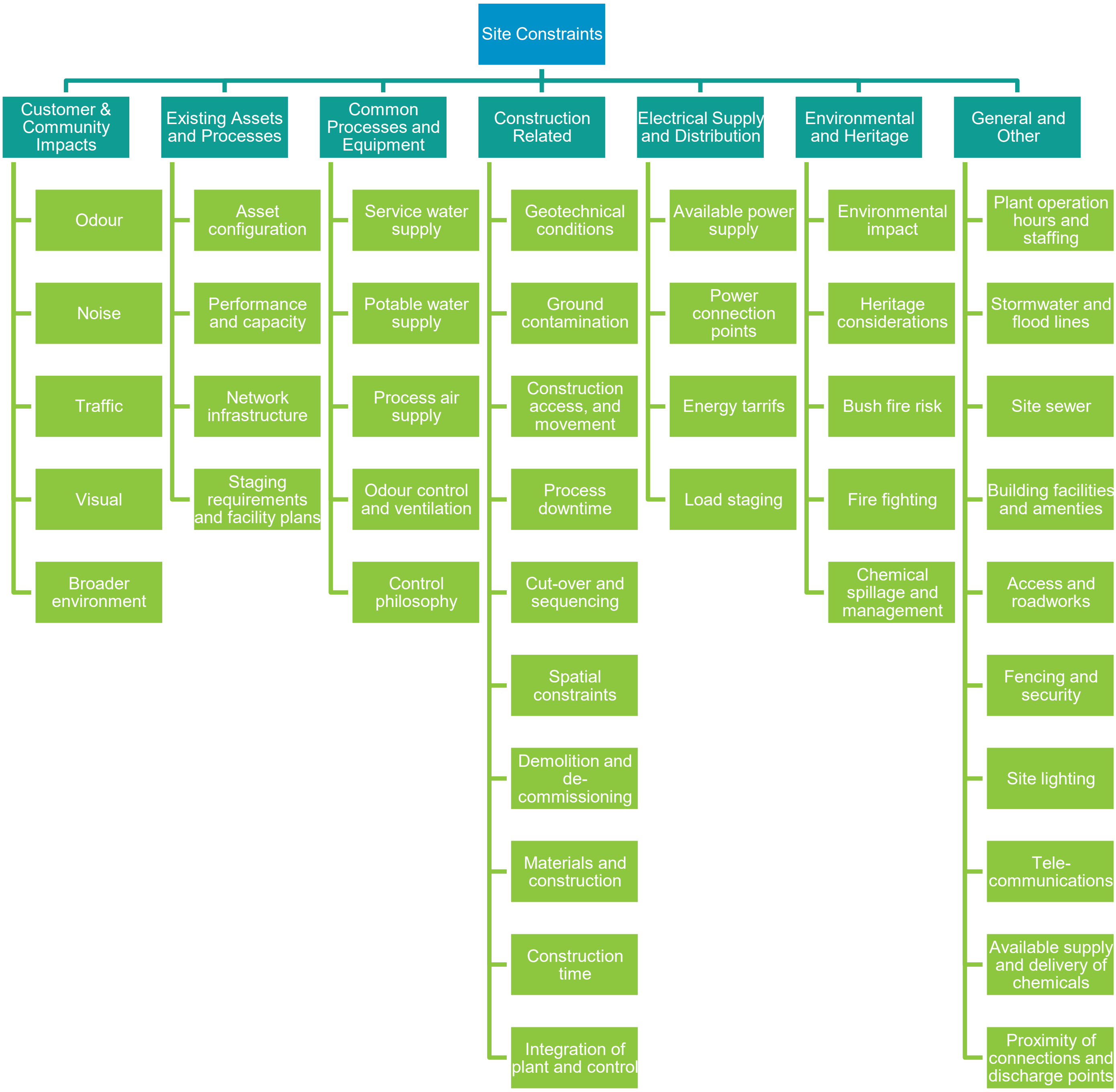


Figure 3-30 Overview of site constraints to be considered for the Basis of Planning

3.5.3.2 Customer and community impacts

3.5.3.2.1 Odour

During planning of new, upgraded or modified treatment processes which are expected to alter the odour profile of a wastewater treatment facility, the planning activities should include odour contour modelling to assess impacts of the proposed works. The need for this modelling should be determined on a site-specific basis taking into consideration project scope and detail requirements.

3.5.3.2.2 Noise

Reference should be made to the Protection of the Environment Operations (Noise Control) Regulation 2017 for noise control requirements. Consider noise modelling and/or assessments for greenfield sites and for existing sites where increased scope of operations is proposed.

3.5.3.2.3 Traffic

Consideration during planning should be given to internal and external traffic movement, for example:

- Impact of traffic movement on nearby roads during normal operation
- Impact of traffic movement on nearby roads during construction activities

When assessing traffic impacts for biosolids disposal consider the required number of disposal trips per annum in relation to the biosolids dryness and volume, the type of truck utilised for disposal, and greenhouse gas impacts due to disposal (typically CO_2 emission per L diesel consumption per 100km travelled)

3.5.3.2.4 Visual

During planning of changes to wastewater treatment infrastructure, consideration of the visual amenity to surrounding areas. This should include landscaping and site remediation requirements following any construction activities.

3.5.3.3 Existing assets and processes

3.5.3.3.1 Existing asset configuration (process flow)

For new or existing treatment plants, it is important to develop a sufficiently detailed process flow diagram of the treatment process to be included in the Basis of Planning. The following information must be included:

- Process flow paths for liquids, solids, and gases for all major process units
- Labels/names of process units as named at the facility
- Number of equipment per major process unit (e.g. settling tanks, bioreactors, digesters, dewatering equipment etc.)
- Influent information (influent location and name of key influent pump stations)
- Location of key dosing points for chemical P removal, carbon, pH control, and poly
- Location of return streams
- Location of discharge points and/or end-user of
- Location of licence sampling points and EPL number

3.5.3.3.2 Existing treatment performance and capacity

Capacity and performance of existing treatment process units should be captured and considering in the planning around an existing facility. Asset condition and reliability should also be considered.

3.5.3.3.3 Existing network infrastructure

When planning new treatment plants or process changes to an existing wastewater treatment facility, consideration should be given to any potential impacts on Sydney Water's wider wastewater operations. Conversely, the impact of on the treatment plant due to network planning and maintenance should be considered, examples of impacts include:

- Chemical dosing for network cleanout
- Pump station control philosophy
- Network capacity and upgrades

3.5.3.3.4 Staging requirements and facility plants

When undertaking planning projects relating to asset renewals, modifications or treatment upgrades at an existing WWTP, the following factors should be considered:

- Compatibility with existing treatment process configuration
- Chemical storage/dosing capacity
- Plant flow profile e.g. diurnal flow 'balancing'/equalisation requirements
- Hydraulic constraints
- Impacts on control philosophy
- Potential changes to process monitoring requirements (both online instrumentation and routine manual sampling/monitoring)
- Required bypasses
- Treatment plant operation during asset delivery/construction
- Changes to onsite RE systems (note: volume, pressure / flow rate, and quality)

3.5.3.4 Common processes and equipment

3.5.3.4.1 Site services

Site water services and auxiliary processes should be included as part of planning activities (where suitable). The following are common across Sydney Water treatment facilities:

- Potable water services for general amenities and chemical showers/eyewash stations
- Site sewer network for potable water services
- Reclaimed effluent supply for site service water demands
- Fire water supply
- Compressed air supply

3.5.3.4.2 Control philosophy

The existing control and instrumentation systems should be considered when planning new assets or processes at existing facilities.

The control philosophies and systems of new assets or processes should function seamlessly with the balance of the plant. This is to optimise overall plant performance, improve simplicity in operation, monitoring, and reporting.

When planning new assets or processes, consider how their respective control philosophies and control systems can be integrated with the balance of the plant – particularly for "blackbox" control systems, and for when there is a step-change in automation requirements.

3.5.3.5 General and Other

3.5.3.5.1 Plant operation hours and staffing

Plant operating hours and staffing availability must be considered for planning projects, particularly if new assets or treatment processes require a change in hours and staffing levels.

Further consider the impact of operation hours on servicing availability of equipment that do not operate on a continuous basis, e.g. thickening and dewatering equipment.

3.5.3.5.2 Proximity of product discharge locations

Points of effluent discharge and/or reuse markets should be identified in all planning works. Process changes which will alter the product outcomes should consider the effects on receiving water bodies or recycled water customers.

3.5.3.5.3 Site access and roads

Site access and roads needs to be considered in planning; and considerations include:

- Access roads to site, parking areas including layout and turning circles for vehicles
- Movement around site for day-to-day operating activities and delivery of chemicals/equipment etc.

3.5.3.5.4 Supply and delivery of chemicals

When specifying new chemical systems, consider the following:

- Available suppliers and accessibility of chemicals
- Delivery format (liquid, powder, gas, and volume of deliveries)
- Storage and shelf-life
- Health and safety requirements

3.5.4 Checklist for the asset/facility basis

Site variables and constraints should be referenced in the Basis of Planning. The list provided in Table 3-19 should be considered. However, each facility is different and thus not all variables or constraints may apply.

Table 3-19 Checklist for site variables and constraints

Checklist	
Site variables	Site altitude
	Ambient temperature
	Humidity
Customer impacts	Odour including odour contours and level of treatment required
	Noise from internal movement of vehicles and ambient noise generated from equipment
	Traffic from external movement of vehicles (e.g. staff vehicles, disposal/delivery vehicles)
	Visual impacts such as tall or obtruding structures
	Renewals and upgrades currently occurring at the site

Existing infrastructure and processes	Network infrastructure such as the location of the influent sewer
	Interconnecting pipework between process units and structures
	Proximity of product discharge locations
	Site water demands such washwater, dilution water, potable water supply, fire water supply
	Site access, roads, and security
	Telecommunication systems
	Auxiliary processes such as compressed air supply
Electricity supply and distribution	Power supply and connection
	Energy grid and tariffing
	Cabling and ducting layouts
Operator and control considerations	Operation philosophy and level of automation of process units
	Safety in design
Environmental and heritage	Environmental impact due to solids, liquids, gas discharges, and asset/site construction requirements
	Contamination of land and buildings (hazardous building materials)
	Heritage and aboriginal considerations
	Bush fire risk
Stormwater and flooding	Site stormwater requirements
	Flood lines
Structural and construction considerations	Ground conditions
	Spatial constraints affecting the construction and installation of equipment/assets
	Materials of construction and impact of the proximity to the coast
	Construction sequencing and commissioning requirements
	Demolition / decommissioning requirements

3.6 Planning horizon and future considerations

3.6.1 Planning horizon

The planning horizon applied for wastewater treatment planning should be determined in initial planning phases. The following design horizons shall be considered as a minimum:

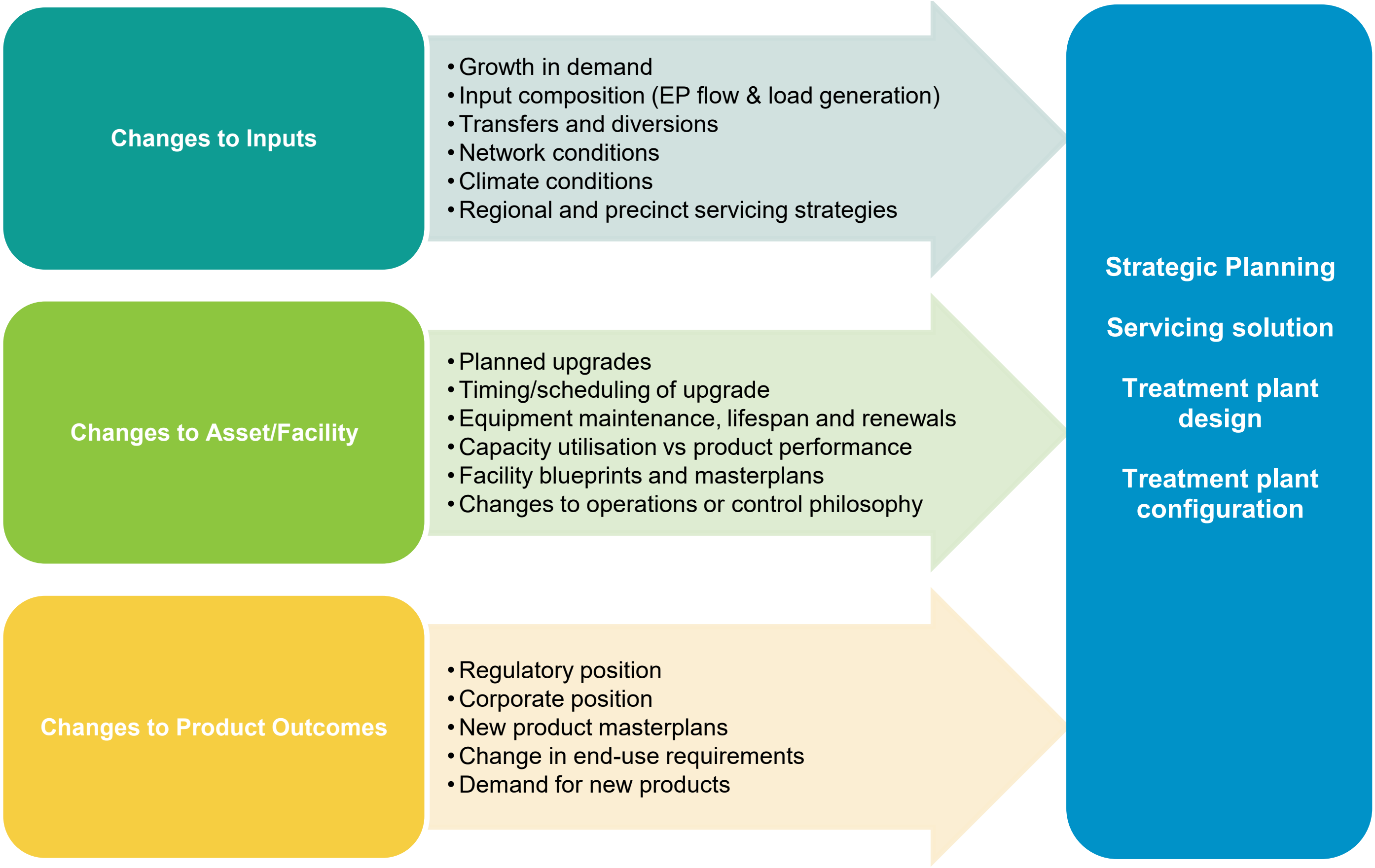
- 30 year horizon – or in proximity if aligning with recent growth servicing exercise
- Current and following budgetary period (i.e. in line with pricing submission period)

3.6.2 Future considerations

During the planning horizon, it is likely that changes in the input, asset/facility, and product basis will occur. This because wastewater servicing is not static and is affected by regulatory changes, asset life-cycle conditions, and growth in demand.

These changes also need to be managed appropriately through strategic planning, robust servicing solutions, treatment plant design and configuration.

Further details of key future considerations are provided in the sub-sections below.



Changes to Inputs

- Growth in demand
- Input composition (EP flow & load generation)
- Transfers and diversions
- Network conditions
- Climate conditions
- Regional and precinct servicing strategies

Changes to Asset/Facility

- Planned upgrades
- Timing/scheduling of upgrade
- Equipment maintenance, lifespan and renewals
- Capacity utilisation vs product performance
- Facility blueprints and masterplans
- Changes to operations or control philosophy

Changes to Product Outcomes

- Regulatory position
- Corporate position
- New product masterplans
- Change in end-use requirements
- Demand for new products

Strategic Planning

Servicing solution

Treatment plant design

Treatment plant configuration

Figure 3-31 Future considerations and causes for change

3.6.2.1 Inputs future considerations

3.6.2.1.1 Flow and load projections

Flow and populations shall be sourced for a 30 year or 40 year horizon if available. Catchment boundaries should be reviewed to ensure all planned areas and associated population are captured in the forecast.

Where uncertainty exists in the forecast, an envelope approach should be adopted – for example a lower demand forecast and an upper bound demand forecast. In the case of treatment planning, this activity has typically been undertaken prior to receiving the forecast data.

Refer to Section 4.6 for further details and methodologies for projecting flows and loads for wastewater treatment planning

Key sensitivities to be assessed when projecting growth demand and servicing solutions include:

- Impact on planning outcomes if future residential wastewater generation rates were 180 L/EP/d instead of the assumed 150 L/EP/d
- Impact on planning outcomes if future non-residential flows (or forecast employment) includes one or more industrial sources (i.e. which represents 5-20% of the plants influent stream) including impact of loss of industrial source or step-change in source characteristics

3.6.2.1.2 Network planning and network servicing strategy

Network planning and network servicing strategy should be included as part of the flow and load projections. Where applicable, include sensitivities for the following:

- Impact of network diversion and transfers, particularly in influent concentrations and mass loads
- Impact of network augmentation on the intensity and length of peak and minimum flows

3.6.2.2 Asset/Facility future considerations

3.6.2.2.1 Planned upgrades

Planned upgrades must be considered in the planning horizon, particularly for upgrades which alter product pathways and/or product outcomes. Facility blueprints and masterplans are useful references highlighting the investment strategies for the treatment plants.

3.6.2.2.2 Equipment maintenance, lifespan and renewals

Consider the impact of equipment maintenance, lifespan and renewals when assessing the facility constraints. Existing assets reaching their end-of-life may require renewal; and depending on the holistic plant drivers, may require technology change or capacity amplification.

3.6.2.2.3 Capacity utilisation vs product performance

Certain process units experience a deterioration in product performance when its capacity utilisation increases, i.e. operating closer designed influent loading or flow rate. Examples of such equipment include grit removal systems, digesters, and thickening and dewatering equipment.

When utilising existing performance data for design activities such as process modelling or product quality modelling, consider the impact of future loads or flows on the equipment or process, and the product outcome that is can achieve under these higher loads.

3.6.2.3 Product future considerations

3.6.2.3.1 Product masterplans

Product masterplans are being developed at Sydney Water. These set the strategy and direction for product classes across Sydney Water. Product Masterplans should be sort and referenced for each relevant product stream.

Examples of product masterplans include:

- Biosolids Masterplan
- Waterways Masterplan
- Energy Masterplan

3.6.2.3.2 Changes to product outcomes

Known or expected changes in the product outcomes shall be considered in the planning activity. Where the expected change horizon is known, this shall be identified in the basis of planning.

Examples of future product outcomes to be considered include:

- Discharge effluent concentration of load limit performance change
- Biosolids stabilisation grade change for beneficial reuse
- Requirements to manage greenhouse gas emissions from treatment processes
- Alternate recycled effluent end uses

3.6.2.3.3 Potential new products and alternative markets

There are potential resource recovery options for treatment product that increase the resource value. There is a driver to change the approach of wastewater treatment plants from a “treat and dispose facility” to a “resource recovery centre”.

When identifying treatment products and product outcomes, consider potential products and alternative pathways or markets which can drive the selection and planning of treatment assets and product outcomes, such examples include (refer to Bioresources Master Plan August 2018 for more information):

- Re-use and movement to water sensitive cities:
  - Potable re-use
  - Aquifer recharge
  - Industrial water supply
- Alternative energy recovery and treatment systems
  - Pyrolysis and Gasification (thermal conversion of waste activated sludge to gas and solid energy sources)
  - Co-digestion (i.e. digestion of municipal sludges with industrial and agricultural carbon)
  - Waste to energy (burning of feedstock and biosolids)
  - Incineration/thermal oxidation
  - Composting and blended soil amendments (i.e. produce compost or blend biosolids with compost additives)
- Nutrient farming and alternative nutrient removal systems:
  - Phosphorous recovery (struvite farming)
  - Ammonia recovery

4. Treatment Plant Configuration Guidelines

"*Treatment plant configuration*" refers to the selection, design, and configuration of treatment processes and assets to achieve the selected product outcomes under a defined set of servicing availability, operating boundaries and input conditions. The principles in which these guidelines are founded are detailed in Section 4.2.

Utilisation of this section will assist in defining the size and number of process units and equipment to the detail necessary for planning projects (e.g. needs and options assessments) for the purpose of budget assessments. For detailed unit sizing and optimisation of process units, as typically required for concept and detailed design, the planner/engineer should refer to the relevant bodies of knowledge for process theory and design procedures.

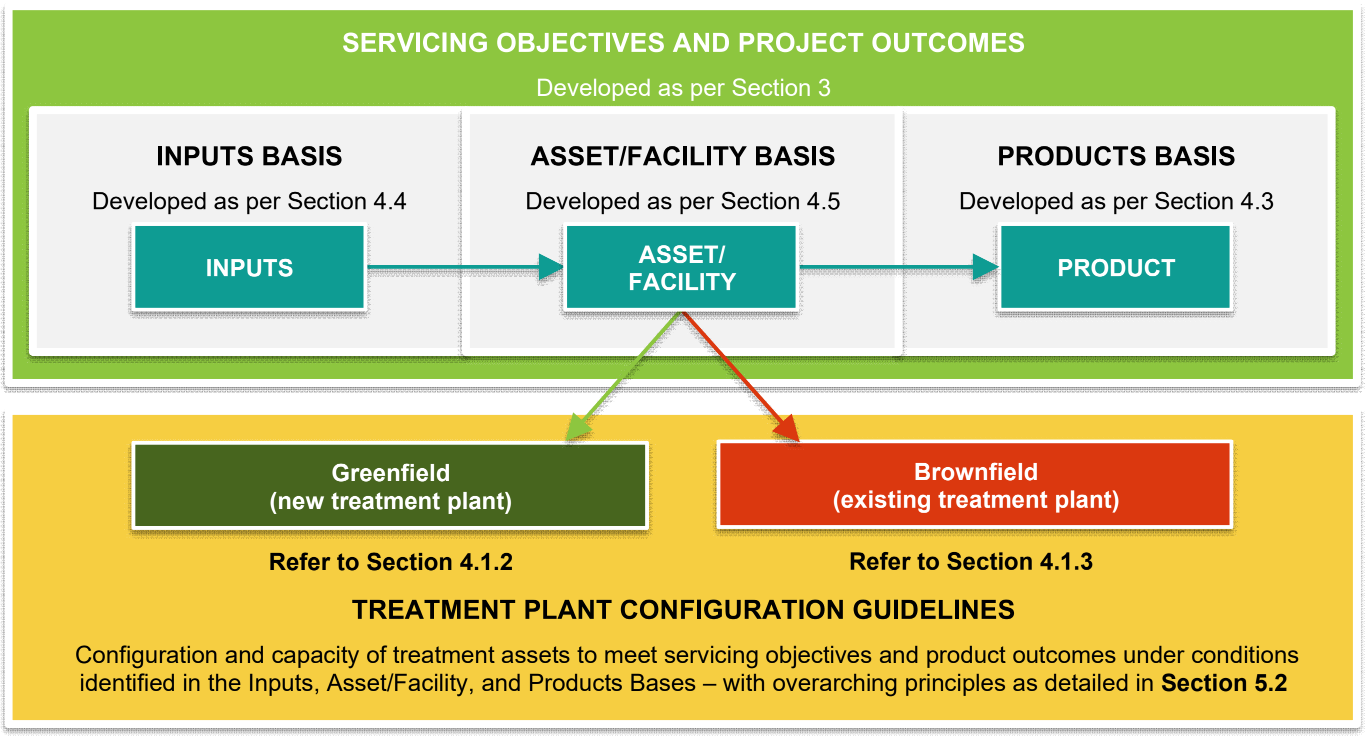
4.1 Application of treatment plant configuration guidelines

4.1.1 General approach for application of configuration guidelines

There are two pathways for the application of the treatment plant configuration guidelines:

- **Greenfield application** where a new asset / facility is developed without constraints imposed by the configuration of existing assets, i.e. new treatment plant. In such scenarios, the selection of assets and configuration of the plant is unhindered, and the planner/designer has freedom to configure the plant to meet product outcomes. However, whilst unhindered, there may still be limitations imposed due to asset/facility interfaces (e.g. network and end-users) and local site conditions (e.g. topography) which can affect the plant configuration.
- **Brownfield application** where an existing asset / facility is developed within the configuration constraints of existing assets. Brownfield applications can be further classified into different types of asset / facility upgrades, aligned with typical Sydney Water business cases, namely: renewal or reliability upgrades, stream amplifications (growth servicing), or product outcome changes (mandatory standards). These categories are typically nominated based on the primary driver and often are combined in nature, resulting in a "mixed driver" project.

The subsections below detail the greenfield and brownfield application of these plant configuration guidelines.



Configuration and capacity of treatment assets to meet servicing objectives and product outcomes under conditions identified in the Inputs, Asset/Facility, and Products Bases – with overarching principles as detailed in **Section 5.2**

Figure 4-1 Application of treatment plant configuration guidelines

4.1.2 Greenfield application of configuration guidelines

Greenfield application is typically driven by catchment growth and regional servicing objectives. When applying the configuration guidelines, the following sequence of activities are required (as shown in Figure 4-2):

a) **Select overall plant configuration to meet the product outcomes identified in the Basis of Planning.**
   i) The expected performance of the plant configuration must align with the product outcomes, refer to Section 4.3.

b) **Determine the minimum flow paths for each major process unit.**
   i) Minimum flow path refers to the flow rate required to be treated through each process unit under different flow conditions with the aim of maintaining an acceptable level of treatment during wet weather events.
   ii) For greenfield development these are to be defined during the design of the facility.
   iii) For high level scoping exercises, the typical flow paths nominated in Section 4.4 can be adopted prior to more detailed assessment and design

c) **Determine the unit capacity and configuration of each major process unit.**
   i) Determine total or ultimate unit capacity to meet the forecasted demand.
   ii) Determine the unit configuration required to meet the forecasted demand. Consider servicing availability requirements and plant configuration principles such as modularity, redundancy, etc. (refer to Section 4.2).
   iii) Review plant-wide system and conduct sensitivity checks and re-iterate designs if required

d) **Determine staging and future provisioning requirements** to enable the demand to match the delivery of process capacity and to facilitate future upgrades at the plant to meet long-term servicing demands (refer to Section 4.6).

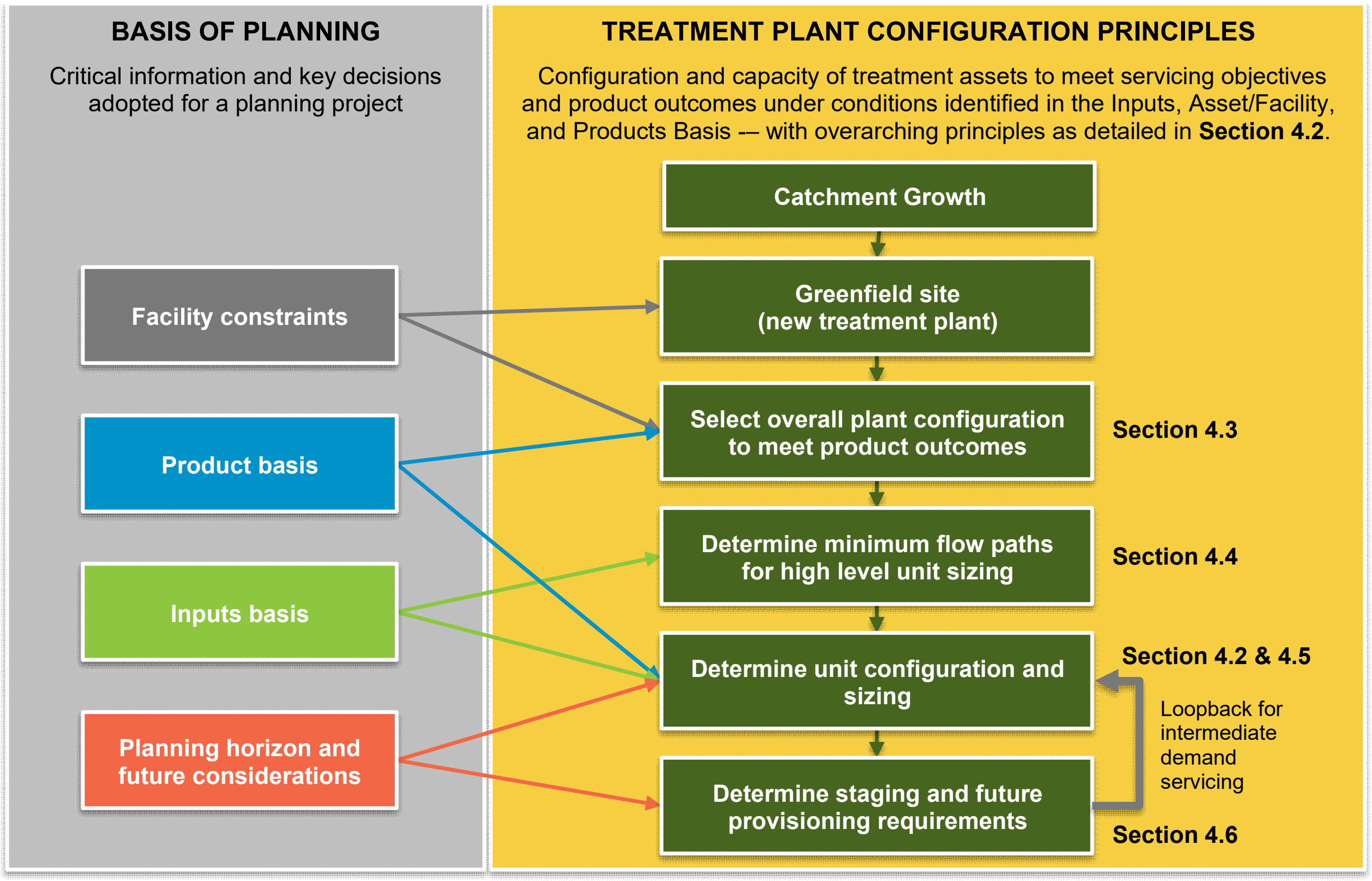


Figure 4-2 Greenfield application of plant configuration guidelines

4.1.3 Brownfield application of configuration guidelines

Brownfield application is typically driven by three needs, as shown in Figure 4-3:

- Reliability or renewal where the continued operation of an existing asset does not provide further favourable operating costs or effort or is deemed as a risk to process reliability or health and safety.
- Demand increase where the unit capacity of a discrete asset or stream can no longer meet the servicing demands. This scenario can be combined with reliability in which a higher capacity is necessary to improve the treatment reliability of a process unit. The demand increase is typically related to growth servicing.
- Change in corporate or regulatory position which affect the product outcome or specification. This is typically externally driven by asset stakeholders.

The method of application of the plant configuration guidelines will vary for the three drivers; further details are provided in the subsections below. It should be noted that the above needs are can be experienced individually or as a combination. The latter scenario creates complex multi-driver projects which can have competing project or product outcomes.

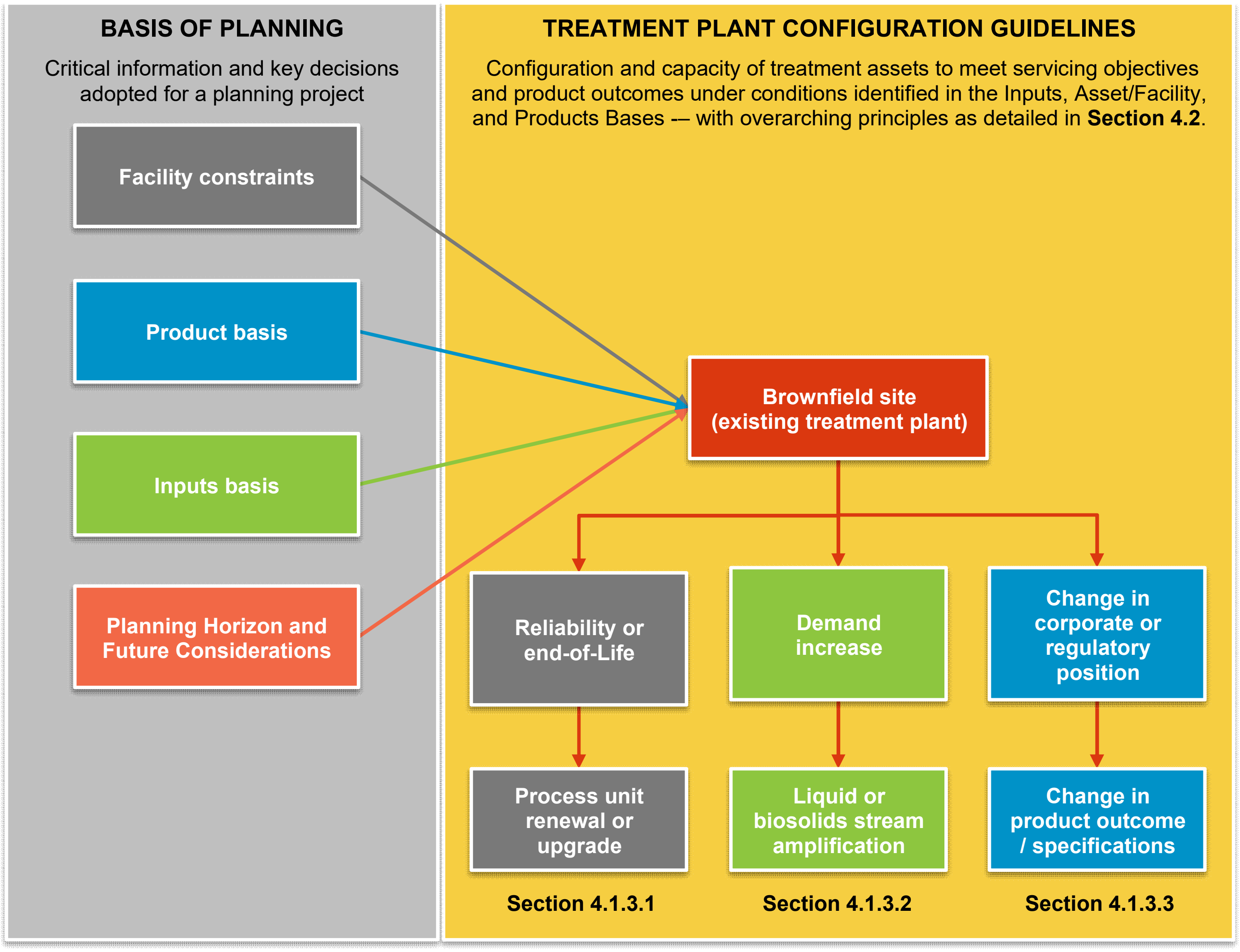


Figure 4-3 Categories of brownfield application of plant configuration guidelines

4.1.3.1 Process unit renewal or upgrade

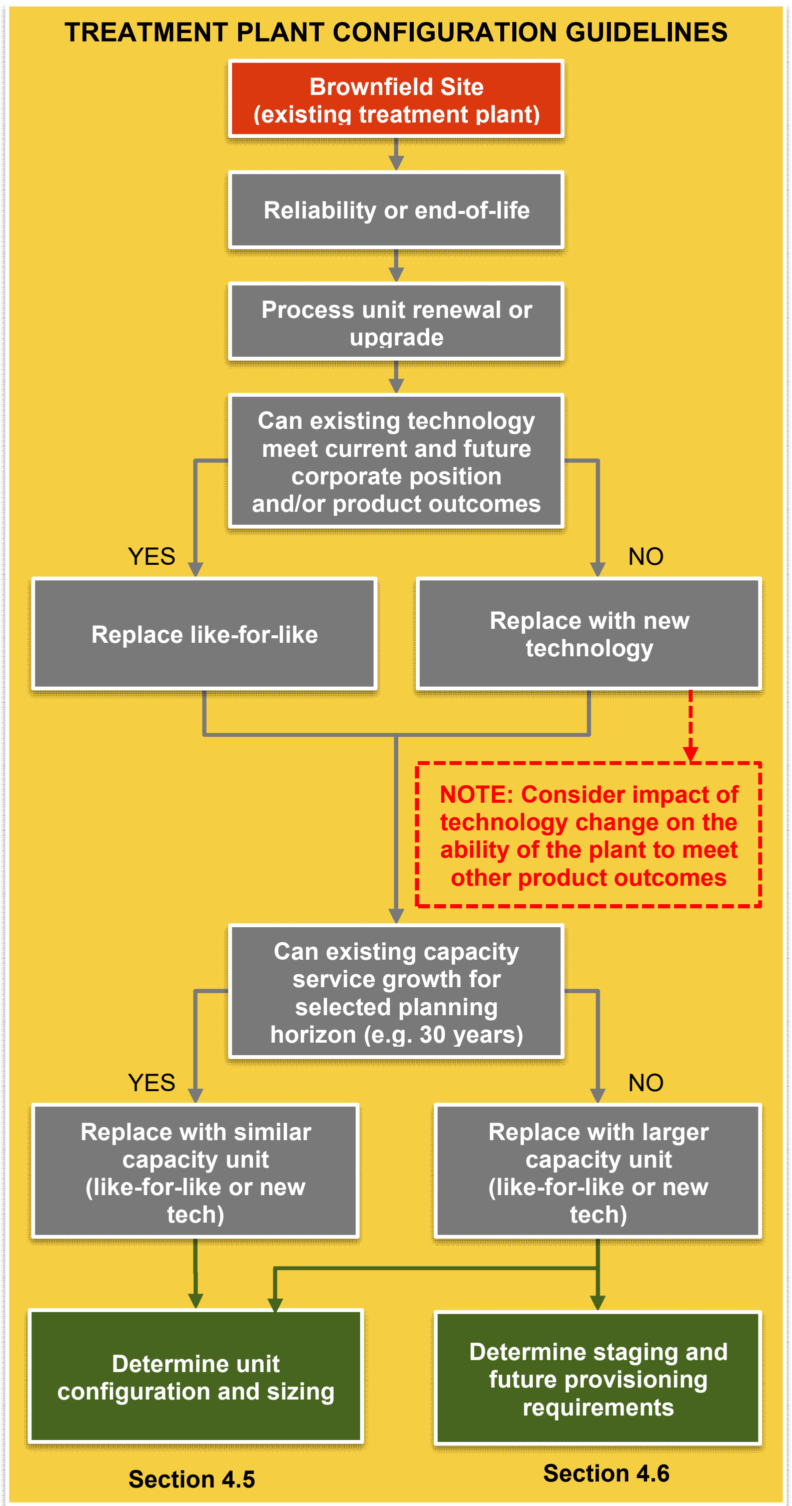


Figure 4-4 Brownfield application of plant configuration guidelines for process unit renewals or upgrades

Process unit renewal or upgrades are driven by the need for improved servicing reliability or for replacement of assets that have reached their end-of-life.

This type of project may be identified through maintenance schedules (based on expected asset life), operator reported performance issues, review of call outs and unit downtime, or a detailed asset assessment such as a Process Capability Assessment.

When planning for the renewal or upgrade, it is essential that the following questions are addressed:

a) **Can the existing technology, before the renewal or upgrade, comply with current and future corporate positions and/or product outcomes?**

   If the technology cannot meet the requirements, then replacement with new technology is required. However, consider the impact of the change in technology on the ability of the plant to meet other product outcomes.

   Examples where of technology change include improvements in treatment technologies which provide better operational performance and/or favourable operating costs (i.e. low energy consumption); or a known future change in product outcome which cannot be met by the existing technology irrespective of the current operational performance or cost.

b) **Can the capacity of the existing asset meet the planning horizon demands?**

   If the capacity of the existing asset is sufficient for the planning horizon demand profile, then the new asset does not need to be upsized.

   Conversely, the capacity should be upsized if it cannot provide servicing for up to the end of the planning horizon. In such a scenario, consider if staging and future provisioning is necessary to optimise investment and improve the adaptivity for future planning and servicing.

4.1.3.2 Stream (liquid/solids/gas) amplification

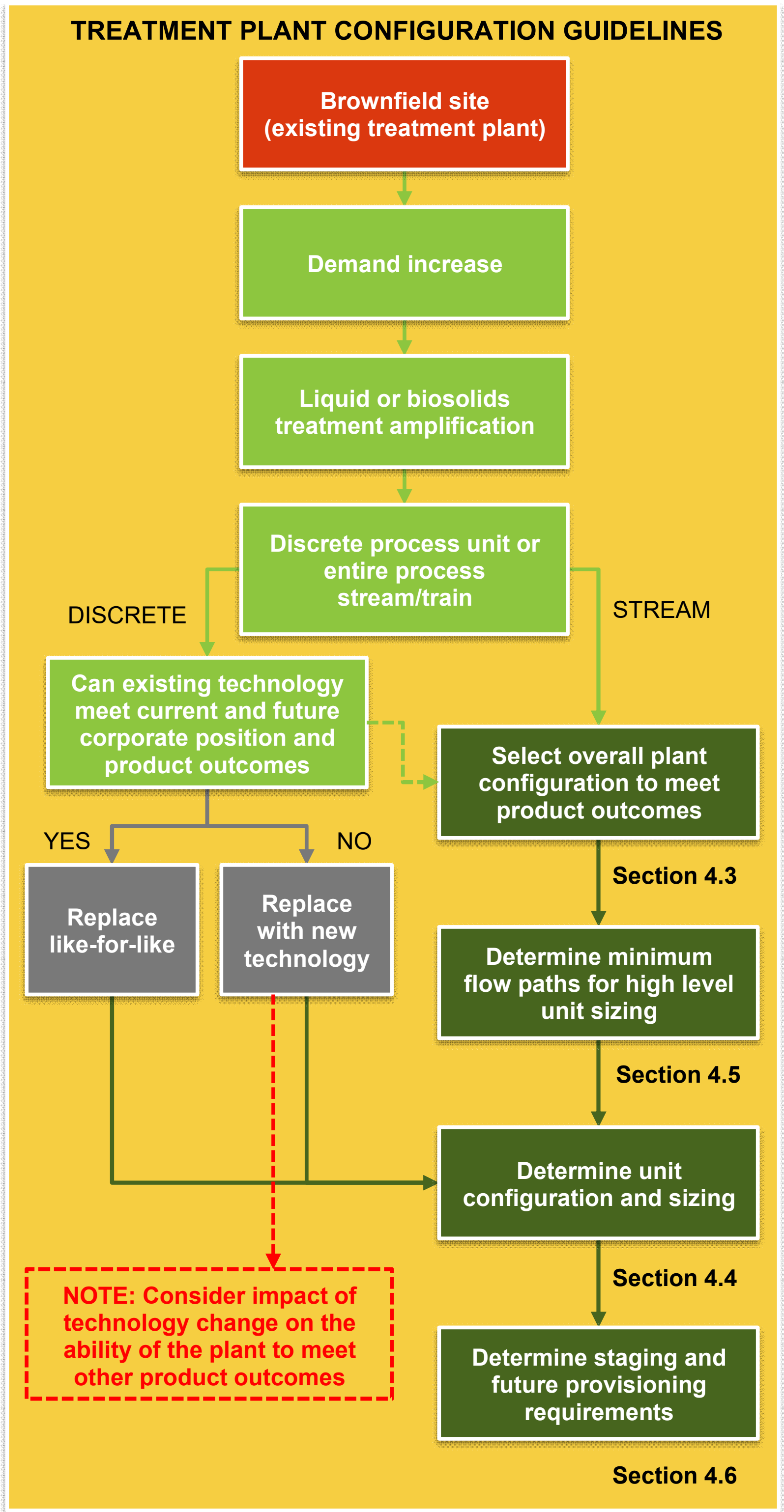


Figure 4-5 Brownfield application of plant configuration guidelines for stream amplification

Stream amplification is driven by the need for higher treatment capacity to meet demand increases, general driven by catchment growth.

Stream amplification can also be driven by reliability conditions in which greater buffer in treatment capacity is needed so that equipment can be taken offline without reducing the capacity of a treatment stream.

The need for this type of project is typically identified through discrete planning activities such as the Process Capability Assessments (PCA) or periodic Growth Servicing Investment Plans.

When planning for a stream amplification, it is essential that the following questions are addressed:

a) **Is the amplification for a discrete process unit?**

   If it is a discrete process unit then the approach will be as per the renewal or upgrade approach and will focus on addressing the technology selection and required unit capacity and staging.

b) **Is the amplification for an entire treatment stream?**

   If it is an entire treatment stream, then the approach will be as per the greenfield application in which the holistic treatment train must be considered from identifying product outcomes to design of minimum flow paths and detailed unit configuration and sizing.

c) **Are there multiple discrete process units, or does the discrete process unit have a plant-wide impact (e.g. bioreactor or digester)?**

   It may be necessary to adopt an “entire stream approach” to ensure that the multiple discrete process units are holistically considered and integrated to efficiently achieve a common project objective.

   Likewise, for discrete process units that require a technology change, consider the impact on the balance of plant and its ability to meet other product outcomes.

4.1.3.3 Product outcome or specification change

Changes to the product outcome or specification are due to changes in corporate or regulatory position. These changes can occur in the liquid stream or the solids stream.

Examples of liquid stream changes include the following:

- Changes to the EPL (e.g. effluent load or concentration limit) resulting in greater demand for process reliability, a change in process technology, or both. Note that, the disruption to the treatment stream will depend on the severity of the regulation change. Severe changes can have a plant-wide impact which necessitate a holistic liquid and biosolids approach to achieving product outcomes.
- Change in product end-use, i.e. the current treatment product is unsuitable for the new end-use requirement or application of the product; an example includes a change from environmental discharge to production of recycled water which necessitates tertiary or advanced treatment to produce a higher quality effluent product.

Examples of biosolids stream changes include the following:

- Change in biosolids classification. An increase in biosolids classification will typically require a technology change and hence induce plant-wide impacts.
- Increase reliability in achieving a biosolids outcome, i.e. greater frequency of compliance to a certain biosolids product outcome. This is in part similar to the liquid stream product end-use scenario in which a downstream process or end-use is driving a greater demand in the quality of the biosolids product. An example statement includes: “100% of biosolids must meet B2 classification”.

When planning for a product or specification changes, it is essential that the reasoning for the change is well-understood and defined and has been assessed holistically with consideration of wider region and system impacts (including those laying outside of the scope of the treatment plant).

After which, if the product change is necessary, it is essential that the following questions are addressed either planning activity:

a) **Can the existing technology, before the product change, comply with the future corporate positions and product outcomes?**

   If the technology cannot meet the requirements, then replacement with new technology is required. However, consider the impact of the change in technology on the ability of the plant to meet other product outcomes.

b) **Can the capacity of the existing asset meet the planning horizon?**

   If the capacity of the existing asset is sufficient for the planning horizon then the new asset does not need to be upsized.

   Conversely, the capacity should be upsized if it cannot provide servicing for up to the end of the planning horizon. In such scenario, consider if staging and future provisioning is necessary to optimise investment and improve the adaptivity of future planning and servicing.

A summary of the approach for this application is shown in Figure 4-6.

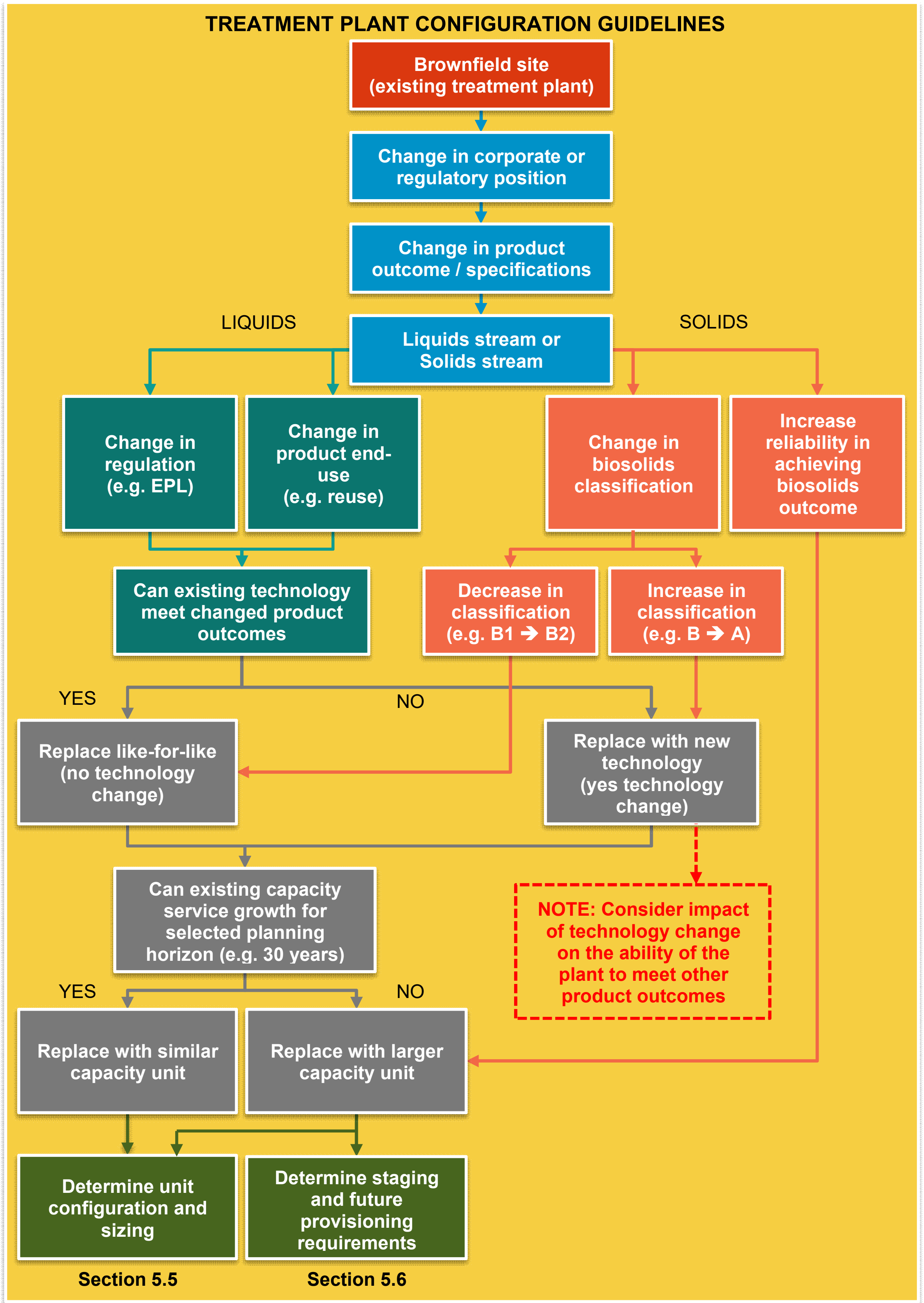


Figure 4-6 Brownfield application of plant configuration guidelines for changes in product outcomes or specifications

4.2 Configuration principles

4.2.1 Governing unit capacity parameters

Each process unit has key operating or design parameters which determine the treatment capacity of the unit in its operating context – these are known as the unit capacity parameters. A process unit typically has one or two critical capacity parameters to be assessed, however more complex process units can have a suite of parameters to be considered.

Depending on the operating scenario and required product outcomes, one or more unit capacity parameters may be more critical than others and thus define the demand that the unit can service. These become the governing unit capacity parameters. Examples of some governing unit capacity parameters are provided in Table 4-1.

Table 4-1 Examples of governing unit process capacity parameters

Process Unit	Capacity Parameters	Comments
Inlet screens	• Hydraulic capacity (L/s)	Instantaneous min and max flow rates will determine both the screening removal performance as well as the maximum flow the screening works can pass without flooding.
Secondary bioreactor	• Total solids retention time (d) • Aerobic solid retention time (d) • Aeration capacity (kgO_2/h) • Hydraulic capacity (L/s)	Multiple criteria, any of which may govern. Prioritisation and threshold value of any parameter will be determined by the required product outcomes.
Dewatering centrifuge	• Hydraulic loading rate (m^3/hr) • Solid loading rate (kg/hr)	Unit throughput capacity is a function of both parameters. Typically, solids loading rate is the limiting parameter. Based on operating experience at SWC, a derating factor is applied to manufacturer's unit capacities to ensure required performance achieved.
Disinfection	• Hydraulic capacity (L/s)	Multiple hydraulic throughput capacities may apply including: flow rate for full disinfection and max hydraulic throughput.

4.2.2 Servicing availability

4.2.2.1 Purpose of servicing availability

Servicing availability is unit capacity and configuration required to achieve treatment product outcomes under different demand and maintenance scenarios. Servicing availability is not redundancy. Redundancy is the provision of discrete standby units as backup to duty units and is an approach to providing servicing availability. There exist other approaches to providing servicing availability, these are detailed in Section 4.2.2.3.

Maintenance downtime is a reality of all equipment, be it electrical, mechanical or civil. Downtime occurs due to a module being taken offline for maintenance (planned or unplanned). This leads to a loss of overall unit capacity and will typically result in a loss of treatment performance and/or a deterioration of product performance against specified product outcomes.

The duration and frequency of maintenance activities for each process unit informs its availability in the short-term and ongoing future horizons. Unit module downtimes may range from daily short runtime reductions, to long-term loss of capacity every few years, and up to one to two years offline for larger digesters.

Planning for servicing availability involves testing of process unit sizing and configuration across expected reduced capacity scenarios to determining if product outcomes can be maintained during these periods. If the product outcomes cannot be maintained, then appropriate provisions in the unit sizing and configuration should be implemented to ensure that manage the deterioration of product outcomes under the assessed capacity scenarios.

4.2.2.2 Identification of required servicing availability

Step 1: Identify servicing availability required for the plant-wide system or treatment pathway (i.e. for process areas: pre-treatment, primary, secondary, tertiary etc.) and link to product outcome requirements. E.g. secondary treatment needs 100% availability and fully compliant product outcomes for full range of demand scenarios, or primary treatment needs 100% availability but can operate at reduced product performance under peak demand scenarios.

Step 2: For each treatment pathway, identify servicing availability required for the individual process units based on:

- Expected duration and frequency of maintenance for major (or limiting) process units
- Link back to key product outcomes and risk of not meeting them
- Impact of loss of active capacity on other process unit outcomes (i.e. WAS thickening impacts on bioreactor)
- Limiting scenarios for each key process: average loads, peak month, peak day, peak hour, L/s max (may be multiple for some units)

Step 3: Identify the right approaches in configuration to ensuring servicing availability (see details below).

4.2.2.3 Approaches to ensuring servicing availability

To meet servicing availability requirements the following options should be considered:

- **Modularity** | process unit capacity should be delivered across multiple modules such that during maintenance activities some treatment capacity is maintained. Increased number of modules results in reduced loss of capacity when any one module is taken offline. Module count should be balanced against capital delivery and operational costs. Module size may vary with upgrade staging, especially in high growth catchments.
- **Modularity** | process unit capacity should be delivered across multiple modules such that during maintenance activities some treatment capacity is maintained. Increased number of modules results in reduced loss of capacity when any one module is taken offline. Module count should be balanced against capital delivery and operational costs. Module size may vary with upgrade staging, especially in high growth catchments.
- **Redundancy** | additional assets (process unit modules) on standby which readily activate when the duty assets are out-of-service. This is usually described as *"n+i"* (i.e. n+1) where *n* is the number of duty units and *i* is the number of standby units, e.g. n+1 with n = 4. Refer to Table 4-2 for example of the redundancy approach.
- **Oversizing** | assets are oversized and have excess capacity under normal operating conditions. When duty units are out-of-service, the excess capacity of the remaining units provide treatment. This is usually described as *"n-i"* i.e. (n-1) where *n* is the number of oversized duty units and *i* is the allowed number of out-of-service units, e.g. n-1 with n = 4. Refer to Table 4-2 for example of the oversizing approach.

  Note that oversizing of assets is different to future provisioning. Future provisioning is the provision of excess capacity to meet future demands such as to service growth.
- **Commonality (installed)** | assets are shared between treatment trains in either assist or standby configuration, for example a common installed standby RDT for WAS thickening and recuperative thickening.
- **Spares** | predominately applies to mechanical and electrical items, instead of an installed redundant module, full module spares or critical component spares can be stocked to be cycled in for out of service modules or components. Risk based assessment required to validate approach.
- **Transfer or Storage** | Transfer or temporary storage systems which trigger under pre-set conditions, to temporarily manage and reduce demand remaining duty units. Typically only applicable for small streams.

An example of the servicing availability approaches is provided in Table 4-2.

Table 4-2 Approach to providing servicing availability

Redundancy approach, n+1 with N =4 to provide 100 ML/d active (duty) capacity		Oversizing approach, n-1 with N = 4 to provide 100 ML/d active (duty) capacity	
Redundancy operation with all assets available	**Redundancy operation with 1 asset out-of-service**	**Oversizing operation with all assets available**	**Oversizing operation with 1 asset out-of-service**
Asset 1 = 25 ML/d Duty	Asset 1 = 25 ML/d Duty	Asset 1 = 25 ML/d Duty	Asset 1 = 33 ML/d Duty
Asset 2 = 25 ML/d Duty	Asset 2 = 25 ML/d Duty	Asset 2 = 25 ML/d Duty	Asset 2 = 33 ML/d Duty
Asset 3 = 25 ML/d Duty	Asset 3 = 25 ML/d Duty	Asset 3 = 25 ML/d Duty	Asset 3 = 33 ML/d Duty
Asset 4 = 25 ML/d Duty	Asset 4 = Out-of-service	Asset 4 = 25 ML/d Duty	Asset 4 = Out-of-service
Asset 5 = Standby	Asset 5 = 25 ML/d Duty	No asset 5	No asset 5
100 ML/d Duty Capacity	**100 ML/d Duty Capacity**	**100 ML/d Duty Capacity**	**100 ML/d Duty Capacity**
25 ML/d Standby Capacity	**0 ML/d Standby Capacity**	**33 ML/d Excess Capacity**	**0 ML/d Excess Capacity**

4.2.3 Governing demand scenarios

This principle is linked to servicing availability.

There may be multiple design demands for a single process unit; therefore, when sizing process units, ensure that all demand scenarios are assessed and considered in planning.

In most cases, the governing demand scenario is the highest expected demand during normal operation, for example, in anaerobic digestion this would be peak month solids. However, there may be demand scenarios under superimposed loading conditions which fall outside of normal operation e.g. unit of equipment out-of-service. Further, the governing demand scenario may occur in the future and therefore forecasting of growth in demand is necessary. Refer to Section 3.4 for details on inputs identification and Section 3.6 for details for demand forecasting.

The size of a process unit should ideally be equal to or greater than the governing demand scenario. If this is not the case, then measures should be in-place to manage product quality risks due to an undersized unit operating outside of its demand capabilities.

4.2.4 Unit sizing and configuration

4.2.4.1 General unit sizing and configuration principles

This principle is linked to servicing availability.

The following considerations should be given when defining the unit capacity and configuration:

- Required unit modularity (i.e. number of standby or assist components)
- Minimum and maximum capacity of a single module – especially for mechanical units
- Capacity derating factors applied to name plate capacity, as determined based on design guidance or observed performance limitations

Consideration should also be given to the servicing availability requirements as defined in Section 4.2.2. This is to ensure that capacity is available under conditions of:

- Short term loss of servicing availability, such as daily module downtime or minor maintenance
- Major maintenance, such as reactor cleanouts or major equipment overhauls

4.2.4.2 Mandated configuration principles

Specific guidance for the sizing and configuration of typical process units are provided in Section 4.5. Across all process units, the following configuration principles shall be consistently applied in the formulation of a treatment train:

- **Single module process units shall be avoided** – especially on the main hydraulic pathway and for key treatment units whose loss would result in a critical risk to product outcomes
- **Close coupling of sequential process unit modules in a treatment train shall be avoided** – cross connections shall be provided, where possible, for interconnected upstream and downstream process unit modules.
- **Auxiliary components of a process unit shall be located as close as practical the main process unit modules to avoid system losses and reliability concerns** – such systems include chemical dosing units, aeration blowers and heat exchangers.
- **Similar process units should be co-located to facilitate common provisioning** – examples include common standby modules for mechanical thickening units for different applications, common polymer dosing facilities for different applications, common aeration blowers for different applications.

4.2.5 System impacts and process interfaces

A treatment plant is a system of integrated process units which are sized, configured and operated to meet assigned product outcomes for a defined demand profile.

The capability of a treatment plant primarily affected by the demand profile and product specification, which are external conditions imparted onto the system. These can be referred to as system impacts and examples include:

- Current and forecasted growth and load
- Transfer schemes and network configuration
- End-use or discharge requirements – e.g. environmental flow requirements, AWTP requirements

In addition to system impacts, there also exists internal factors which can affect treatment capability. These factors arise due to the interface or connection of processes and are a function of the configuration and operation of the treatment plant include. Examples of such interfaces include:

- Return flows and loads from thickening and dewatering
- Return flows and loads from digestion, with increased risk with centralised biosolids facilitates and co-digestion
- Servicing availability of interconnected treatment pathways, e.g. reduction in solids stream capacity leading to reduction in liquid stream performance
- Operating philosophy or operation mode resulting in varied demand to connected processes, e.g. a bioreactor varying its SRT to manage nitrification will increase or decrease solids loading rates to the digestion process
- Capabilities of auxiliary treatment processes and the interfacing of these process with mainstream processes

System impacts and process interfaces should be proactively considered during planning. This is especially important when assessing existing assets, upgrading existing treatment processes with new technology or amplified capacity, and for when considering changing the operating philosophy from the design intent.

In terms of new technologies, projects involving changes to required product outcomes or standardisation programs may drive the need to assess options using new treatment technologies. Consideration of the suitability of new treatment technologies being implemented at brownfield sites must include an assessment of the impacts on performance requirements of upstream and downstream processes. A high-level ‘balance of plant’ assessment should be undertaken on projects involving the introduction of a new or additional treatment technology to an existing treatment facility. For example, inclusion of RO treatment at an existing plant to reduce nutrient discharge loads will have significant impacts on upstream and auxiliary process requirements. Diurnal flow balancing needs, upstream solids removal and capacity of power supply and compressed air systems may be impacted by introduction of RO treatment.

4.2.6 Dry and wet weather treatment outcomes

Treatment assets must be designed for dry and wet weather conditions. Dry and wet weather conditions may have different product outcomes and treatment objected. Refer to Section 4.4 for further details.

4.2.7 Staging and future provisioning

Staging of assets should be considered during the planning process. Staging involves modularising infrastructure, and hence capital expenditure, so that assets can meet current treatment demands but have flexibility and adaptability to meet future unknown demands. This key principle is detailed further in Section 4.6.

4.3 Configuration options

4.3.1 Common treatment process units

The selection of a suitable treatment plant configuration should consider the required product outcomes to achieve the project objectives, with consideration of the technological limitations and site considerations.

For high-level planning purposes, it is possible to adopt a typical treatment plant configuration based on specific product outcomes and discharge locations.

Table 4-3 summarises the common treatment processes utilised, or considered, at Sydney Water treatment plants. Examples of how these treatment technologies are combined for liquids, solids, and gas treatment to achieve specific product outcomes are provided in:

- Section 4.3.2: for the liquids stream treatment at deep ocean outfall, ocean outfall (coastal discharge) plants, inland treatment plants for specific nutrient targets, sewer mining, and advanced water treatment plants
- Section 4.3.3: for biosolids and biogas treatment to achieve the specific biosolids outcomes and complementing the liquids stream treatment configuration options

Table 4-3 Common treatment process units at Sydney Water treatment plants

Process Area	Typical Process Units	Purpose of Process
Preliminary Treatment	• Screening • Grit removal	Removal of debris and grit which can damage downstream equipment. Screening and grit removal is site-specific and tailored to influent wastewater and downstream secondary treatment requirements.
	• Flow equalisation	Dampening of diurnal peaks, can also be utilised in biosolids processing train
Primary Treatment	• Gravitational settling • Mechanical primary	Removal of suspended solids and COD to reduce load on secondary treatment. Produces primary sludge which is treated further in biosolids processing train.
Secondary Treatment	• IDAL • MLE • BNR 4 Stage	Biological wastewater treatment, followed by solids-liquid separation, is utilised to remove pollutants and nutrients from the wastewater. Solids-liquid separation is typically with gravitational setting tanks. However, plants exist with ultrafiltration membranes.

	• BNR 5 Stage • Membrane bioreactors • Integrated fixed film activated sludge • Attached growth systems • Activated granular sludge • Short-cut nitrogen removal	Secondary treatment system is selected based on liquid stream product outcomes driven by EPL requirements. BNR systems are generally adopted when strict effluent TN and TP is required. Attached growth systems (MBBR, trickling filters), integrated fixed film activated sludge (IFAS), activated granular sludge, and short-cut nitrogen removal (annamox) is considered on a case-by-case basis.
Tertiary Treatment	• Deep bed filters • Dual media filters • Micro and ultrafiltration • Tertiary denitrification	Tertiary treatment is the cleaning process that improves the treated effluent quality before it is reused, recycled or discharged to the environment. Filtration processes remove inorganic compounds and substances, such as the nitrogen and phosphorus.
Disinfection	• Micro and ultrafiltration • Chlorination and dechlorination • Ultraviolet (UV) disinfection • Ozonation	Disinfection, with chemicals or physical barriers, remove viruses and harmful bacteria.
Advanced water treatment	• Activated carbon treatment with ozonation (BAC) • Activated carbon treatment (GAC) • Reverse osmosis • UV advanced oxidation	Advanced water treatment processes to produce higher quality product water for environmental discharge, water recycling or purified recycled water for drinking. The configuration of the advanced water treatment process will be driven by the end-use requirements such as health requirements, log removal requirements, TDS, TOC etc.
Biosolids Processing	• Feed averaging tank • Sludge screening • Sludge conditioning • Rotary drum thickeners • Dewatering • Dissolved air flotation • Aerobic digestion • Anaerobic digestion • Sludge lagoons • Storage and outloading systems	Biosolids processing is utilised to thicken, stabilise, and dewater biosolids before land application (horticulture or agriculture). The configuration of the biosolids processing train is selected based on the biosolids product outcomes and end-use requirements.
Gas processing	• Biogas storage and collection • Biogas cleaning and scrubbing • Cogeneration and flaring • Odour control	Biogas processing are utilised for the beneficiation of the biogas generated from anaerobic digestion processes. Biogas processing is site-specific, and inclusion will depend on the volume and quality of biogas produced therefore not all anaerobic digesters include biogas processing.
Auxiliary and other processes	• Compressed air • Service water supply • Potable / industrial water supply • Chemical dosing systems	Processes and equipment which support and are common across the above treatment processes.

4.3.2 Liquid stream treatment configuration examples

4.3.2.1 Liquid stream treatment configuration

The configuration of the liquid stream treatment is driven largely by the effluent product outcomes as determined by the EPL or similar regulatory document (e.g. recycled water guideline), which in turn is determined by the health risks and environmental requirements. These regulatory documents have a significant impact on technology selection and unit sizing and configuration of liquid stream treatment. In general, higher quality product outcomes infer higher levels of treatment and hence more complicated and energy intensive treatment configurations.

4.3.2.2 For ocean discharge plants

The ocean discharge plants category comprises (i) Deep Ocean Outfall (DOOF) and (ii) ocean outfall plants. DOOF plants discharge treated effluent via a deep ocean outfall pipeline. The liquid stream configuration of the DOOF plants is primarily driven by the need for suspended solids removal. Ocean outfall plants discharge treated effluent via a shallow ocean outfall pipeline and thus, because of the proximity to the coastline, the liquid stream configuration includes additional drivers of BOD and nutrient removal. Examples of ocean discharge plant configurations are shown in Table 4-4.

4.3.2.3 For inland or reuse plants

The configuration of inland and reuse plants is similar to the ocean outfall plants, both are driven by the need for suspended solids, BOD, and nutrient removal. However, for inland and reuse plants, the discharge load and effluent concentration requirements are typically of higher standard than ocean outfall plants due to the greater the sensitivity of the receiving water bodies or end-users. Examples of inland and reuse plant configurations are shown in Table 4-5.

Table 4-4 Liquid stream treatment configuration option for ocean discharge plants

Process Area	Sub-Process	Liquids Stream Treatment Configuration Options	
		Deep ocean outfall	Ocean outfall
Key Product Outcomes		Suspended solids	Suspended Solids, BOD, Nutrients
Preliminary treatment	Screening	Yes	Yes
	Grit removal	Yes	Yes
Primary treatment	Primary settling	Yes	Yes
Secondary treatment	Biological treatment	No	MLE, UCT, JHB, 3Stage, 4Stage, 5Stage
	Solids-liquid separation	No	Clarifiers or Membrane
Tertiary treatment	Tertiary Denitrification	No	Site specific
	Tertiary P Removal	No	Site specific
	Tertiary Filtration	No	Yes
Disinfection		No	Yes
Chemical Dosing		No	pH, P, Carbon
Advanced Water Treatment		No, unless RW required	Site specific

Table 4-5 Liquid stream configuration options for inland or re-use plants

Process Area	Sub-Process	Liquids Stream Treatment Configuration Options				
		TN15	TN10	TN5, TP0.3	TN3, TP0.05	<TN3, <TP0.05
Key Product Outcomes		TN15	TN10	TN5, TP0.3	TN3, TP0.05	<TN3, ≤TP0.05
Preliminary treatment	Screening	Yes	Yes	Yes	Yes	Yes
	Grit removal	Yes	Yes	Yes	Yes	Yes
Primary treatment	Primary settling	Site specific	Site specific	Site specific	Site specific	Site specific
Secondary treatment	Biological treatment	IDAL, MLE	IDAL, MLE, SBR, 4Stage	UCT, JHB, 3Stage, 4Stage+ChemP	4Stage+ChemP, 5Stage+Carbon	5Stage +Carbon +ChemP
	Solids-liquid separation	Clarifiers	Clarifiers	Clarifiers or Membrane	Membrane, maybe clarifiers	Membrane
Tertiary treatment	Tertiary Denitrification	No	No	No	Dependent on secondary process and nbsTKN	Varying need and configurations based on limits, secondary process and nbsTKN. Advanced treatment may not be required for 2.2 - 3.0mgTN/L range. For TP<0.05, need to consider need for tertiary membrane filtration (UF) and/or UF/RO depending on upstream processes and effluent levels.
	Tertiary P Removal	No	No	No	Yes	
	Tertiary Filtration	Yes	Yes	Yes	Yes	
Advanced Water Treatment		No, unless RW required	No, unless RW required	No, unless RW required	No, unless RW required	
Disinfection		Yes	Yes	Yes	Yes	Yes
Chemical Dosing		pH	pH	pH, P	pH, P, Carbon	pH, P, Carbon

Notes:

1. Example configurations only – adopted solutions should be based on effluent requirement and influent characteristics.
2. For upgrades to existing facilities, it is likely that the secondary treatment process will drive the need for, and type of tertiary and/or advanced treatment adopted.
3. For low and very low nutrient effluents, sites variables (i.e. influent fractionation and facility performance) need to be carefully considered. Advanced treatment on TN3 to TN5 effluent (with chemical P removal) expected to be able to achieve removal down to 0.35 mgTN/L and 0.01mgTP/L.

4.3.3 Biosolids and biogas stream treatment configuration examples

4.3.3.1 Biosolids processing configuration

The treatment configuration for the biosolids stream is selected based on the targeted biosolids product outcomes (i.e. grade of sludge) with consideration of the type, specification, and volume of sludge produced from the liquid stream.

The target biosolids product outcome is the key driver for the **front-end** biosolids processing configuration as it affects the sludge stabilisation process (i.e. digestion) and all the upstream processes required for its successful operation. For example:

- **GRADE A BIOSOLIDS** will typically require heat treatment of sludge (e.g. thermal hydrolysis or similar technology) which commands the need for feed averaging, pre-dewatering, anaerobic digestion, and boiler systems.
- **GRADE B BIOSLIDS** will not require heat treatment of sludge; therefore, screening, thickening, and anaerobic digestion will suffice. Alternatively, anaerobic digestion can be replaced with aerobic digestion.
- Refer to Table 4-8 for examples of biosolids processing configurations. Section 4.5.7 provides guidelines for unit sizing, configuration and arrangement of biosolids processing units

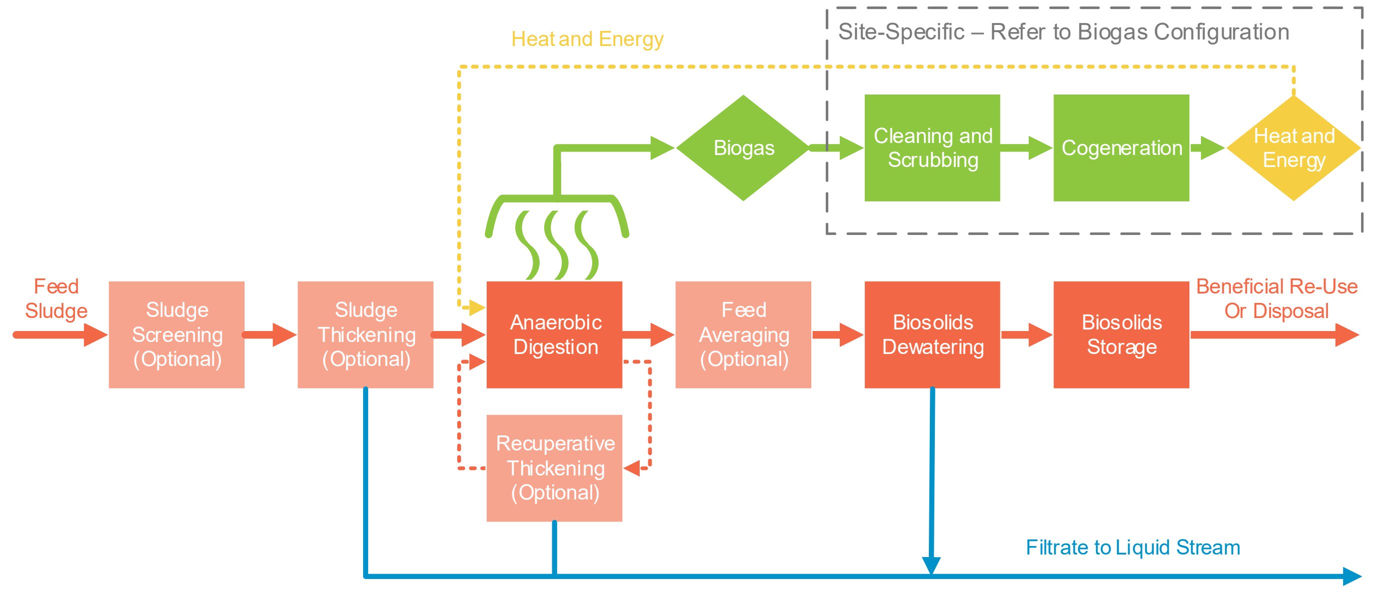
At the **back-end**, i.e. storage, outloading, and disposal, the key drivers for the configuration of these units will primarily relate to community and market drivers. These drivers place constraints on how the final biosolids product are managed and utilised off-site. An outline of the various drivers and risk affecting the biosolids processing configuration is provided in Table 4-6 below.

Table 4-6 Drivers and Risks impacting the selection of biosolids treatment configuration options

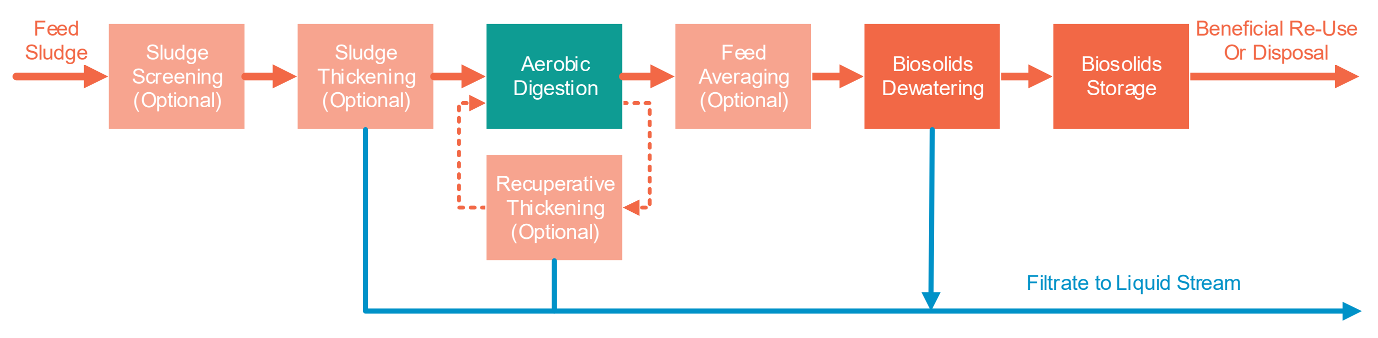
Driver / Risk	Description
Corporate	Corporate position on the generation, management, and application of biosolids including energy strategy
Regulatory	Biosolids classification suitable for end-use application as stipulated by NSW Biosolids Guidelines
Markets	Market specific end-use requirements, such as physical and nutritional characteristics, TSR, and quantity
Logistics	Handling, outloading, and removal of biosolids
Odour	Reduction of odour to reduce risk of odour complaints
Community	Community impacts due to odour, removal logistics (traffic), and social acceptance of biosolids
Cost	Financial feasibility of biosolids processing assets (i.e. scale of application)
Growth	Impact on digester capacity and ability to service growth
Renewal	Related to asset condition and equipment lifespan
Reliability	Related to reliability of equipment and the impact of reliability on upstream liquid stream treatment capacity
Liquid stream	Sludge composition from the liquid stream and the selection of suitable biosolids processing technology

Table 4-7 Configuration options for conventional biosolids processing

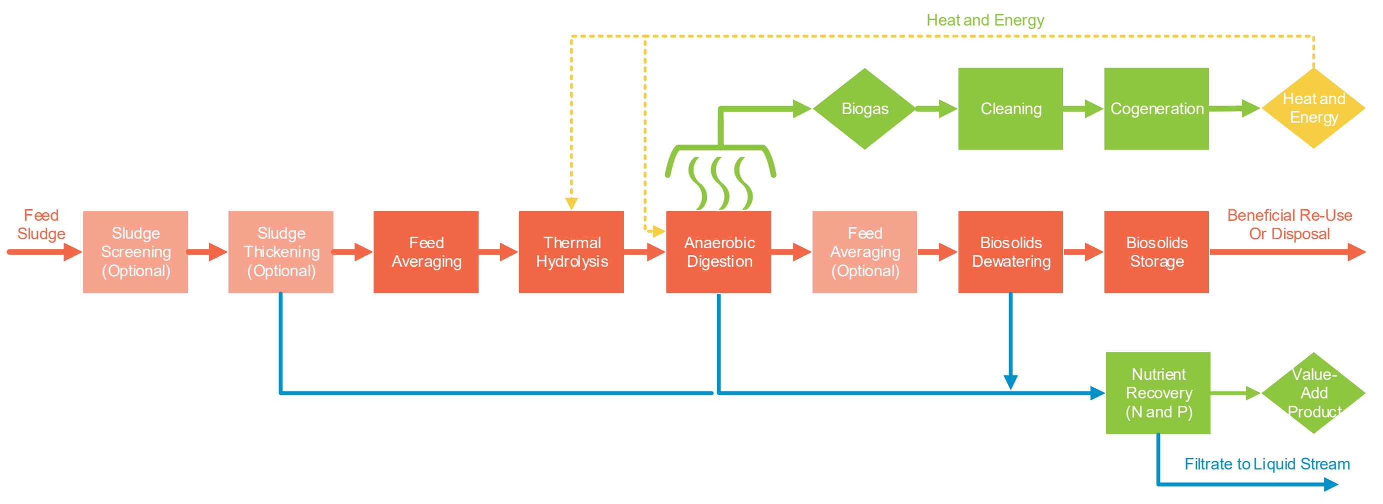
General Configuration for Biosolids Processing with Anaerobic Digestion



General Configuration for Biosolids Processing with Aerobic Digestion



General Configuration for Biosolids Processing with Anaerobic Digestion, Thermal Treatment, and Nutrient Recovery

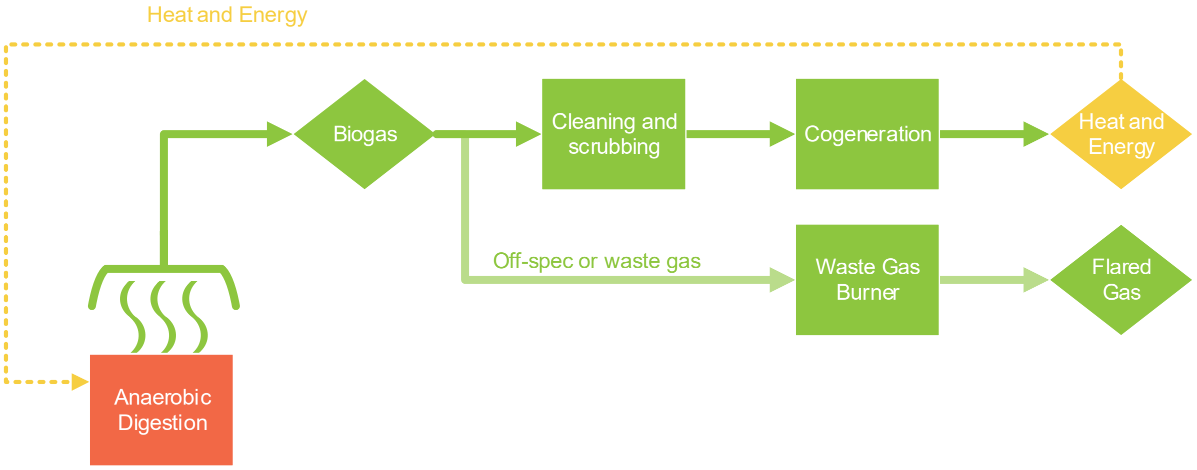


4.3.3.2 Biogas processing configuration

The biosolids process configuration will determine if biogas is produced and can be captured and beneficially utilised. Once this is defined, the treatment configuration for the biogas stream is selected based on the specification and volume of biogas produced from the biosolids stabilisation process, and the key product outcome as required for the servicing objective of the biogas (e.g. heat and energy generation or environmental protection).

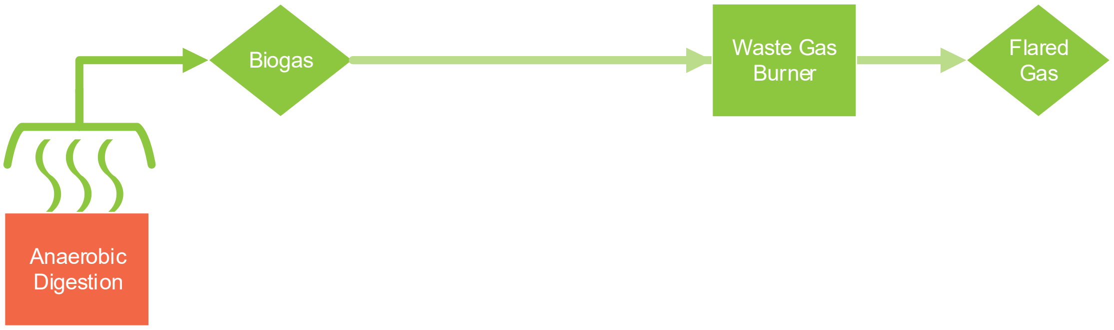
Table 4-8 Configuration options for conventional biogas processing

General Configuration for Biogas Processing with Cogeneration and Waste Gas Burning



Note: Refer to Section 4.5.8.1 for guidelines for duty / standby arrangement of biogas processing units

General Configuration for Biogas Processing with Waste Gas Burning only



Note: Refer to Section 4.5.8.1 for guidelines for duty / standby arrangement of biogas processing units

4.4 Configurations for wet weather treatment

Under dry weather conditions, target product outcomes should be easily achieved provided that demand profile and product specifications are within the defined design boundary of the treatment assets.

In wet weather events the characteristics of the plant influent changes as the influent volume increases. Changes in influent typically include a dilution of pollutant concentrations; additional particulate mass loading (sometimes in slug loads); peak grit and screenings loading. Due to the erratic nature of wet weather events, there is an increased uncertainty in efficacy of a treatment process.

The consideration of how influent characteristics and loading rate change in wet weather is important to determine what level of treatment is required for different proportions of influent flows under different wet weather events.

The aim of wet weather treatment varies per process unit and is a function of the required product outcomes. The key treatment outcomes in wet weather are to:

- Protect the environment
- Maintain hydraulic containment
- Maintain discharge effluent performance requirements (event based and annual)
- Protect the treatment train from wet weather impacts

4.4.1 Minimum level of required treatment (flow paths)

The **"minimum level of required treatment"** is defined as the minimum expected volume, expressed as a peaking factor applied to the ADWF or PDWF, is the indicative hydraulic throughput for a process unit.

The minimum level of required treatment needs to be outcome driven and site specific and the volume undergoing minimum treatment must be determined based on the ability of the plant-wide configuration to meet product outcomes.

For planning activities involving existing treatment plants, the plant's existing EPL should be consulted to determine the minimum level of required treatment for each process.

Key effluent performance criteria to be assessed include:

- Hydraulic containment
- Removal of gross pollutants
- Solids liquid separation performance
- Nutrient removal performance
- Disinfection performance
- Maintaining or interlocking supply to recycled water systems

In addition to effluent product outcomes, protection of the treatment train process units is a key concern in wet weather. This can range from deposition of screens and grit into reactors and digesters, through to managing wash out and impacts to post wet weather treatment performance.

Table 4-9 summarises the treatment outcomes of each key treatment step under dry and wet weather flows. It is noted that wet weather flows can be include minor relative increases in flow, through to flood like conditions. The treatment outcomes and bypassed processes will vary accordingly.

Table 4-9 Summary of Treatment Outcomes in Wet and Dry Conditions

Flows	Process Area and Intent of Treatment					
	Screening	**Grit Removal**	**Primary**	**Secondary**	**Tertiary**	**Disinfection**
Dry Weather Flows	Protect downstream process units from rag and coarse object accumulation.	Protect downstream process units from grit accumulation.	Reduce particulate loading to the secondary treatment process and divert volatile solids for energy generation.	Remove organic and nutrient pollutants as required to meet discharge or end use out comes and separate effluent from particulates and activated sludge.	Provide additional nutrient removal and particulate removal. May include advanced treatment processes.	Achieve required log removal of pathogens for environmental outcomes and human health. May include dechlorination or residual chlorine dosing.
Wet Weather Flows	Protect downstream process units from rag and coarse object accumulation. Protect environment for bypasses flows (rag accumulation in receiving waterway).	Protect downstream process units from grit accumulation.	Reduce particulate loading to the secondary treatment process and reduce particulate pollutants discharged.	Remove organic and nutrient pollutants as required to meet discharge or end use out comes and separate effluent from particulates and activated sludge.	Provide additional nutrient removal and particulate removal. May include advanced treatment processes.	Full or partial disinfection to achieve required log removal of pathogens for environmental outcomes and human health. Different streams may receive different dose rates.

4.4.2 Defined standards for minimum level of required treatment

4.4.2.1 Environmental Protection Licence limits

Existing wastewater treatment plant EPLs stipulate the “appropriate treatment processes” to be achieved under nominated plant effluent flow ranges. These rates the reflect plant’s design process flow paths, rather than any consistently assigned heuristic rate. They are stipulated as a mode of compliance assurance – effluent performance is monitored every six days, therefore if the same flows paths are maintained in the intervening days, the periodic monitoring is assumed to provide indication of ongoing treatment performance. The appropriate treatment processes are nominated in Section O4.1 of the Environmental Protection Licences.

- For new treatment plants: no EPL exists and the minimum level of required treatment shall be defined on a site by site basis
- For any planning or design works on existing treatment plants: the existing EPL limits shall be treated as a compliance requirement and a minimum standard to achieve
- Amplification of existing plant capacity: the minimum level of required treatment shall be redefined and negotiated with the regulator in relation to achieving product outcomes

4.4.2.2 Peak design flows for secondary and tertiary treatment processes

A Sydney Water technical memorandum titled “*Peak Design Flow for Settled Sewage Treatment Plants*” defines the minimum level of required treatment required for secondary and tertiary treatment process units at treatment plants with primary treatment. The key requirements from the memorandum are:

- A minimum design peaking factor of 1.2×PDWF shall be adopted for settled wastewater secondary treatment and tertiary treatment processes
- The peaking factor does not consider servicing availability, and thus product risk analysis along with servicing availability assessments must be conducted to determine the necessary provisions to meet target outcomes (e.g. standby, oversizing, redundancy etc.)

This standard was intended for the design of new treatment plants or for upgrading of existing treatment trains. It is a minimum standard, and additional flows may be passed as required after detailed assessments.

The intent of this standard was to avoid oversizing of secondary and tertiary treatment process. Historically, secondary and tertiary treatment processes were simply designed with a peaking factor of 2×ADWF; redundancy was then included over this peaking factor. As a result, the secondary and tertiary treatment processes were effectively sized for 3×ADWF. This was then commonly adopted into requirements for minimum flows under wet weather conditions.

The revised standard of “1.2×PDWF + servicing availability considerations” provides a more accurate reflection of the peak flows through secondary and tertiary treatment as there is a direct link between design peak flow and real flow data (from network modelling or from observed plant data).

For direct fed (raw wastewater) secondary treatment, a defined standard for peak flows does not exists. However, it is unfeasible to size secondary and tertiary treatment systems for the full peak flow, as this can often exceed 6×ADWF. Therefore, direct fed systems typically include bypasses with bypass (wet weather) treatment which is sized according to the required discharge product outcomes.

4.4.3 Indicative minimum level of required treatment for planning

To facilitate project scoping and high-level planning activities, a range of typical appropriate treatment processes and flow path ranges are provided for guidance of liquid stream process units for the following types of treatment plants:

- Primary treatment deep ocean outfall plant (Figure 4-7)
- Tertiary treatment ocean outfall plant (Figure 4-8)
- Tertiary treatment Inland or re-use plant with primary treatment (Figure 4-10)
- Tertiary treatment Inland or re-use plant with step-feed primary treatment (Figure 4-11 and Figure 4-12)
- Tertiary treatment Inland or re-use plant without primary treatment (Figure 4-9)
- Other facilities: sewer mining (Figure 4-13), facilities with advanced water treatment process (Figure 4-14)

Special note…

The provided process configurations are generalised for guidance only, detailed assessment should always be undertaken to formulate the required levels of treatment and configurations in the options assessment. Moreover, the nominated peak factors are for guidance only, and localised peak factors backup up by plant data or network modelling will take precedence. In particular, the nominal 3 x ADWF and 6 x ADWF may be challenged based on assessment of historical flow data and/or network modelling data can be analysed. For example, if the 95th%ile inflow is less than 3 x ADWF, it may be appropriate for it to be adopted over the nominal dry weather factor.

Discretion should be applied to specific or high-end applications, especially for new trains which have no performance data to reference – greater levels of treatment may be required.

4.4.3.1 Deep ocean outfall plants

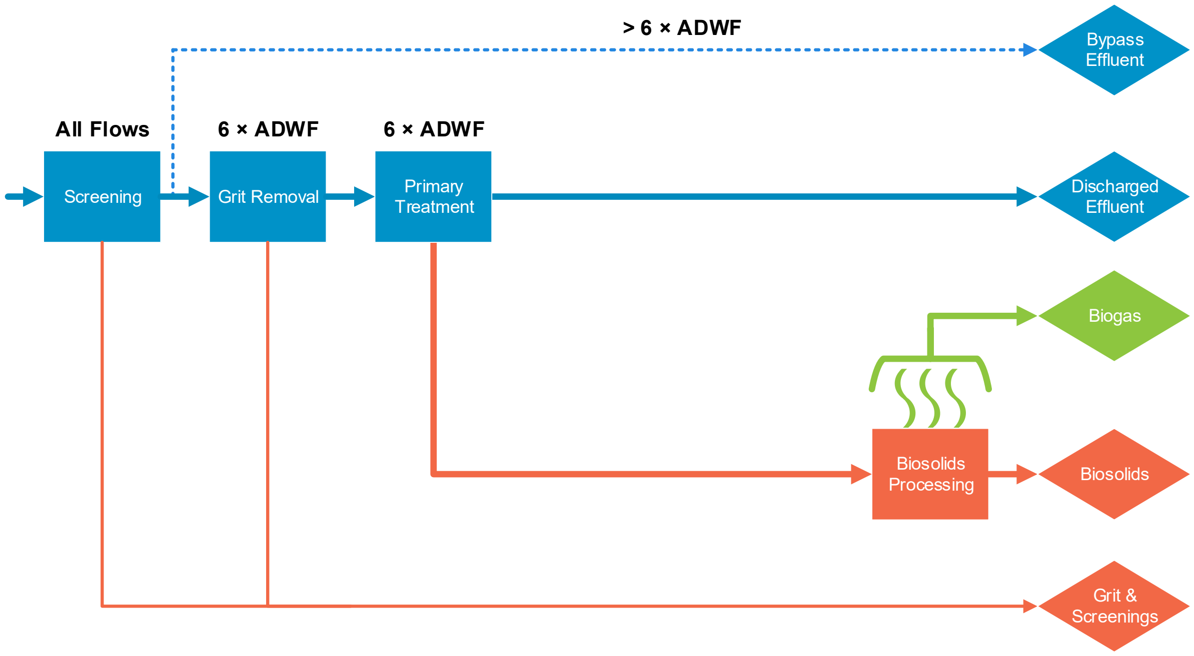


Figure 4-7 Minimum levels of treatment for DOOF plants

4.4.3.2 Ocean outfall plants

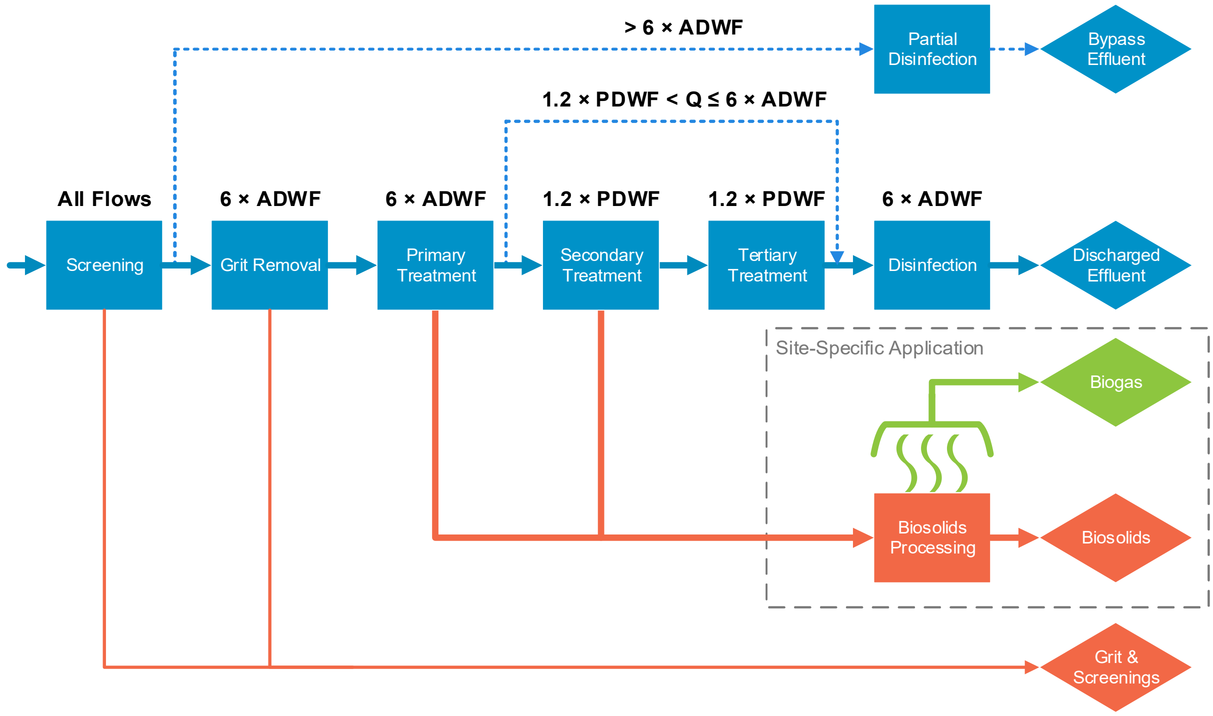
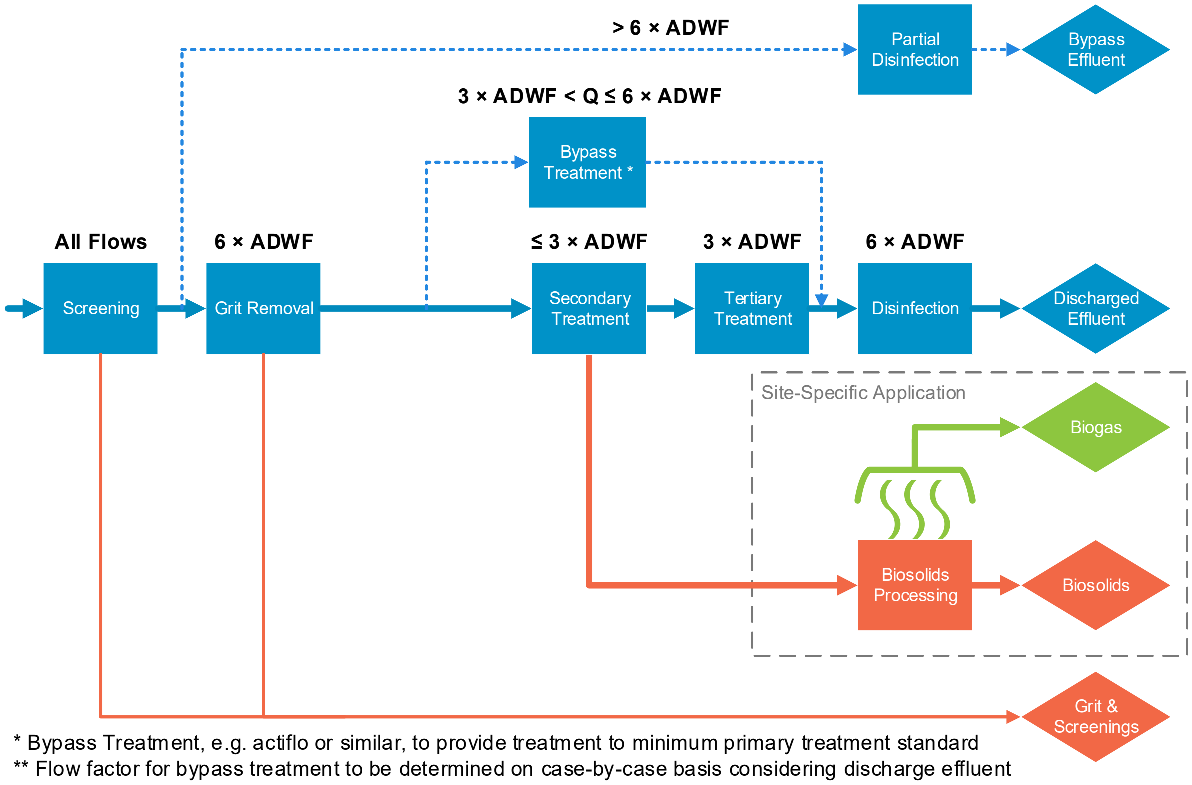


Figure 4-8 Minimum levels of treatment for ocean outfall plants

4.4.3.3 Inland plants without primary treatment



* Bypass Treatment, e.g. actiflo or similar, to provide treatment to minimum primary treatment standard
** Flow factor for bypass treatment to be determined on case-by-case basis considering discharge effluent product outcomes

Figure 4-9 Minimum levels of treatment for inland/re-use plants without primary treatment

4.4.3.4 Inland plants with primary treatment

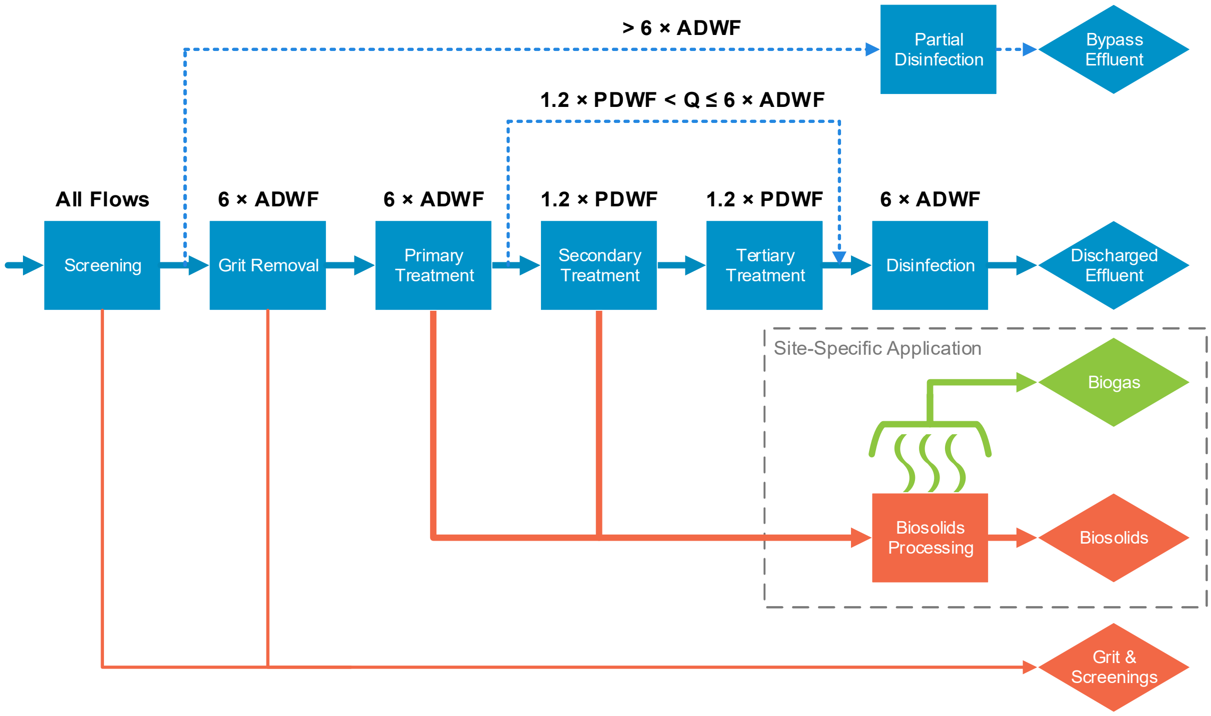
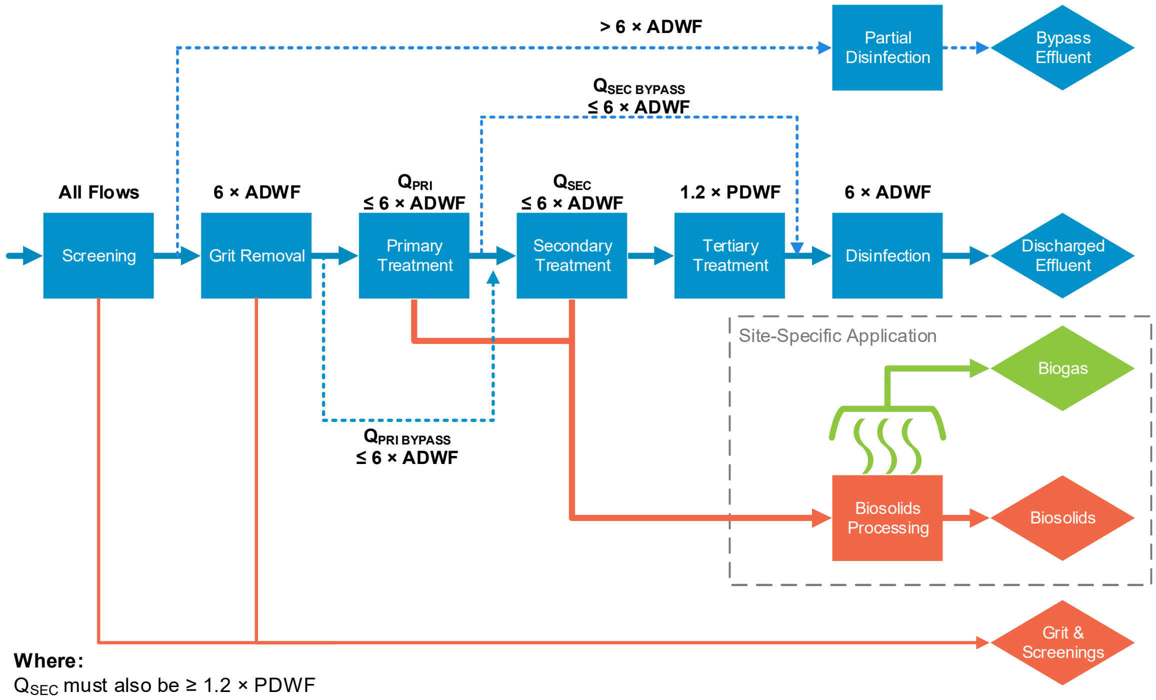


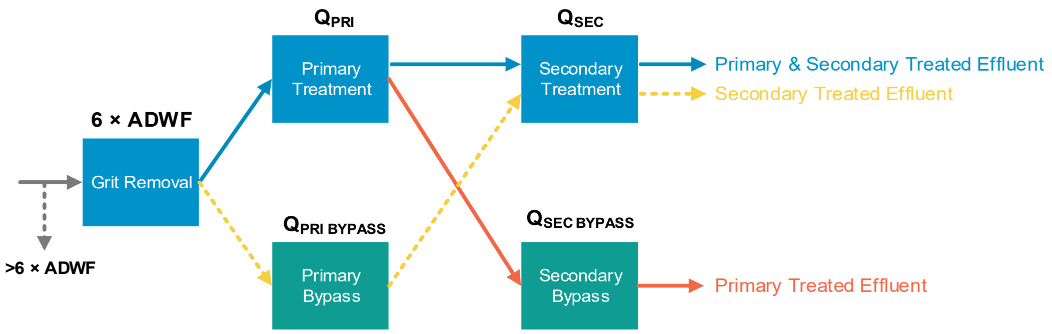
Figure 4-10 Minimum levels of treatment for inland/re-use plants with primary treatment

4.4.3.5 Inland plants with step feed primary treatment



Where:
Q_{SEC} must also be ≥ 1.2 × PDWF
$Q_{SEC\ BYPASS} = (6 \times ADWF) - Q_{SEC}$
$Q_{PRI\ BYPASS} = (6 \times ADWF) - Q_{PRI}$
And:
All flows ≤ 6 × ADWF must receive primary **OR** secondary treatment
All flows through $Q_{SEC\ BYPASS}$ must receive primary treatment
All flows through $Q_{PRI\ BYPASS}$ must receive secondary treatment
(See Bypass Pathways Diagram Below)

Figure 4-11 Minimum levels of treatment for inland/re-use plants with step feed primary treatment



Example:

Q_{SEC} is sized for: 2.5 × ADWF = 1.2 × PDWF
Q_{PRI} is sized for 3.5 × ADWF

If influent Q = 2.5 × ADWF then:
Q_{PRI} = 2.5 × ADWF (Blue)
$Q_{PRI\ BYPASS}$ = 0 × ADWF (Yellow)
Q_{SEC} = 2.5 × ADWF (Blue)
$Q_{SEC\ BYPASS}$ = 0 × ADWF (Red)
Flows receiving primary & secondary treatment = 2.5 × ADWF
Flows receiving only secondary treatment = 0 × ADWF
Flows receiving only primary treatment = 0 × ADWF

If influent Q = 3.5 × ADWF then:
Q_{PRI} = 3.5 × ADWF (Blue)
$Q_{PRI\ BYPASS}$ = 0 × ADWF (Yellow)
Q_{SEC} = 2.5 × ADWF (Blue)
$Q_{SEC\ BYPASS}$ = 1.0 × ADWF (Red)
Flows receiving primary & secondary treatment = 2.5 × ADWF
Flows receiving only secondary treatment = 0 × ADWF
Flows receiving only primary treatment = 1 × ADWF

If influent Q = 6.0 × ADWF then:
Q_{PRI} = 3.5 × ADWF (Blue)
$Q_{PRI\ BYPASS}$ = 2.5 × ADWF (Yellow)
Q_{SEC} = 2.5 × ADWF (Blue)
$Q_{SEC\ BYPASS}$ = 3.5 × ADWF (Red)
Flows receiving primary & secondary treatment = 0 × ADWF
Flows receiving only secondary treatment = 2.5 × ADWF
Flows receiving only secondary treatment = 3.5 × ADWF

Figure 4-12 Bypass pathways for step feed primary treatment in accordance to EPL requirements

4.4.3.6 Sewer mining facilities

Sewer mining facilities will have a lower peak factor the wastewater is “mined” to the facility. It should be noted that the purpose of the sewer mining facility will affect the selection of the peak factor. Generally, sewer mining facilities are for dry weather treatment and thus a peak factor of 1.3× average influent flow is typical. Further, because this influent flow is pump controlled, the downstream process units will also have peak factor of 1.3× (unless flow balancing is provided in downstream process units). An example configuration of a sewer mining facility is provided below.

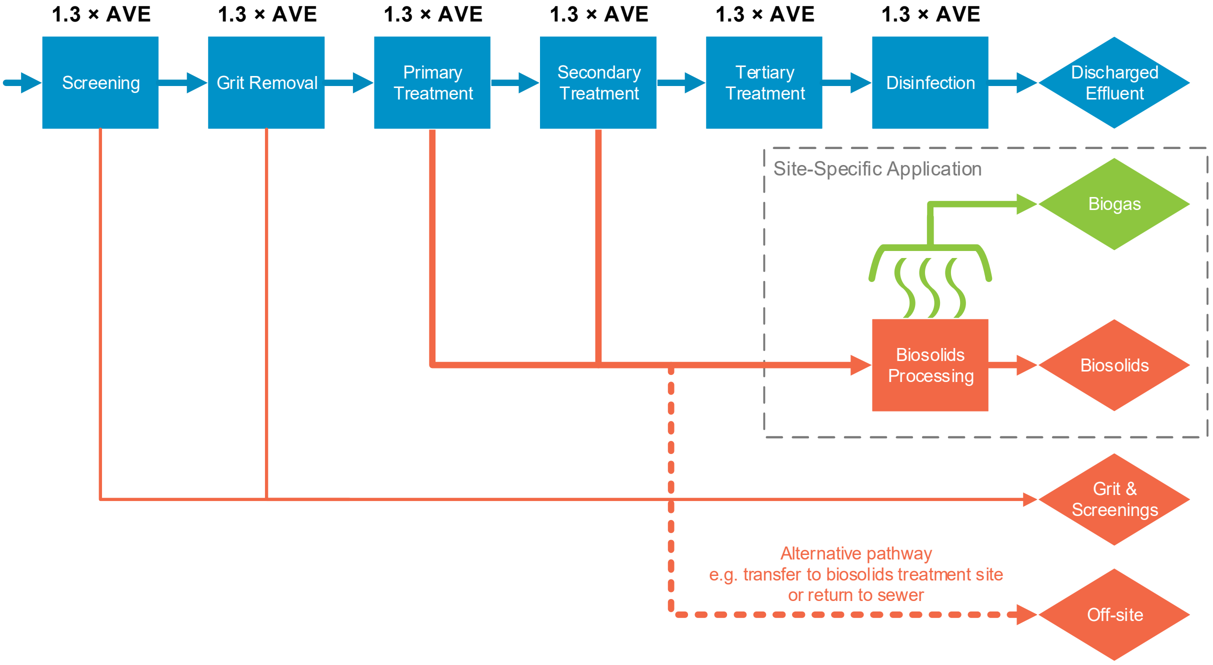


Figure 4-13 Example of minimum levels of treatment for dry weather flow sewer mining facility

4.4.3.7 Plants with advanced water treatment

Advanced water treatment processes such as reverse osmosis, ozone-activated carbon, UV/AOP, can be added after secondary or tertiary treated effluent. Inclusion of these processes will change the peak factors and bypass pathways, an example of such is shown below in Figure 4-14. Further details on how these processes affect the design of the secondary and tertiary wastewater treatment processes are provided in Section 4.5.11.

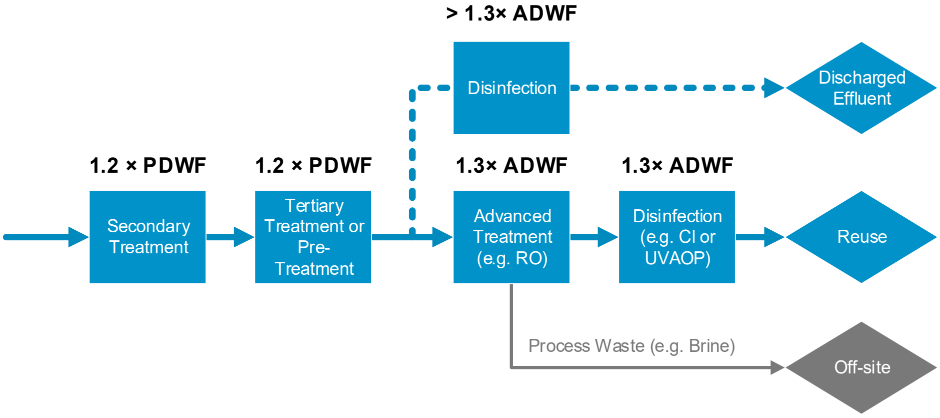


Figure 4-14 Example of minimum levels of treatment for advanced water treatment facility

4.5 Configuration of treatment process units

4.5.1 General approach for configuration of process units

Treatment plant configuration is an iterative process. It involves efforts in understanding the site constraints, required demand, and prioritised product outcomes. This context should be well-defined before undertaking configuration activities such that the iterations in plant configuration can be minimised.

Once defined, the plant configuration activities can be initiated. This is a sequential three-part process:

1. Determine the total capacity required, i.e. how much load and flow needs to be treated?
2. Determine the servicing availability needed, i.e. how often will the unit be available for servicing accounting for planned maintenance and operational considerations?
3. Determine the configuration of the process, i.e. how many units are required to provide the total treatment capacity considering the key availability approaches of modularity, oversizing, redundancy, commonality, and spares?
4. Refine and optimise the configuration, i.e. how can the units be configured to optimise performance and cost considering future (staging) requirements?
5. Review the configuration considering holistic plant impacts, i.e. will the process affect upstream/downstream process units and/or product outcomes?

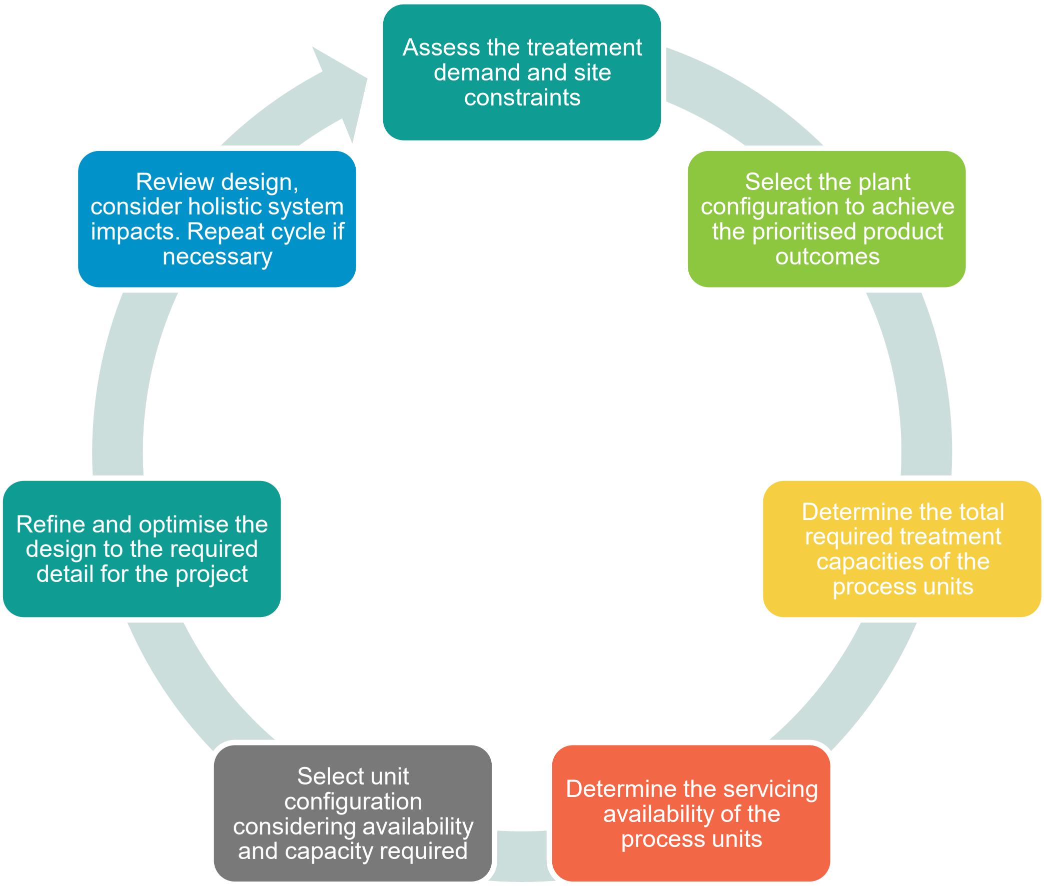


Figure 4-15 General approach for treatment plant configuration

4.5.2 Preliminary treatment

The configuration of the preliminary treatment system has a wide impact on the downstream treatment processes and equipment. Preliminary treatment involves the removal of debris and grit in the influent wastewater so that asset lifecycle of downstream treatment assets is maximised. It can also include flow equalisation to balance the hydraulic and solids load to the secondary treatment system to reduce peak demands.

4.5.2.1 Screening

Table 4-10 Configuration guidelines for screening

Preliminary Treatment – Screening		
Determine peak flow rate	Identify downstream treatment technology Determine the minimum level of screening (screening size and availability) Select suitable screening technology (band, step, other)	Determine capacity and configuration of screening units
Process unit outcomes	Screening technology and the size of screening aperture must be suitable for the secondary treatment system, the civil and hydraulic constraints of the inlet work, and the upstream and downstream hydraulic conditions. Target process outcomes: • Screen all influent flows for protection of equipment (rag removal) • Screen all bypass flows for protection of bypass effluent (rag removal)	
Process streams	**Inputs**	**Outputs**
	• Raw unscreened wastewater	• Screened wastewater • Screenings
Demand to be serviced	• Peak flow rate, where peak flow rate is serviced by the following: – 6mm mechanical screening for flows ≤ 6xADWF for conventional treatment plants (see comment below regarding peak factors) – 3mm or as defined by the secondary treatment technology for flows ≤ 6xADWF for non-conventional treatment plants (e.g. UF MBR systems require 2mm) – Typically, the preferred screening technology is band screen for inlet works. For MBR, preferred is two stage screening at inlet works and drum screen upstream of MBR – 20mm manual screening (raked bar) for bypass flows, i.e. flows ≥ 6xADWF • Note: screening shall be provided for the maximum expected flow rate: – For existing treatment plants, consider superseding 6xADWF with a localised peaking factor based on local site and network considerations and/or measured flow data. – For new treatment plants, a network model should be used to determine the peak factor. – If flow data is known, consider sizing screening based on frequency of flow. This will replace the “6xADWF” design. Sizing for frequency of flow involves setting a % value of which flow must be fully screened (e.g. 99%); the remaining % value will be serviced by a manual rake screen.	
Process unit governing capacity parameters	• Assumed process unit technologies to be adopted, typically: band screens or step screens • Refer to *Inlet Works Decision Framework* • Equipment hydraulics loading rate capacity (HLR, L/s)	
	Regular maintenance	**Major maintenance**

Servicing availability	- Regular and ongoing maintenance downtime for minor preventative and reactive maintenance:
	  – Band screens: 1 day
	  – Step screens: 1 day
		- Major servicing and overhaul downtime durations and frequencies:
		  – Band screens: 1 day / up to 2 months
		  – Step screens: 1 day / 1 month
		  – Major servicing durations less if spares available

Process unit capacity derating	- No capacity derating factor - Determine on case-by-case basis	
Unit configuration	- N-1 for all flows ≤ 1.2 PDWF - N+1 for all flows ≤ 6xADWF – Where 1 is a bypass lane(s) with manually raked screen for flows > 6xADWF Note: Unit sizing and configuration can be based on frequency of exceedance. In this case the “6xADWF” will be superseded by the frequency of exceedance, for example: screening is required for 99% of all flows which equates to *FQ* x ADWF where *FQ* is a factor linked to the 99th percentile of flow. The remaining 1% is then provided by a manually raked screen (bypass lane). This method may be more suitable for influent profiles that have very high and infrequent flow spikes.	

Process unit sizing	- The minimum number of duty units is determined such that:
	$N_{DUTY,MIN} = \frac{Q_{PEAK}\ (m^3/h)}{HLR_{EQUIPMENT}\ (m^3/h)}$
	- Where:
	  – Q_{PEAK} is the peak flow that requires screening, i.e. 6×ADWF
	  – $HLR_{EQUIPMENT}$ is the nominal equipment hydraulic loading rate capacity as provided by equipment supplier – typically limited by HLR (m^3/h or L/s)	

Application considerations	- Turn down ratio and minimum approach velocity to meet screening requirements at minimum flow rate
	- Screening lanes must be decoupled from grit removal lanes
	- For existing plants, consider head loss and retrofit requirements (civil, mechanical, and electrical)
	- Consider the risk impact of screening out-of-service on:
	  – Frequency of peak flow events
	  – Risk increase of bypass events
	  – Maintenance and deterioration of downstream equipment
	- Refer to *Inlet Works Decision Framework* for further details	

Auxiliary or connected units	- Screenings handling, dewatering, and disposal - Screenings centrate returns - Odour control and ventilation for management and treatment of off-gases - Service water (RE supply) for cleaning – check quality and pressure	
Sensitivity analysis considerations	- Screenings capture efficiency vs HLR - Screenings efficiency vs disposal requirements	

4.5.2.2 Grit removal

Table 4-11 Configuration guidelines for grit removal

<table>
<tr><th colspan="3">Preliminary Treatment – Grit Removal</th></tr>
<tr><td colspan="3">
</td></tr>
<tr><td>Process unit outcomes</td><td colspan="2">Grit removal systems use controlled velocity chambers or conduits to separate grit from the wastewater.
Target process outcomes:
• Reduce long-term grit build-up in downstream reactors, digesters, and other water retaining structures (i.e. protection of active volume)
• Reduce long-term wear of internal mechanical parts (i.e. life-cycle optimisation of mechanical equipment)</td></tr>
<tr><td rowspan="2">Process streams</td><td>Inputs</td><td>Outputs</td></tr>
<tr><td>• Raw unscreened wastewater</td><td>• De-gritted flow rate
• Grit</td></tr>
<tr><td>Demand to be serviced</td><td colspan="2">• Full grit removal at flows ≤1.2×PDWF
• Partial grit removal at flows 1.2×PDWF ≤ Q ≤ 6×ADWF
– As per screening, grit removal shall be provided for the maximum expected flow rate, i.e. the capacity of the grit removal units should not exceed capacity of the screenings unit; this may supersede the nominal flow ranges above
– “Level” of partial treatment to be determined on risk basis based on reduction in target process outcomes listed above</td></tr>
<tr><td>Process unit governing capacity parameters</td><td colspan="2">• For velocity-based grit removal:
– Hydraulic loading rate capacity of grit removal system, typically L/s and minimum velocity through grit chamber or channels
• For aeration-based grit removal:
– Hydraulic loading rate capacity
– Air flow capacity</td></tr>
<tr><td rowspan="2">Servicing availability</td><td>Regular maintenance</td><td>Major maintenance</td></tr>
<tr><td>• Grit removal equipment require regular and ongoing maintenance downtime for minor preventative and reactive maintenance:
– 4 hours/weeks on average
– Typically reactive following storm events</td><td>• Grit channels and chambers require periodic major servicing and overhaul:
– 2 Weeks / 5 years</td></tr>
<tr><td>Process unit capacity derating</td><td colspan="2">• No capacity derating factor
• Determine on case-by-case basis</td></tr>
<tr><td>Unit configuration</td><td colspan="2">• N+1 process unit, where:
– N is for all flows ≤6×ADWF</td></tr>
</table>

	– 1 is standby grit removal train for flows ≤1.2×PDWF
Process unit sizing	• For vortex grit removal systems and aerated grit chambers, the minimum number of duty units is determined such that: $$N_{DUTY,MIN} = \frac{Q_{PEAK}\ (m^3/h)}{HLR_{EQUIPMENT}(m^3/h)}$$ Where: – Q_{peak} is 6×ADWF – $HLR_{EQUIPMENT}$ is the nominal equipment hydraulic loading rate capacity as provided by equipment supplier – typically limited by HLR (L/s) • For constant velocity grit channels, consider maximum horizontal velocity and grit settling velocity to determine channel dimensions.
Application considerations	• Consider minimum flow conditions for turn-down sizing • Screening lanes must be decoupled from grit removal lanes • Vortex grit removal systems: self-priming pump, direct draw positive pressure pump, air lift pump (should be avoided for new installations) • Consider auxiliary requirements: grit handling, dewatering, disposal, wash water returns, air supply etc. – Refer to Inlet Works Decision Framework for further details
Auxiliary or connected units	• Grit classifier and dewatering, including service water supply for cleaning/washing • Grit collection and out loading and storage • Specialised grit removal equipment (e.g. mixers, blower, pipework, hopper etc.) • Odour control and ventilation for management and treatment of off-gases
Sensitivity analysis considerations	• Grit capture efficiency vs HLR • Grit dewatering efficiency vs disposal requirements

4.5.2.3 Flow equalisation

Table 4-12 Configuration guidelines for flow equalisation

<table>
<tr><th colspan="3">Preliminary Treatment – Flow equalisation</th></tr>
<tr><td colspan="3">Determine total flow or load per day for equalisation
Determine the flow or load pattern (e.g. m³/h or kg/h)
Select level of equalisation required, e.g. 100%, partial)
Calculate the total equalistion tank volume required
Determine the configuration of equalisation tank</td></tr>
<tr><td>Process unit outcomes</td><td colspan="2">Flow equalisation (or feed averaging) involves the use of a tank or retaining structure to attenuate the peak flow (or loading rate). Flow equalisation can be used for influent wastewater and sludge flows upstream of biosolids processes.
Target process outcomes will depend on the demands by the downstream process unit:
• 100% equalisation (in-line equalisation) = Steady outflow is maintained to downstream process unit
• Partial equalisation (side equalisation) = Steady outflow is partially maintained to downstream process unit</td></tr>
<tr><td rowspan="2">Process streams</td><td>Inputs</td><td>Outputs</td></tr>
<tr><td>• Screened and de-gritted wastewater</td><td>• Equalised wastewater</td></tr>
<tr><td>Demand to be serviced</td><td colspan="2">• Flows ≤ 1.2×PDWF for 100% equalisation
• Peak factor for flow/load</td></tr>
<tr><td>Process unit governing capacity parameters</td><td colspan="2">• Peak factor for flow/load
• Volume of equalisation tank
• Equalised flow rate pump capacity</td></tr>
<tr><td rowspan="2">Servicing availability</td><td>Regular maintenance</td><td>Major maintenance</td></tr>
<tr><td>• Flow equalisation tanks do not have regular and ongoing maintenance downtime for minor preventative and reactive maintenance. However, consider maintenance requirements for auxiliary or connected units.</td><td>• Major servicing and overhaul downtime durations and frequencies:
– 6 weeks / 10 years
– Will be size dependent</td></tr>
<tr><td>Process unit capacity derating</td><td colspan="2">• None, daily withdrawal and operation of equalisation tank will reduce solids and grit build-up</td></tr>
<tr><td>Unit configuration</td><td colspan="2">• N for equalisation tank, where N=1 in most all applications
• N+1 for outflow pumps</td></tr>
<tr><td>Process unit sizing</td><td colspan="2">• Equalisation tank should be sized using a cumulative inflow volume graph
• The size of the equalisation tank will depend on the following:
– Size of flow variation (peak to trough) and total inflow volume
– Required effective level of equalisation (e.g. full or partial elimination of peak)
– Maximum allowed storage time
– In some recycled water schemes and RO applications, night time minimum flows will govern required volume to be balanced</td></tr>
</table>

Application considerations	- Flow equalisation should be after screening and grit removal - Consider in-line or side equalisation (see Figure 4-16 below) where side equalisation is active under peak flow events - Consider modularisation or partitioning of equalisation tank to improve maintainability - Consider purpose of flow equalisation (e.g. cost driven or process performance driven) - Consider impact on downstream process capacity and performance when flow equalisation is unavailable - Consider ventilation and odour control cost
Auxiliary or connected units	- Mixing requirements - Feed and outlet pumping - Bypass pipework - Odour control and ventilation
Sensitivity analysis considerations	- Equalisation efficacy for loss active volume due to grit build-up and inefficient drainage - Impact of partial equalisation on downstream process

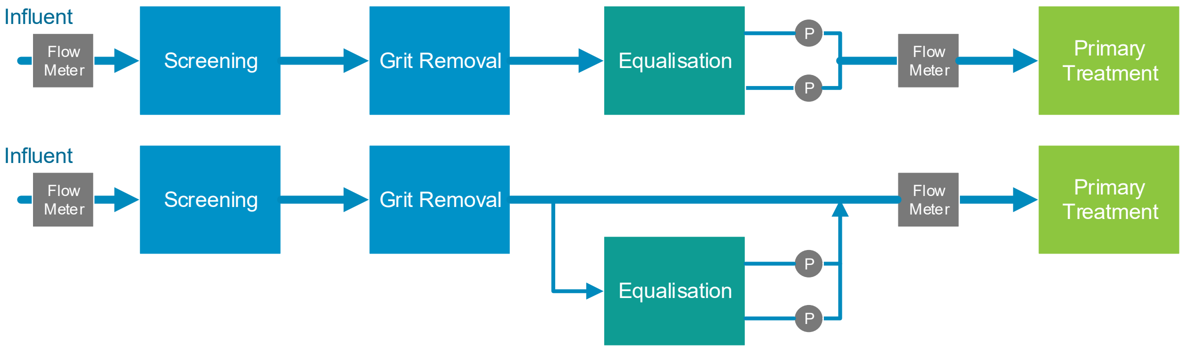
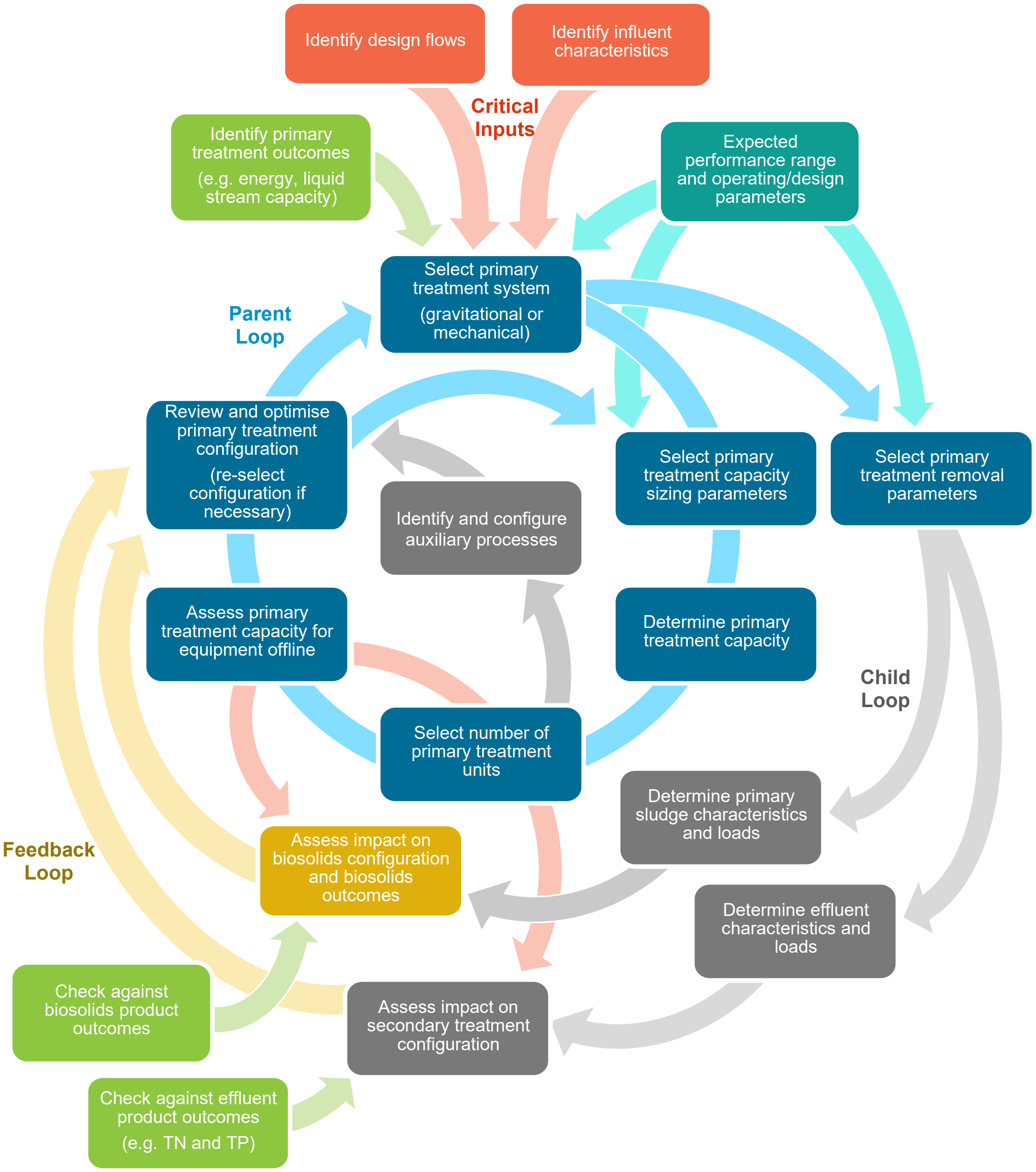


Figure 4-16 Arrangement options for equalisation tank in liquid stream treatment

4.5.3 Primary treatment

Primary treatment reduces the solids load to the secondary treatment process. The solids are diverted to the biosolids processing stream for stabilisation and potential energy generation. The configuration of the primary treatment system should aim to optimise solids capture but also ensure that nutrient removal in the secondary treatment system is not severely compromised. The generation of primary sludge adds complexity due to the additional sludge stabilisation and handling requirements. Therefore, assessment of plant-wide impacts should always be conducted to determine the impact and cost benefit of incorporating primary treatment in the liquid stream treatment process. The general approach to configuration of the primary treatment system and its plant-wide impacts is shown in Figure 4-17.



Identify design flows

Identify influent characteristics

Critical Inputs

Identify primary treatment outcomes (e.g. energy, liquid stream capacity)

Expected performance range and operating/design parameters

Select primary treatment system (gravitational or mechanical)

Parent Loop

Review and optimise primary treatment configuration (re-select configuration if necessary)

Identify and configure auxiliary processes

Select primary treatment capacity sizing parameters

Select primary treatment removal parameters

Assess primary treatment capacity for equipment offline

Determine primary treatment capacity

Child Loop

Select number of primary treatment units

Determine primary sludge characteristics and loads

Feedback Loop

Assess impact on biosolids configuration and biosolids outcomes

Determine effluent characteristics and loads

Check against biosolids product outcomes

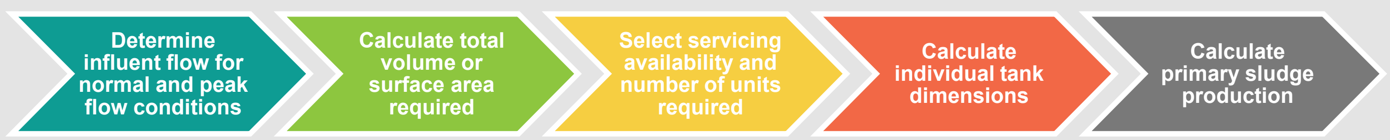
Assess impact on secondary treatment configuration

Check against effluent product outcomes (e.g. TN and TP)

Figure 4-17 General approach for configuration of primary treatment

4.5.3.1 Gravitational primary treatment

Table 4-13 Configuration guidelines for gravitational primary treatment

Primary Treatment – Gravitational Primary Treatment		
		
Process unit outcomes	Gravitational settling tanks (aka primary sedimentation tanks) utilise the settling velocity of solids to separate the solids from the liquids. Target Outcomes: • Reduce suspended solids on secondary treatment system (reduction in reactor volume, aeration demand, and waste activated sludge production) • Generate primary sludge for biosolids processing	
Process streams	**Inputs**	**Outputs**
	• Screening and de-gritted wastewater	• Settled wastewater (primary effluent) • Primary sludge
Demand to be serviced	• Full primary treatment for flows ≤ 1.2×PDWF • Step feed operation or partial treatment for flows 1.2×PDWF ≤ Q ≤ 6×ADWF (or as otherwise determined based on network data)	
Process unit governing capacity parameters	• Tank dimensions, including settling area (m^2), tank width, length and depth (m) • Hydraulic retention time (HRT, h)	
Servicing availability	**Regular maintenance**	**Major maintenance**
	– Maintenance downtime dependent on cause: minor up to a day for minor mechanical through to months for major drive components (if not in stock)	– 2-3 months every 5 years for major tank and mechanical mechanism overhaul and/or cleanout
Process unit capacity derating	• No capacity derating factor • Determine on case-by-case basis	
Unit configuration	• N-1 (i.e. oversize N tanks to allow 1 out-of-service when required), where: – Full primary treatment must be provided for all flows ≤1.2×PDWF with 1 tank out-of-service – Partial primary treatment (contact stabilisation) is provided flows 1.2×PDWF ≤ Q ≤ 6×ADWF with 1 tank out-of-service	
Process unit sizing	• As based on HRT specification, the minimum number of duty units is determined such that: $N_{DUTY,MIN} = \frac{Q_{PEAK}\ (m^3/h)}{HRT\ (m/h)} \times \frac{1}{VOL_{TANK}\ (m^3)}$ • Alternatively, based on overflow specification, the minimum number of duty units is determined such that:	

	$N_{DUTY,MIN} = \frac{Q_{PEAK}\ (m^3/h)}{V_{OVERFLOW}\ (m/h)} \times \frac{1}{AREA_{TANK}\ (m^2)}$ • Where: – Q_{PEAK} is the maximum flow to the settling tanks, i.e. 1.2×PDWF or as superseded by plant data (m^3/h). – *HRT* is selected hydraulic retention time in hours, recommend 2.5 hours minimum for 60%SS capture – VOL_{TANK} is the volume of the tank in m^3 as determined by the physical design constraints (e.g. surface area, scraper/bridge size, allowed tank depth and width to length ratio etc.) – $V_{OVERFLOW}$ is selected overflow rate (m/h), recommend 1.2 m/h minimum for 60%SS capture – A_{TANK} is the water surface area of the tank in m^2 as determined by the physical design constraints
Application considerations	• Ensure gravitational primary treatment trains are not close coupled with preliminary treatment trains • Settling velocity of suspended solids varies per site, use settling velocity to refine tank dimensions • Solids removal rates decrease during peak flow conditions • Chemical dosing can be utilised to increase solids capture, remove oil and grease at primary plants and enhance biogas generation but will generate chemical sludge, impacting the sizing of the solids processing systems and potentially impacting overall performance of the plant where nitrogen removal is a consideration • Tank design in sizing (floor sloping requirements, effluent channels and weirs, freeboard etc.) • Impact of solids removal on the secondary treatment system's TN and TP removal efficacy (COD balance)
Auxiliary or connected units	• Primary sludge collection and sludge pumping including pipework and instrumentation • Odour control and ventilation for management and treatment of off-gases
Sensitivity analysis considerations	• HRT vs TSS removal including impact on HRT for loss of settling tank • TSS removal and settled wastewater characteristics for increasing step-feed operation

Table 4-14 Gravitational conventional primary treatment unit sizing parameters

For rectangular settling tanks:	For circular settling tanks:
• HRT @ADWF: >2.5 hours • HRT @PWWF: >0.5 hours • Surface loading: 20 - 60 m^3/m^2.d • Weir loading: 125 - 500 m^3/m.d • Water depth: 3 - 5m	• Overflow @ADWF: ≤1.2 m/h • Overflow @PWWF: ≤4.2 m/h • Surface loading: 20 - 60 m^3/m^2.d • Weir loading: 125 - 500 m^3/m.d • Water depth: 3 - 5m
Removal rates and primary sludge production:	
• The following removal rates w.r.t to influent can be expected: 30-36%COD; 50-60%TSS; 9-11%TKN; 10-12%TP • Note that for short HRT PSTs, such as those installed at the DOOF plants, lower removal rates are observed: approximately 30 to 40%TSS. Removal rates for COD, TKN, TP are unknown (not tested) • 1%TS concentration for primary sludge (10,000 mgTSS/L); however, this varies with the underflow rate, typically underflow rate is between 0.5% to 1.0% of the influent flow. • For existing systems, use plant data or conduct campaign monitoring around the primary settling tank to obtain removal rates and primary sludge production.	
• For lamella primary settlers, plates are installed at 25mm to 50mm spacing and at a pitch (angle) of between 45° to 60°. Higher capture rates can be achieved due to the greater surface area and shorter settling distance. Typically 60%TSS	

removal without chemicals and 70%TSS with chemicals. The latter also provides higher TKN and TP removal, up to 15% and 40% due to coagulation). For assessment of such systems, contact suitable equipment suppliers for equipment sizing.

4.5.3.2 Mechanical primary treatment

Table 4-15 Configuration guidelines for mechanical primary treatment

Primary Treatment – Mechanical Primary Treatment		
Determine influent flow for normal and peak flow conditions Calculate total number of mechanical units Determine servicing availability and configuration of units Identify auxillary service requirements Calculate primary sludge production		
Process unit outcomes	Mechanical primary treatment involves using a physical barrier to remove the suspended solids from the influent wastewater. These units typically have higher solids capture rates than gravitational primary treatment. However, the capability of mechanical primary screens is initially assessed by supplier by doing particle size analysis and jar testing. Target Outcomes: • Reduce suspended solids on secondary treatment system • Generate primary sludge for biosolids processing • May also function as fine screens upstream of MBR process	
Process streams	**Inputs**	**Outputs**
	• Screening and de-gritted wastewater	• Settled wastewater (primary effluent) • Primary sludge
Demand to be serviced	• Full primary treatment for flows ≤ 1.2×PDWF – Step feed operation (partial treatment) for flows 1.2×PDWF ≤ Q ≤ 6×ADWF (for step-feed system) – Refer to Section 4.4.3.5 for an example of step feed application	
Process unit governing capacity parameters	Equipment specific, but generally: • Hydraulic loading rate (L/s) or solids loading rate (kg/h) • Influent suspended solids concentration (mg/L)	
Servicing availability	**Regular maintenance**	**Regular maintenance**
	– 1 hour per day	– 2-3 months every 5 years for major equipment maintenance or overhaul
Process unit capacity derating	• No capacity derating factor • Determine on case-by-case basis, consider deterioration of solids removal at higher loading rates	
Unit configuration	• N-1 (i.e. oversize N units to allow 1 out-of-service when required), where: – Full primary treatment for flow ≤ 1.2×PDWF with 1 unit out-of-service – Step feed operation for flows 1.2×PDWF ≤ Q ≤ 6×ADWF with 1 unit out-of-service (i.e. bypass portion of the raw feed)	

	– Number of units out-of-service can be higher than 1, conduct risk assessment to determine suitable number of units considering design and type of mechanical primary
Process unit sizing	• The minimum number of duty units is determined such that: $$N_{DUTY,MIN} = \frac{Q_{PEAK}\,(m^3/h)}{XLR_{EQUIPMENT}\,(m^3/h \text{ or } kg/h)}$$ • Where: – Q_{PEAK} is the maximum flow to the settling tanks, i.e. 1.2×PDWF or as superseded by plant data (m^3/h). – $XLR_{EQUIPMENT}$ is the nominal equipment hydraulic loading rate capacity as provided by equipment supplier. This can be limited by HLR (m^3/h or L/s) or SLR (kgTSS/h)
Application considerations	• Increase the modularity (i.e. number of mechanical units) to reduce impact on capacity loss during unit out-of-service conditions • Equipment bypasses and isolation of individual units • Coagulant and/or poly dosing to improve solids capture, can increase solids capture to >70%TSS – Polymer is generally required to increase capture rate >55% – Polymer can be dosed in line or in floc mixing tanks where typical retention time 4 minutes • Material composition of the mechanical screens and their design specific requirements • Potential for mechanical primary screens can function also as MBR fine screens • Consider utilisation of step-feeding to reduce the unit sizing of the primary treatment system • Higher thickness sludge may negate need for primary sludge thickening processes
Auxiliary or connected units	• Service water, compressed air, odour control for equipment specific needs • Odour control and ventilation for management and treatment of off-gases • Primary sludge collection and sludge pumping including pipework and instrumentation
Sensitivity analysis considerations	• HLR vs TSS removal including impact on HLR for loss of mechanical unit • SS removal and settled wastewater characteristics for increasing step-feed operation • No dosing vs dosing of coagulant and/or poly dosing including impact on downstream operations

4.5.3.3 Guideline for raw or settled wastewater system selection

The inclusion of primary treatment will have a significant impact on the design, operation, and complexity of the overall wastewater treatment plant. The key impact relates to nutrient removal in the secondary system, size of bioreactors and aeration equipment, and requirements for biosolids treatment.

Nutrient removal

Primary treatment removes organics (COD) and nutrients (TP and TN) in different quantities. This is because primary treatment is a physical treatment process where particulate compounds are removed with high efficacy. Dissolved constituents are mostly not affected, such as ammonia. The result is a change in the nutrient ratios where settled wastewater (i.e. primary effluent) will have a higher TN:COD and TP:COD ratio than raw wastewater.

Subsequently, the efficacy of TN removal in secondary treatment decreases as there is less carbon available to facilitate TN removal (via denitrification) and external carbon sources may be required to address the shortfall (e.g. methanol). More prevalent for TP, as the sludge yield is lower in a settled wastewater system, the uptake of P into sludge mass is lower and TP removal is also lowered necessitating higher chemical dosing for P removal.

Bioreactors and aeration

Primary treatment reduces the solids loading to the secondary treatment system. This means that the size of the bioreactor and aeration system can be smaller. For existing treatment plants without primary treatment, conversion to settled wastewater system by installing primary treatment can be an effective approach to augmenting treatment capacity. Likewise, for greenfield treatment plants, capacity staging can include staged primary treatment where raw wastewater systems are initially constructed and then converted when required.

Biosolids treatment

Primary treatment produces highly volatile, energy rich, primary sludge. This sludge is typically treated with anaerobic digestion processes which is more complex and carries higher process risks than aerobic digestion. Furthermore, due to its high volatile organic content, primary sludge has different characteristics and physical behaviour to waste activated sludge. Primary sludge is generally more odorous and less responsive to mechanical thickening. However, the key benefit of anaerobic digestion is in lower net energy demand due to the absence of aeration and the ability to generate biogas which can be converted to heat and power.

Impact on planning

The above must be considered when planning treatment plants and detailed sensitivity modelling must be conducted to determine impacts of primary settling on the overall treatment system.

As a minimum, when considering primary treatment as part of the treatment system, the following assessments must be conducted:

- Impact of primary treatment to on secondary treatment sizing and configuration, including its efficacy of nutrient removal, bioreactor volume and aeration demands, and external carbon sources.
- Impact of primary treatment on bioreactor and aeration capacity and capacity staging, i.e. quantitative increase in capacity due to conversion from raw to settled wastewater system
- Impact of primary treatment on biosolids processes and biosolids production volume, including biosolids treatment capacity, technology selection, and outloading/disposal requirements
- Sensitivity analysis of blending of raw influent and primary effluent and step feeding arrangements on secondary, tertiary, and biosolids treatment process

4.5.4 Secondary treatment

Secondary treatment involves the use a purposely designed bioreactor to facilitate anaerobic, anoxic, and aerobic environments to remove pollutants (organic and nutrients) in the wastewater. A solid-liquid separation process is then utilised to separate the sludge from the water. The clear effluent is further treated before discharged to environment.

The general approach for the configuration of the secondary treatment system is shown in Figure 4-18. The configuration needs to be holistically considered with all upstream and downstream processes to optimally achieve effluent product outcomes. As such, the approach is an iterative and can require multiple steps of refinement.

Critical to the approach the selection of a suitable bioreactor configuration, and the optimisation of the internal design, process equipment (aeration, mixing, recycle pumps), and the solids-liquid separation unit. The integrated operation of these three components have the greatest impact on effluent product outcomes.

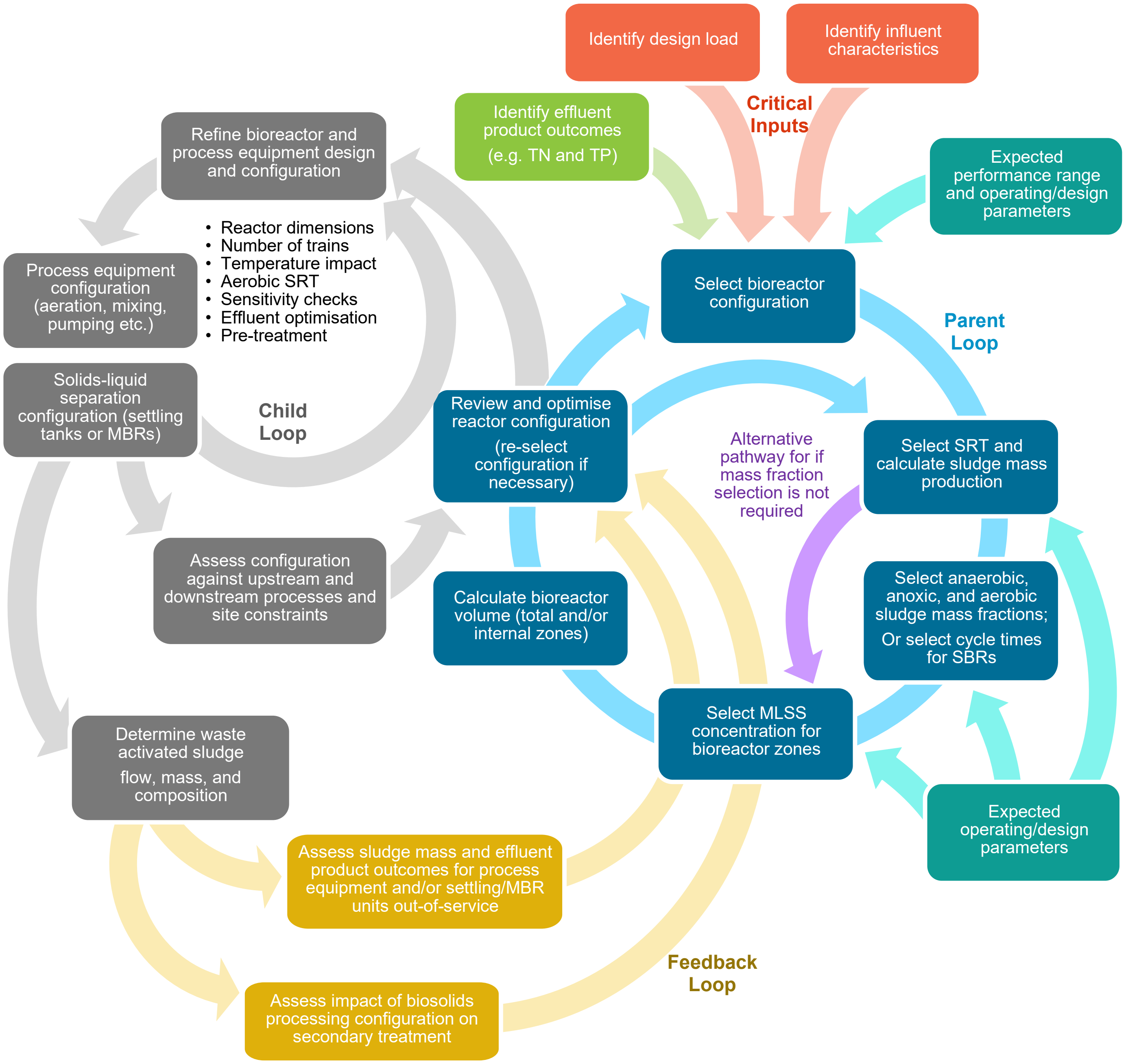
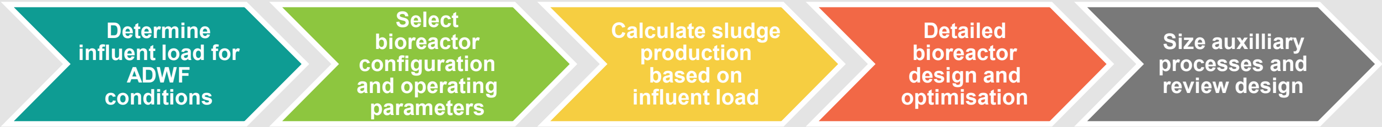


Figure 4-18 General approach for configuration of secondary treatment

4.5.4.1 Bioreactor configuration

4.5.4.1.1 Continuous flow bioreactors (MLE, BNR, MBR)

Table 4-16 Configuration guidelines for continuous flow bioreactors

<table>
<tr><th colspan="3">Secondary Treatment – Continuous Flow Bioreactor</th></tr>
<tr><td colspan="3">
</td></tr>
<tr><td>Process unit outcomes</td><td colspan="2">Secondary treatment involves a biological reactor with controlled anaerobic, anoxic, and aerobic environments to remove organic and inorganic pollutants in the wastewater. A solids-liquid separation steps follows the biological reactor to separate the biological material from the water.
Target process outcomes vary depending on application and technology, may include
- Organics removal
- Ammonia removal (full or partial nitrification)
- Biological nutrient removal (nitrification, denitrification and phosphorous removal)</td></tr>
<tr><td rowspan="2">Process streams</td><td>Inputs</td><td>Outputs</td></tr>
<tr><td>- Screened and de-gritted raw wastewater or primary effluent
- Plant returns from downstream processes
- Oxygen (process air or mechanical energy)
- Chemicals (where applicable)</td><td>- Mixed liquor (to secondary clarifier or membrane filtration tank)
- Waste activated sludge</td></tr>
<tr><td>Demand to be serviced</td><td colspan="2">- Demand to be serviced is related to the effluent product outcomes (e.g. mg/L or kg/y) and the required percentile compliance (50th or 90th percentiles or annual load) for effluent COD, BOD, SS, TN, and TP.
- Note: Bioreactor volume should be sized for minimum temperature conditions and 90th percentile loading. However, aeration demands (Section 4.5.4.2) should be designed for maximum temperature conditions and 90th percentile TOD loading conditions (i.e. COD and TN), and solids-liquid separation is average temperature and 50th percentile TSS loading.</td></tr>
<tr><td>Process unit governing capacity parameters</td><td colspan="2">- Solids retention times (SRT) shall be calculated based on:
  – Reactor mixed liquor suspended solids concentrations as limited by the secondary solids/liquid separation process
  – Available active reactor volume for existing bioreactors, or maximum active reactor volume based on site constraints for new reactors
  – Effluent TN and TP product requirements
  – Waste activated sludge stability requirements and its impact on biosolids processing demands
- For plants discharging to inland waterway, plants with chlorine disinfections, and plants producing recycled water or supplying membrane advance treatment:
  – Minimum 7d aerobic SRT shall be adopted for new installations unless superseded by detailed nitrification process simulation modelling for peak TN loading under minimum temperature scenario
  – Minimum 6d aerobic SRT shall be adopted for existing installations as validated by performance data
- Flow (L/s)
- Sludge volume index should be considered in relation to limitations of operating MLSS concentrations</td></tr>
</table>

Servicing availability	**Regular maintenance**	**Major maintenance**
	• No regular downtime expected to result in loss of tank function – Component parts may receive regular maintenance however including valves, mixers, monitoring and control probes	• Diffused air reactors major overhaul downtime: 4 to 8 weeks per reactor every 10 years for diffused aeration system • Surface aerator aerobic tank and anoxic tank major overhaul downtime: 1-3 months every 25 years
Process unit capacity derating	• Active volume shall be used in the determination of reactor capacity, active volume should consider – Operating water depth – Loss of active volume due to accumulated inert mass or due to significant amount of embedded equipment (i.e. membrane cassettes) • Reduction of treatment kinetics in cooler periods must be considered – i.e. higher sludge generation rates during lower temperatures and longer SRT required for full nitrification (see temperature impact in sizing guidelines below and Table 3-18) • Aeration capacity and efficiency – refer Section 4.5.4.2 for detailed consideration of aeration capacity and performance parameters	
Unit configuration	• Total required process capacity shall be serviced by N process units; where N is the minimum number of duty units for servicing of all product parameters • N shall be such that the required rate of flow, organic removal and nutrient removal performance is met during N-1 conditions, noting that performance requirements may be lower at these times • Under N-1 conditions, minimum 6 days SRT applies • For amplifications, the existing reactor capacities, configuration and availability limitations shall be considered	
Process unit sizing	• SRT based total reactor volume shall be determined such that: $V_{REACTOR,TOTAL}(m^3) = \frac{SRT_{TOTAL}(d) \times Sludge\ Production\ Rate\ (kg/d)}{C_{MLSS}(g/L)}$ $V_{REACTOR,AEROBIC}(m^3) = \frac{SRT_{AEROBIC}(d) \times Sludge\ Production\ Rate\ (kg/d)}{C_{MLSS}(g/L)}$ • Where – SRT_{TOTAL} (d) and $SRT_{AEROBIC}$ (d) are selected as per servicing demands to achieve effluent product outcomes – *Sludge Production Rate* is the sludge production rate which is the unit biomass generation per input load (i.e. gSS/gCOD). Generally, sludge production in secondary process reduces with installation of a primary treatment step, reducing the size of the secondary process and energy input needed for nitrification. However, this may require addition of chemicals to meet TN requirement. – *Sludge Production Rate* can be determined from observed data (i.e. yield factor); however, consider using steady-state models to determine sludge production. See Section 4.5.4.1.6. – Sludge production, and other bioreactor assessments such as TN removal estimation, reactor zone configuration, aeration sizing etc., must include consideration of temperature impacts: – 14°C minimum temperature, 22°C maximum temperature, 18°C average temperature. Note that these temperature inputs are guideline values and should be superseded by site-specific data. – C_{MLSS} is the target MLSS concentration in the bioreactor	

	– C_{MLSS} will range between 3000 - 4000 mgTSS/L for conventional activated sludge bioreactors, and 6000 to 8000 mg/L for membrane bioreactors (refer to Section 4.5.4.3.3 for MBR systems) – Note: C_{MLSS} can be pushed to 5000 mg/TSS/L depending on the number of clarifiers available (i.e. total surface area) and the flow peak factors observed in the bioreactor and clarifier. This should be confirmed with clarifier state-point modelling. • Consider holistic assessment of the treatment system to unit sizing to meet servicing demands, e.g. plant returns; settled, raw and step-feed input conditions; average, median and peak loading; and other sensitivity parameters
Application considerations	• Technology selection, unit sizing, availability and unit modularity will vary depending on application and product outcomes, refer to Section 4.5.4.1.3 and 4.5.4.1.4 for details • For intensification of existing bioreactors, it is critical to confirm that hydraulic capacity and flow paths are adequate to meet performance requirements and contain conveyed flows • Consider the impact of influent wastewater fractionation and nutrient ratios (fup, fbs, VSS:TSS, TN:COD and TP:COD) when optimising product outcomes. • For MBR systems, consider the impact of flow conveyance to/from the membranes and the impact on the bioreactor design (especially hydraulics). Refer to to Section 4.5.4.3.3 for MBR systems.
Auxiliary or connected units	• Aeration system – surface aerators or diffused air system • Monitoring in control probes and systems • Mixers • Scum removal system • Flow splitters and valving • RAS and WAS pumping • Secondary solid/liquid separation unit – secondary clarification, supernatant decanting or membrane filtration • Chemical dosing systems – metal salts, alkalinity, carbon • Primary sludge fermenters • Primary effluent and/or secondary effluent pumping stations
Sensitivity analysis considerations	• Impact of influent TN:COD and TP:COD ratios on the effluent product • Impact of mass fraction distribution (or aerobic SRT) on effluent product • Impact of SRT on effluent product • Impact of SRT on WAS product (flow, mass, and composition) • Impact of solids-liquid separation process on bioreactor MLSS concentration • Impact of temperature on solids generation and bioreactor MLSS concentration • Impact of MLSS concentration on bioreactor volume and aeration efficiency • Refer to Section 4.5.4.1.5 for more details

4.5.4.1.2 Intermittently decanted aerated lagoon (IDAL)

Table 4-17 Configuration guidelines for intermittently decanted aerated lagoon (IDAL)

<table>
<tr><th colspan="3">Secondary Treatment – Intermittent Bioreactors</th></tr>
<tr><td colspan="3">
</td></tr>
<tr><td>Process unit outcomes</td><td colspan="2">Intermittently Decanted Aerated Lagoon (IDAL) systems are widely adopted for Sydney Water WWTPs. These reactors can treat large variations in influent flow and are typically designed to biologically reduce effluent TN levels to less than 7.5mg/L, and ortho-phosphorus levels to less than 0.5mg/L by chemical precipitation (with dosing upstream of the IDAL).
Target process outcomes:
• Organics removal
• Ammonia removal (full or partial nitrification)
• Biological nutrient removal (nitrification, denitrification and phosphorous removal)
• Suspended solids removal (by decanting mechanism)</td></tr>
<tr><td rowspan="2">Process streams</td><td>Inputs</td><td>Outputs</td></tr>
<tr><td>• Screened and de-gritted raw wastewater or primary effluent
• Plant returns from downstream processes
• Oxygen (process air or mechanical energy)
• Chemicals (where applicable)</td><td>• Secondary effluent (decanted)
• Waste activated sludge</td></tr>
<tr><td>Demand to be serviced</td><td colspan="2">• Demand to be serviced is related to the effluent product outcomes (e.g. mg/L or kg/y) and the required percentile compliance (50th or 90th percentiles) for effluent COD, BOD, SS, TN, and TP.
• Note separate demands under different flow conditions:
– Dry weather flow mode (normal mode of operation, typically up to 3×ADWF)
– Wet weather flow mode (typically, 3 to 6×ADWF)
– Solids contact mode (i.e. storm mode, typically, > 6×ADWF)</td></tr>
<tr><td>Process unit governing capacity parameters</td><td colspan="2">• Available active reactor volume for existing bioreactors, or maximum active reactor volume based on site constraints for new reactors. IDAL active reactor volume (m^3) is linked to:
– Flow (L/s)
– Solids retention time (SRT, d)
– Reactor mixed liquor suspended solids (as limited by settling duration and weir approach velocities)
– Selected cycle-time
– Waste activated sludge stability requirements and its impact on biosolids processing demands
• IDAL cycle-time (minutes) linked to:
– Number reactors online
– Nitrification/denitrification kinetics
– Sludge settling characteristics</td></tr>
</table>

Servicing availability	**Regular maintenance**	**Major maintenance**
	• No regular downtime expected to result in loss of tank function – Component parts may receive regular maintenance however including valves, mixers, monitoring and control probes	• Diffused air reactors major overhaul downtime: 1-6 months every 10 years for diffused aeration system • Surface aerator aerobic tank and anoxic tank major overhaul downtime: 1-3 months every 25 years
Process unit capacity derating	• Active volume shall be used in the determination of reactor capacity, active volume should consider – Typical operating water level – Loss of active volume due to accumulated inert mass or due to significant amount of embedded equipment (i.e. membrane cassettes) • Reduction of treatment kinetics in cooler periods must be considered – i.e. higher sludge generation rates during lower temperatures and longer SRT required for full nitrification • Aeration efficiency – refer Section 4.5.4.2 for detailed consideration of aeration capacity and performance parameters	
Unit configuration	• Total required process capacity shall be serviced by N process units; where N is the minimum number of duty units for servicing of all product parameters • N shall be such that the required rate of flow, organic removal and nutrient removal performance is meet during N-1 conditions, noting that performance requirements may be lower at these times • Minimum N = 2 which is to allow staggered operation of the IDALs and a more consistent level in outflow equalisation basis. • N is usually an even number to allow IDAL pairing • For amplifications, the existing reactor capacities, configuration and availability limitations shall be considered	
Process unit sizing	• SRT based total reactor volume shall be determined such that: $V_{REACTOR,TOTAL}(m^3) = \frac{SRT_{TOTAL}(d) \times Sludge\ Production\ Rate\ (kg/d)}{C_{MLSS}(g/L)}$ • Where – *SRT_{TOTAL}* (d) are selected as per servicing demands to achieve effluent product outcomes – *Sludge Production Rate* is the sludge production rate which is the unit biomass generation per input load (i.e. gSS/gCOD) – *Sludge Production Rate* can be determined from observed data (i.e. yield factor); however, consider using steady-state models to determine sludge production – C_{MLSS} is the target MLSS concentration in the bioreactor – C_{MLSS} will range between 3000 - 4000 mgTSS/L depending on wet weather treatment capacity requirements; in some cases, this may be stretched to 5000 mgTSS/L • Aerobic and anoxic "reactor volume" is cycle-time controlled, typically 50/50 split by: – 120 minutes aeration – 50 minutes anoxic (settling) – 70 minutes anoxic (decant) • Consider holistic assessment of the treatment system to unit sizing to meet servicing demands, e.g. plant returns; settled, raw and step-feed input conditions; average, median and peak loading; and other sensitivity parameters	

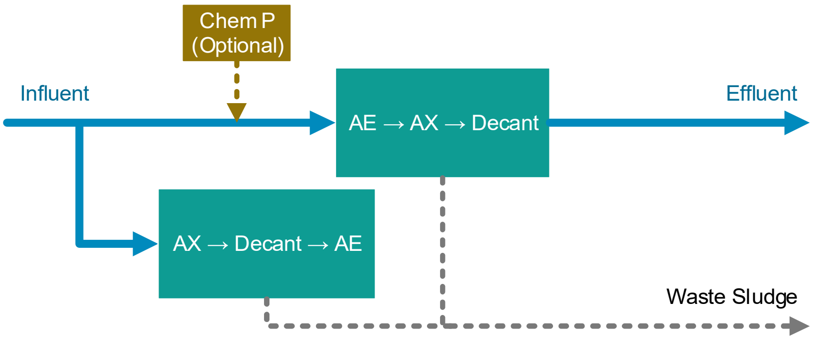
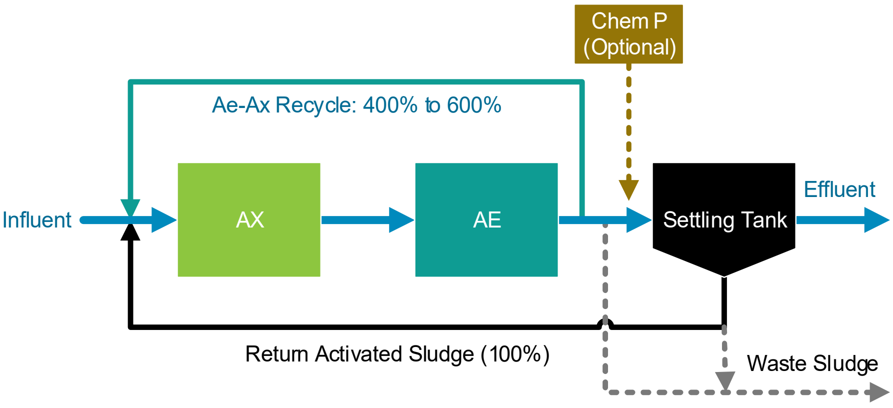
Application considerations	• Technology selection, unit sizing, availability and unit modularity will vary depending on application and product outcomes, refer to Section 4.5.4.1.3 and 4.5.4.1.4 for details • Consider the impact of influent wastewater fractionation and nutrient ratios (fup, fbs, VSS:TSS, TN:COD and TP:COD) when optimising product outcomes. • Where deemed necessary, IDAL tanks shall incorporate "selector(s)" to enhance the settle-ability of the sludge. Refer to section below for guidelines for selector configuration.
IDAL Selectors (if adopted)	• If adopted, selectors typically have as a minimum: – Three (3) compartments operating in-series with bypass abilities for each compartment – Total hydraulic retention time of at least 30 minutes at PDWF across all three compartments – One RAS system which is capable of continuously providing RAS to the first selector, at a rate which can be varied between 0.1 to 0.5 x ADWF (refer to Section 4.5.4.4.3 for RAS pumping) – Mixers or hydraulic design to prevent settlement of MLSS. – Where mixers are used, the mixing energy shall be at least 10 W/m^3 (refer to Section 4.5.4.4.1 for bioreactor mixing) • Facilitate cleaning of grit
Auxiliary or connected units	• Other units as per Continuous flow bioreactors (MLE, BNR, MBR), refer to details in Table 4-16. However, additional connected units for IDALs include: • Flow distribution chamber • Decanting unit • Equalisation basin
Sensitivity analysis considerations	• As per Continuous flow bioreactors (MLE, BNR, MBR), refer to details in Table 4-16 and Section 4.5.4.1.5.

4.5.4.1.3 Expected performance and key variables for conventional secondary treatment technology

Conventional technology refers to treatment systems that are well understood and widely applied for wastewater treatment. These systems include IDAL (SBR) systems, conventional activated sludge systems for nitrogen or biological nutrient (N and P) removal, and membrane bioreactor systems.

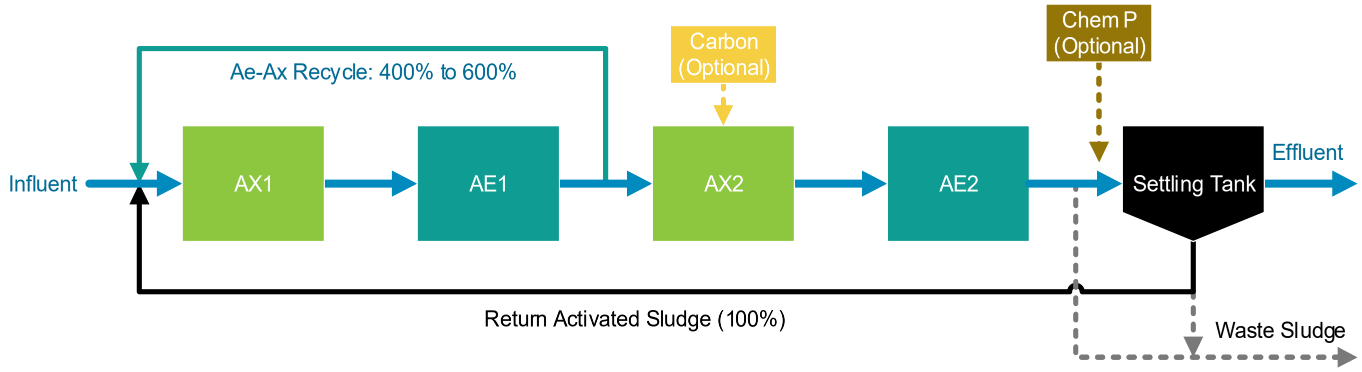
The typical performance range and design characteristics of conventional technologies is provided in Table 4-18. This table can be utilised as a reference for selecting conventional technologies for new treatment facilities or for when reviewing the performance of existing secondary treatment systems.

Table 4-18 Typical performance range and design characteristics of conventional technology

<table>
<tr><th colspan="5">IDAL configuration for COD and N removal with optional Chemical P Removal</th></tr>
<tr><td>MLSS: 3000-4000</td><td>SRT: 20d</td><td>Cycle time (typical):
120min aeration / 50min anoxic (settling) / 70min decant</td><td>TN: 6-10</td><td>TP: 4 - 8
(no Chem P removal)</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><th colspan="5">MLE configuration for COD and N removal with optional Chemical P Removal</th></tr>
<tr><td>MLSS: 3000 - 4000</td><td>SRT: 20d</td><td>Anoxic mass fraction: < 0.60</td><td>TN: 6 - 10</td><td>TP: 4 - 8
(no Chem P removal)</td></tr>
<tr><td colspan="5">
</td></tr>
</table>

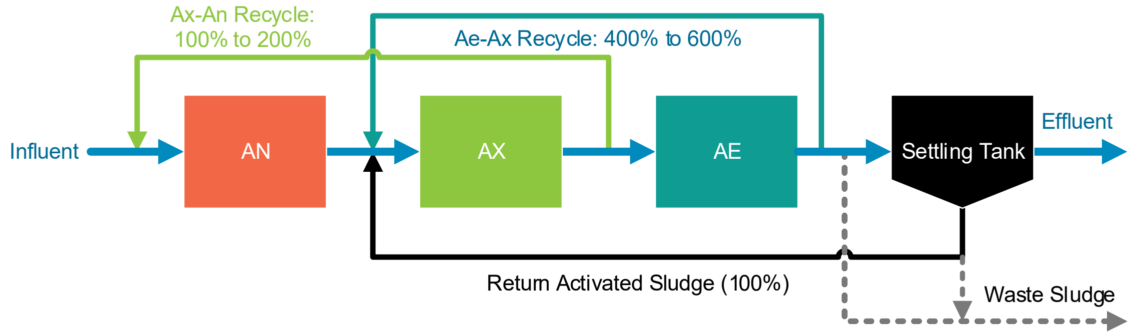
4-Stage configuration for COD and N removal with optional Carbon Dosing and chemical P removal

MLSS: 3000 - 4000	SRT: 20d	Anoxic mass fraction: < 0.60	TN: 1 - 3 (no carbon dosing)	TP: 4 - 8 (no Chem P removal)



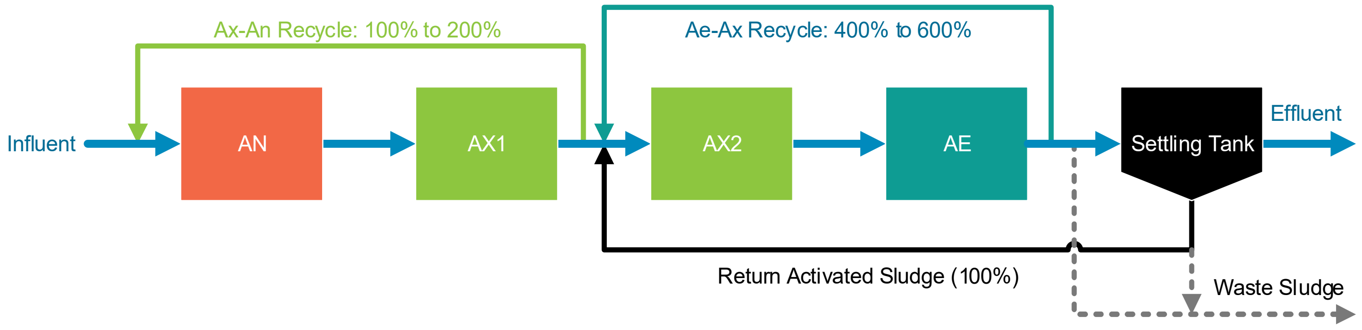
UCT configuration for COD, N, and biological P removal

MLSS: 3000 – 4000 MLSS (AN): 1500 - 2000	SRT: 20d	Anaerobic mass fraction: 0.10 Anoxic mass fraction: < 0.50	TN: 6 - 10	TP: < 1



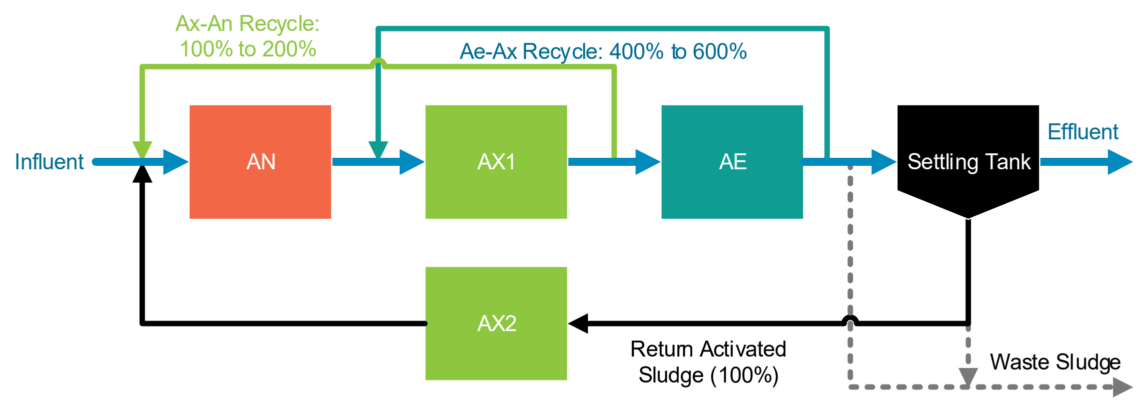
Modified UCT configuration for COD, N, and biological P removal

MLSS: 3000 – 4000 MLSS (AN): 1500 - 2000	SRT: 20d	Anaerobic mass fraction: 0.10 Anoxic mass fraction: < 0.50	TN: 6 - 10	TP: < 1



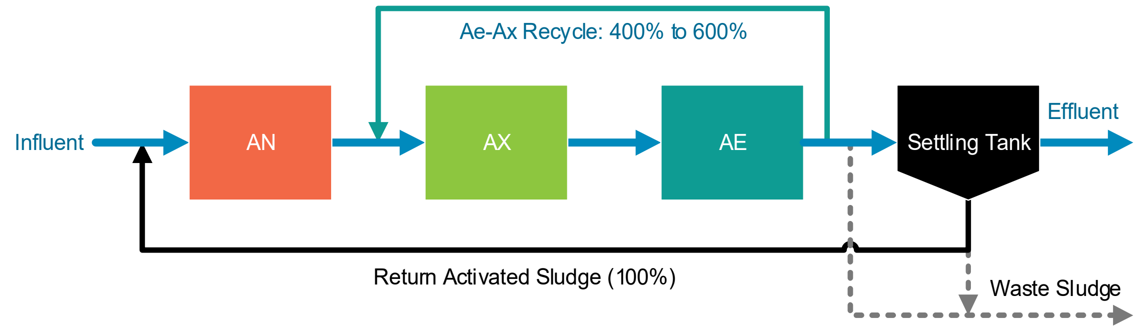
JHB configuration for COD, N, and biological P removal

MLSS: 3000 – 4000 MLSS (AX2): 6000 - 8000	SRT: 20d	Anaerobic mass fraction: 0.10 Anoxic mass fraction 1: < 0.40 Anoxic mass fraction 2: < 0.10	TN: 6 - 10	TP: < 1



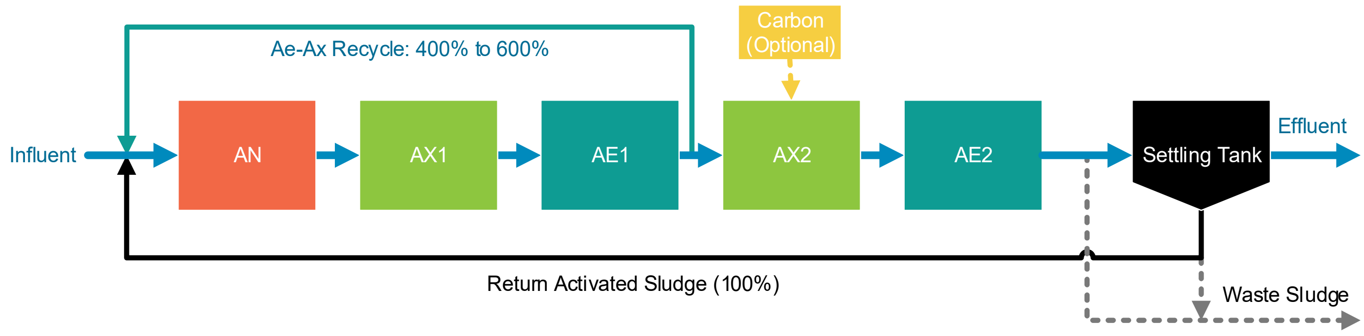
A²O (3-Stage) configuration for COD, N, and biological P removal

MLSS: 3000 – 4000	SRT: 20d	Anaerobic mass fraction: 0.10 Anoxic mass fraction: < 0.50	TN: 6 - 10	TP: < 1

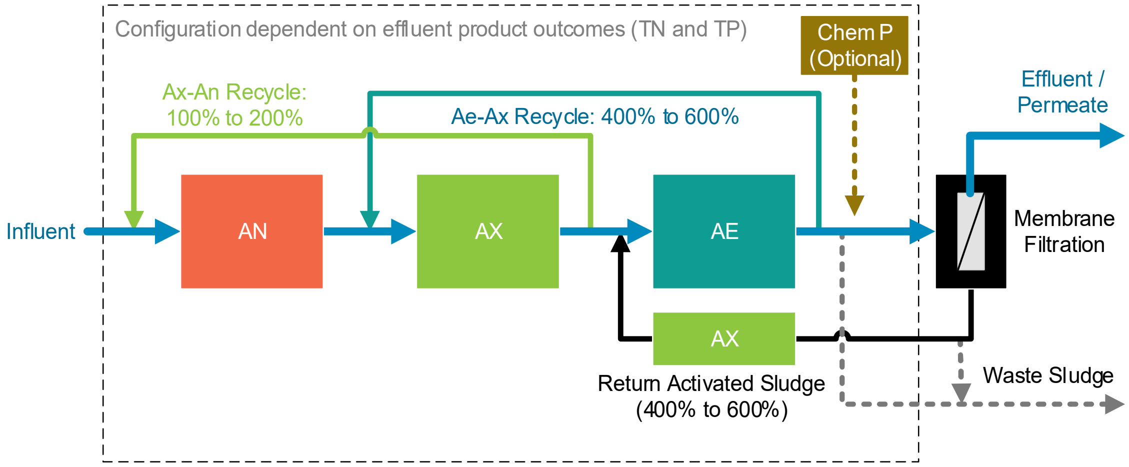


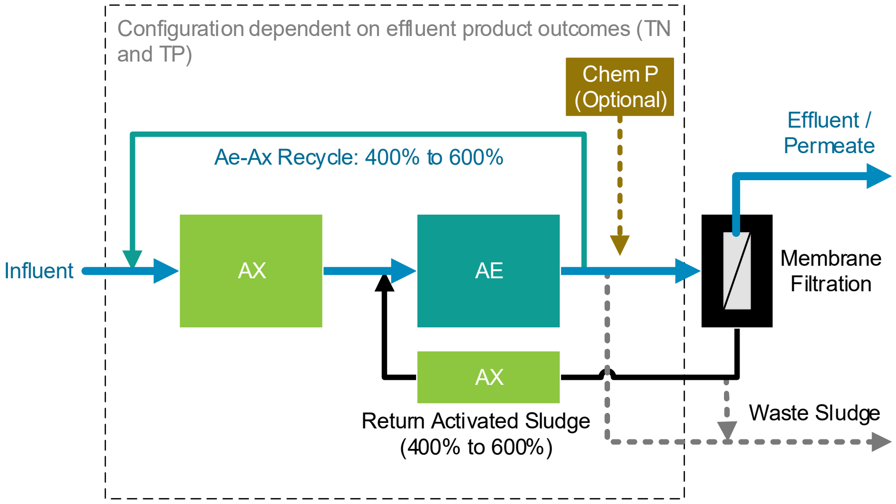
5-Stage Bardenpho configuration for COD, N, and biological P removal

MLSS: 3000 – 4000	SRT: 20d	Anaerobic mass fraction: 0.10 Anoxic mass fraction 1: < 0.40 Anoxic mass fraction 2: < 0.10	TN: 1 - 3 (no carbon dosing)	TP: < 1



Membrane Bioreactor (MBR) for COD, N and biological P removal (or COD and N removal only)				
MLSS (AN/AX/AE): 4000 – 8000 MLSS (MBR): 8000 – 12000	SRT: 20d	Mass fractions are configuration dependent (e.g. MLE or BNR)	TN is bioreactor configuration dependent	TP bioreactor configuration dependent





4.5.4.1.4 Expected performance and key variables for alternative secondary treatment technology

Alternative technologies include the following:

- Integrated Fixed Film Activated Sludge (IFAS)
- Moving Bed Biofilm Reactor (MBBR)
- Membrane Aerated Biofilm Reactor
- Activated Granular Sludge
- Short-cut nitrogen removal

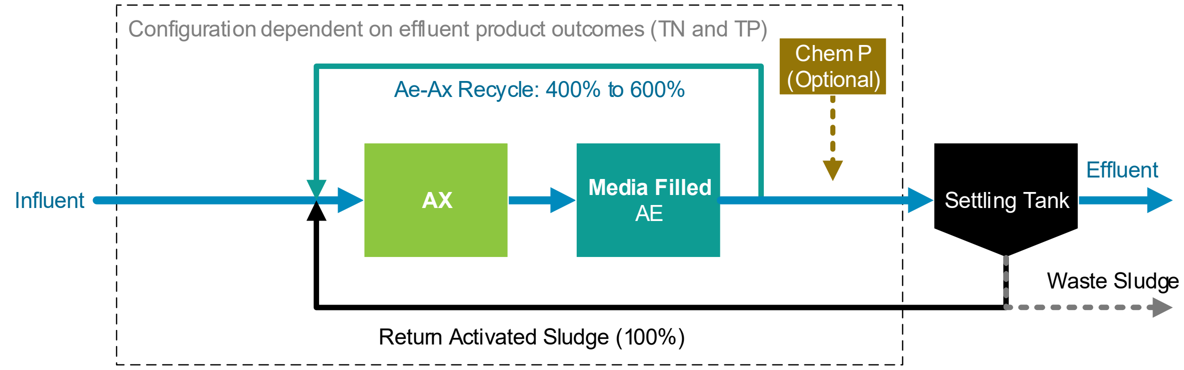
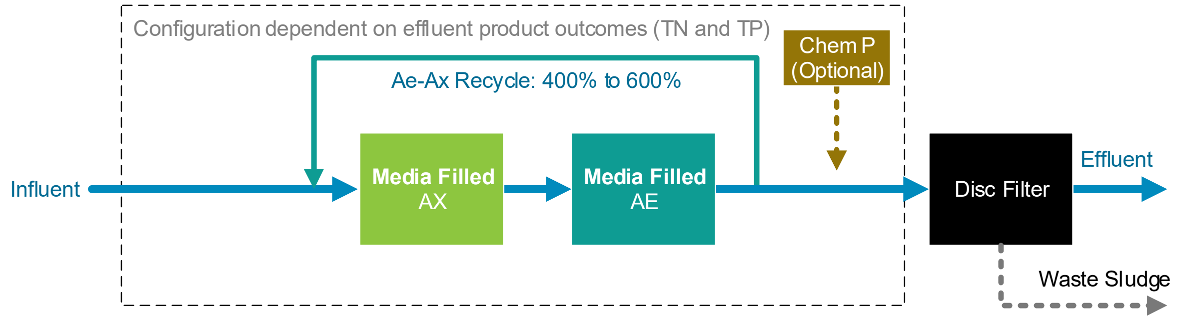
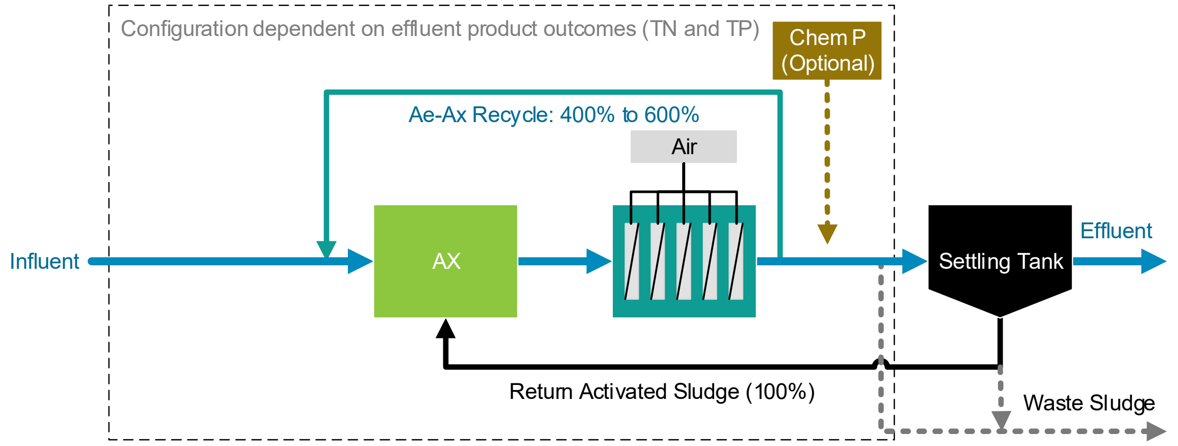
Each configuration/technology has specific advantages, disadvantages, expected performance outcomes, and operational features, for example:

- Expected BOD, COD, TN, TP, and SS removal performance
- Operational complexity and familiarity
- Operational requirements (maintenance, energy, chemicals, automation)
- Infrastructure footprint requirements including internal design features
- Upstream and downstream process impacts (e.g. screening, solids-liquid separation, biosolids processing)
- Construction and commissioning requirements, including start-up times

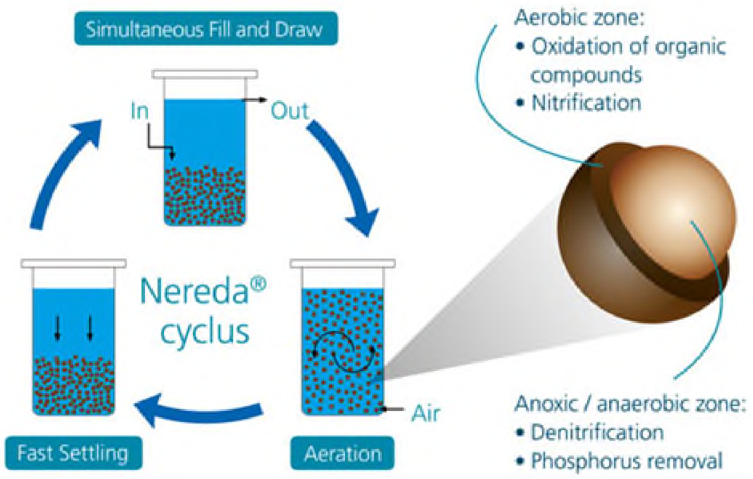
Application of alternative secondary treatment technology is on case-by-case basis. When assessing suitability of alternative processes, the above points should be evaluated along with:

- Ability to meet project outcomes
- Alignments with Sydney Water experiences
- Life-cycle cost compared to conventional treatment and other alternatives which can meet product outcomes
- Interface with the balance of plant processes

Table 4-19 Typical performance range and design characteristics of alternative technologies

<table>
<tr><th colspan="5">Integrated Fixed Film Activated Sludge (IFAS) configuration for COD, N, and (optional) biological P removal</th></tr>
<tr><td>MLSS (suspended): 3000 – 4000
MLSS (effective): 8000 – 12000</td><td>Bulk SRT: 6d
Media SRT: >20d</td><td>Mass fractions are configuration dependent</td><td>TN: 1 – 10 (configuration dependent)</td><td>TP: < 1 (configuration dependent)</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><th colspan="5">Attached Growth Systems (MBBR)</th></tr>
<tr><td>MLSS (suspended): 200 – 800
MLSS (effective): 8000 – 12000</td><td>HRT: 6 – 24h</td><td>Mass fractions are configuration dependent</td><td>TN: 1 – 10 (configuration dependent)</td><td>TP: < 1 (configuration dependent)</td></tr>
<tr><td colspan="5">
</td></tr>
<tr><th colspan="5">Membrane Aerated Biofilm Reactor (MABR)</th></tr>
<tr><td>MLSS (AN/AX/AE): 4000</td><td>SRT: 20d</td><td>Mass fractions are configuration dependent (e.g. MLE or BNR)</td><td>TN is bioreactor configuration dependent</td><td>TP bioreactor configuration dependent</td></tr>
<tr><td colspan="5">
</td></tr>
</table>

Activated granular sludge (e.g. Nereda®)



Activated granular sludge processes such as Nereda® have the following characteristics:

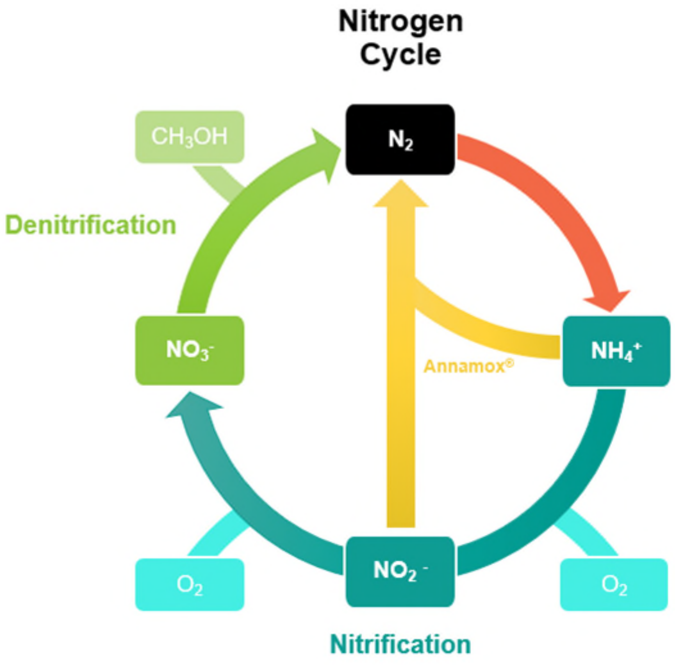
- High sludge settling rates
- Small physical footprint

Currently, the only plant with this technology in Sydney Water is at Quakers Hill. However, there are multiple case studies where it has been successfully implemented in Australia and internationally.

Note:

- An AGS bioreactor is typically deeper (>6.5m) than a conventional activated sludge reactor
- AGS process usually have an integrated control system provided by the technology supplier.
- AGS has a drawback of long start-up time (slow growing bacteria)
- Typical effluent concentrations:
  - TN: 4 - 8 mg/L
  - TP: 0.5 - 1 mg/L
  - SS: 30 mg/L

Shortcut nitrogen removal processes



Shortcut nitrogen processes such as have the following characteristics:

- Lower oxygen demand
- Lower power consumption
- Reduction in CO_2 emissions
- Reduction or elimination of additional carbon source needed.
- Overall reduction in direct operating costs (e.g. electricity, chemicals)
- Reduction in plant footprint compared to conventional suspended solids systems

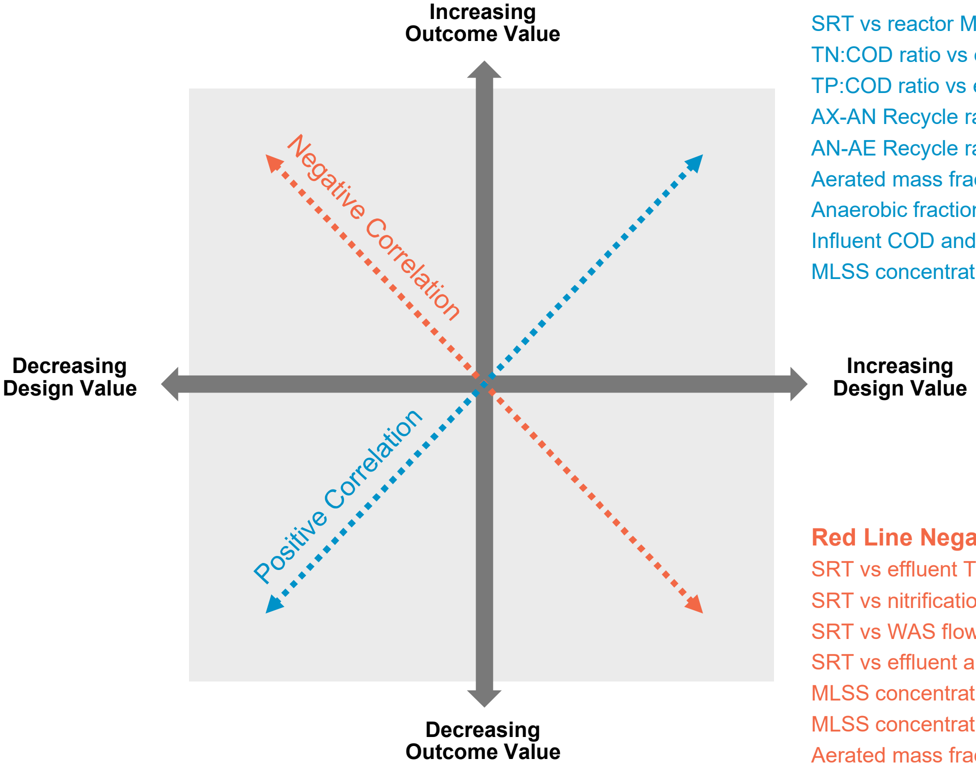
Whilst it provides the above advantages, the process has limited application in mainstream treatment in Sydney Water. However, there are multiple case studies where it has been successfully implemented in Australia and internationally.

4.5.4.1.5 Sensitivity analysis and biological wastewater treatment principles for bioreactor configuration

The design and configuration of a bioreactor is a complicated procedure that involves in-depth understanding of activated sludge theory. Figure 4-19 below illustrates the interrelationships between key design parameters, influent wastewater characteristics, and product outcomes (effluent concentration and sludge production) in the biological wastewater (activated sludge system).

It is important to understand these interrelationships when configuring a bioreactor (and secondary treatment system). These principles can be utilised to develop the assessment scenarios in a bioreactor sensitivity analysis. These assessment scenarios can be done with BioWin or similar process models, for example by varying input or process operating parameters.

However, consider the number of assessment scenarios required for the sensitivity analysis and the data or model calibration requirements to obtain robust results. For broader planning outcomes, it is suggested to focus on the governing unit capacity parameters and select product outcomes (e.g. TN) because these have the most significant impact on project costing and servicing strategy.



Blue Line Positive Correlation:

SRT vs effluent TN
SRT vs reactor MLSS
TN:COD ratio vs effluent TN
TP:COD ratio vs effluent TP
AX-AN Recycle ratio vs effluent TN
AN-AE Recycle ratio vs effluent TP
Aerated mass fraction vs nitrification capacity
Anaerobic fraction vs effluent TP
Influent COD and TN load vs oxygen demand
MLSS concentration vs secondary settling area

Red Line Negative Correlation:

SRT vs effluent TP
SRT vs nitrification stability
SRT vs WAS flow rate
SRT vs effluent ammonia
MLSS concentration vs reactor volume
MLSS concentration vs aeration efficiency
Aerated mass fraction vs denitrification capacity
Operating temperature vs effluent TN

Figure 4-19 Principles and interrelationships to be considered when designing or assessing an activated sludge process

4.5.4.1.6 Sludge yield estimates

Sludge yield refers to the expected mass of sludge in secondary treatment system, as Volatile Suspended Solids (kgVSS) or Total Suspended Solids (kgTSS). The key parameter which determine the sludge yield are primarily:

1. COD loading rate (kgCOD/d) and COD fractionation (i.e. f_{up}, f_{bs}, f_{us} etc.)
2. ISS loading rate (kgISS/d) for TSS estimate (note: ISS = TSS – VSS)
3. Bioreactor operating conditions such as:
   a. Solids retention time (sludge age, d)
   b. Bioreactor water temperature (°C)
4. Biological kinetics and growth behaviour of the bacteria

For activated sludge systems, an estimate of the sludge yield can be determined using a steady-state activated sludge model and standard literature inputs for biological kinetic parameters – provided that influent loading, fractionation, and bioreactor operating conditions are known. Further knowing the influent ISS load and SRT, an estimate of the bioreactor TSS can be determined. ISS varies between 20 to 60mgISS/L depending on the network and pre-treatment.

For the purpose of planning, reference graphs have been generated for sludge yield. These graphs are presented as a “per unit loading rate” and are independent of total COD concentration. They can be utilised for cross-checking of sludge mass calculations; however, careful application of the graphs is required as they cannot substitute for understanding of process theory and detailed activated sludge modelling. Further, they are only suitable for conventional activated sludge systems and cannot be used for biologically enhanced phosphorous removal systems (BEPR). The assumed model parameters for these reference graphs are shown below. The full calculation procedure for the graphs is provided in the Appendices, this can be used to generate site-specific yield graphs.

Table 4-20 Model parameters utilised for sludge yield reference graphs

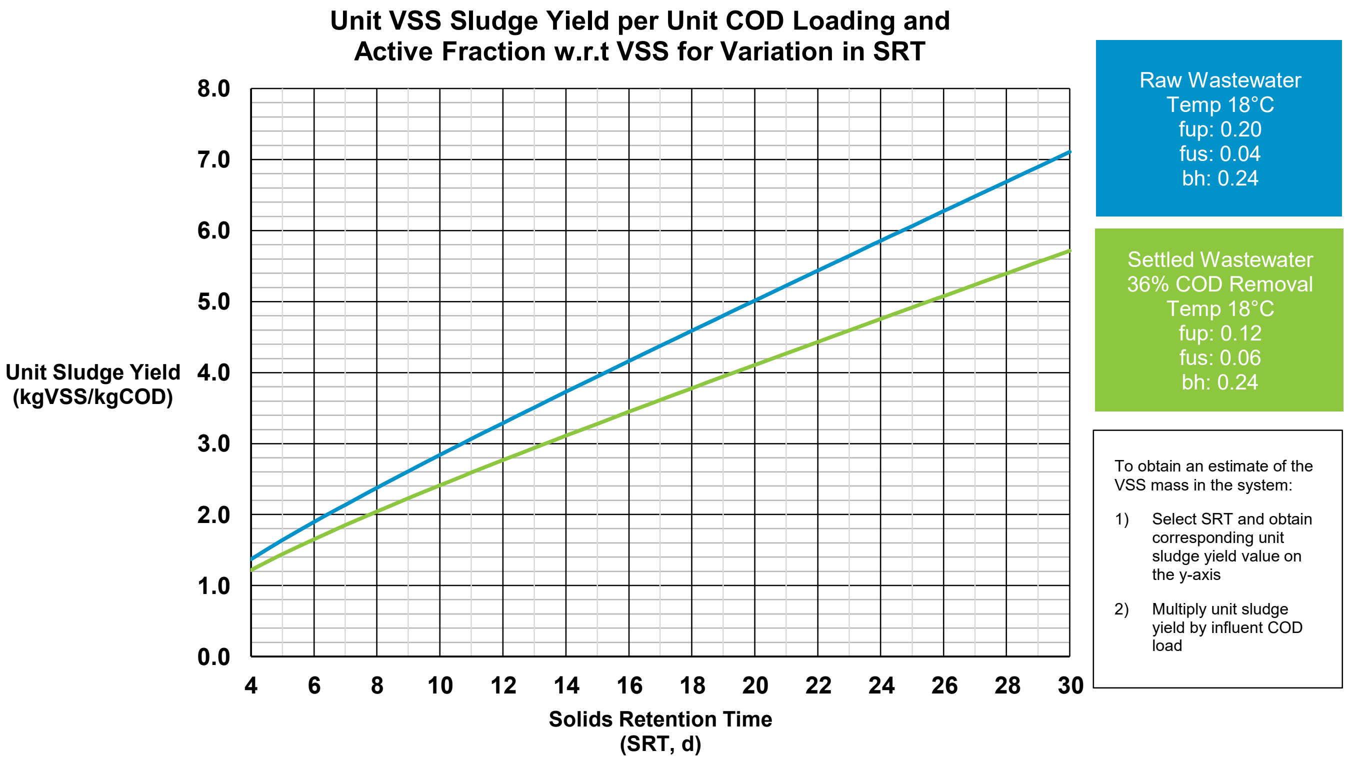
Parameter	Symbol	Raw Wastewater	Settled Wastewater
Unbiodegradable particulate fraction of COD	Fup	0.200	0.060
Unbiodegradable soluble fraction of COD	Fus	0.040	0.060
Biodegradable soluble fraction of COD	Fbs	0.200	0.820
Endogenous respiration rate	bH	0.24/d @ 20°C (Θ = 1.024)	0.24/d @ 20°C (Θ = 1.024)
Temperature	T	18°C	18°C
PST COD removal rate	%COD	-	36%

To obtain an estimate of the VSS mass (MXv) in the system:

1. Select SRT and obtain corresponding unit sludge yield value on the y-axis
2. Multiply unit sludge yield by influent COD load to obtain VSS mass (MXv)
3. Example: If SRT = 20d, unit sludge yield = 5.0 (raw wastewater); and if influent COD load = 1000 kgCOD/d then estimated VSS mass in system = 5000kgVSS. Then daily waste VSS mass = 5000kgVSS ÷ SRT = 250kgVSS/d.

To obtain an estimate of the TSS mass (MXt) in the system:

4. ISS load = FXio = ISS concentration × flow
5. ISS mass in system = MXio = (FXio × SRT)
6. Then total TSS mass = MXt = MXv + MXio
7. Alternatively, if ISS load is unknown, then multiply MXv by an assumed VSS/TSS fraction (fi)



To obtain an estimate of the VSS mass in the system:

1) Select SRT and obtain corresponding unit sludge yield value on the y-axis
2) Multiply unit sludge yield by influent COD load

Figure 4-20 Unit sludge yield graphs for raw and settled wastewater systems

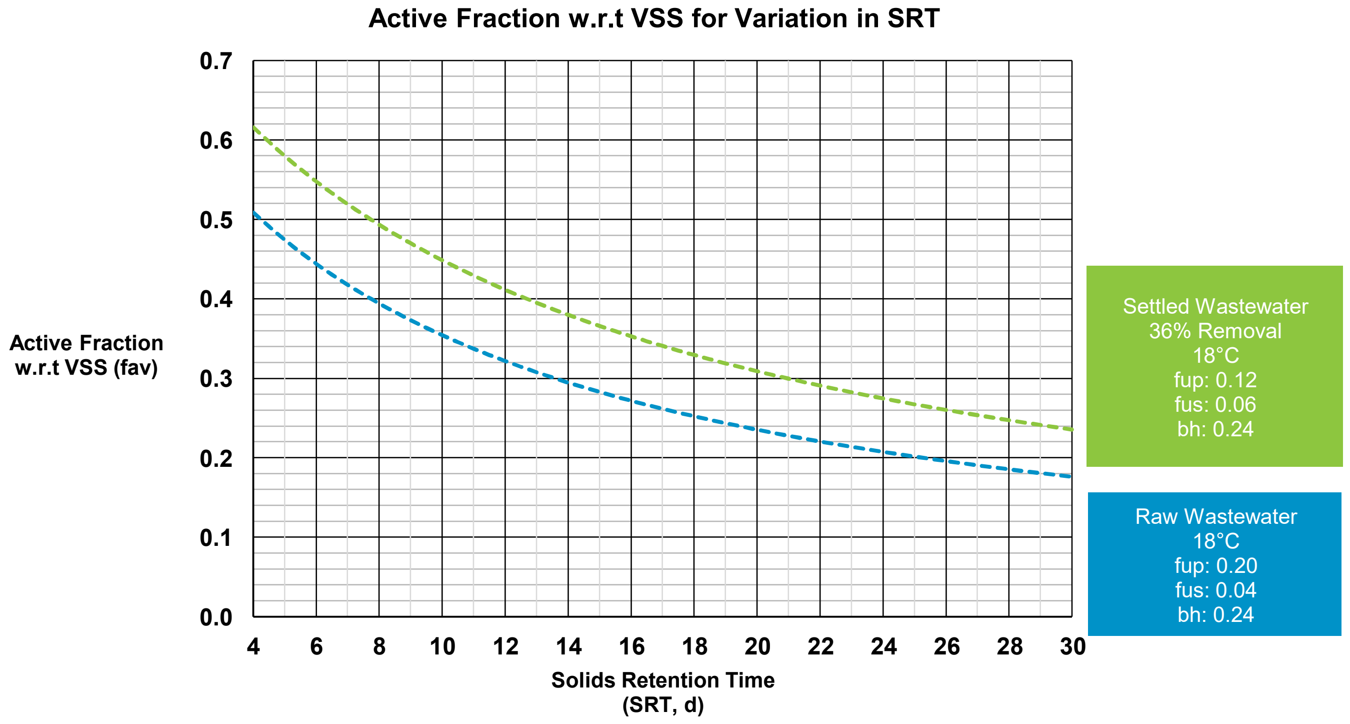
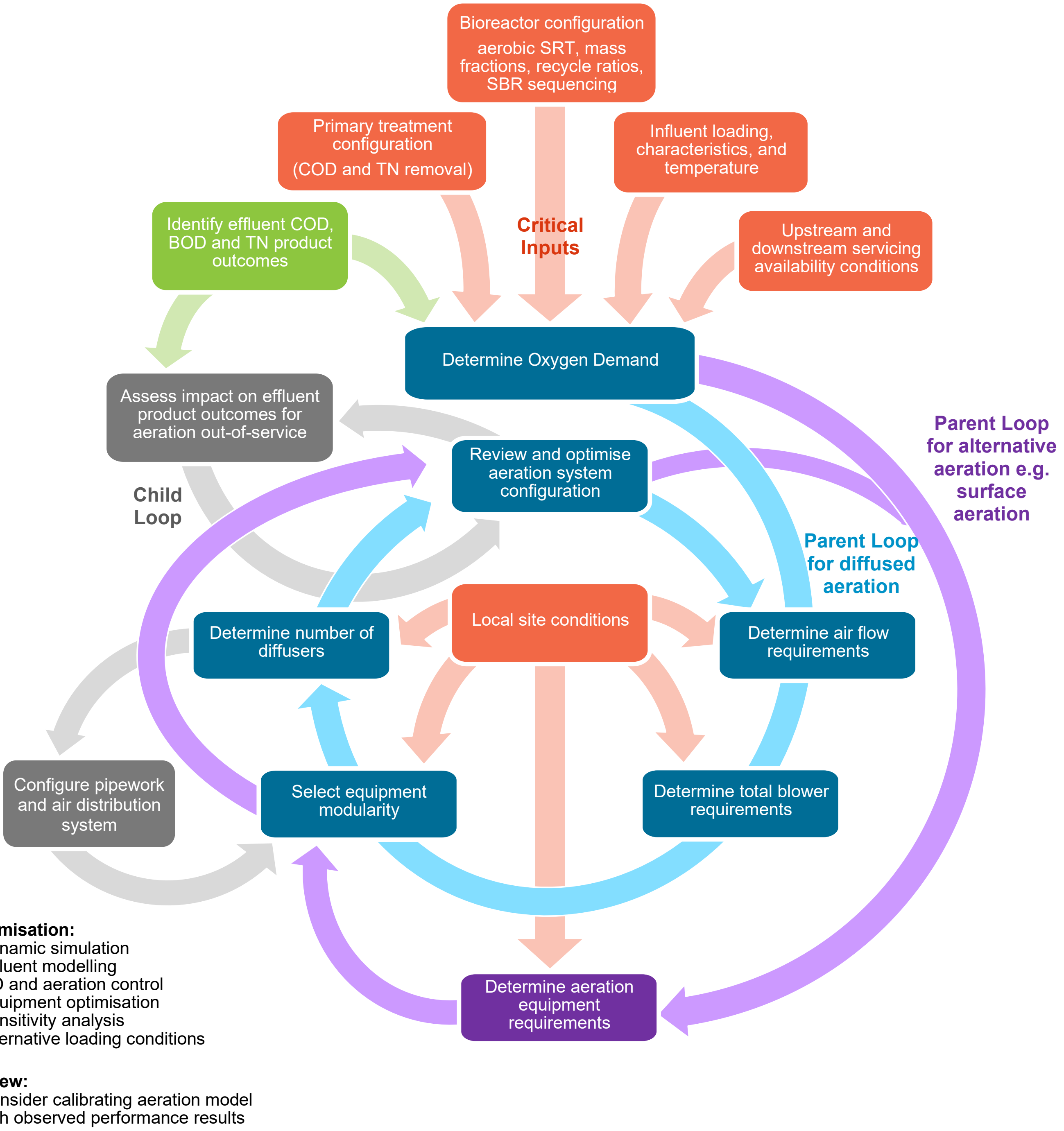


Figure 4-21 Active fraction w.r.t VSS for raw and wastewater systems

4.5.4.2 Aeration system



Optimisation:
- Dynamic simulation
- Effluent modelling
- DO and aeration control
- Equipment optimisation
- Sensitivity analysis
- Alternative loading conditions

Review:
- Consider calibrating aeration model with observed performance results

Figure 4-22 General approach for configuration of aeration system

4.5.4.2.1 Aeration system configuration guidelines

Table 4-21 Configuration guidelines for aeration system

<table>
<tr><th colspan="3">Secondary Treatment – Aeration</th></tr>
<tr><td colspan="3">
</td></tr>
<tr><td>Process unit outcomes</td><td colspan="2">Configuration of the aeration system involves determining the capacity of the system to meet the oxygen demands of the biological process under a defined loading condition, typically peak oxygen demand under dry weather flow.
Target process outcomes:
• Meet minimum, average, and peak oxygen demands as determined by bioreactor configuration (to meet effluent TN product outcomes)
• Maintain targeted dissolved oxygen concentration in aeration zones</td></tr>
<tr><td rowspan="2">Process streams</td><td>Inputs</td><td>Outputs</td></tr>
<tr><td>• Mixed liquor (oxygen demand)</td><td>• Oxygen</td></tr>
<tr><td>Demand to be serviced</td><td colspan="2">• Demand to be serviced is related to the following:
– Effluent product outcomes (e.g. mg/L or kg/y) and the required percentile compliance (50th or 90th percentiles) for effluent COD, BOD, TN, and TP.
– Minimum, average, and maximum oxygen demand as determined by the bioreactor loading profile for COD and TN and temperature conditions. Typically: 90th percentile TOD (i.e. COD + 4.57xTKN) and maximum temperature.</td></tr>
<tr><td>Process unit governing capacity parameters</td><td colspan="2">• Alpha factor (α) or AlphaF (αF) – where AlphaF considers fouling of aeration diffusers
• Equipment aeration capacity, i.e. equipment oxygen transfer rate (kgO$_2$/h) and/or airflow rate (Nm^3/h)</td></tr>
<tr><td rowspan="2">Servicing availability</td><td>Regular maintenance</td><td>Major maintenance</td></tr>
<tr><td>• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance:
– 1-2 months every 5 years per blower
– 1-2 months every 5 years for diffusers
– 1-2 months every 5 years per surface aerator</td><td>• Typically linked to major bioreactor maintenance, blower/diffuser renewal, or surface aerator shaft or blade renewal
• Major servicing and overhaul downtime durations and frequencies:
– Diffused air reactors major overhaul downtime: 4 to 8 weeks every 10 years for diffused aeration system
– Surface aerator aerobic tank and anoxic tank major overhaul downtime: 1-3 months every 25 years per basin (tank maintenance only)</td></tr>
<tr><td>Process unit capacity derating</td><td colspan="2">• No capacity derating factor
• Determine on case-by-case basis (e.g. for loss of diffusers)
• Consider aeration efficiency in relation to operating MLSS concentration</td></tr>
</table>

Unit configuration	• Unit configuration will depend on the demand to be serviced, servicing availability, and the product outcomes, particularly for TN removal. • Consider modularity to reduce the impact of the capacity loss due to equipment out-of-service scenarios; however, note the cost benefit of modularity versus auxiliary and civil infrastructure costs (e.g. blower building size and pipework requirements) • Consider modularity to increase the turn down and turn up ability of the aeration system to manage minimum and maximum oxygen demand
Process unit sizing	• Aeration process unit sizing is best conducted with process model spreadsheets or software. • In general, the total power (size) of aeration equipment is determined such that $POW_{Total}(kW) = \frac{Oxygen\ Demand\ (kgO_2/h)}{Equipment\ OTR\ (kgO_2/kWh)}$ • And then, the minimum number of duty units is determined such that: $N_{duty,min} = \frac{POW_{TOTAL}(kW)}{POW_{UNIT}(kW)\ \times\ Eff\%}$ • Where – *Oxygen Demand* (kgO_2/h) is oxygen required by the biological system (estimated using a process model/software such as BioWin, and cross-checked with a steady-state activated sludge model) – Note temperature impacts on oxygen demand, refer to Table 3-18. In general, oxygen demand highest at maximum temperature. – *Equipment OTR* (kgO_2/kWh) is oxygen transfer rate per unit power of the aeration system – POW_{UNIT} is the kW rating of the aeration unit (blower or surface aerator) – *Eff%* is the equipment’s mechanical efficiency, i.e. power transferred into the water divided by the power uptake at the motor and gearbox. • Consider the different oxygen demand scenarios: minimum, average, and maximum as determined by the bioreactor loading profile for COD and TN, and temperature conditions. • Consider impact of bioreactor aerobic and anoxic configuration on oxygen demand
Application considerations	**4.5.4.2.2 Refer to Diffused and surface aeration technology guidelines** • Table 4-22 for further detailed application considerations for aeration technology. When selecting aeration technology consider: – Cost benefit of surface or diffused aeration, particularly for small treatment plants where surface aeration can have lower life-cycle costs due to lower civil and mechanical infrastructure requirements. – Level of aeration control, optimisation, including turn down/up capabilities – Aeration process application (e.g. for secondary treatment or biosolids processing) – Impact of water level variation – Bioreactor design on aeration coverage
Auxiliary or connected units	**4.5.4.2.3 Refer to Diffused and surface aeration technology guidelines** • Table 4-22 for further detailed application considerations for aeration technology
Sensitivity analysis considerations	• Impact of Alpha factor (α) or AlphaF (αF) versus MLSS • Impact of Alpha factor (α) or AlphaF (αF) on equipment sizing • Impact of dissolved aeration concentration on equipment sizing and effluent TN product outcome

	- Impact of water depth on oxygen transfer efficiency - Impact of diffuser coverage on oxygen transfer efficiency

4.5.4.2.4 Diffused and surface aeration technology guidelines

Table 4-22 Aeration technology specific guidelines

Parameter	Diffused aeration	Surface aeration
Unit configuration	- N+1, oxygen demand is met with one blower offline, regardless of number, configuration, or type of blower	- N, as limited by aerator platform design. - Consider use of critical spares to reduce service availability downtime
Process unit sizing	- AlphaF (αF) = 0.65 [1] - Or use α vs MLSS graph and F factor 0.65 - 0.90. - Beta (β) = 0.95 - SOTE/m depth: ~5.5 - 6.5 %/m - Consider minimum water depth, >4.5m. Excluding allowance for diffuser mounting height (typically 0.3m). For total reactor depth, add minimum 0.5m freeboard. - Consider diffuser density (floor coverage), 20% to 30% is typical, and diffuser air flow rate specifications	- Alpha (α) = 0.80 - Beta (β) = 0.95 - Typical R_{std} = 1.8 kgO_2/kWh (unless specified by equipment supplier).

Application considerations	- Efficiency of blower vs type of blower
	  – Positive displacement (PD) blowers: 70% to 75%
	  – Centrifugal blowers: 80%
	- PD blowers are more suitable for small treatment plants (2-5ML/d).
	- Consider life-cycle-cost of diffused aeration for small treatment plants. LCC of surface aeration may be more favourable for plants <5ML/d.
	- Turbo blowers are more suitable for large treatment plants (5> ML/d)
	- Air piping and headers
	- Diffuser system design (type, airflow limitations, coverage, mounting height, maintenance etc.)
	- Blower building requirements including cooling, ventilation, and noise control
	- Site air temperature, altitude, and humidity
		- *Eff%* is particularly applicable for surface aerators where motor efficiency and gearbox efficiency need to be considered:
		  – **Wire** power: power consumed by the aeration system as observed in the electrical demands
		  – **Water** power: power transfer to the fluid, which excludes motor and gearbox inefficiencies
		- Motor efficiency is typically, between 90% to 95% but can be less than 80% for small and/or older motors (<20 kW).
		- Gear box efficiency is around 90%.
		- Aeration energy density < 75W/m^3. Energy input density higher than this value may result undesirable splash distance and loss of aeration efficiency (i.e. cannot impart more energy into the water)
		- Splash distance and aeration coverage
		- Number of platforms for fixed aerators
		- Float maintenance for floating aerators
		- Local site altitude

1. AlphaF (αF) of 0.65 can be adopted for extended aeration bioreactors with SRTs in the range of 15-20 days and operating MLSS of 4-6 g/L. For other applications and for detailed design, alpha factor shall be determined based on site and technology specifics.

4.5.4.3 Solids-liquid separation

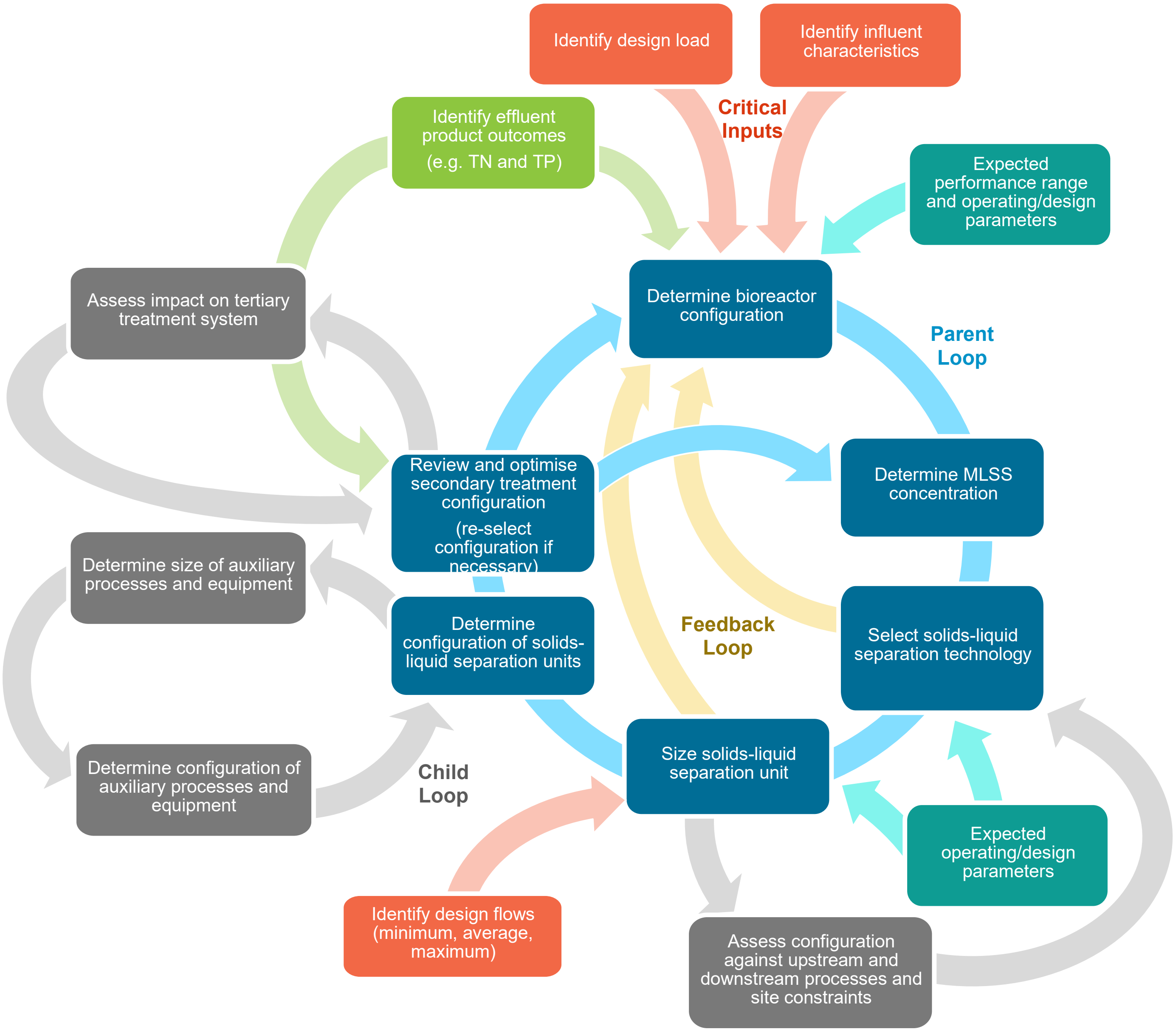


Figure 4-23 General approach for configuration of solids-liquid separation

4.5.4.3.1 Secondary settling (clarification)

Table 4-23 Configuration guidelines for secondary settling tanks

Secondary Treatment – Solids-Liquid Separation with Settling Tanks

Process unit outcomes	Secondary settling utilises gravity as the solids-liquid separation step in secondary treatment. Target Outcomes: • Remove suspended solids from the water to enable clear secondary effluent discharge • Thicken and collect activated sludge for it be returned to the upstream biological reactor	
Process streams	**Inputs**	**Outputs**
	• Mixed liquor	• Secondary effluent • Return activated sludge
Demand to be serviced	• Demand to be serviced is related to the following: – Effluent product outcomes (e.g. mg/L or kg/y) and the required percentile compliance (50th or 90th percentiles) for effluent SS. – Minimum, average, and maximum MLSS as determined by the bioreactor loading profile for COD and TSS and temperature conditions. Typically design for average temperature and 50th percentile loading but check for other conditions (e.g. reactor train offline). – Maximum settling index as determined by site-specific bacterial characteristics of the activated sludge or adopted design input	
Process unit governing capacity parameters	• Total settling area • RAS pump capacity (refer to Section 4.5.4.4 for pumping systems) • Note: capacity is also indirectly governed by operating conditions such as the settling characteristics of the suspended solids (SVI, DSVI, SSVI etc). and feed sludge MLSS concentration	
Servicing availability	**Regular maintenance**	**Major maintenance**
	• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: – Mechanical items as required	• Major servicing and overhaul downtime durations and frequencies: – 1-3 months every 10 years per settling tank
Process unit capacity derating	• No capacity derating factor as gravitational settling models incorporate a safety factor into the sizing of the settling area • However, an explicit (superimposed) de-rating factor can be applied if there is an observed deterioration of settling performance in comparison to settling models. This should be determined on case-by-case basis	
Unit configuration	• N-1 for PDWF conditions to ensure 100% compliance during dry weather conditions • N for PWWF conditions	

	• Note: Depending on flow factors and SVI, the N-1 for PDWF and N for PWWF may not have a significant difference. In such scenario, consider risk-based assessment to determine the optimum unit configuration for PDWF and PWWF but prioritising 100% dry weather compliance.
Process unit sizing	• Sludge settling (e.g. flux model) and state-point analysis should be used to design and assess secondary settling tanks. • For sludge settling model (e.g. State-Point Analysis): – Adopt an SVI = 150 mL/g unless superseded by plant data – Note: sludge settling models convert the sludge index to a sludge settling parameters (V_0 and n). Different relationships apply for the sludge indexes (SVI, DSVI, SSVI etc.). Consider the impact of this conversion when conducting a state-point analysis. – Where there is uncertainty in the SVI, conduct sensitivity analysis to assess impact of higher / lower SVI (e.g. 130 and 180 SVI – Adopt MLSS as estimated by bioreactor model. However, consider impact of higher MLSS concentrations on settling tank demands. Higher MLSS can occur to unintended sludge build up bioreactor (e.g. reactor train or biosolids unit offline). – Use suitable flux safety factor for SPA models, typically 120% • For high-level assessments on effluent performance, assume effluent SS: 15 – 30 mgSS/L unless superseded by plant data • Maximum overflow rate 1.1 m/h @ PWWF as a rule, to be superseded by SPA analysis
Application considerations	• Consider the impact of the settling model requirements on the hydraulic design requirements, weir loading rates, size of effluent channels, launders, pump stations, and feed and RAS pipelines. • Splitter chamber and inflow distribution mechanism (including flow control and isolation) • Settling tank features such as effluent channels and launders • Maximum weir loading rate • Maximum bridge length • Scum removal system
Auxiliary or connected units	• Splitter chamber • RAS and/or WAS pump station (refer to Section 4.5.4.44.5.4.4.3 for pumping systems) • Scum control system
Sensitivity analysis considerations	• Impact of MLSS on settling tank capacity and effluent product outcomes • Impact of SVI (or similar settling index) on settling tank capacity and effluent product outcomes • Impact of peak flow factor on settling tank capacity and effluent product outcomes • Impact of settling tank volume on sludge storage capacity for sludge buffering under PWWF conditions

4.5.4.3.2 Intermittent decanting (IDALs and SBRs)

Table 4-24 Configuration guidelines for intermittent decanting for IDAL and SBR plants

Secondary Treatment – Solids-Liquid Separation with Intermittent Decanting (for IDALs)

Process unit outcomes	Intermittent decanting utilises gravity and a decanter unit as the solids-liquid separation step in secondary treatment. Decanter unit is located below the water surface and acts as a water skimming device. Target Outcomes: • Remove suspended solids from the water to enable clear secondary effluent discharge • Maintain IDAL tank operating modes (normal, wet, or contact stabilisation)	
Process streams	**Inputs**	**Outputs**
	• Mixed liquor	• Secondary effluent
Demand to be serviced	• Demand to be serviced is related to the following: – Effluent product outcomes (e.g. mg/L or kg/y) and the required percentile compliance (50th or 90th percentiles) for effluent TSS. – Minimum, average, and maximum MLSS as determined by the bioreactor loading profile for COD and TSS and temperature conditions. – Maximum settling index as determined by site-specific bacterial characteristics of the activated sludge or adopted design input	
Process unit governing capacity parameters	• Total settling area (m^2) • RAS pump capacity (refer to Section 4.5.4.4 for pumping systems) • Note: capacity is also governed by operating conditions such as the settling characteristics of the suspended solids (SVI, DSVI, SSVI etc). and feed sludge MLSS concentration	
Servicing availability	**Regular maintenance**	**Major maintenance**
	• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: – As required	• Major servicing and overhaul downtime durations and frequencies: – Decanter structure/mechanism or boot replacement if required 1 week every 10-15 years – Periodic decanter levelling recommended
Process unit capacity derating	• No capacity derating factor as gravitational settling models incorporate a safety factor into the sizing of the settling area • However, an explicit (superimposed) de-rating factor can be applied if there is an observed deterioration of settling performance in comparison to settling models. This should be determined on case-by-case basis	
Unit configuration	• Unit configuration is linked to the intermittent biological process, as detailed in Section 4.5.4.1.2	

Process unit sizing	• Use sludge setting models for sizing of setting area • Refer to secondary settling tank section for more guidelines on settling area sizing. • Refer to Section 4.5.4.1.2 for IDAL cycle-times
Application considerations	• Consider use of selectors to improve settleability of the sludge (refer to Section 4.5.4.1.2)
Auxiliary or connected units	• Splitter chamber • RAS and/or WAS pump station (refer to Section 4.5.4.4 for pumping systems) • Scum control system • Equalisation basin
Sensitivity analysis considerations	• Impact of MLSS on settling capacity and effluent product outcomes • Impact of SVI (or similar settling index) on settling capacity and effluent product outcomes • Impact of peak flow factor on settling capacity and effluent product outcomes • Impact of settling volume on sludge storage capacity for sludge buffering under PWWF conditions

4.5.4.3.3 Membrane filtration (MBR)

Table 4-25 Configuration guidelines for membrane filtration units

<table>
<tr><th colspan="5">Secondary Treatment – Solids-Liquid Separation and Biological Treatment with Membrane Filtration</th></tr>
<tr><td>Determine bioreactor volume and reactor MLSS</td><td>Select type of membrane filtration technology</td><td>Determine filtration area and filtration tank dimensions</td><td>Review upstream bioreactor configuration</td><td>Determine supporting equipment requirements</td></tr>
<tr><td>Process unit outcomes</td><td colspan="4">Membrane filtration can be utilised as a solids-liquid separation process and as part of the biological treatment process. It therefore can have multiple outcomes:
• Solids-liquid separation and thickening as per secondary settling
• Increase nutrient removal and secondary effluent quality (i.e. lower effluent TN, TP and SS)
• Higher MLSS concentration and reduction in secondary treatment footprint</td></tr>
<tr><td rowspan="2">Process streams</td><td colspan="2">Inputs</td><td colspan="2">Outputs</td></tr>
<tr><td colspan="2">• Mixed liquor
• Oxygen (process air)</td><td colspan="2">• Membrane permeate (i.e. secondary effluent)
• Return activated sludge
• Waste activated sludge</td></tr>
<tr><td>Demand to be serviced</td><td colspan="4">• Demand to be serviced is related to the following:
– Effluent product outcomes (e.g. mg/L or kg/y) and the required percentile compliance (50th or 90th percentiles) for effluent SS.
– Minimum, average, and maximum MLSS as determined by the bioreactor loading profile for COD and TSS and temperature conditions.
– Minimum, average, and maximum flow conditions as determined by the influent flow profile. Filtration capacity must be maintained under for all influent flow conditions to the MBR</td></tr>
<tr><td>Process unit governing</td><td colspan="4">• Total membrane area</td></tr>
</table>

capacity parameters	- Membrane flux (LMH) - Membrane reactor volume	
Servicing availability	**Regular maintenance**	**Major maintenance**

	- Regular and ongoing maintenance downtime for minor preventative and reactive maintenance:
	  – 1 day recovery clean (per reactor tank) every year
		- Major servicing and overhaul downtime durations and frequencies:
		  – 1-6 week (per train) every 10 years for membrane and diffuser replacements

Process unit capacity derating	- No capacity derating factor - However, an explicit (superimposed) de-rating factor can be applied if there is an observed deterioration of membrane filtration performance/capacity in comparison to design specifications. This should be determined on case-by-case basis.	
Unit configuration	- N+i - Unit configuration is site-specific and is affected by the type and design of the membrane filtration units, operating MLSS conditions, design of the bioreactor, and the influent flow pattern including the intensity and length of peak flows. - Filtration capacity must be maintained under all influent flow conditions and during various membrane operating procedures (e.g. cleaning, backwashing) and unit availability scenarios (e.g. N filtration trains offline).	

Process unit sizing	- The membrane flux (LMH, L/m²h) will determine the required filtration area, the total filtration area shall then be determined as follows:
	$$A_{FILTRATION}\,(m^2) = \frac{Q_{PEAK}\,(m^3/h)}{LMH\,(L/m^2h)\ \times\ 1/1000\,(L/m^3)}$$
	- Following which, the minimum number of membrane modules is then determined such that:
	$$N_{MODULE,MIN} = \frac{A_{FILTRATION}\,(m^2)}{A_{MODULE}\,(m^2)}$$
	- Where
	  – Q_{PEAK} is the peak flow rate that the membrane equipment must treat
	  – *LMH* is specific to the membrane design, obtain LMH from the equipment supplier, or use typical LMH for the selected membrane technology, or obtain from existing asset design specification. For secondary treatment application with submerged membranes, flux is typically between 20 and 25LMH
	  – $A_{FILTRATION}$ is the membrane filtration area required
	  – A_{MODULE} is the filtration area provided by each membrane module as per supplier specifications	

Application considerations	- Impact of the membrane design (e.g. LMH) vs lifecycle cost of the membrane unit including chemical consumption, membrane replacement, labour costs, footprint and capital costs.
	- Membrane filtration area and number of membrane units (e.g. modules and cassettes)
	- Membrane filtration equipment (feed pumps, permeate pumps, air scour blowers etc.)
	- Membrane filtration tank dimensions and volume, including allowances for freeboard, dividing walls, channels, and weirs
	  – Consider staging of filtration capacity by means of installing larger tank volume but with partial membrane fit-out/installation
	  – Consider isolation requirements for discrete maintenance of filtration trains
	- Impact on bioreactor configuration such as bioreactor reactor volume in relation to MLSS concentration:
	  – MLSS inside filtration tank: 8000 – 12000 mg/L (or as per membrane equipment specifications)	

	– MLSS inside bioreactor: 6000 – 8000 mg/L (consider aeration efficiency vs bioreactor volume) • Impact on upstream and downstream systems, e.g. fine screening requirements, tertiary treatment, disinfection, sludge thickening etc. • Building requirements to house membrane tanks, equipment, pumps etc. • Distribution of sludge mass (and aerobic SRT) due to the RAS recycle ratio selection of the MBR system • RAS will have high DO concentration due to air scouring, typically 4.0 mg/L. Consider de-aeration of oxygen rich RAS or discharge RAS to aerobic zone in the bioreactor. • Selection of “Pumped To” or “Pumped From” MBR configuration and subsequent impact on design, hydraulics, membrane selection, construction, and control. See subsection below.
Auxiliary or connected units	Critical supporting equipment include: • Flow equalisation • Pumps (membrane feed, backwash, waste, return activated sludge). Including backup power (battery or generator) for critical pumps – as required based system configuration and resilience • Membrane cleaning systems (air scouring and chemical cleaning) including waste/neutralisation tanks • Scum removal system Configuration of the above supporting equipment must be conducted in parallel to the configuration of the membrane filtration units. • The capacity of the above equipment must meet the same servicing availability demands as the membrane filtration units.
Sensitivity analysis considerations	• Impact of operating MLSS on MBR volume and membrane design • Impact of LMH selection on MBR volume and design • Impact of peak flow MBR filtration area demands • Impact of MBR vs non-MBR on effluent product outcomes (i.e. TN, TP, and SS) • Impact of MBR RAS on upstream bioreactor (i.e. high oxygen returns), • Inclusion of de-aeration zones.

Table 4-26 Configuration guidelines for supporting membrane equipment

Equipment Group	Pumps:	Air scouring:	All other equipment
Unit configuration	• N+1 • N+2 (where N>4)	• N+1 (as per diffused aeration blowers)	• N for non-critical equipment • N+1 for critical equipment
Process unit sizing	• Pumps include feed/RAS permeate, backwash • Size pumps to match MBR demands • MBR RAS ratio: 4 to 6 × Influent flow. High RAS ratio is required to prevent solids concentrating in the membrane tank and to provide shear across membrane surface to prevent fouling.	• Coarse bubble aeration is typically utilised. This system will have lower oxygen transfer efficiency that fine bubble diffused aeration.	• Size to match MBR demands • Scum removal system is mandatory for an MBR system as there is no overflow mechanism to remove filamentous bacteria. • Upstream flow balancing should be utilised to reduce peak flow to membrane system. Consider size and cost-benefit of flow equalisation.

Note: preference for permeate pumps and blowers to be configured on a ‘per cell’ basis. Redundancy can be based on MBR tank redundancy.

MBR flow conveyance options ("pump to" vs "pumped from")

There are two options for flow conveyance of mixed liquor in an MBR system:

1. "Pumped To" or "Pump Feed" in which a mixed liquor is pumped to the membrane tank. This option is suitable for submerged or pressurised membranes. The return activated sludge (RAS) flows back to the bioreactor by gravity. In this option, the mixed liquor pumps have a dual function of providing feed flow to the membranes and flow for the return activated sludge (RAS) and thus a total of 5Q is pumped (for assuming a RAS of 4Q).

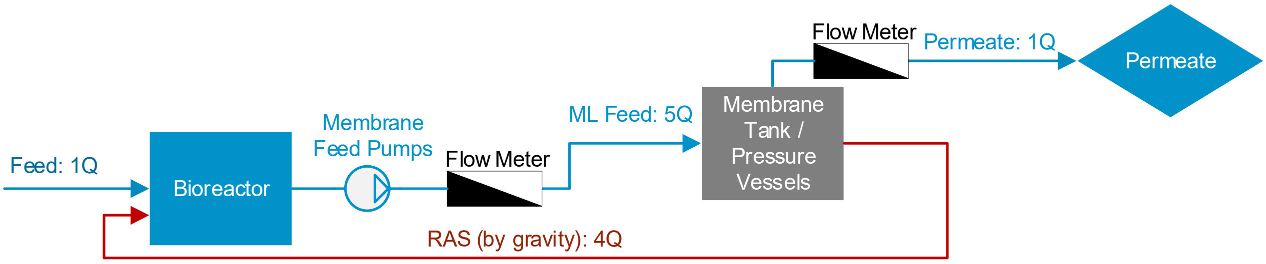


Figure 4-24 MBR "Pumped To / Pump Feed" flow conveyance

2. "Pumped From" or "Gravity Forward" in which mixed liquor flows by gravity to the membrane tank. This option is only available for submerged membranes. The RAS pumps are sized for the RAS flow only, and thus the total pumped flow is lower than the "Pumped To" option, i.e. 4Q only.

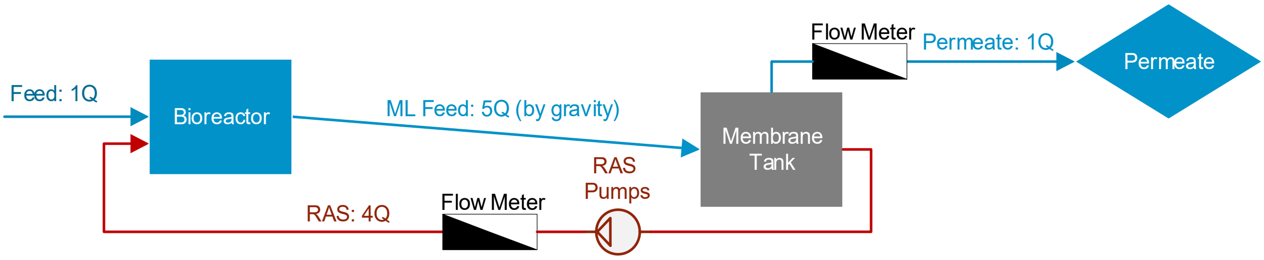


Figure 4-25 MBR "Pumped From / Gravity Feed" flow conveyance

The key differences between the two options are in pumping, control and location in flow meters, and construction requirements. The latter due to the hydraulic requirements for the flow between the membrane tank and bioreactor:

Table 4-27 Key difference between MBR flow conveyance options

Description	"Pumped To"	"Pumped From"
Pumping requirements	Influent + RAS; higher energy costs [1]	RAS only; lower energy costs [1]
Control requirements	Direct control over feed flow to membrane tank. Flow meter located directly on feed line to membrane tank.	Indirect control over feed flow to membrane tank. Flow meter located on recycle line. Note potential for lag-time in flow control.
Construction and hydraulics	Membrane tank water level can be level with or higher than the bioreactor.	Membrane tank water level must be below bioreactor to facilitate gravity flow

[1] Energy costs will be affected by the reactor design and pumping head requirements. The latter is linked to the flow conveyance option (channel or pipes), pumping distance, and static head. Under certain conditions, the "Pumped From" system can have higher energy demands.

Note: as per the above, there are two similar options for the permeate flow. The first involves pumping the permeate to the permeate tank; the second involves a siphon design to hydraulically pull the permeate to the permeate tank.

4.5.4.4 Mixed liquor mixing and pumping

4.5.4.4.1 Bioreactor mixing

Table 4-28 Configuration guidelines for bioreactor mixing

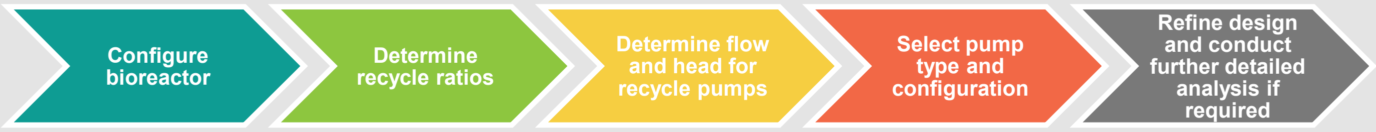
Secondary Treatment – Bioreactor Mixing		
Determine bioreactor volume and detailed bioreactor design	Determine mixing requirements for anaerobic and anoxic zones	Refine mixer design conduct further detailed analysis if required
Process unit outcomes	Configuration of the mixing system involves determining the sizes and number of mixers required for bioreactor. Note that certain bioreactor configurations may not require mixing equipment (e.g. SBRs). Target process outcomes: • Maintain mixing conditions to avoid settling of solids • Support bioreactor in achieving its effluent product outcomes	
Process streams	**Inputs**	**Outputs**
	• None	• None
Demand to be serviced	• N/A	
Process unit governing capacity parameters	• Mixing system size and design (power and mixing efficiency)	
Servicing availability	**Regular maintenance**	**Major maintenance**
	• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: – As required	• Major servicing and overhaul downtime durations and frequencies: – 1-5 days per tank each 10-15 years
Process unit capacity derating	• No capacity derating factor • Determine on case-by-case basis	
Unit configuration	• Unit configuration will depend on bioreactor design (layout, volume, and fluid dynamics) • Consider modularity to reduce the impact of the capacity loss due to equipment out-of-service scenarios	
Process unit sizing	• Typically conducted by equipment supplier • Mixing systems include various design features and operating criteria such as liquid viscosity, mixing volume, horizontal velocities, blade design etc. • Empirical mixer sizing involves using a mixing density, 7 to 10 W/m^3, applied to the volume of the reactor. Use upper value unless superseded by mixer design/recommendations provided by equipment supplier.	
Application considerations	• Consider mixer technology selection and bioreactor design requirements	

	• Examples of mixers include vertically mounted, horizontally mounted, and pumped mixing systems – Vertically and horizontally mounted are most suitable for bioreactor zones (anaerobic and anoxic) – Mixers are typically not required in the fully aerobic zones as mixing is provided by the aeration system. – For surface mounted or floating aeration systems, submersible mixers are sometimes installed for dead corner zones, for example in oxidation/ditch systems. – Likewise, for intermittent aeration systems, mixers may be provided to assist in specific process steps characterised by on/off aeration • Mixing systems are often sized and designed by equipment suppliers. The following information is often required by equipment suppliers: – Purpose of mixing and type of process tank – Process tank volume, dimensions and geometry, inlet/outlet arrangement, available mounting positions – Water depth and freeboard – Inlet and outlet flow rates – Density of fluid of fluid characteristics (e.g. solids concentration, temperature, pH etc.)
Auxiliary or connected units	• None for vertically or horizontally mounted mixers • Intake and discharge pipework for pumped mixing systems
Sensitivity analysis considerations	• Computational fluid dynamics should be used for sensitivity analysis

4.5.4.4.2 Bioreactor mixed liquor pumping

Table 4-29 Configuration guidelines for bioreactor mixed liquor pumping

Secondary Treatment – Mixed Liquor Pumping



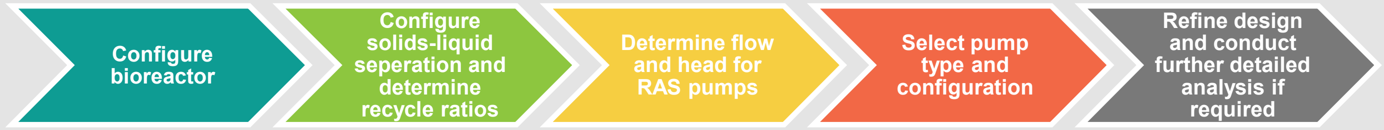
Process unit outcomes	Configuration of the pumping system involves determining the sizes and number of pumps required for the various mixed liquor recycles in the bioreactor configuration, e.g. aerobic-anoxic, and anoxic-anaerobic recycles. Target process outcomes: • Maintain target pump recycle ratio to achieve bioreactor effluent product outcomes	
Process streams	**Inputs**	**Outputs**
	• Mixed liquor	• Mixed liquor
Demand to be serviced	• Demand to be serviced will be related to the flow rate specified by the pump recycle ratio as determined by the bioreactor configuration, technology, and effluent product outcomes	
Process unit governing	• Flow rate (m^3/h) • Pumping head (h)	

capacity parameters		
Servicing availability	**Regular maintenance**	**Major maintenance**
	• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: – Short duration as required	• Major servicing and overhaul downtime durations and frequencies: – 1-2 day every 10 years per pump
Process unit capacity derating	• No capacity derating factor • Determine on case-by-case basis	
Unit configuration	• Consider modularity to reduce the impact of the capacity loss due to equipment out-of-service scenarios • Recommended: N+1 or N+2 (where N>4)	
Process unit sizing	• The minimum number of duty units for the mixed liquor recycle pumps should be determined based on the following: $N_{duty,min} = \frac{Q_{PEAK}\ (m^3/h)\ \times\ RR}{Q_{PUMP}\ (m^3/h)}$ • Where – *Q*Q_{PEAK} is the dry weather flow condition used to size the recycle pumps – Q_{PEAK} is typically the PDWF; however, an alternative flow condition can be used depending on the demand to be serviced as determined by the effluent product outcomes. – PWWF should not be used in the above equation to size bioreactor mixed liquor recycle pumps. Utilising PWWF will lead to oversizing and difficulty in achieving the required turn down ratios for minimum flow conditions. Recycle pumps will operate under reduced recycle ratios during PWWF. – *RR* is the recycle ratio and is depend on the bioreactor configuration and the type of recycle pump (i.e. aerobic-anoxic, anoxic-anaerobic, or return activated sludge) – Q_{PUMP} is the flow rate that the pump can achieve as per its pump curve and equipment design • Above equation can be also be utilised to size turn down requirements	
Application considerations	• Consider modularity to reduce the impact of the capacity loss due to equipment out-of-service scenarios and to increase the turn down ratio that is achievable by the pumps • Required recycle ratio to achieve product outcomes (i.e. optimum TN removal occurs at recycle ratios between 4 and 6 w.r.t influent flow) • Pump head & flow requirements and pump selection including capacity of hydraulic conduits (i.e. channels, pipes, and sumps)	
Auxiliary or connected units	• None	
Sensitivity analysis considerations	• Impact of recycle ratio on sludge mass distribution and concentrations of the bioreactor zones • Impact of recycle ratio on effluent product outcomes for peak and minimum flow conditions • Impact of reduced recycle ratio, during PWWF, on effluent product outcomes • Impact of recycle ratio on pumping energy and cost	

4.5.4.4.3 Return activated sludge pumping

Table 4-30 Configuration guidelines for RAS pumping for solids-liquid separation

Secondary Treatment – Return Activated Sludge Pumping

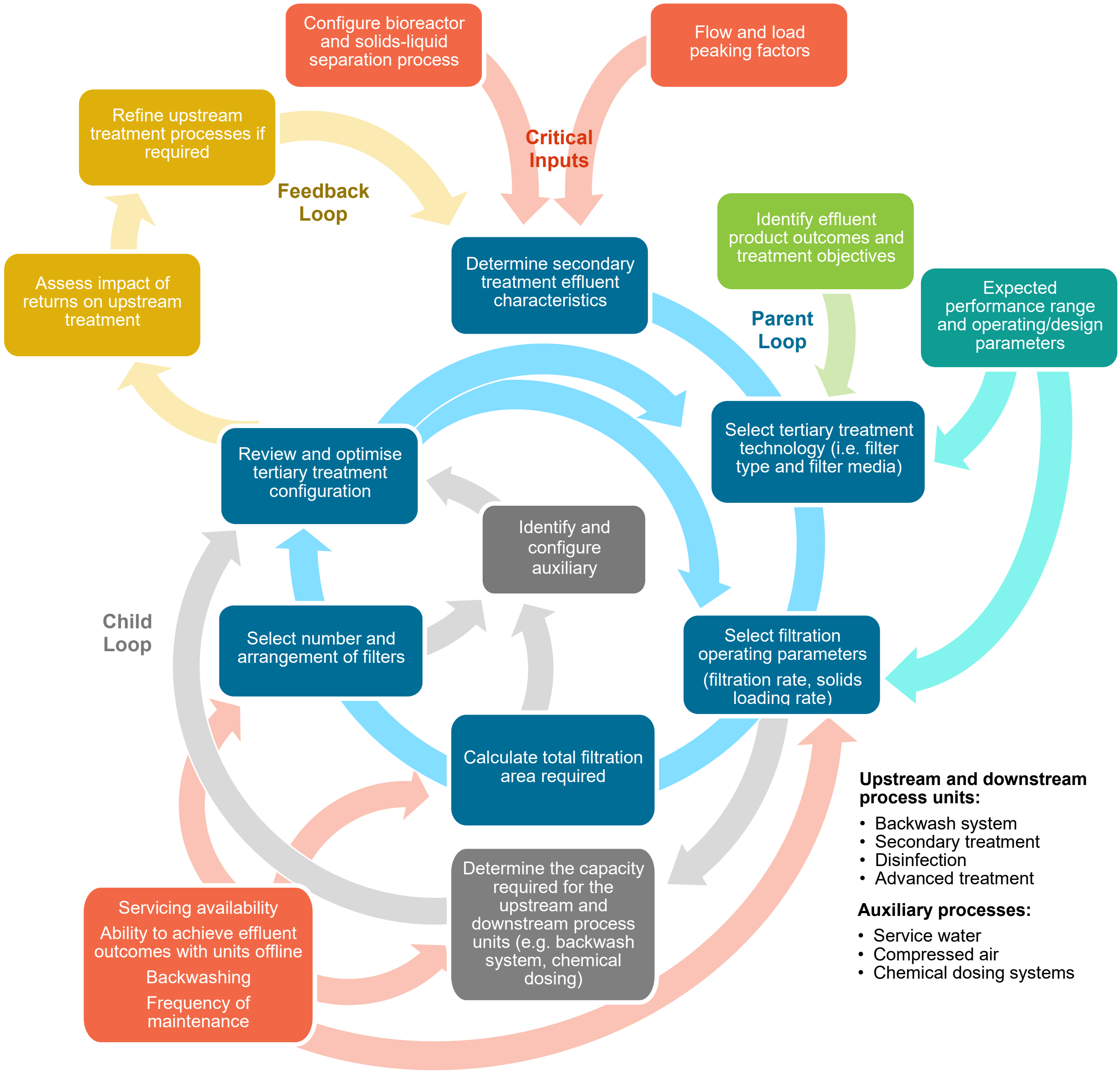


Process unit outcomes	Configuration of the return activated sludge pumps follows similar principles as per the mixed liquor recycle pumps. However, RAS pumps also include thickening and MLSS concentration control as target processes outcomes. Target process outcomes: • Maintain return activated sludge flow rates as per biological process requirements • (Indirectly) thickening in solids-liquid separation process and distribution of sludge mass in biroeactor	
Process streams	**Inputs**	**Outputs**
	• Mixed liquor	• Mixed liquor
Demand to be serviced	• Demand to be serviced will be related to the flow rate specified by the pump recycle ratio as determined by the solids-liquid separation technology and design	
Process unit governing capacity parameters	• Flow rate (m^3/h) • Pumping head (h)	
Servicing availability	**Regular maintenance**	**Major maintenance**
	• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: – Short duration as required	• Major servicing and overhaul downtime durations and frequencies: – 1-2 day every 10 years per pump
Process unit capacity derating	• No capacity derating factor • Determine on case-by-case basis	
Unit configuration	• Consider modularity to reduce the impact of the capacity loss due to equipment out-of-service scenarios • Recommended: N+1 or N+2 (where N>4)	
Process unit sizing	• The minimum number of duty units for the RAS pumps should be determined based on the following: $N_{duty,min} = \frac{Q_{PEAK}\,(m^3/h) \times RR}{Q_{PUMP}\,(m^3/h)}$ • Where – Q_{PEAK} is the maximum flow condition used to size the RAS pumps – Q_{PEAK} is typically the PWWF; however, an alternative flow condition can be used depending on the demand to be serviced as determined by the effluent product outcomes AND solids-liquid separation demands under the alternative flow conditions.	

	– *RR* is the recycle ratio will depend on the solids-liquid separation technology and design, for gravitational settling this is typically between 0.8 and 1.0; for membrane systems this 4.0 to maintain membrane permeability (however, confirm with supplier) – Q_{PUMP} is the flow rate that the pump can achieve as per its pump curve and equipment design • Above equation can be also be utilised to size turn down requirements
Application considerations	• Consider modularity to reduce the impact of the capacity loss due to equipment out-of-service scenarios and to increase the turn down ratio that is achievable by the pumps • Pump head & flow requirements and pump selection including capacity of hydraulic conduits (i.e. channels, pipes, and sumps) • Consider pumping / gravity flow arrangements for MBR systems (i.e. “Pumped To” vs “Pumped From”). Refer to Section 4.5.4.3.3 for MBR systems)
Auxiliary or connected units	• Solids-liquid separation process (settling tank or MBR)
Sensitivity analysis considerations	• Impact of recycle ratio on sludge mass distribution and concentrations of the bioreactor zones • Impact of recycle ratio on effluent product outcomes • Impact of recycle ratio on pumping energy and cost

4.5.5 Tertiary treatment

Various tertiary treatment technologies exist with each providing a specific process to improve effluent quality prior to discharge, reuse or further treatment. The selection of the tertiary treatment system must be suitable to the project objectives and product outcomes.



Upstream and downstream process units:

- Backwash system
- Secondary treatment
- Disinfection
- Advanced treatment

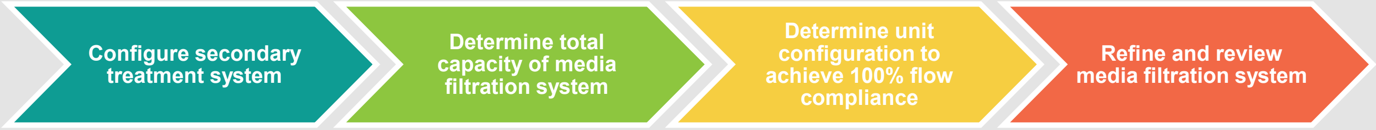
Auxiliary processes:

- Service water
- Compressed air
- Chemical dosing systems

Figure 4-26 General approach for configuration of tertiary treatment

4.5.5.1 Media filtration

Table 4-31 Configuration guidelines for media filtration

Tertiary Treatment – Media Filtration		
 Configure secondary treatment system Determine total capacity of media filtration system Determine unit configuration to achieve 100% flow compliance Refine and review media filtration system		
Process unit outcomes	Tertiary media filtration is utilised to remove colloidal or suspended particulate material not removed by the secondary settling tank. Target process outcomes: - Suspended solids removal	
Process streams	**Inputs**	**Outputs**
	- Secondary effluent - Chemicals (coagulant/flocculants)	- Tertiary effluent - Filter sludge
Demand to be serviced	- Peak flow demands, 1.2×PDWF through 1 filter unit, unless otherwise required by EPL or to meet effluent load limit objectives.	
Process unit governing capacity parameters	- Filtration area (m^2) - Filtration rate (m/h)	
Servicing availability	**Regular maintenance**	**Major maintenance**
	- Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: – 1 hour per day (backwash)	- Major servicing and overhaul downtime durations and frequencies: – 3 months every 10 years per filter (may be more frequent deepened on fouling)
Process unit capacity derating	- No capacity derating factor - Determine on case-by-case basis	
Unit configuration	- Unit configuration must achieve 100% flow-based compliance - Minimum required is number of filters is N+2, where each filter is sized for 100% flow capacity. This configuration will allow for: – 1 duty operating at 100% flow rate – 1 backwash – 1 out-of-service	
Process unit sizing	- The filtration rate ($m^3/m^2/h$) will determine the required filtration area, the total filtration area shall then be determined as follows: $A_{FILTRATION}\,(m^2) = \dfrac{Q_{PEAK}\,(m^3/h)}{Filtration\ Rate\ (m^3/m^2/h)}$ - Following which, the minimum number of filtration units is then determined such that:	

	$N_{DUTY,MIN} = \frac{A_{FILTRATION}\,(m^2)}{A_{FILTER}\,(m^2)} + 2$ • Where – Q_{PEAK} is the peak flow rate that the media filter must treat, i.e. 1.2×PDWF – *Filtration Rate* is the filtration rate of the media filter, this is typically: 12 m/h under peak flow conditions (or 5.5 m/h under average flow conditions). – Peak flow conditions can also occur when 1 filter is in backwash mode or offline. – $A_{FILTRATION}$ is the media filtration area required – $A_{FILTER\ is}$ the filter area per filter module as per the limitations of the existing filter system (or site constraints of a new filter system) – +2 to allow for 1 filter unit in backwash and 1 filter unit out-of-service
Application considerations	• Filtration area required under ADWF conditions can be higher than the area required under peak flow conditions. • Consider oversizing filter units to maintain filtration capacity for deterioration in filtration rates between filter media replacement • Typical filtration performance: – < 2 mgSS/L – < 2 NTU; or 0.5 NTU if downstream of tertiary clarifier
Auxiliary or connected units	• Backwash system • Air scouring • Service water • Chemical dosing to improve filtration performance
Sensitivity analysis considerations	• Filtration rate vs filtration area

4.5.5.2 Tertiary denitrification

Table 4-32 Configuration guidelines for tertiary denitrification

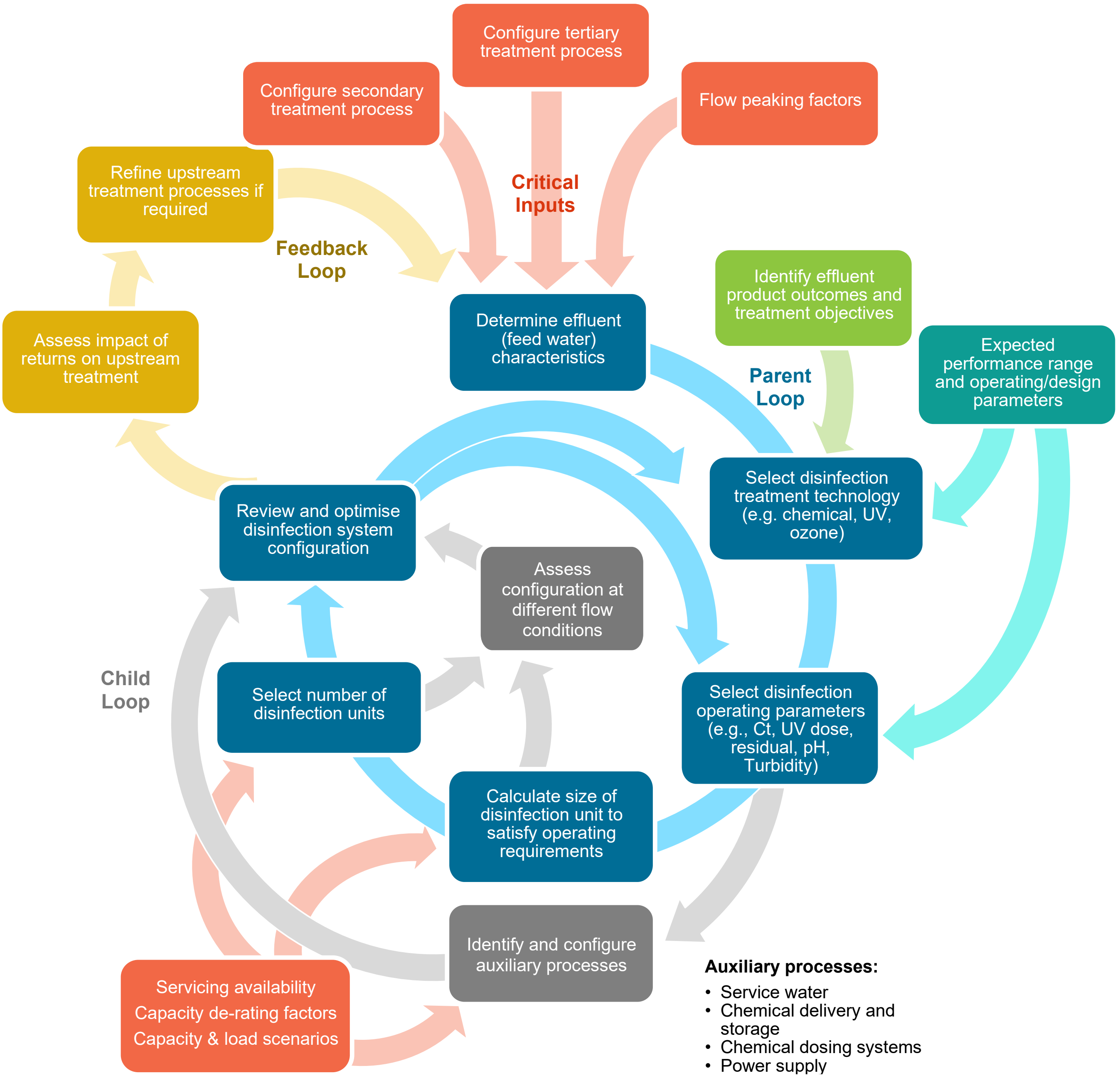
<table>
<tr><th colspan="3">Tertiary Treatment – Tertiary Denitrification</th></tr>
<tr><td colspan="3"> </td></tr>
<tr><td rowspan="1">Process unit outcomes</td><td colspan="2">Tertiary denitrification is utilised to remove residual TN from the secondary treatment process
Target process outcomes:
• TN removal</td></tr>
<tr><td rowspan="2">Process streams</td><td>Inputs</td><td>Outputs</td></tr>
<tr><td>• Secondary effluent</td><td>• Tertiary effluent</td></tr>
</table>

Demand to be serviced	• Demand to be serviced must be determined by length of time and risk of effluent non-compliance	
Process unit governing capacity parameters	• Will vary according to the type of tertiary denitrification process, in most cases it will be the HLR (m^3/s or L/S) of the tertiary denitrification unit	
Servicing availability	**Regular maintenance**	**Major maintenance**
	• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: – 1 hour per day (backwash)	• Major servicing and overhaul downtime durations and frequencies: – 1 – 4 weeks every 10 years per filter (may be more frequent deepened on fouling)
Process unit capacity derating	• No capacity derating factor • Determine on case-by-case basis	
Unit configuration	• Configuration of tertiary denitrification processes may include, depending on the chosen technology: – Denitrification filters – Fluidised or moving bed biofilm reactors – Carbon source dosing system – typically methanol	
Process unit sizing	• NO_3-N removal: typically reduced to 1.0 mg/L of nitrate $N_{DUTY,MIN} = \frac{Q_{PEAK}\ (m^3/h)}{HLR_{EQUIPMENT}\ (m^3/h)}$ • Where: – Q_{peak} is 1.2×PDWF (unless otherwise required by EPL or to meet load limits) – $HLR_{EQUIPMENT}$ is the nominal equipment hydraulic loading rate capacity as provided by equipment supplier – typically limited by HLR (L/s)	
Application considerations	• Additional solids production due to biomass growth and impact on any downstream processes, such as tertiary filters and disinfection • Compatibility with upstream treatment processes and EPL requirements • Secondary effluent characteristics and impact of denitrification process performance • Implementing P-removal upstream may inhibit effectiveness of denite process.	
Auxiliary or connected units	• Chemical dosing system (e.g. carbon, chemical P, coagulants etc.) • Sludge management and treatment • Downstream filter requirements • Service water and compressed air	
Sensitivity analysis considerations	• Loading rate of tertiary denitrification unit vs effluent performance vs capital and footprint requirements • Carbon dosing and effluent TN outcomes	

4.5.6 Disinfection

The configuration of the disinfection system must be tailored to the site-specific demands for disinfection and discharge or end-product uses. The disinfection system can include chemical and/or physical methods, vendor or non-vendor supplied package systems. However, irrespective of the disinfection method, the general approach shown in Figure 4-27 should be adopted for the configuration of the disinfection system.

Refer to Section 4.5.11 for indicative log removals of the indicative range of microbial log reductions for various treatment processes including the disinfection processes detailed in this section.



Auxiliary processes:

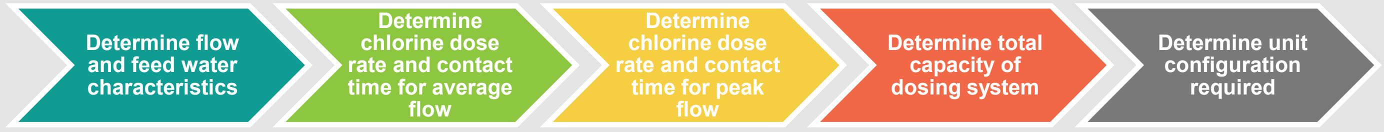
- Service water
- Chemical delivery and storage
- Chemical dosing systems
- Power supply

Figure 4-27 General approach for configuration of disinfection

4.5.6.1 Chlorination

Table 4-33 Configuration guidelines for chemical disinfection

Disinfection – Chlorination



Disinfection – Chlorination		
Process unit outcomes	Chlorine disinfection must be provided for all effluent flows (discharged effluent and bypass flows). The disinfection requirements will be set by the EPL for existing WWTPs. Target process outcomes: • Maintain public health • Maintain environmental health	
Process streams	**Inputs**	**Outputs**
	• Tertiary effluent • Chlorine solution	• Disinfected effluent
Demand to be serviced	• Full disinfection @ PDWF (L/s) • Partial disinfection @ PWWF (L/s)	
Process unit governing capacity parameters	• Ct (mg.min/L) – Maximum dose rate – Maximum contact time	
Servicing availability	**Regular maintenance**	**Major maintenance**
	• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: – Minor as required	• Major servicing and overhaul downtime durations and frequencies: – 1 week every 15 years per tank
Process unit capacity derating	• No capacity derating factor • Determine on case-by-case basis	
Unit configuration	• N chlorine contact units with adequate baffling and chlorine dosing arrangements ensuring dry weather CT is maintained with one unit offline. This may include having one tank with 2 compartments or streams which are separately maintainable. • Require a separate tank if recycled water is to be provided.	
Process unit sizing	**Free residual chlorine × contact time (CT):** Free residual chlorine and contact time must be selected to achieve required pathogen removal or to maintain a disinfectant residual as required by treated effluent destination or end use. The following Ct values can be adopted for preliminary planning level CCT and dosing system unit sizing – nominated Ct values shall be superseded during design based on site specific variables and effluent product requirements. An 80th percentile performance requirement of <200cfu/100mL for effluents discharged to waterways is assigned for the nominated Ct value. Note: in planning, higher Ct values than those nominated may need to be adopted for water reuse/recycling application. Guidance on log removal achieved disinfection under different treatment trains and contexts, can	

	be found in the *Guidelines for validating treatment processes for pathogen reduction – Supporting Class A recycled water schemes in Victoria* (Vic DoH, 2013). • ADWF: Ct = 15 mg.min/L • 1.2xPDWF: Ct = 15 mg.min/L • PWWF: partial disinfection may be considered depending on catchment characteristics, treatment plant configuration, and licence requirements **Free residual chlorine** The need for a free chlorine residual is site and system specific. The following values can be adopted for preliminary planning. • 0.5 - 3 mg/L for long transfer schemes and reuse applications (depending on end application) • 0.1 mg/L limit for effluents discharged to waterways (de-chlorination prior discharge typically required)
Application considerations	• Formation of by-products – disadvantage compared to alternate methods of disinfection, potentially a future risk. • The expected levels of contamination with pathogens, and any specific pathogens of concern for the site • The extent and performance of secondary and tertiary treatment prior to final disinfection • Consider the efficiency of the baffling design, plug flow design is ideal • Expected variations in temperature and pH, typical pH between 6.5 and 8.5. • Supply and delivery of options including available bottle/tank sizes, changeover requirements, impact on building design and storage requirements • Recycled water chlorination requirements supersede environmental discharge. Consider separate CCT for recycled water plants supplying to minimise chemical consumption, otherwise the whole tank is chlorinated at very high dosage levels.
Auxiliary or connected units	• Dosing system (chemical delivery, solution make-up, dilution water, dosing pumps, dosing control) • Health and safety requirements
Sensitivity analysis considerations	• Ct value, flow variation, and disinfection system sizing

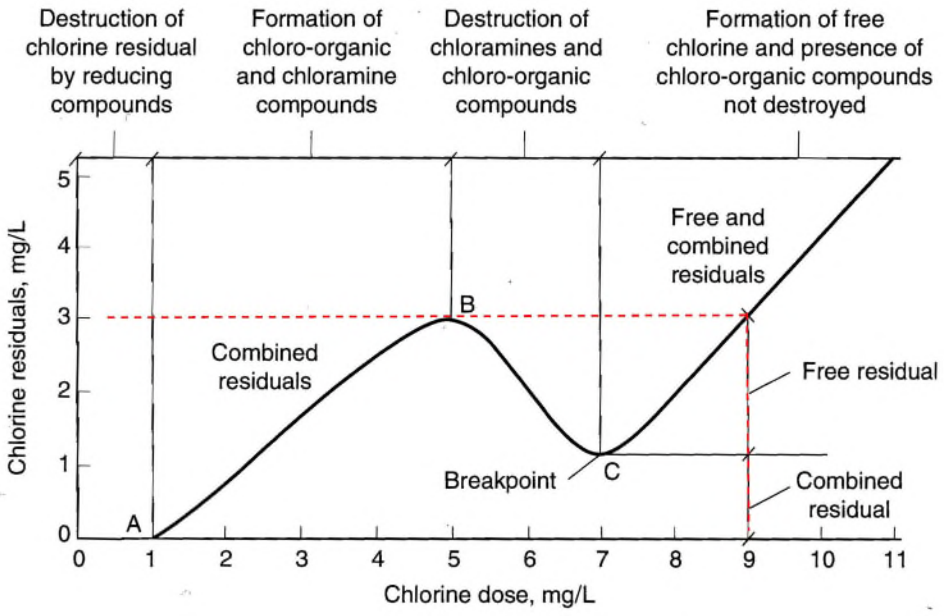
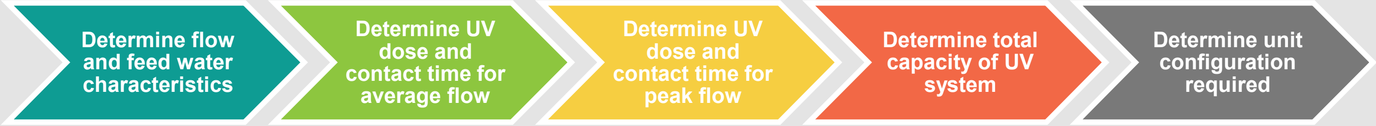


Figure 4-28 Breakpoint chlorination design principle

4.5.6.2 UV disinfection

Table 4-34 Configuration guidelines for UV disinfection

Disinfection – UV disinfection		
		
Process unit outcomes	UV disinfection must be provided for all effluent flows (discharged effluent and bypass flows). The disinfection requirements will be set by the EPL for existing WWTPs. Target process outcomes: • Maintain public health • Maintain environmental health	
Process streams	**Inputs**	**Outputs**
	• Chlorine disinfected effluent • UV	• Disinfected effluent
Demand to be serviced	• Full disinfection @ PDWF (L/s) • Partial disinfection @ PWWF (L/s)	
Process unit governing capacity parameters	• Maximum contact time for the UV vessel (i.e. volume) • Maximum UV dose determined by the UV dosing system • UVT – indicative values to be adopted for UVT% (where site specific information is not available) are – Secondary treated effluent: 55% – Tertiary treated effluent: 65% – RO treated effluent: >95%	
Servicing availability	**Regular maintenance**	**Major maintenance**
	• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: – 1 day every 3-6 months	• Major servicing and overhaul downtime durations and frequencies: – Refer to manufactures requirements – Risk assessment based on critical parts or unit replacement
Process unit capacity derating	• No capacity derating factor • Determine on case-by-case basis	
Unit configuration	• 2N, minimum 2 UV units to ensure disinfection requirements are maintained with one unit offline • Consider a dry weather and wet weather stream to allow for unit maintenance following wet weather. This requirement may be superseded by proven self-cleaning technology.	
Process unit sizing	Unless superseded by site specific requirements: • Contact time ≥10 seconds • UV dose ≥40 mJ/cm^2	

	• Consider the turbidity and UV transmissivity of the effluent (UVT%)
Application considerations	• Various technologies exist for these systems and examples include closed vessel and in-channel systems. The configuration of the UV disinfection unit should include consultation with the equipment supplier. • Consider minimum, average, and maximum dose UV rates • Recycled water – require a USEPA validated UV system. For other applications, may consider alternates.
Auxiliary or connected units	• None other than UV specific requirements (e.g. power supply)
Sensitivity analysis considerations	• UVT% vs UV dose requirements • UV dose rates at various flow conditions

4.5.6.3 Other disinfection

4.5.6.3.1 Ozonation

Ozone is a very strong oxidant and virucide. Ozonation can achieve higher levels of disinfection than either chlorine or UV, and at shorter contact times (typically 10 – 30min). However, the ozonation system is a more complicated than chlorine or UV disinfection systems, requiring equipment that is capital and maintenance intensive. Further, due to the hazardous nature of ozone, ozonation will have greater health and safety considerations.

In addition to the higher levels of disinfection, ozonation provides other benefits such as improvement in UVT, effective over a wider pH range, no harmful residuals after ozonation due to the rapid decomposition of ozone, can have on-site generation facilities therefore mitigating delivery and handling of disinfection chemicals.

Sizing of the ozonation system is best conducted by an equipment supplier as the system components are typically packaged as a single unit (package plant). However, in general, the configuration of the ozonation system will include:

- Feed gas preparation unit
- Ozone generation unit
- Contact vessel
- Off-gas ozone destruction unit

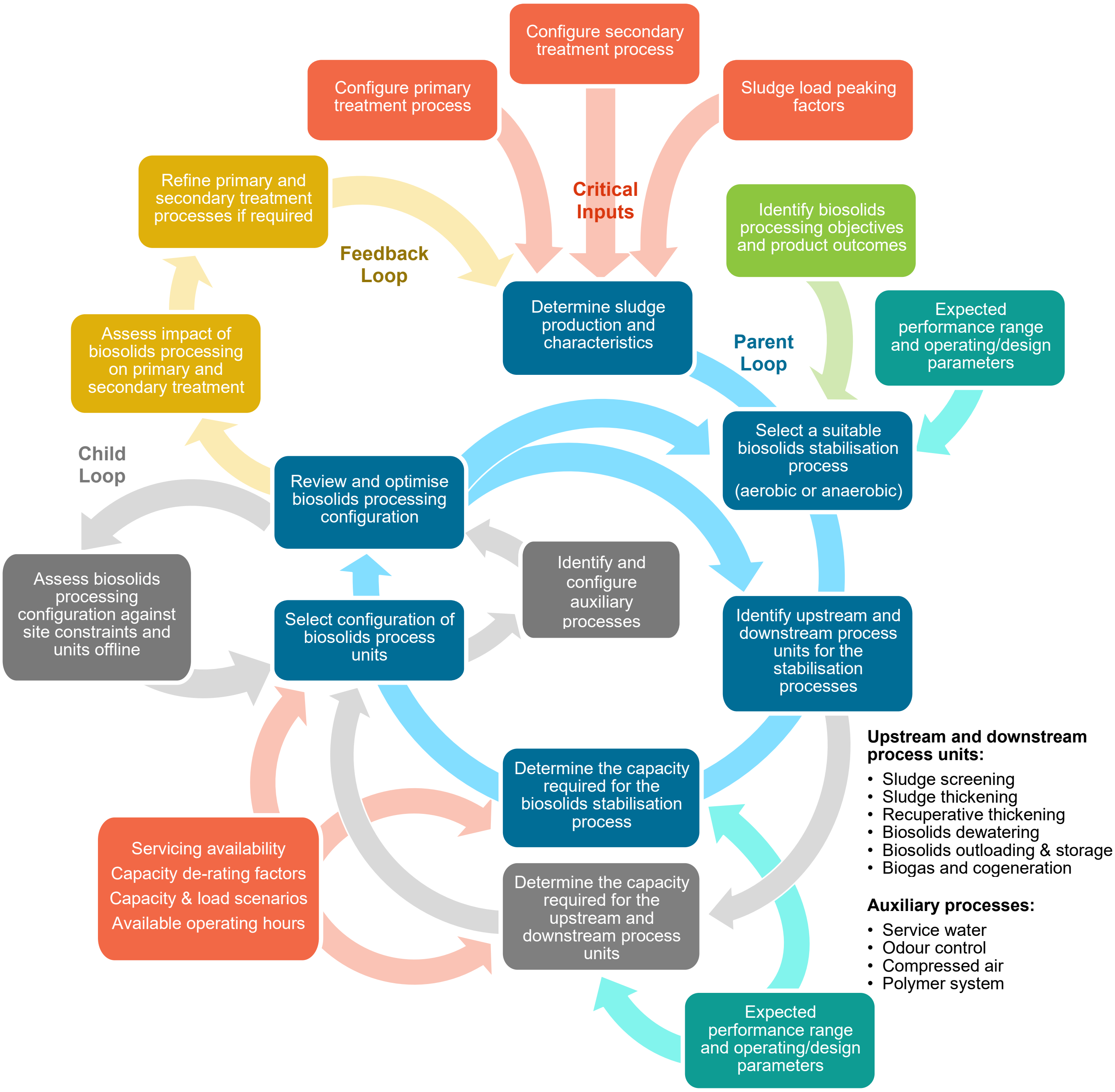
4.5.6.3.2 Maturation ponds

Maturation ponds are generally not considered for application as a disinfection technology for Sydney Water. However, for site-specific needs, maturation ponds can be considered for effluent overflow protection.

4.5.7 Biosolids processing

Primary and/or waste activated sludge generated from the liquid stream treatment requires further processing before beneficial land application or disposal. It is critical to identify the quantity and composition of the feed sludge(s) to the biosolids processing facility so that the biosolids outcomes can be achieved.

The general approach to configuration of the biosolids processing units is shown in Figure 4-29. The approach is an iterative approach that requires review and optimisation of the biosolids processing configuration units against the plant-wide treatment system. This is important as the under sizing or loss of capacity in biosolids processing can have a severe impact on the upstream liquid stream.



Upstream and downstream process units:

- Sludge screening
- Sludge thickening
- Recuperative thickening
- Biosolids dewatering
- Biosolids outloading & storage
- Biogas and cogeneration

Auxiliary processes:

- Service water
- Odour control
- Compressed air
- Polymer system

Figure 4-29 General approach for configuration of biosolids processing

4.5.7.1 Peak factor and demand scenarios

The peak sludge load should be calculated for existing treatment plants. The peak sludge load is the average yearly sludge load multiplied by the sludge peaking factor. The sludge peaking factor is defined as the ratio of the peak sludge loading rate at a selected recurrence interval to the average annual sludge loading rate.

Use percentile measurements to compute the sludge peaking factor, but also ensure to cross-check the validity of the sludge peaking factor by plotting a trend graph (as per the flow example shown in Figure 3-20).

For example, as per the *2011 Biosolids Strategy*: the 98 percentile, 92 percentile and 50 percentile sludge loading rates can be used to compute the weekly and monthly peaking factors from the median annual load.

Sludge Peak Week Factor:

$$PF_{SLUDGE,WEEK} = \frac{SLR_{PERCENTILE,98\%}\ (kg/h)}{SLR_{PERCENTILE,50\%}\ (kg/h)}$$

Sludge Peak Month Factor:

$$PF_{SLUDGE,MONTH} = \frac{SLR_{PERCENTILE,92\%}\ (kg/h)}{SLR_{PERCENTILE,50\%}(kg/h)}$$

For where data does not exist, and for validation of above calculation, typical sludge peaking factors are:

i) Peak week: 1.3 – 1.6 (for mixed primary and waste activated sludge)
ii) Peak week 1.4 – 2.3 (primary only)
iii) Peak month: 1.2 – 1.4 (for mixed primary and waste activated sludge)
iv) Peak month 1.3 – 1.8 (primary only)

Table 4-35 Sludge load peaking factors and capacity demands for biosolids processing units

Category	Example Processes	Peaking Factors	Capacity Demands
Sludge Pre-treatment	• Feed averaging tank • Sludge screening • Sludge conditioning	Highest of peak month or peak week load	Capacity must be maintained to not impact stabilisation process.
Sludge Stabilisation	• Aerobic digestion • Anaerobic digestion	Highest of peak month or peak week load	Capacity must be maintained with 1 Digester out-of-service (1OOS).
Thickening and Dewatering	• Rotary Drum Thickeners • Dewatering Centrifuges	Highest of peak month or peak week load	Capacity must be maintained with de-rating factors for equipment capacity and operating hours.
Storage and Outloading	• Biosolids Storage • Biosolids Outloading	4 days at peak month or peak week load	Capacity must be maintained to not impact stabilisation process. Capacity can be provided in the digester and upstream holding tanks

4.5.7.2 Sludge thickening

4.5.7.2.1 Mechanical sludge thickening

Table 4-36 Configuration guidelines for sludge thickening by mechanical thickening

Biosolids Processing - Sludge Thickening – Mechanical Sludge Thickening		
Detemine daily sludge production and charcteristics	Identify sludge peaking factors and operating conditions Select equipment and identify loading capacity	Determine number of duty equipment required Determine number of standby equipment required
Process unit outcomes	The following sizing and configuration guidelines apply to mechanical sludge thickening installations for primary sludge and waste activated sludge at Sydney Water treatment plants. Target process outcomes: • For **raw sludge thickening** application: thicken primary sludge and waste activated sludge to required feed concentration for digestion process • For **recuperative thickening** application: thicken digester sludge to maintain target digester concentration to maintain target digester SRT • Maintain ≥95% solids capture rate to minimise load return to liquid stream processes in the return stream	
Process streams	**Inputs**	**Outputs**
	• Primary sludge • Waste activated sludge • Polymer dose stream	• Thickened sludge • Centrate/filtrate return stream
Demand to be serviced	• Peak month sludge daily mass rates for digestion (kgTS/d), where peak month is defined as the greater of: – 1.3 × average daily sludge mass rate (refer to Section 4.5.7.1 Table 4-35 for guidance on peak factors) – the measured ratio of peak month sludge daily mass rate to the average daily sludge mass rate	
Process unit governing capacity parameters	Assumed process unit technologies to be adopted: rotary drum thickener or centrifuge • Equipment solids loading rate capacity (SLR, kgTS/h) • Equipment hydraulics loading rate capacity (HLR, m^3/h)	
Servicing availability	**Regular maintenance**	**Major maintenance**
	• Mechanical thickening units have regular and ongoing maintenance downtime for minor preventative and reactive maintenance: Refer to Table 4-37 for equivalent average hours per day operation	• Refer to Table 4-37 for technology specific periodic servicing and major overhaul downtime durations and frequencies
Process unit capacity derating	• Refer to Table 4-38 for technology specific equipment capacity de-rating factor of 0.5 to be applied to manufactures nominal unit loading rates for new installations • For existing units, the standard derating factors may be superseded by assessed operating performance: including centrate TSS and cake TSR performance against unit loading rates	
Unit configuration	• N+1 process units; where N is the minimum number of duty units for servicing • +1 unit may operate in either standby or assist mode; risk assessment shall be made for common standby unit opportunities with other dewatering/thickening processes	

Process unit sizing	• Minimum number of duty units shall be calculated based on the following $$N_{DUTY,MIN} = \frac{S_{LOADING,AVE} \times F_{PEAK,MONTH} \times F_{RUNTIME,1} \times F_{RUNTIME,2}}{XLR_{EQUIPMENT} \times 24 \times F_{DE-RATING}}$$ • Where: – $S_{LOADING,AVE}$ is the average daily sludge production rate (kgTS/d for SLR calculations and m^3/d for HLR calculations) – $N_{DUTY,MIN}$ is the minimum number of duty units required; N shall be rounded up to a whole unit count or a lower unit count must be specifically demonstrated to be sufficient and any impacts accounted for – $F_{PEAK,MONTH}$ is the peak month sludge peaking factor as determined from loading scenarios. Can be replaced by peak week, maximum week demands exceed the capabilities of the thickening units with higher runtime operation. – $F_{RUNTIME,1}$ is the ratio of expected average hours of operation each day to total hours in a day (i.e. hours of operation/24 hours) as limited by regular minor unit maintenance downtime or operating constraints – $F_{RUNTIME,2}$ is the ratio of expected days per week of operation each day to total hours in a day (i.e. days of operation/7 days) as limited by operating constraints – $XLR_{EQUIPMENT}$ is the nominal equipment loading rate capacity as provided by equipment supplier – typically limited by SLR (kgTS/h) but may be limited by HLR (m^3/h) in low feed concentration applications – $F_{DE-RATING}$ is the equipment capacity de-rating factor as derived by observed application across Sydney Water applications • Refer to Table 4-38 for technology specific variables
Application considerations	• Run times and days of operation may be practically limited by: – Turndown of equipment – reduced daily runtimes may result – Noise impacts on neighbours (centrifuges) • Thickened sludge concentration must be suitable for downstream pumping and mixing requirements • Typical range for raw sludge thickening with RDTs is 5-6%TS • Feed averaging to ensure stable solids load to the mechanical units – Feed averaging tank typically sized for 6hours HRT • Additional redundancy can be provided with additional running hours
Auxiliary or connected units	• WAS or PS feed averaging tank • Polymer dosing system (typically liquid polymer RDTs) • TWAS/TPS feed average tank and thickened sludge pumping • Dilution water for thickened sludge concentration control
Sensitivity analysis considerations	• Thickened sludge concentration and downstream capacity impacts (e.g. digester capacity) • Decrease in solids capture rate and impact on liquid stream

Table 4-37 Mechanical thickening unit minor and major unit maintenance downtime duration and frequency

Parameter	High-G centrifuge	Low-G centrifuge	Rotary drum thickener
Regular maintenance downtime – average daily (h/d)	4 h/d	4 h/d	1 h/d
Periodic major maintenance downtime duration and frequency (weeks/years)	6 w / 5 y	6 w / 5 y	6 w / 5 y

Table 4-38 Mechanical thickening unit sizing factors

Parameter	High-G centrifuge	Low-G centrifuge	Rotary drum thickener
$F_{RUNTIME,1}$	23/24	23/24	23/24
$F_{RUNTIME,2}$	7/7		7/7
$F_{DE\text{-}RATING}$	0.75	0.75	1.0

* Typically adopt seven days a week operation – however may be less due to operating constraints such as noise impact limitations, or limited by minimum equipment turndown constraints such as at very small sites which may only operate dewatering one or two days a fortnight

4.5.7.2.2 Dissolved air flotation

Table 4-39 Configuration guidelines for sludge thickening by dissolved air flotation

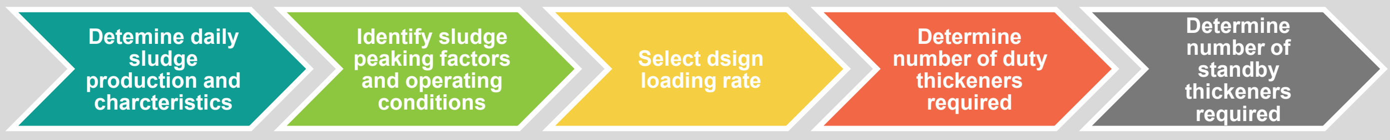
<table>
<tr><th colspan="3">Biosolids Processing - Sludge Thickening – Dissolved Air Flotation</th></tr>
<tr><td colspan="3">
</td></tr>
<tr><td>Process unit outcomes</td><td colspan="2">Dissolved air flotation (DAF) is an alternative to mechanical thickening. Application of dissolved flotation will be project specific. There is effort to standardise thickening processes to mechanical thickening; however, DAF can be considered if there are project specific outcomes that cannot be achieved with mechanical thickening, e.g. O&G recovery from return streams.
Target process outcomes:
• Sludge thickening and solids capture
• Project specific outcomes (e.g. oil and grease recovery)</td></tr>
<tr><td rowspan="2">Process streams</td><td>Inputs</td><td>Outputs</td></tr>
<tr><td>• Primary sludge
• Waste activated sludge
• Return streams</td><td>• Thickened sludge (float)
• Filtrate return</td></tr>
<tr><td>Demand to be serviced</td><td colspan="2">• Peak month sludge daily mass rates for digestion (kgTS/d), where peak month is defined as the greater of:
– 1.3 × average daily sludge mass rate (refer to Section 4.5.7.1 Table 4-35 for guidance on peak factors)
– the measured ratio of peak month sludge daily mass rate to the average daily sludge mass raterate</td></tr>
<tr><td>Process unit governing</td><td colspan="2">Assumed process unit technologies to be adopted: rotary drum thickener or centrifuge</td></tr>
</table>

capacity parameters	• Equipment solids loading rate capacity (SLR, kgTS/h) • Equipment hydraulics loading rate capacity (HLR, m^3/h)	
Servicing availability	**Regular maintenance**	**Major maintenance**
	• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: – As required	• Major servicing and overhaul downtime durations and frequencies: – 1-6 weeks every 10-15 years
Process unit capacity derating	• No capacity derating factor • Determine on case-by-case basis	
Unit configuration	• N+1 to allow for 1 unit out-of-service	
Process unit sizing	• The following typical design parameters can be used for DAF design: – 85% Solids capture without polymer – >95% Solids capture with polymer – 4-6%TS float concentration	
Application considerations	• The DAF system should be sized using a suitable air to solids ratio and recycle ratio, both should be determined with bench scale or pilot testing. • Consider the following requirements: – Float layer removal and design – DAF tank design (circular, rectangular, enclosed vs open, – Energy requirements	
Auxiliary or connected units	• Polymer dosing system • White water production system: air saturator, air receiver, compressor, recycle pump, nozzle/discharge system etc.	
Sensitivity analysis considerations	Energy and maintenance requirements compared to gravity or mechanical thickening systems	

4.5.7.2.3 Gravity sludge thickeners

Table 4-40 Configuration guidelines for sludge thickening by gravity thickening

Biosolids Processing - Sludge Thickening – Gravity Thickening



Process unit outcomes	Gravity thickening is an alternative to mechanical thickening. Application of gravity thickening will be project specific. There is effort to standardise thickening processes to mechanical thickening; however, gravity thickening can be considered if there are project specific outcomes that cannot be achieved with mechanical thickening. Target process outcomes:

	• Sludge thickening and solids capture (note, gravity thickening more effective on primary sludge) • Project specific outcomes (e.g. minimisation of mechanical maintenance)	
Process streams	**Inputs**	**Outputs**
	• Primary sludge • Waste activated sludge	• Thickened primary sludge • Thickened waste activated sludge • Supernatant
Demand to be serviced	• Peak month sludge daily mass rates for digestion (kgTS/d), where peak month is defined as the greater of: – 1.3 × average daily sludge mass rate (refer to Section 4.5.7.1 Table 4-35 for guidance on peak factors) – the measured ratio of peak month sludge daily mass rate to the average daily sludge mass rate	
Process unit governing capacity parameters	• Solids loading rate (kgTS/m^2/d) • Hydraulic loading rate (m^3/m^2/d)	
Servicing availability	**Regular maintenance**	**Major maintenance**
	• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: – Minor as required	• Major servicing and overhaul downtime durations and frequencies: – 1-3 weeks every 10 years
Process unit capacity derating	• No capacity derating factor • Determine on case-by-case basis	
Unit configuration	• N+1 where: – N is sized to treat peak demand – 1 is standby to allow for operation of 1 unit out-of-service • Alternatively: – N is sized to treat peak demand – Redundancy is provided by upstream sludge storage (e.g. in PSTs)	
Process unit sizing	The thickening performance and solids-loading rate to the gravity thickener will be site-specific as performance and loading rate are affected by the composition and settling behaviour of the feed sludge (primary, WAS or blend). The following typical inputs can be used for gravity thickener design: • SLR for primary sludge: 120 kgTS/m^2/d • SLR for WAS: 25 kgTS/m^2/d • SLR for primary + WAS mix: 40 kgTS/m^2/d • HLR: ≤ 20 m^3/m^2/d (for odour prevention) • Sidewater depth: ≥ 3.0m	
Application considerations	• Consider risk-based assessment for sizing of average demand (instead of peak) and impact of reduced process unit outcomes under peak conditions • Consider use of polymer or coagulants to improve settling characteristics	

Auxiliary or connected units	- Thickened sludge pump - Supernatant return pump - Polymer or coagulant dosing system
Sensitivity analysis considerations	- Loading rate vs size of gravity thickeners

4.5.7.3 Sludge dewatering

Table 4-41 Configuration guidelines for sludge dewatering

Biosolids Processing - Sludge Dewatering		
		
Process unit outcomes	The following sizing and configuration guidelines apply to mechanical dewatering installations for digested sludge dewatering at Sydney Water treatment plants. Target process outcomes: - Maximise dewatered sludge (cake) total solids residual concentration - Maintain ≥95% solids capture rate to minimise load return to liquid stream processes in the return stream	
Process streams	**Inputs**	**Outputs**
	- Digested sludge stream - Polymer dose stream	- Dewatered biosolids cake - Centrate stream
Demand to be serviced	- Peak month digested sludge daily mass rate for out loading (kgTS/d), where peak month is defined as the greater of: – 1.2 × average daily sludge mass rate (refer to Section 4.5.7.1 Table 4-35 for guidance on peak factors) – the measured ratio of peak month sludge daily mass rate to the average daily sludge mass rate	
Process unit governing capacity parameters	Assumed process unit technologies to be adopted: high-g centrifuge, low-g centrifuge, rotary screw press - Equipment solids loading rate capacity (SLR, kgTS/h) - Equipment hydraulics loading rate capacity (HLR, m^3/h)	
Servicing availability	**Regular maintenance**	**Major maintenance**
	- Mechanical dewatering units have regular and ongoing maintenance downtime for minor preventative and reactive maintenance: refer to Table 4-42 for equivalent average hours per day operation	- Refer to Table 4-42 for technology specific periodic servicing and major overhaul downtime durations and frequencies
Process unit capacity derating	- Refer to Table 4-43 for technology specific equipment capacity de-rating factor of 0.5 to be applied to manufactures nominal unit loading rates for new installations - For existing units, the standard derating factors may be superseded by assessed operating performance: including centrate TSS and cake TSR performance against unit loading rates	

Unit configuration	• N+1 process units; where N is the minimum number of duty units for servicing • +1 unit may operate in either standby or assist mode; risk assessment shall be made for common standby unit opportunities without dewatering/thickening processes
Process unit sizing	• Minimum number of duty units shall be calculated based on the following $N_{DUTY,MIN} = \frac{S_{LOADING,AVE} \times F_{PEAK,MONTH} \times F_{RUNTIME,1} \times F_{RUNTIME,2}}{XLR_{EQUIPMENT} \times 24 \times F_{DE-RATING}}$ • Where: – $S_{LOADING,AVE}$ is the average daily digested sludge production rate (kgTS/d for SLR calculations and m^3/d for HLR calculations) – $N_{DUTY,MIN}$ is the minimum number of duty units required; N shall be rounded up to a whole unit count or a lower unit count must be specifically demonstrated to be sufficient and any impacts accounted for – $F_{PEAK,MONTH}$ is the peak month sludge peaking factor as determined from loading scenarios. Can be replaced by peak week, maximum week demands exceed the capabilities of the thickening units with higher runtime operation. – $F_{RUNTIME,1}$ is the ratio of expected average hours of operation each day to total hours in a day (i.e. hours of operation/24 hours) as limited by regular minor unit maintenance downtime or operating constraints – $F_{RUNTIME,2}$ is the ratio of expected days per week of operation each day to total hours in a day (i.e. days of operation/7 days) as limited by operating constraints – XLR is the nominal equipment loading rate capacity as provided by equipment supplier – typically limited by SLR in dewatering (kgTS/h) but may be limited by HLR (m^3/h) in low feed concentration applications – $F_{DE-RATING}$ is the equipment capacity de-rating factor as derived by observed application across Sydney Water applications • Refer to tables below for technology specific variables for application in the above equation
Application considerations	• For small applications: – Days of operation may be limited to a day a week or fortnight – Only N units may be provided for very small plants where sludge tankering is a practical alternative • For large applications: – Where N count is high, consider the need for N+2 • Run times and days of operation may be practically limited by: – Noise impacts on neighbours – Operator availability – i.e. is site unattended on weekdays or weekends • Dewatered sludge concentration must be suitable for end-use application and any pumping, storage, and outloading limitations. • Refer to Table 4-44 for typical range of dewatered sludge concentrations • Feed averaging to ensure stable solids to the mechanical units – Feed averaging tank typically sized for 6h HRT • Additional redundancy can be provided with additional running hours
Auxiliary or connected units	• Digested sludge feed averaging tank • Polymer dosing system (powder polymer is typical for dewatering due to high dose demands) • Dewatered biosolids conveyers and/or storage

	• Service water demands (reclaimed effluent or potable water) • Odour control and ventilation
Sensitivity analysis considerations	• Dewatered sludge concentration and downstream capacity impacts (e.g. storage capacity/days) • Decrease in solids capture rate and impact on liquid stream

Table 4-42 Dewatering unit minor and major unit maintenance downtime duration and frequency

Parameter	High-G centrifuge	Low-G centrifuge	Rotary screw press
Regular maintenance downtime – average daily (h/d)	4 h/d	4 h/d	1 h/d
Periodic major maintenance downtime duration and frequency (weeks/years)	6 w / 5 y	6 w / 5 y	6 w / 5 y

Table 4-43 Dewatering unit sizing factors

Parameter	High-G centrifuge	Low-G centrifuge	Rotary screw press
$F_{RUNTIME,1}$	20/24	20/24	23/24
$F_{RUNTIME,2}$	7/7		7/7
$F_{DE\text{-}RATING}$	0.5	0.5	0.6

* Typically adopt seven days a week operation – however may be less due to operating constraints such as noise impact limitations, or limited by minimum equipment turndown constraints such as at very small sites which may only operate dewatering one or two days a fortnight

Table 4-44 Typical dewatered sludge solids concentration based on feed sludge type

Parameter	Dewatered Sludge Solids Content (%TS)
Anaerobically digested primary sludge	28-30
Anaerobically digested primary and WAS	19-23
Anaerobically digested WAS	23
Aerobically digested WAS	17-21

Note: solids capture rate of 95% shall be adopted for new installation; measured centrate TSS concentrations shall be used for determining unit solids rates at existing dewatering installations

4.5.7.4 Sludge feed averaging

Table 4-45 Configuration guidelines for sludge feed averaging tank

<table>
<tr><th colspan="3">Biosolids Processing – Sludge Feed Averaging</th></tr>
<tr><td colspan="3">Determine the total flow per day
Determine the flow rate pattern
Select level of feed averaging, e.g. 100% or partial
Calculate the total tank volume required
Determine the configuration of tank</td></tr>
<tr><td>Process unit outcomes</td><td colspan="2">The biosolids processing configuration can include feed averaging to equalise the sludge flow to downstream process units to improve the performance downstream mechanical equipment rates.
Target process outcomes:
• Equalise the sludge loading rate to downstream equipment (or processes)</td></tr>
<tr><td rowspan="2">Process streams</td><td>Inputs</td><td>Outputs</td></tr>
<tr><td>• Feed sludge (raw or digested)</td><td>• Feed averaged sludge</td></tr>
<tr><td>Demand to be serviced</td><td colspan="2">• Demand to be serviced will relate to the upstream sludge flow rate. This process may not be required if there is adequate sludge holding capacity in the process units.</td></tr>
<tr><td>Process unit governing capacity parameters</td><td colspan="2">• Feed averaging tank volume
• Outflow pump capacity</td></tr>
<tr><td rowspan="2">Servicing availability</td><td>Regular maintenance</td><td>Major maintenance</td></tr>
<tr><td>• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance:
• Minor as required</td><td>• Major servicing and overhaul downtime durations and frequencies:
• 1-3 weeks every 10 years per tank</td></tr>
<tr><td>Process unit capacity derating</td><td colspan="2">• No capacity derating factor
• Determine on case-by-case basis</td></tr>
<tr><td>Unit configuration</td><td colspan="2">• 1 Duty</td></tr>
<tr><td>Process unit sizing</td><td colspan="2">• Feed averaging tank should be sized using a cumulative inflow volume graph
• The size of the feed averaging tank will depend on the following:
– Size of flow variation (peak to trough) and total inflow volume
– Required effective level of averaging (e.g. full or partial elimination of peak)
– Maximum allowed storage time
– Outflow demand (m^3/h or L/s) as determined by the HLR or SLR of downstream mechanical equipment</td></tr>
<tr><td>Application considerations</td><td colspan="2">• Tank must be sized for both average and peak sludge flows
• The retention time at average and peak flow will be specific to the sludge type and downstream demands
• Feed averaging tanks can be used for liquid sludge storage for sludge management during long weekends and/or maintenance periods</td></tr>
</table>

Auxiliary or connected units	• Mixing system (static mixers or pump mixing depending on sludge concentration/composition) • Odour control and ventilation
Sensitivity analysis considerations	• Impact of partial averaging on downstream process • Impact of loss of feed averaging on downstream process • Increase in sludge storage capacity due to the volume provide by the feed averaging tank

4.5.7.5 Aerobic digestion

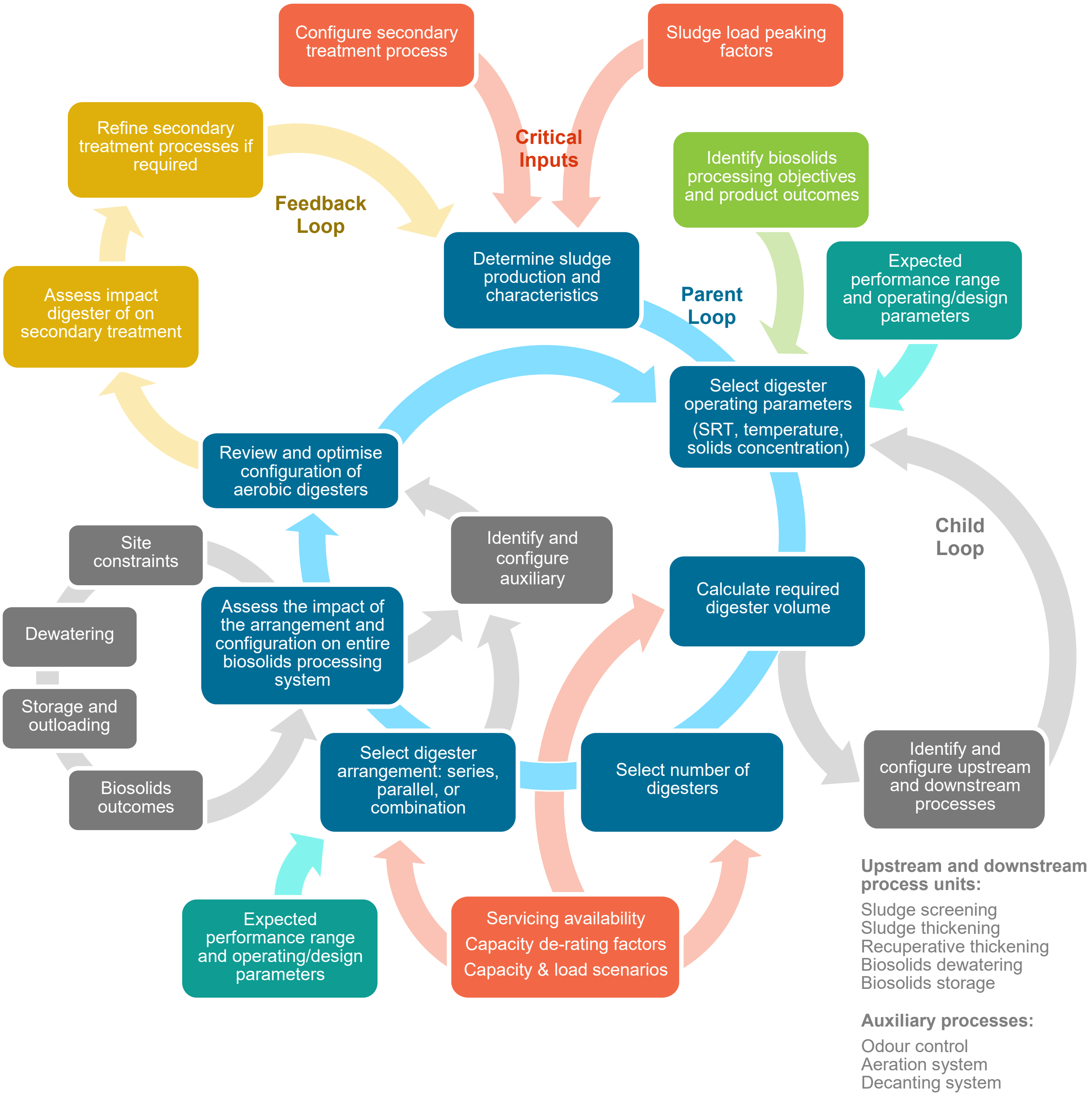


Figure 4-30 General approach for aerobic digestion sizing and configuration

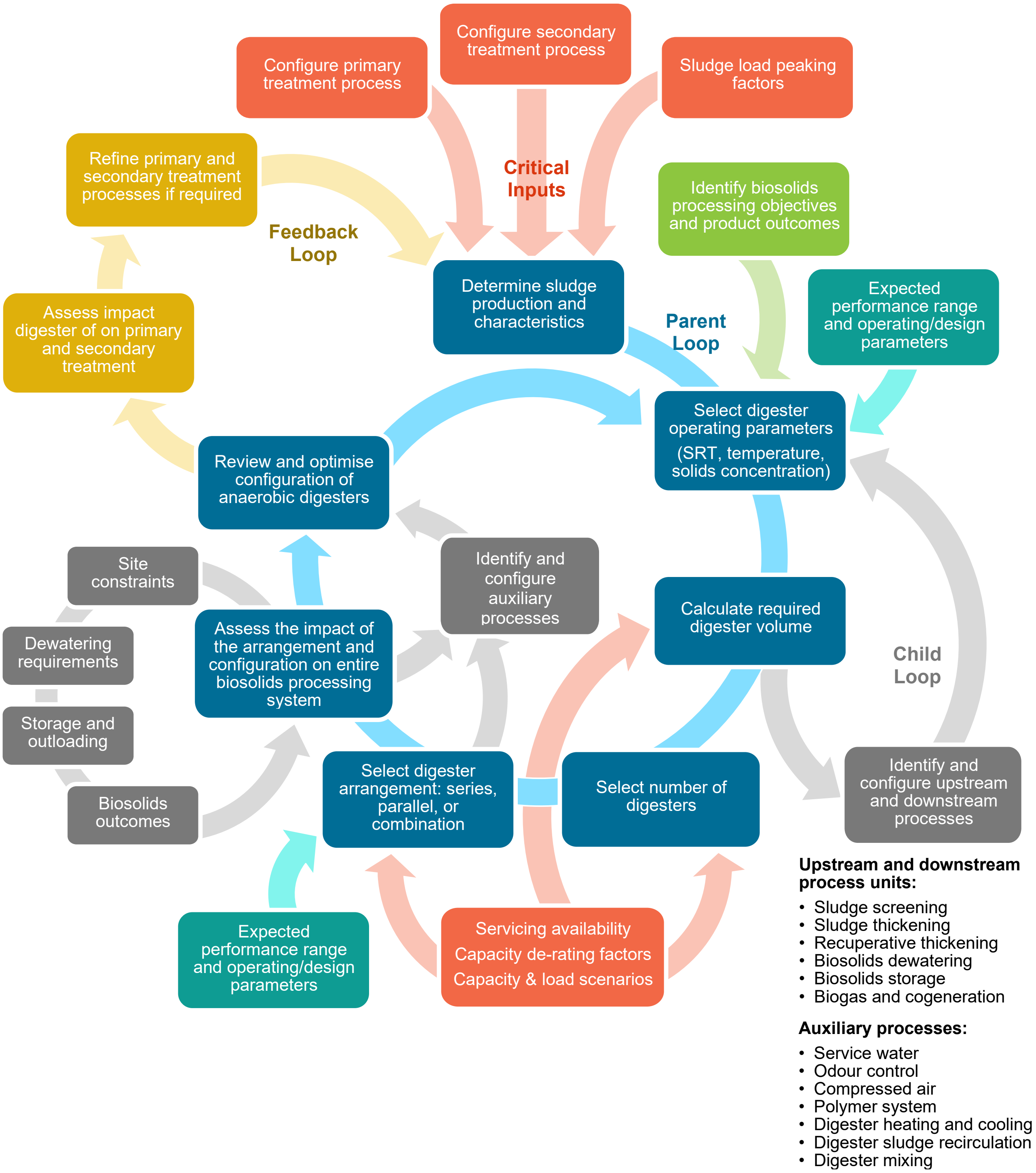
Table 4-46 Configuration guidelines for aerobic digestion

<table>
<tr><th colspan="3">Biosolids Processing – Aerobic Digestion</th></tr>
<tr><td colspan="3"> </td></tr>
<tr><td>Process unit outcomes</td><td colspan="2">Aerobic digestion is utilised to stabilise waste activated sludge. The configuration and capacity of the digestion system is will significantly affect the configuration and capacity of upstream and downstream processes. It is important that the aerobic digester and all interconnected process units achieve their target process outcomes, as failure of one process can result in deterioration of biosolids product outcomes.
Target process outcomes:
• Process outcomes as per EPA guidelines and risk requirements (e.g. odour, healthy, environment etc.)
• VSR ≥ 38% as per EPA biosolids guidelines or as required for end-use application
– Note that the above VSR may not be possible when treating waste sludge from secondary treatment systems with long SRTs
– Measurement of SOUR may be used to validation instead
• Reduction in biosolids product quality is allowed with 1 digester out-of-service, with N-1 digesters achieving a minimum of 10 day SRT at peak month</td></tr>
<tr><td rowspan="2">Process streams</td><td>Inputs</td><td>Outputs</td></tr>
<tr><td>• Raw sludge (waste activated)</td><td>• Digested sludge
• Supernatant (site-specific)</td></tr>
<tr><td>Demand to be serviced</td><td colspan="2">• Peak month sludge daily mass rates for digestion (kgTS/d), where peak month is defined as the greater of:
– 1.3 × average daily sludge mass rate (refer to Section 4.5.7.1 Table 4-35 for guidance on peak factors)
– the measured ratio of peak month sludge daily mass rate to the average daily sludge mass rate</td></tr>
<tr><td>Process unit governing capacity parameters</td><td colspan="2">• Active volume shall be used in the determination of reactor capacity, active volume should consider
– Typical operating water level
– Loss of active volume due to accumulated inert mass
– 90% active volume (unless superseded by plant data)
• Reduction of treatment kinetics in cooler periods must be considered – i.e. lower sludge destruction rate during lower temperatures
• Aeration capacity and efficiency – refer to Section 4.5.4.2 for detailed consideration of aeration capacity and performance parameters
• For digesters with recuperative thickening, the solids loading rate and thickened sludge concentration will also affect the digester capacity (i.e. the ability to maintain the target %TS in the digester)</td></tr>
<tr><td rowspan="2">Servicing availability</td><td>Regular maintenance</td><td>Major maintenance</td></tr>
<tr><td>• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance:
• Minor as required</td><td>• Major servicing and overhaul downtime durations and frequencies:
• 2 – 6 weeks every 10 years per tank</td></tr>
</table>

Process unit capacity derating	• 90% active volume (unless superseded by plant data)
Unit configuration	• N-1, digesters must meet 10 days SRT with 1 digester out-of-service (OOS). However, sensitivity modelling must be conducted to assess if 10 days SRT can achieve EPA biosolids requirements. Refer to unit sizing section. • Configuration can be in parallel, series, or combination. The arrangement will depend on biosolids outcomes and the arrangements ability to achieve the sludge stabilisation required. • Consider multiple compartments in each aerobic digester to allow aeration cycling • Ensure sludge balancing upstream (sludge thickening FAT) and/or downstream (dewatering FAT) to ensure constant sludge level in digesters – If variable level digesters utilised, digesters shall be sized such that the minimum SRT requirement is met when the digester is at the bottom operating water level
Process unit sizing	• Digester %TS ≤ 2.0%TSS • Minimum SRT – for 1OOS ≥ 10d – for All online ≥ 15d – EPA biosolids requirements for VSR ≥ 38%, which may require higher SRTs than listed above for 1OOS and All Online scenarios. • Active volume: 90%
Application considerations	• Not suitable for primary sludge. • VSR will vary according to feed sludge composition and digester SRT, consider using aerobic digestion model to determine digested sludge VSR vs SRT. – Note: VSR only applies to the volatile solids. Inorganic solids do not undergo significant degradation in the digester – i.e. Feed TSS = Feed VSS + Feed ISS ➔ Digested TSS = Feed VSS x (1-VSR%) + Feed ISS – It is important to determine the feed sludge composition to any upstream process models in order to accurately determine the VSS:TSS split. • Digester capacity and performance can be improved with conditioning processes such as sludge pre-conditioning or recuperative thickening. If recuperative thickening, ensure TSS always < 2%. • Recuperative thickening will increase digester SRT and TS – Digester TS ≤ 3.5%TS – SRT ≥ 40d – Note additional demands for pipework, polymer demand, and filtrate management • Consider impact of VSR on downstream biosolids storage and outloading requirements
Auxiliary or connected units	• Refer to aeration approach for secondary treatment; however, note typically lower alpha factors due to aeration of thickened sludge: – Alpha: 0.6 (for surface aeration digesters) – AlphaF: 0.4 (for diffused aeration digester) • The configuration of the digester equipment and the impact of the interlocked, upstream and downstream processes must be considered when configuring the digester. Failure of this equipment or processes can result in failure of the digestion system and non-compliance with biosolids product outcomes.

Sensitivity analysis considerations	• Upstream liquid stream treatment and impact on WAS characteristics (e.g. active fraction, VSS:TSS ratio), and subsequent impact on digester performance • Consider impact of digester arrangement (in-series plug flow, in-series step-feed, parallel, or combination) on VSR performance and servicing availability. • Aeration efficiency vs digester %TS

4.5.7.6 Anaerobic digestion



Upstream and downstream process units:

- Sludge screening
- Sludge thickening
- Recuperative thickening
- Biosolids dewatering
- Biosolids storage
- Biogas and cogeneration

Auxiliary processes:

- Service water
- Odour control
- Compressed air
- Polymer system
- Digester heating and cooling
- Digester sludge recirculation
- Digester mixing

Figure 4-31 General approach for anaerobic digestion sizing and configuration

Table 4-47 Configuration guidelines for anaerobic digestion

Biosolids Processing – Anaerobic Digestion		
Process unit outcomes	Anaerobic digestion is utilised to stabilise primary and/or waste activated sludge. The configuration and capacity of the digestion system is will significantly affect the configuration and capacity of upstream and downstream processes. It is important that the anaerobic digester and all interconnected process units achieve their target process outcomes, as failure of one process can result in deterioration of biosolids product outcomes. Target process outcomes: • Process outcomes as per EPA guidelines and risk requirements (e.g. odour, healthy, environment etc.) • VSR ≥ 38% as per EPA biosolids guidelines or as required for end-use application • Reduction in biosolids product quality is allowed with 1 digester out-of-service, minimum stabilisation requirements must be met	
Process streams	**Inputs**	**Outputs**
	• Raw sludge (primary and/or waste activated)	• Digested sludge • Supernatant (site-specific) • Biogas
Demand to be serviced	• Peak month sludge daily mass rates for digestion (kgTS/d), where peak month is defined as the greater of: – 1.3 × average daily sludge mass rate (refer to Section 4.5.7.1 Table 4-35 for guidance on peak factors) – the measured ratio of peak month sludge daily mass rate to the average daily sludge mass rate • For 1OOS conditions, i.e. N-1, digesters must meet 15 days SRT with 1 digester out-of-service (OOS) • For All Digester online, i.e. N, SRT ≥ 30 days	
Process unit governing capacity parameters	• Active volume shall be used in the determination of digester capacity, active volume should consider – Typical operating water level – Loss of active volume due to accumulated inert mass or due to significant amount of embedded equipment (i.e. membrane cassettes) – 90% active volume (unless superseded by plant data) • For digesters with recuperative thickening, the solids loading rate and thickened sludge concentration will also affect the digester capacity (i.e. the ability to maintain the target %TS in the digester)	
Servicing availability	**Regular maintenance**	**Major maintenance**
	• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: • Minor as required	• Major servicing and overhaul downtime durations and frequencies: • 1-24 months every 10 years per digester
Process unit capacity derating	• 90% active volume (unless superseded by plant data)	

Unit configuration	• N-1, digesters must meet 15 days SRT with 1 digester out-of-service (OOS). However, sensitivity modelling must be conducted to assess if 15 days SRT can achieve EPA biosolids requirements. Refer to unit sizing section. • Unit configuration must allow treatment of all sludge loads under digester all online and 1OOS conditions. • Configuration can be in parallel, series, or combination. The arrangement will depend on biosolids outcomes and the arrangements ability to achieve the sludge stabilisation required.
Process unit sizing	• Digester TS ≤ 2.0%TS • Minimum SRT – for 1OOS ≥ 15d – for All online ≥ 30d – EPA biosolids requirements for VSR ≥ 38%, which may require higher SRTs than listed above for 1OOS and All Online scenarios. Further, odour risk and local site constrains may necessitate higher SRTs. – For existing digestion facilities, minimum design SRT with all online can be <30days, but no less than 25 days, if supported by existing system performance • Active volume: 90% • Loading rates – TBC – we should document here
Application considerations	• VSR will vary according to feed sludge composition and digester SRT, consider using anaerobic digestion model or a VSR curve to determine VSR vs digester SRT, refer to Figure 4-32 – Note: VSR only applies to the volatile solids. Inorganic solids do not undergo significant degradation in the digester – i.e. Feed TSS = Feed VSS + Feed ISS ➔ Digested TSS = Feed VSS x (1-VSR%) + Feed ISS – It is important to determine the feed sludge composition to any upstream process models in order to accurately determine the VSS:TSS split. • Consider impact of VSR on downstream biosolids storage and outloading requirements • Digester capacity and performance can be improved with conditioning processes such as sludge pre-conditioning or recuperative thickening. • Recuperative thickening will increase digester TS. It is typically used to assist in the digester in maintainin 30 days SRT – Digester TS ≤ 6.0%TS – Note additional demands for pipework, polymer demand, and filtrate management • Consider the impact of phosphorous precipitation when digesting BNR WAS
Auxiliary or connected units	• Heating requirements to maintain digester temperature: mesophilic or thermophilic. • Sludge recirculation and mixing system • Biogas collection and processing – Assume biogas quality: 60% CH_4, 30% CO_2, 10% Other (unless superseded by performance data) – Specific biogas generation rate: 0.9 Nm^3/kgVSS • The configuration of the digester equipment and the impact of the interlocked, upstream and downstream processes must be considered when configuring the digester. Failure of this equipment or processes can result in failure of the digestion system and non-compliance with biosolids product outcomes.
Sensitivity analysis considerations	• Upstream liquid stream treatment and impact on primary and waste activated sludge characteristics (e.g. active fraction, VSS:TSS ratio)

	• Consider impact of digester arrangement (in-series plug flow, in-series step-feed, parallel, or combination) on VSR performance and servicing availability.

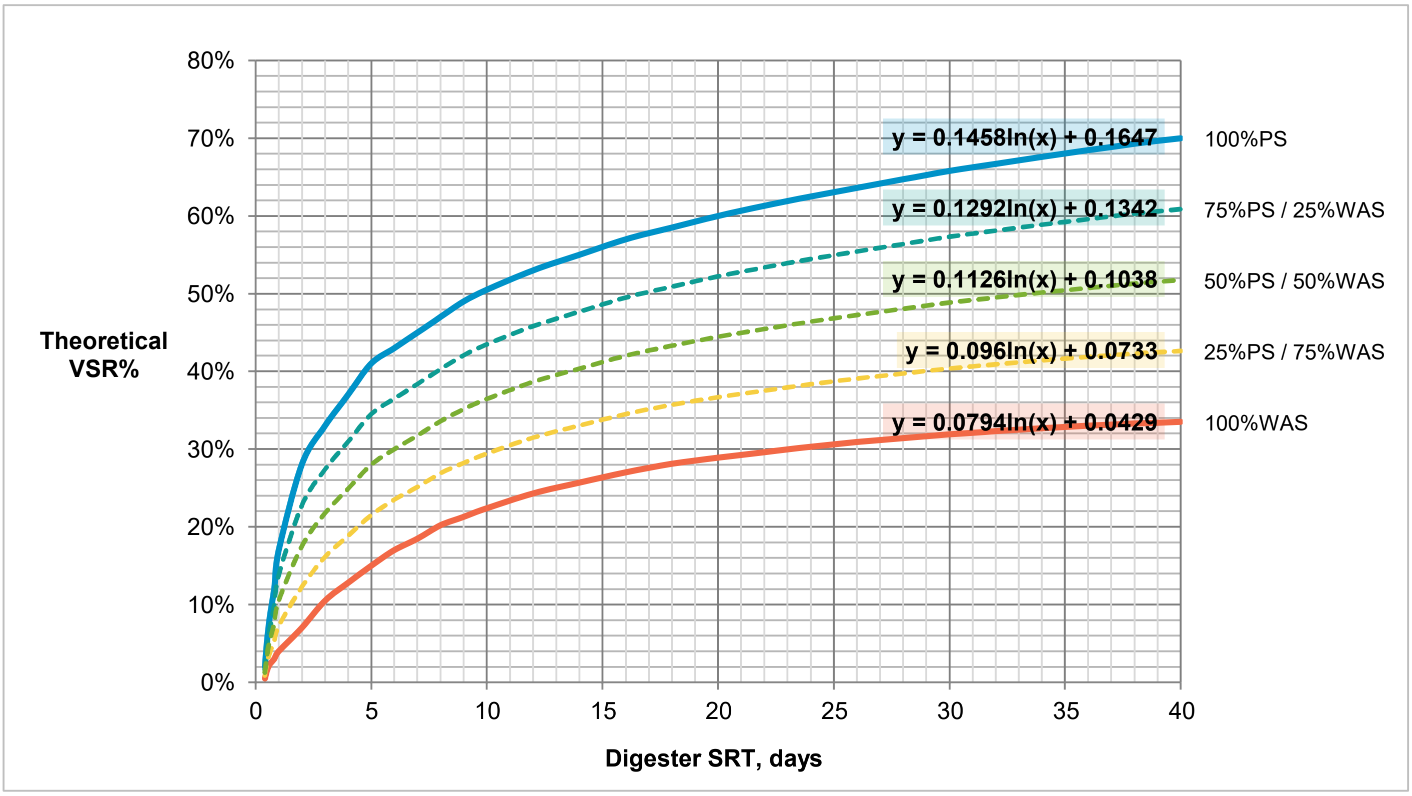
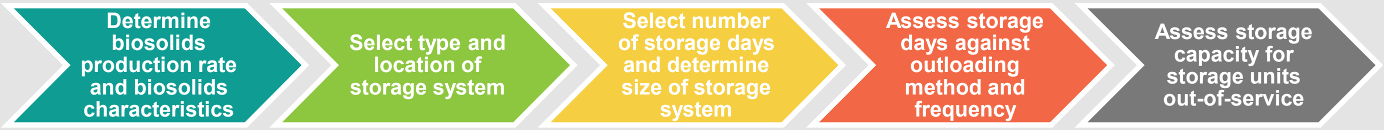


Figure 4-32 Theoretical VSR% for varying SRT and sludge composition (developed from St Marys Biosolids Upgrade)

4.5.7.7 Biosolids storage and outloading

Table 4-48 Configuration guidelines for biosolids storage and outloading

Biosolids Processing – Biosolids Storage and Outloading



Process unit outcomes	The configuration of the biosolids storage and outloading must maintain servicing availability such that the upstream biosolids processing can operate as intended in terms. Target process outcomes: • 4 days storage	
Process streams	**Inputs**	**Outputs**
	• Dewatered biosolids • (or liquid sludge if upstream storage)	• Dewatered biosolids •
Demand to be serviced	• N, biosolids storage to provide minimum 4 days storage • Note: Existing sites may be able to leverage liquid storage in the form of FAT volume	
Process unit governing capacity parameters	• Storage volume (m^3)	
Servicing availability	**Regular maintenance**	**Major maintenance**
	• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: • Minor as required	• Major servicing and overhaul downtime durations and frequencies: • 1-4 weeks every 10 years per silo
Process unit capacity derating	• No capacity derating factor • Determine on case-by-case basis	
Unit configuration	• This will involve identifying and providing enough storage capacity in the storage silos, or upstream holding tanks, with considerations given to the available outloading frequency and the expected frequency of storage units out-of-service. • Storage is provided by combination of dewatered biosolids silos and upstream liquid sludge holding tanks (but excluding the volume of digesters). • Must provide minimum – 2 duty silos for dewatered biosolids for 4 days storage, or – 1 exchangeable bin or trailer (small facilities)	
Process unit sizing	• The number of days storage must be determined as follows: $$DAYS\ STORAGE\ (d) = \frac{V_{TANK}\ (m^3) \times \%Active}{Q_{LIQUID\ SLUDGE}\ (m^3/d)} + \frac{V_{SILO}\ (m^3) \times \%Active}{Q_{DEWATERD\ SLUDGE}\ (m^3/d)}$$ • Where:	

	– V_{TANK} is the volume of the sludge holding tanks for liquid sludge storage (m^3) – V_{SILO} is the volume of the sludge silos for dewatered biosolids storage (m^3) – $Q_{LIQUID\ SLUDGE}$ is the daily liquid sludge generation rate (m^3/d) – $Q_{DEWATERDE\ SLUDGE}$ is the daily dewatered biosolids generation rate (m^3/d) – %Active is the active volume of the storage tank and silos
Application considerations	• Consider impact of biosolids trucking on storage days (may necessitate shorter or longer storage capacity to accommodate trucking availability) • Consider the capacity of the outloading vehicle and the impact on biosolids storage requirements (volume, days, and turnover of stored solids)
Auxiliary or connected units	• Silo feed and outloading conveyors – Direct discharge into storage by locating dewatering units over silos – Outloading vehicle and volumetric or tonnage capacity of vehicle – Aim to minimise conveyor systems
Sensitivity analysis considerations	• Impact of dewatered biosolids concentration on storage volume • Impact of liquid sludge concentration on feed averaging tank volume

4.5.7.8 Other and auxiliary biosolids processes

4.5.7.8.1 Sludge screening

Sludge screening should be considered if there is inadequate upstream screening to protect the digesters and biosolids processing system from screening build-up. Configure the sludge screening as follows:

- Size sludge screening for peak sludge flow demands
- Typical screening equipment HLR for primary sludge: 80 m^3/h @1.6%TSS
- Typical screening equipment HLR for WAS: 30 m^3/h for WAS @ 2%DS
- Typical volumetric screening capture rate: 1 – 3 L/m^3 sludge
- Typical screenings dry mass: 0.4 kg/m^3
- Typical dewatered screening concentration: 30%DS
- Primary sludge only: peak flow demands + 1 standby
- WAS only: peak flow demands + 1 standby
- Primary + WAS: peak flow demands + 1 shared standby

4.5.7.8.2 Thermal hydrolysis

Thermal hydrolysis of sludge should be considered on case-by-case basis. Thermal hydrolysis systems typically involve heating and pressurisation in a specialised process plant to condition the sludge before anaerobic digestion to improve biogas yield and biosolids product quality.

Product outcomes

Thermal hydrolysis will typically produce Class A biosolids products which offers the following benefits:

- Negligible pathogen risk
- Drier biosolids product thereby decreasing storage, outloading and transport requirements

- Lower odours than conventional anaerobically digested biosolids.

Application drivers

The drivers and objectives around implementing thermal hydrolysis need to be clearly understood to optimise the configuration to minimise whole of life cost and meet desired product outcomes. Thermal hydrolysis should be noted:

a) Digester capacity: thermal hydrolysis requires processing at higher dry solids concentrations and thus increases the effective volume of existing anaerobic digesters.

b) Energy: thermal hydrolysis can increase biogas production by up to 30% depending on the condition of the raw sludge but the economy of scale and infrastructure to capture, produce and utilize the energy in a cost-effective manner needs to be considered.

c) Class A biosolids: the production of Class A biosolids can enable entry of the biosolids product to sensitive peri-urban markets in Sydney. However, the capital cost of thermal hydrolysis plant and auxiliary processes need to be included in the cost benefit assessment.

Auxiliary requirements

In terms of the thermal hydrolysis process and its auxiliary requirements, the following should be noted:

- Digester capacity and equipment demands with the conditioning system out-of-service
- Dewatering system required to achieve the feed concentration
  - Feed concentration required for the conditioning plant (typically around 16%TSS)
  - Sludge dilution after conditioning (typically around 4%TSS or as required for the digester)
- Heating and cooling requirements including boiler system (duty and backup)
- Diesel and water supply for the boiler system

4.5.7.8.3 Polymer dosing

Where polymer is to be supplied as a dry solid, storages should be sized to limit the frequency of manual handling and loading. Control system requirements for automation of polymer batch preparation should also be considered. Note that potable/ industrial water quality preferred for some make-up systems due to chemical composition of reclaimed effluent.

Liquid polymer is typically used for RDTs whereas powder polymer for dewatering (due to large quantities).

- Polymer dosing system
  - Type of polymer and cost impacts
  - Storage, make-up and dosing
  - Polymer chemical supply and delivery
  - Consider minimising pipe runs and protection from heat and UV

Polymer systems should be provided for thickening and dewatering processes, typical dosing rates are:

- 2-4 kgPoly/tDS for raw sludge thickening
- 2-5 kgPoly/tDS for recuperative thickening
- 7-18 kgPoly/tDS for dewatering has been observed; however, most typically around 10-14 kg/tDS
- 10 kgPoly/tDS for off-spec process demand
- Typically, polymer batching concentration is at 0.3% whereas dosing concentration is 0.1%.

4.5.7.8.4 Sludge mixing

Sludge mixing is required for all sludge tanks, e.g. sludge feed averaging tanks (FAT), anaerobic digesters, digested sludge tanks etc. Purpose of sludge mixing is as follows:

- Avoid stratification and possible crust formation at the tank surface
- Avoid settling
- Improve pumpability of sludge, and therefore reducing the power uptake by pumps
- Deliver a homogeneous mixture to biosolids processes

As per mixed liquor mixing (in the liquid stream) sludge mixing systems are best designed by equipment suppliers. Paddle mixers or pump mixers can be used for sludge mixing; the equipment selection depends on the mixing requirements and operating conditions. The following information is often required by equipment suppliers:

- Purpose of mixing and type of process tank
- Process tank volume, dimensions and geometry, inlet/outlet arrangement, available mounting positions
- Water depth and freeboard
- Inlet and outlet flow rates
- Density of fluid of fluid characteristics (e.g. solids concentration, temperature, pH etc.)
    - Note this is particularly important for sludge mixing as the concentration has an impact on the liquid viscosity which in turn has impact on the mixer sizing and design.

4.5.7.8.5 Return flows management

Consider the following for the management of return flows (i.e. sludge thickening and dewatering filtrate):

- Expected solids capture rate and mass of solids and nutrients returns.
- Return location and its impact on the liquid stream treatment performance
- Return location and its impact on monitoring systems.
- Return location and the pipework and pumping (or gravity flow) requirements

4.5.7.8.6 Sludge lagoons

Sludge lagoons can be as overflow protection to store excess sludge during periods where the primary stabilisation method (aerobic or anaerobic digestion) is unavailable. The configuration and unit sizing of the sludge lagoon is site-specific. However, the following general unit sizing and configuration guidelines should be utilised:

- Minimum storage time of 6 months
- Minimum two sludge lagoons to allow for rotational duty (i.e. 1 duty and 1 standby/cleanout)

4.5.8 Gas processing

Gas processing relates to the management and treatment of gas related products from the treatment plant such as biogas from anaerobic digestion and off-gases or odours from solids or liquids processing equipment e.g. screening equipment.

4.5.8.1 Biogas processing

The quality and quantity of the biogas product from anaerobic digestion is a function of the digester performance and the sludge feed mass and sludge composition/type (e.g. waste activated, primary, or external sources). The general approach to configuration of the biogas processing is shown in Figure 4-33.

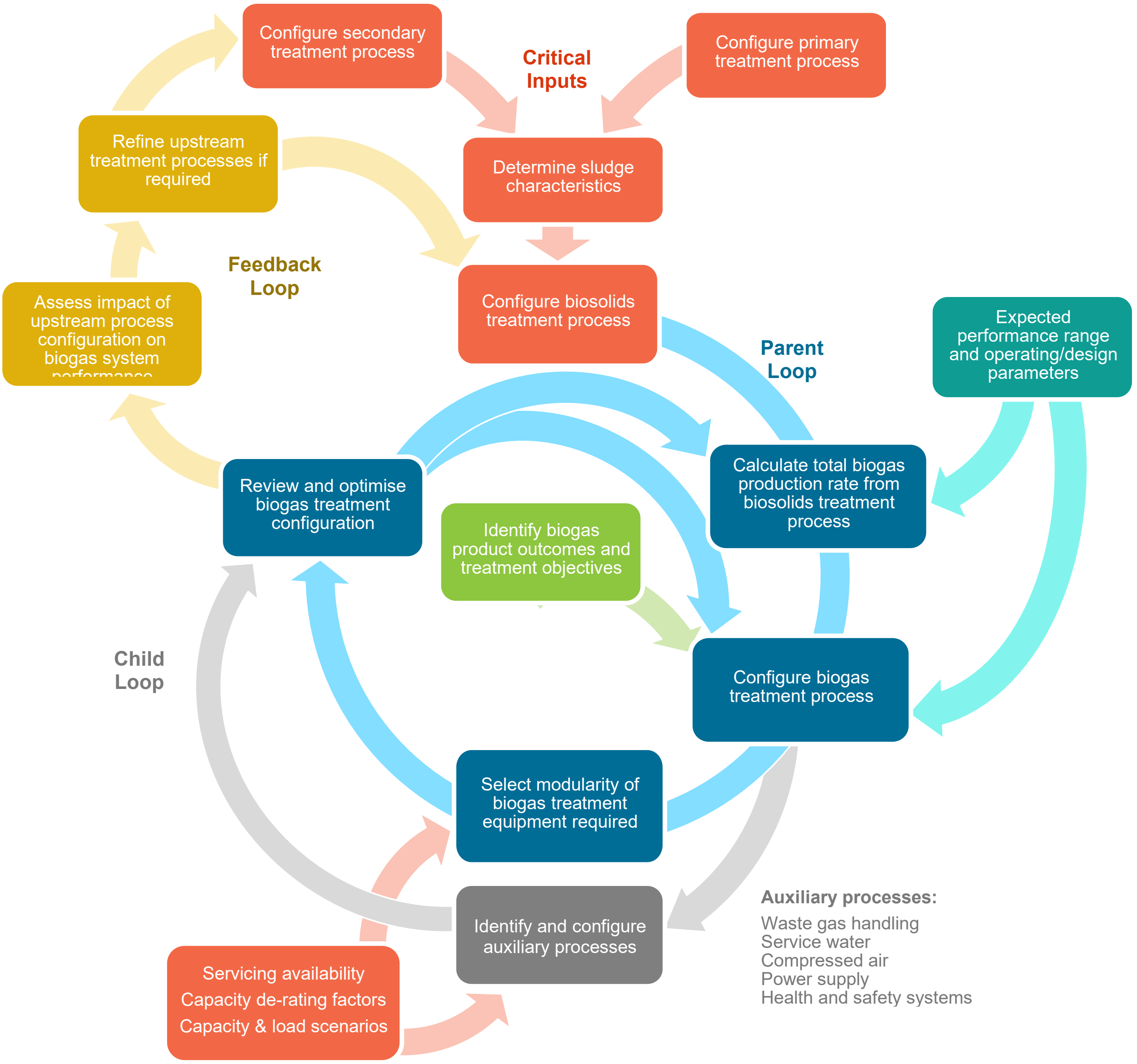
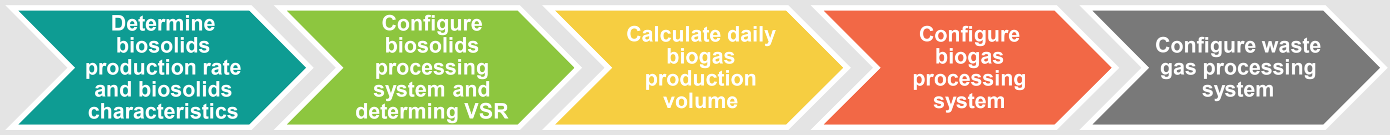


Figure 4-33 General approach for configuration of biogas processing

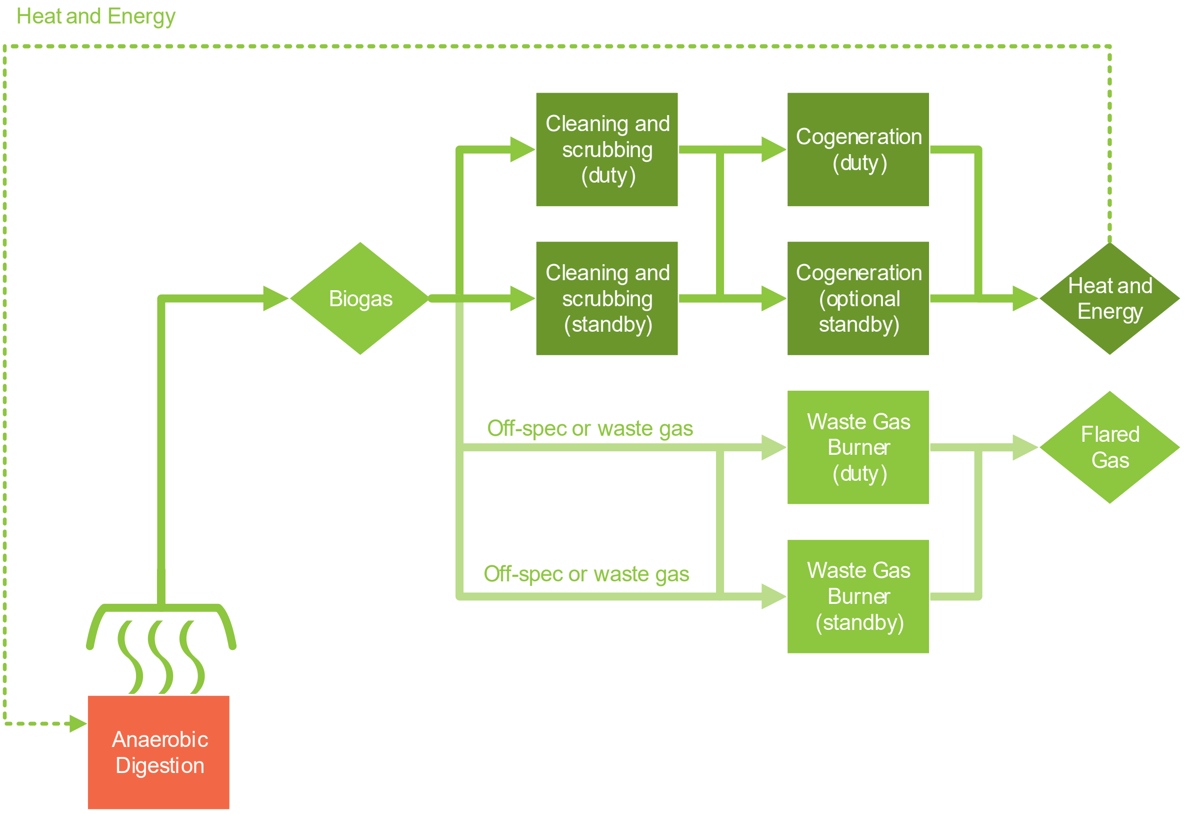
Table 4-49 Configuration guidelines for biogas processing

Gas Processing – Biogas		
		
Process unit outcomes	The configuration of the biogas system must meet the biogas demands as generated by the digestion process. All gas must be treated either through a cogeneration pathway or through a flaring pathway (with a waste gas burner). Target process outcomes: • Cogeneration for heat and energy generation • Flaring of waste or off-spec biogas	
Process streams	**Inputs**	**Outputs**
	• Biogas	• Cogeneration (heat and energy) • Flared gas
Demand to be serviced	• Demand to be serviced will be linked to the biogas production rate (minimum, average, and peak) of the anaerobic digester	
Process unit governing capacity parameters	• Cogeneration capacity (L/s) • Waste gas burner capacity (L/s)	
Servicing availability	**Regular maintenance**	**Major maintenance**
	• Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: • Minor as required	• Major servicing and overhaul downtime durations and frequencies: • Replace cogeneration units every 7 years • Replace waste gas burner every 10 years
Process unit capacity derating	• No capacity derating factor • Determine on case-by-case basis	
Unit configuration	• Refer to Table 4-50 below for examples of standard biogas treatment configurations • All biogas must be treated under all conditions either through cogeneration or flaring. • The following unit configuration must be provided as a minimum: – Scrubbing and cleaning: N duty + 1 assist/standby – Cogeneration: N duty + 1 **optional** assist/standby – Waste gas burner: N duty + 1 standby – For the above, N duty is site and vendor specific related to the biogas output and the equipment’s unit capacity for biogas treatment. Consider modularisation of N units.	
Process unit sizing	• The following parameters can be used for sizing biogas systems: – Peak gas production (Nm^3/h or L/s) typically 0.9 Nm^3/kgVSS	

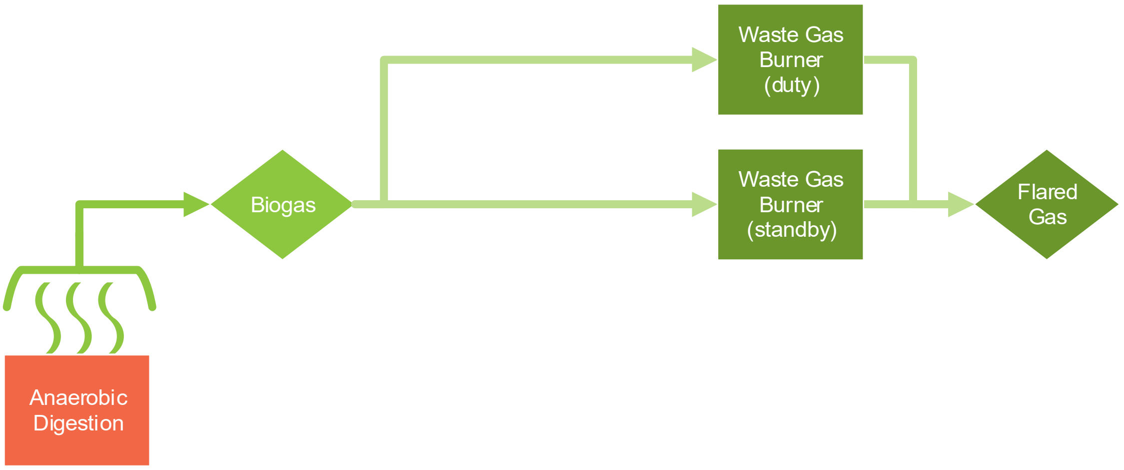
	– Methane content of biogas typically in the range of 55-75% v/v – Co-generation efficiency coefficients typically in the range of 60-70% – Biogas calorific value: 23 MJ/m^3
Application considerations	• Consider site-specific biogas peak factors • Consider economic feasibility of small-scale anaerobic digestion + cogeneration systems (i.e. scale of application)
Auxiliary or connected units	• Typical biogas system will include the following units: – Biogas collection and distribution system – Biogas blowers – Biogas chillers and reheaters – H_2S scrubber/filter – Siloxane scrubber/filter – Cogeneration – Waste gas burner
Sensitivity analysis considerations	• Impact of anaerobic digestion performance and operation on biogas production

Table 4-50 Duty and standby arrangement options for biogas processing

General Configuration for Biogas Processing with Cogeneration and Waste Gas Burning

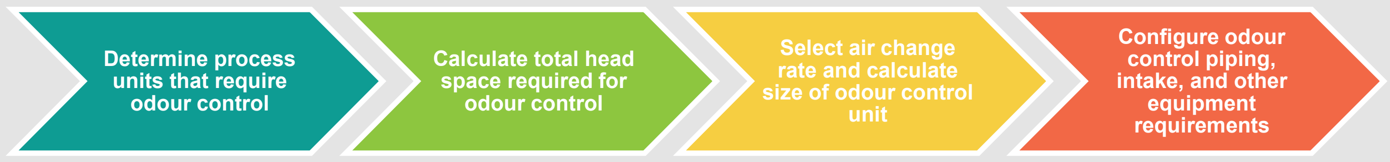


General Configuration for Biogas Processing with Waste Gas Burning only



4.5.8.2 Ventilation and odour control

Table 4-51 Configuration guidelines for odour control

Ventilation and Odour Control		
		

Process unit outcomes	Odour control is required to collect and treat odours and off-gasses to reduce risk of odour complaints and as well as for corrosion protection of equipment
	Target process outcomes:
	- Collect and treat odours (>99% H_2S reduction)
	- For vent stacks, at the outlet:
	  – Hydrogen Sulphide (H2S) ≤ 0.05 ppm_v or
	  – Mercaptans (Thiols) ≤ 0.02 ppm
	  – Odour concentration ≤ 500 Odour Units (OU)
	- Corrosion protection of equipment	

Process streams	**Inputs**	**Outputs**
	- Odour / Off-gas	- None
Demand to be serviced	- All odours	

Process unit governing capacity parameters	- Volumetric flow treatment capacity of
	  – Odour control unit
	  – Intake pipework and fans	

Servicing availability	**Regular maintenance**	**Major maintenance**
	- Regular and ongoing maintenance downtime for minor preventative and reactive maintenance: - Technology dependent	- Major servicing and overhaul downtime durations and frequencies: - Technology dependent
Process unit capacity derating	- No capacity derating factor - Determine on case-by-case basis	
Unit configuration	- N for intake pipework - N+1 for fan equipment - N+1 for odour cleaning unit – Note standby capacity provided by activated Carbon where appropriate - N for vent stack	
Process unit sizing	- Minimum of 20 × airspace/ headspace for OCU	

Application considerations	• The following treatment processes will require ventilation and odour control: – Screening and grit removal systems including conveyors, washers, and bins – Primary treatment – Thickening and dewatering equipment – Sludge holding tanks including hoppers, silos, and feed averaging tanks – All other anaerobic environments where there is potential for H_2S generation • Treatment can be provided with the following technologies – Bio trickling filters – Chemical scrubbers – Soil bed • Consider the type of OCU that will perform best given the type, volume, concentration and variability of the foul air odorous components • Refer to the following regulatory documents – Draft NSW Best Practice Odour Guideline – Sewerage Systems (Department of Planning, April 2010) – Technical Framework for Assessment and Management of Odour from Stationary Sources in NSW (Department of Environment and Conservation NSW, 2006).
Auxiliary or connected units	• The odour control system will include the following equipment: – Intake equipment – Odour pipework – Odour cleaning unit (e.g. carbon unit, biofilter, air scrubber etc.) – Vent stack (note typically 14m height restriction)
Sensitivity analysis considerations	• Cost of OCU system for different technologies

4.5.9 Chemical dosing systems

Chemical storages should be appropriately sized to ensure reasonable and manageable frequency of chemical deliveries and decay / shelf-life. For chemical dosing skids - general layout guidance is as follows:

- Storage (+ sizing guidance) + delivery/unloading considerations
- Dosing pumps (D/S, N+1); digital pumps are preferred
- Scour lines
- Waste and neutralisation tanks/system for CIP and cleaning systems

Table 4-52 Common chemicals for wastewater treatment processes

Chemical	Short Name / Symbol	Use in treatment processes	Comments and considerations	Typical dose ranges
Aluminium chloride	Alum	ChemP removal, coagulation	Residual aluminium levels, jar testing may be required for more detailed planning projects	10 – 12 mg/L
Ferric and ferrous salts		ChemP removal, coagulation	Jar testing may be required for more detailed planning project	0.5 – 2 mg/L 7 – 10.0 mg/L
Calcium carbonate	Lime	pH correction, ChemP removal,	Batching and storage, lime slurry transport/pumping requirements	As required for alkalinity or pH correction
Polyaluminium chloride	PACl	ChemP removal, coagulation		
Methanol	MeOH	Carbon source	Considerations relating to fire safety may impact storage and dosing system configuration requirements	See carbon dosing section below
Ethanol	EtOH	Carbon source		
Acetic acid	AcOH, CH_3COOH	Carbon source		
Sulphuric acid	H_2SO_4	pH correction		
Hydrochloric acid	HCl	pH correction		
Sodium hydroxide	NaOH, caustic	pH correction		
Chlorine gas	Cl_2	Disinfection	Control and monitoring systems, safety and storage requirements	
Sodium hypochlorite	Hypo, NaOCl	Disinfection		1.0 – 10.0 mg/L (could be higher up to 14 mg/l for Super chlorination)
Ammonia		Disinfection (chloramination)		
Ozone	O_3	Disinfection and O_3AC processes	Ozone systems typically supplied as vendor packages	
Sodium (meta)bisulphite		Dechlorination		2 – 5 mg/L
Polymer (various)		Sludge thickening, filter/floc aide	Storage, handling/unloading and batching equipment	Refer to Section 4.5.7.8.3

4.5.9.1 Phosphorous removal

Chemical P removal requires the use of chemical such as:

- Ferric chloride or ferrous chloride - in reactor or preliminary dosing
- Aluminium chloride (Alum) - second point dosing in upper stream of tertiary clarifier or filter
- Polyaluminium Chloride (PACl)
- Lime

The phosphorus in the wastewater is primarily removed in waste sludge streams.

4.5.9.2 Carbon dosing

Carbon dosing may be required at various stage in the treatment process to increase COD. Circumstances which may require the inclusion of carbon dosing include:

- Enhanced biological nutrient removal (secondary treatment)
- Tertiary denitrification processes
- Low influent COD

Carbon dosing systems often use methanol, ethanol, acetic acid or organic waste products such as molasses. Consider the practical considerations of high-volume dosing as high volumes of methanol or ethanol impart fire safety standards for the storage and dosing system. Generally, this means higher costs due to below ground-level storage.

For an estimation of the carbon dose required, the following formulas can be used:

- Methanol as carbon source: $5CH_3OH + 6NO_3^- \rightarrow 3N_2 + 5CO_2 + 7H_2O + 6OH$
- Ethanol as carbon source: $5CH_3CH_2OH + 12NO_3^- \rightarrow 6N_2 + 10CO_2 + 9H_2O + 12OH$
- Acetic Acid as carbon source: $5CH_3COOH + 8NO_3^- \rightarrow 4N_2 + 10CO_2 + 7H_2O + 8OH$

The above stoichiometric equations can be utilised to estimate the carbon dose requirements, for example, the following dosing rates are obtained for using methanol:

  - 160g methanol / 372 gNO_3 = 0.43 g methanol / gNO_3 (as NO_3) or
  - 160g methanol / 84 gNO_3-N = 1.9 g methanol / gNO_3-N
  - This above are typical values reported in literature; however, in practice, unit dose rates are typically 2.5 to 3.0 g methanol / gNO_3^-N to account for dosing inefficiencies and uptake of carbon for cell synthesis.

4.5.9.3 pH control

Control of pH is important for many chemical and biological treatment processes and for meeting EPL requirements. To optimise the pH for operation of certain processes, the following chemicals may be required:

- Sulfuric acid (H_2SO_4)
- Hydrochloric acid (HCl)
- Sodium hydroxide/caustic (NaOH)
- Lime

For biological processes in secondary treatment, a pH between 6.5 to 7.5 must be maintained to ensure nitrification and denitrification is not inhibited. Alkalinity is often used to determine if pH control is needed. Typically, the alkalinity must be >40 $mgCaCO_3$/L to ensure pH remains above 7.0. Nitrification decreases alkalinity by 7.14 mg/L as $CaCO_3$ per mgN/L ammonia nitrified. This loss in alkalinity can be recovered through denitrification in the bioreactor, and for every mgN/L nitrate denitrified, an alkalinity gain of 3.57 mg/L as $CaCO_3$ is achieved.

4.5.9.4 Coagulants

The use of coagulants at various stages in the treatment process can improve the performance of existing

- Chemically enhanced settling
- Media or membrane filtration

The suitability of coagulants to certain treatment technologies may vary and can also vary between influent characteristics. For example: At Brooklyn WWTP (MBR plant) ferric lead to significant fouling; subsequence switch to alum had less fouling impact on the membranes.

Chemical coagulants should also be considered carefully in conjunction with the site’s EPL requirements, as residual levels of certain chemical species such as aluminium may be breached if dosing is properly optimised.

Where detail on expected dose rates is required, jar testing should be undertaken with representative effluent samples to confirm the optimum coagulation pH and coagulant dose rates.

4.5.9.5 Dechlorination

Sodium bisulphite (SBS) is typically used for dechlorination, note dechlorination ratio is typically 1.5:1 $NaHSO_3$:Cl.

4.5.9.6 Polymer

Refer to Section 4.5.7.8.3.

4.5.10 Auxiliary and common processes

Other auxiliary processes required across the treatment plant include the following:

4.5.10.1 Compressed air

Compressed air is used in a variety of processes in a WWTP:

- Diffuser aeration of biological reactors
- DAF
- Membrane and filter backwashing
- Digesters
- Sludge and grit slurry pumps
- Valve actuating mechanism

The capacity of existing compressed air systems should be evaluated when undertaking planning projects that may require use of compressed air.

4.5.10.2 Service water

For Sydney Water plants with an ADWF capacity >5ML/d, the observed service water demand is typically between 1 ML/d to 1.3 ML/d irrespective of the ADWF capacity of the plant.

Note, moving to higher consuming technologies will change service water consumption. Two big shifts are RDTs for sludge thickening and band screens for preliminary treatment. Both consume much more water than existing technologies. Further, both may require industrial water (i.e. potable water system supply) if reclaimed effluent quality isn’t sufficient.

In most cases, service water can be reclaimed effluent (RE) taken after chlorination, or potable water for process specific purposes (such as boiler systems or chemical dilution).

4.5.11 Recycled water and advanced water treatment processes

It should be noted that the design of AWTP processes vary significantly based on feed water quality, technology selection, and end-use requirements. The intent of this section is to provide general guidelines and approaches to configuring and sizing AWTP processes for recycled water production, for non-potable use or for purified recycled water (PRW) application.

4.5.11.1 Application of advanced water treatment processes (AWTP)

The advanced water treatment process (AWTP) is as an extension of wastewater treatment process. It is typically included due to the need for water recycling, potable reuse, or environmental discharge. The latter application arises when the effluent discharge requirements call for very low TN and TP concentrations, e.g. TN <3 and TN<0.1.

4.5.11.2 AWTP configuration

The configuration of the AWTP will depend on the feed water quality and end-use requirements. There are typically three end-use categories:

- On-site services,
- Non-potable recycled water
- Purified recycled water (PRW)

This section focuses on guidelines for PRW application as this is the most stringent application of the three categories.

4.5.11.2.1 Case study configuration examples

For potable application (direct or indirect), there is no standard approach as it depends the feed water quality, presence of chemical contaminants, local regulations, required LRV, experiences and site-specific constrains (e.g. footprint). In most applications, the configuration of the AWTP is either a RO-based treatment train or an Ozone/Activated Carbon treatment train. Examples of various applications are shown below.

Figure 4-34 Configuration examples for direct and indirect potable re-use [1]

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[1] Adapted from World Health Organisation, *POTABLE REUSE: GUIDANCE FOR PRODUCING SAFE DRINKING-WATER*, 2017, pg18

4.5.11.2.2 Example of suitable Sydney Water AWTP configurations

There are two main categories of AWTP configurations, namely reverse osmosis (RO) based treatment and ozone activated carbon (O_3AC) based treatment. Examples of these two AWTP configurations are shown below.

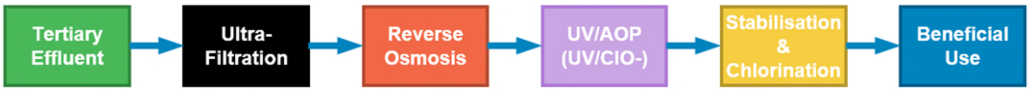


Figure 4-35 RO based AWTP treatment train

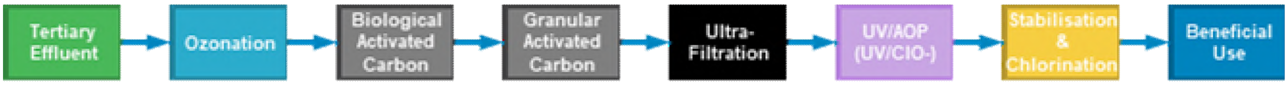


Figure 4-36 Ozone activated carbon based AWTP treatment train

4.5.11.2.3 Key differences between AWTP configuration

A key difference between the two configuration is in the product water quality in terms of Total Dissolved Solids (TDS), Total Organic Carbon (TOC), and TN and TP concentrations. In terms of the recovery rates, the following assumptions can be utilised for planning and flow balancing:

- Ultra-filtration: 95% to 98% for polymeric membranes, 99% for ceramic membranes
- Reverse osmosis: >85% for standard 3-stage RO technology, >93% for advanced RO technology
- BAC: 95% recovery
- GAC: 95% to 98% recovery

Based on the above recovery rates, for 1 ML/d feed water, the production volume is:

- RO based train = 0.81 ML/d with polymeric UF membranes and standard RO technology; and
- O_3AC based train = 0.91 ML/d assuming 98% GAC recovery, and 98% polymeric UF recovery

Table 4-53 AWTP configuration product water characteristics

Configuration Type	TDS	TOC	TN	TP	Overall Recovery
RO based treatment	40 to 60 mg/L	0.08 to 0.15 mg/L	0.35 mg/L to 1 mg/L	0.01 mg/L to 0.025 mg/L	80%
O_3AC based treatment	No change, typically 400 to 600 mg/L	2 to 3 mg/L	2 mg/L	0.050 mg/L with coagulation	90%

Note: product water nutrient concentrations will vary depending on feed water concentrations and membrane configuration. On a well performing tertiary BNR plant effluent, median concentrations of 0.35 mgTN/L and 0.01 mgTP/L should be expected.

There also exists differences in operation and maintenance requirements, waste/brine management, remineralisation requirements, expected recovery rates, process validation and overall life-cycle costs. These criteria should be evaluated on case-by-case basis.

4.5.11.2.4 Process unit sizing guidelines

Table 4-54 AWTP unit configuration and process unit sizing

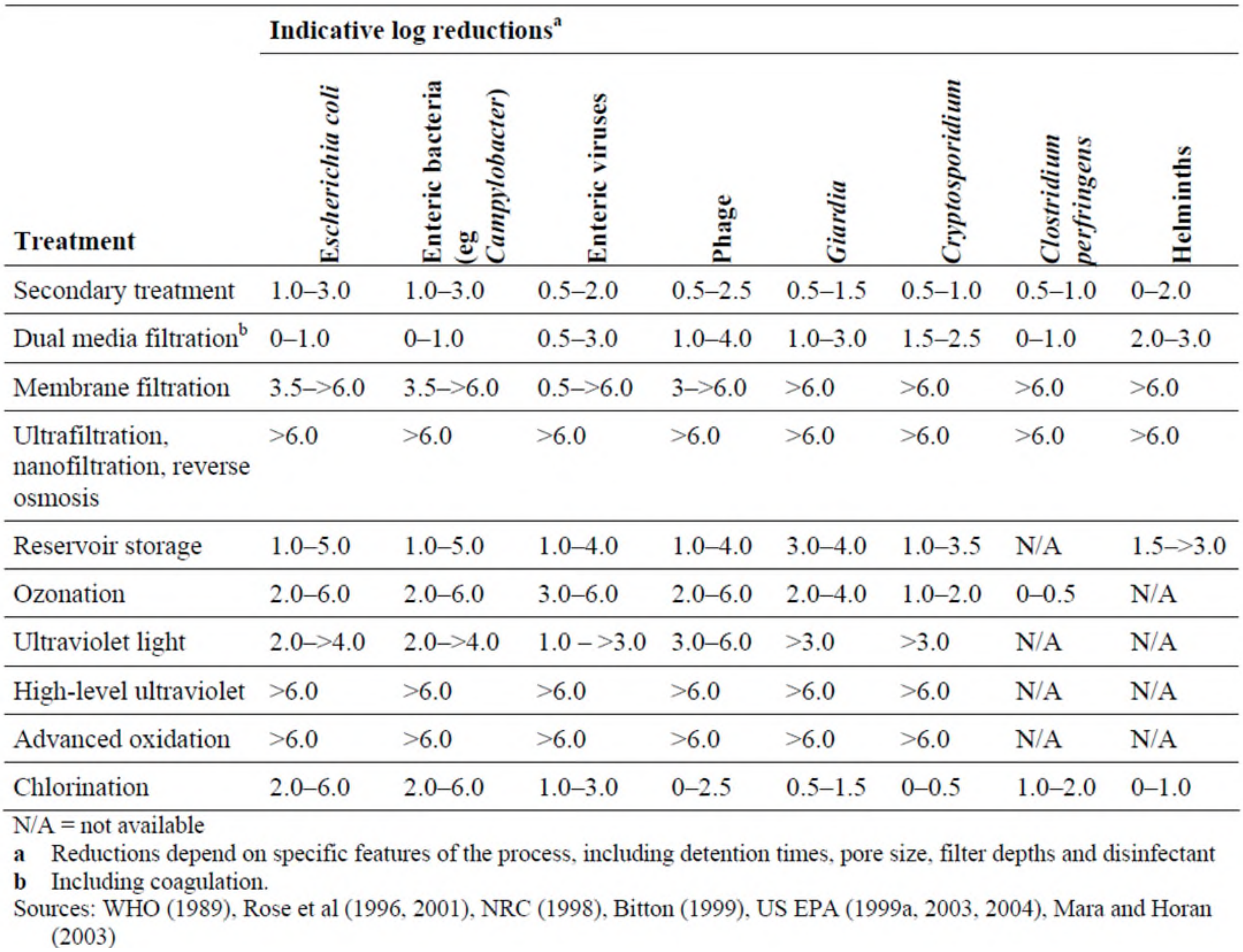
Train Type	Process Unit	Process Unit Sizing Guidelines
RO-Based Treatment	UF	30 to 60 LMH (note UF pre-RO is typically not required if secondary treatment system includes UF MBR; however, this is case-specific, e.g. UF pre-RO is required MBR is flat sheet type.
	RO	15 to 20 LMH, typically 3 stage with or without inter-stage pumping depending on feedwater TDS and element selection. Note membrane aging should be considered when conducting RO projections, e.g. size system with 5 year-old membranes.
	UV/AOP	>900 mJ/cm UV dose with: H_2O_2 (4 to 6mg/L) or NaOCl (2 to 3 mg/L). Confirm with technology supplier. Note LRV requirements for NDMA (1.1LRV) and 1,4 Dioxane (0.4LRV).
O_3AC Based Treatment	O_3	Ozone dose: 5 to 12 mg/L Contact time: 20min Power consumption: 9.5 kWh/kgO_3 to 12 kWh/kgO_3 production Transfer efficiency: 85% (i.e. 15% ozone as off-gas)
	BAC	Empty bed contact time: >15min @ maximum flow Bed depth: 2.5m Backwash Bed Expansion: 30% maximum
	GAC	Empty bed contact time: >20min @ maximum flow Bed depth: 2.5m Backwash Bed Expansion: 40% maximum
	UF	30 to 60 LMH
	UV/AOP	>900 mJ/cm UV dose with: H_2O_2 (4 to 6mg/L) or NaOCl (2 to 3 mg/L). Confirm with technology supplier. Note requirement LRV requirement for NDMA (1.1LRV) and 1,4 Dioxane (0.4LRV)
Chemicals (common to both configurations)		• Chloroamination (Ammonia + Hypochlorite) • UF cleaning: Sulfuric/Citric, Hypochorite, EDTA • RO pre-treatment: antiscalant, SBS, sulfuric • RO cleaning: Base, Acid, EDTA, others • UV/AOP: pH control, oxidant • Stabilisation: Sodium hydroxide / other • Chlorination: Hypochlorite, SBS • Remineralisation: Lime, CO_2, fluoride, etc
Power		• RO based treatment: typically 1.0 kWh/m^3 product water without UV/AOP or 1.2 kWh/m^3 product water with UV/AOP • O_3AC based treatment: typically 0.5 kWh/m^3 product water without UV/AOP or 0.7 kWh/m^3 product water with UV/AOP

4.5.11.3 Indicative log reductions

4.5.11.3.1 Australian Guidelines for Water Recycling

Refer to Section 3.3.4.1.2 for an outlined of the development of product outcomes for recycled water.

When recycled water is a required product, consider the indicative range of microbial log reductions as reported in the literature for different treatment processes. An example of this is provided in Figure 4-37 as extracted from the Australian Guidelines for Water Recycling (2008) (External Link). However, note that for any given process, the guidelines stipulate that the **maximum log removal that can be claimed per process is 4.0**. This is a conservative approach as some processes can be validated and monitored to be certain that the process has achieved much more than this limit. Nevertheless, this limit is implemented to promote a multiple barrier approach in the design and construction of AWTPs.



	Indicative log reductions[a]							
Treatment	***Escherichia coli***	**Enteric bacteria (eg *Campylobacter*)**	**Enteric viruses**	**Phage**	***Giardia***	***Cryptosporidium***	***Clostridium perfringens***	**Helminths**
Secondary treatment	1.0–3.0	1.0–3.0	0.5–2.0	0.5–2.5	0.5–1.5	0.5–1.0	0.5–1.0	0–2.0
Dual media filtration[b]	0–1.0	0–1.0	0.5–3.0	1.0–4.0	1.0–3.0	1.5–2.5	0–1.0	2.0–3.0
Membrane filtration	3.5–>6.0	3.5–>6.0	0.5–>6.0	3–>6.0	>6.0	>6.0	>6.0	>6.0
Ultrafiltration, nanofiltration, reverse osmosis	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0
Reservoir storage	1.0–5.0	1.0–5.0	1.0–4.0	1.0–4.0	3.0–4.0	1.0–3.5	N/A	1.5–>3.0
Ozonation	2.0–6.0	2.0–6.0	3.0–6.0	2.0–6.0	2.0–4.0	1.0–2.0	0–0.5	N/A
Ultraviolet light	2.0–>4.0	2.0–>4.0	1.0 – >3.0	3.0–6.0	>3.0	>3.0	N/A	N/A
High-level ultraviolet	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	N/A	N/A
Advanced oxidation	>6.0	>6.0	>6.0	>6.0	>6.0	>6.0	N/A	N/A
Chlorination	2.0–6.0	2.0–6.0	1.0–3.0	0–2.5	0.5–1.5	0–0.5	1.0–2.0	0–1.0

N/A = not available

a Reductions depend on specific features of the process, including detention times, pore size, filter depths and disinfectant

b Including coagulation.

Sources: WHO (1989), Rose et al (1996, 2001), NRC (1998), Bitton (1999), US EPA (1999a, 2003, 2004), Mara and Horan (2003)

Figure 4-37 Indicative Log Removals for different treatment processes (as provided by the Australian Guidelines for Water Recycling)

4.5.11.3.2 Case study log reductions

With reference to the example AWTP configurations, the expected LRVs are shown below in Table 4-55.

Table 4-55 Expected Log Removals for proposed AWTP configuration

Process Barriers		**Bacteria**	**Viruses**	**Protozoa**
		Campylobacter	Rotavirus or Norovirus	Cryptosporidium or Giardia
Dual Membrane Treatment	WWTP	1	0.5	0.5
	Chemical Clarification & Dual Media Filters	1.5	1	1.5
	MF/UF	4	0	4
	RO	2	2	2
	UV/AOP	4	4	4
	Chlorination	3	3	0
	TOTAL LRV for Train 1	**15.5**	**10.5**	**12**
Ozone-BAC Treatment	WWTP	1	0.5	0.5
	Chemical Clarification & Dual Media Filters	1.5	1	1.5
	Ozone	2	2	0.5
	BAC	0	0	0
	GAC	0.5	1	0.9
	UF	4	0	4
	UV/AOP	4	4	4
	Chlorination	3	3	0
	TOTAL LRV for Train 2	**16**	**11.5**	**11.4**
Guideline LRVs	AGWR (2008)	8.1	9.5	8 (Crypto)
	WHO (2017)	8.5	9.5	8.5 (Crypto)
	California	ns	12	10 & 10
	Texas	ns	8	5.5 & 6

Note:

- AGWR, WHO & California LRVs are from Raw Sewage, while Texas values are from WWTP effluent to product.
- Above LRV credits are a guideline only. Detailed design/assessment is required to more accurately defined the expected LRV
- Note LRV credits are affected by the surrogate organism utilized for validation.

4.5.11.4 Impact of AWTP on WWTP product outcomes and configuration

4.5.11.4.1 Feed water quality restrictions

It is important to consider the feed water quality requirements for the AWTP when defining the configuration of the wastewater treatment process. This is critical as reliable production of high-quality water should be included as key project outcome of the AWTP.

If reverse osmosis (RO) is the selected as the base process of AWTP, then the feed water quality must be low in chlorine, iron, manganese, and suspended solids. This therefore imparts the need for pre-treatment using ultrafiltration, installed after tertiary treatment or not installed if the activated sludge plant is an UF MBR plant. Likewise, the process waste (e.g. brine, neutralised chemicals etc.) generated from this example needs to be managed appropriately, particularly if the brine is sent back to the head of the wastewater treatment plant.

4.5.11.4.2 Flow balancing for and peak factors

Another example includes the need for storage tank for the feed flow to the AWTP.

In most applications, a storage tank is provided immediately before the AWTP. The volume of the storage tank must be sized to provide feed flow during zero WWTP effluent flow conditions for a specified time (e.g. storage volume for 6 hours runtime) and to equalise the effluent diurnal flow variation from the WWTP.

For the latter, a consistent feed to the AWTP is required to improve the efficiency of the AWTP process. Furthermore, certain processes cannot accommodate high peak factors, for example a RO system has a turn up/down range of -10% to +15% of the average design flow rate.

4.5.11.4.3 Brine, process waste, and off-spec water management

Brine, process waste, off-spec and feedwater water management are important when detailing the AWTP configuration and its interactions with the WWTP.

- Process units which generate brine or process wastes are ideally discharged offsite. However, in certain cases it can be considered for return to the head of works, for example if the AWTP is significantly smaller in capacity than the WWTP, or for emergency scenarios (e.g. draining and decommissioning the AWTP units). Irrespective of the reasoning, an assessment of the hydraulic and quality/process impacts must be conducted.
- As per the above, off-spec water from the AWTP can be returned to the head of works if there are no hydraulic or quality/process impacts on the WWTP.
- The AWTP can be out-of-service due to planned maintenance or due to poor feed water quality. In such conditions, there must be strategies to manage of the feedwater (i.e. WWTP effluent), including options for full discharge to the environment or temporary storage.

4.5.11.4.4 Power and chemical requirements

Power consumption and chemicals will depend on the AWTP configuration, typical power consumption for the example AWTPs' are 1 kWh/m^3 product water for RO-based treatment, 0.5 kWh/m^3 for O_3AC based treatment.

Additional chemical requirements, should the AWTP be located on the WWTP site, include:

- Cleaning/maintenance chemicals for filtration and reverse osmosis, e.g. acid CIP, base CIP, EDTA, antiscalant etc.
- Pre-treatment chemicals e.g. sulfuric acid or sodium hydroxide (pH control), ammonia and chlorine (chloroamination, note monochloroamination ratio typically 4:1 $Cl:NH_4OH$)
- Ozone generation chemicals, e.g. liquid oxygen, for O_3AC based treatment processes,
- Oxidant for UV/AOP, e.g. hypochlorite or hydrogen peroxide, for if end use is potable reuse.

4.5.11.4.5 Nutrient removal and treatment efficacy

Blending of AWTP product water with the WRP effluent or full advanced treatment of WRP effluent can be utilised to reduce nutrients discharge load. Blending has benefit of also reducing concentration of environmental discharges and provides greater flexibility is in WRP operations to manage its effluent performance. The following nutrient concentrations can be expected from an AWTP adopting the either a reverse osmosis or ozone activated carbon based treatment train (detailed further in Section 4.5.11.2)

- TN: 1 mg/L for RO based treatment, 2 mg/L for O_3AC based treatment
- TP: 0.025 mg/L for RO based treatment, 0.05 mg/L for O_3AC based treatment

It should be noted that the nutrients in the AWTP product water is contingent on the feed water quality and design of the AWTP process units. Furthermore, further research is required to validate the efficacy of TN and TP removal in advanced treatment processes as these are not currently well-understood, as historicity, nutrient removal was not driver for the development of these treatment processes (driver for RO technology is dissolved removal).

Table 4-56 Typical analyte removal rates across AWTP treatment processes

Analyte	UF	RO	UV/AOP	O_3	BAC	GAC
Total Nitrogen	30%	80%	0%	0%	20% *	20% *
Total Phosphorus	30%	98%	0%	0%	20% *	20% *
Total Dissolved Solids	0%	99%	0%	0%	0%	0%
Total Suspended Solids	99%	100%	0%	90%	10%	10%
Dissolved Organic Carbon	30%	95%	100%	35%	0%	40%
Chemical Oxygen Demand (COD)	30%	95%	0%	0%	50%	50%

* Estimated value. Removal % to be confirmed.

4.5.12 Instrumentation and monitoring

The following table provides an indication of the critical instrumentation and process monitoring requirement. Instrument requirements will be site-specific and must align with the required product outcomes. The location of instruments used in process control is critical to achieving product outcomes. Instruments should be regularly re-calibrated according to suppliers' recommendations or when routine grab sampling identifies a discrepancy with online instruments. Refer to WW&RW Instrumentation strategy for further details.

Table 4-57 Common instrumentation for online monitoring for wastewater treatment

Critical Parameter	Monitoring location
Flow	Monitoring of the influent flow must be at a location high turbulent flow to ensure good mixing. The monitoring location must not be affected by return or side streams. Preferable influent wastewater sampling locations include: • After a macerator • At a distribution box • Aerated grit chamber • Flume throat • Pump wet well when the pump is operating • Downstream of preliminary screening Monitoring of the effluent flow must be as per EPL requirements.
MLSS	MLSS meters must be installed in all critical process units that hold sludge or that require control of sludge age. Examples include: bioreactor, digester
Dissolved oxygen	DO meters must be installed in all critical process units that hold mixed liquor and that require aeration or DO control. Examples include: aerobic zone of bioreactor, aerobic digester.
pH	pH meters must be installed at all stages of the process where control of pH is critical to plant performance in achieving product outcomes. Typical pH monitoring locations within a WWTP include: • Bioreactors • Digesters • Chemical dosing points • Point of disinfection (CCT) Monitoring of the effluent pH must be as per EPL requirements.
Performance analytes	Analyte monitors for ammonia, nitrate, VFA, gas flows, etc. should be installed at suitable locations to provide sufficient performance monitoring for operators.
Free chlorine residual	Free chlorine analysers must be installed at: • Outlet of CCT • Dechlorination points Monitoring of free chlorine residual of treated effluent must be as per EPL requirements or recycled water quality requirements based on end use.

4.5.13 Summary of treatment plant configuration guidelines

Table 4-58 Summary of treatment plant configuration guidelines

Process Unit	Unit Configuration	Minimum Level of Treatment	Minimum Design Capacity	Comments
Screening	N-1 & N+1	6xADWF	See comment.	N-1 is for all flows ≤1.2xPDWF N+1 is for all flows ≤6xADWF where 1 is bypass lane with manually raked screen for flows > 6xADWF; or as defined for catchment flow peaks
Grit Removal	N+1	6xADWF	Full removal at flows ≤ 1.2×PDWF Partial removal at flows ≥ 1.2×PDWF up to 6xADWF	N is for all flows ≤6×ADWF 1 is standby grit removal train for flows ≤1.2×PDWF but activate at flows ≥ 1.2×PDWF up to PWWF; or as defined for catchment flow peaks
Flow equalisation	N	Project specific	Project specific	Configuration and capacity to be project specific to meet equalisation needs for downstream treatment
Primary Treatment (gravitational)	N-1	Varies depending on liquid stream configuration. See comment and refer to Section 4.4.	1.2×PDWF (+ any additional recycles)	Full primary treatment must be provided for all flows ≤1.2×PDWF with 1 tank out-of-service Partial primary treatment (contact stabilisation) is provided flows 1.2×PDWF ≤ Q ≤ 6×ADWF with 1 tank out-of-service Refer to Section 4.4.3.3 and 4.4.3.5 for step-feed (partial treatment) configuration
Primary Treatment (mechanical)	N-1	Varies depending on liquid stream configuration. See comment and refer to Section 4.4.	1.2×PDWF (+ any additional recycles)	Full primary treatment for flow ≤ 1.2×PDWF with 1 unit out-of-service Step feed operation for flows 1.2×PDWF ≤ Q ≤ 6×ADWF with 1 unit out-of-service (i.e. bypass portion of the raw feed) Number of units out-of-service can be higher than 1, conduct risk assessment to determine suitable number of units considering design and type of mechanical primary
Bioreactors (continuous flow)	N-1	Varies depending on liquid stream configuration. See comment and refer to Section 4.4.	Load based design to meet interim and future DRY WEATHER demands	Bioreactors to meet hydraulic and treated effluent standards through increased solids inventory (assuming all clarifiers online)
Bioreactors (intermittent)	N-1	Varies depending on liquid stream configuration. See comment and refer to Section 4.4.	Load based design to meet interim and future DRY WEATHER demands	Dry weather flow mode (normal mode of operation, typically up to 3×ADWF) Wet weather flow mode (typically, 3 to 6×ADWF) Solids contact mode (i.e. storm mode, typically, >6×ADWF)

Aeration	N+1	N/A	Load based design to meet interim and future DRY WEATHER demands	Process needs met with one blower on standby (regardless of number, configuration, or type of blowers)
Secondary Clarifiers	N+1	Varies depending on liquid stream configuration. Must match bioreactor. See comment and refer to Section 4.4.	1.2×PDWF	N+1 for PDWF conditions to ensure 100% compliance during dry weather conditions N for 6×ADWF conditions Consider risk-based assessment to determine the optimum unit configuration for PDWF and PWWF but prioritising 100% dry weather compliance
Intermittent Decanting	Unit configuration linked to biological process	6×ADWF	1.2×PDWF	Sizing of settling area is linked to bioreactor volume
Membrane filtration (MBR)	N+i Unit configuration is site-specific	Varies depending on liquid stream configuration. Must match bioreactor. See comment and refer to Section 4.4.	Load based design to meet interim and future DRY WEATHER demands	Filtration capacity must be maintained under all influent flow conditions and during standard membrane operating procedures (e.g. cleaning, backwashing)
Media Filters	N+2	1.2×PDWF	1.2×PDWF	1 duty operating at 100% flow rate 1 backwash 1 out-of-service Unit configuration must achieve 100% flow-based compliance
Tertiary Denitrification	N	1.2×PDWF	1.2×PDWF	With clarifier offline, filters need to meet requirements (could include operational changes)
Disinfection	N	1.2×PDWF with allowance for partial PWWF disinfection	1.2×PDWF with allowance for partial PWWF disinfection	N CCTs with adequate baffling and chlorine dosing arrangements ensuring dry weather CT is maintained with one unit offline
Mechanical Thickening	N+1, N+2 (where N>4)	N/A	Peak solids, e.g. 1.3×average daily sludge Include allowances for de-rating factors	N is the minimum number of duty units for servicing +1 unit may operate in either standby or assist mode; risk assessment shall be made for common standby unit opportunities with other dewatering/thickening processes Additional redundancy can be provided with additional run time
Dissolved air flotation	N+1	N/A	Peak solids, e.g. 1.3×average daily sludge	Demand to be met with 1 standby

Gravity sludge thickening	N+1	N/A	Peak solids, e.g. 1.3×average daily sludge	Demand to be met with 1 standby
Mechanical Dewatering	N+1	N/A	Peak solids, e.g. 1.3×average daily sludge Include allowances for de-rating factors	N+1 process units; where N is the minimum number of duty units for servicing +1 unit may operate in either standby or assist mode; risk assessment shall be made for common standby unit opportunities with other dewatering/thickening processes Additional redundancy can be provided with additional run time
Sludge feed averaging	N	N/A	Determined by upstream sludge flow rate	N is the minimum number of duty units for servicing +1 unit may operate in either standby or assist mode;
Aerobic digesters	N-1	N/A	Peak solids, e.g. 1.3×average daily sludge Include allowances for volume de-rating factors	Digesters to meet EPA biosolids standards with 1OOS, typically: 1OOS ≥ 10d SRT All online ≥ 15d SRT
Anaerobic digesters	N-1	N/A	Peak solids, e.g. 1.3×average daily sludge Include allowances for volume de-rating factors	Digesters to meet EPA biosolids standards with 1OOS, typically: 1OOS ≥ 10d SRT All online ≥ 30d SRT
Biosolids Storage	N-1	N/A	Peak solids, e.g. 1.3×average daily sludge	Biosolids storage to provide minimum 4 days storage with 1 silo out-of-service. Existing sites may be able to leverage liquid storage in the form of FAT volume
Other biosolids processes	N or N+1	N/A	Capacity must be sized to support critical process units	
Biogas processing	N+1 for gas scrubbers/ cleaning N for cogeneration units (+1 optional) N+1 for waste gas burners	Peak gas production	All gas flows under all conditions	All biogas must be processed via cogeneration or flaring
Ventilation	N	N/A	20×air changes	

Odour Treatment	N+1	N/A	2 ‘BTF+AC’ duty / duty streams	Redundancy provided by e.g. Activated Carbon where appropriate
Other Mechanical Equipment	N+1 N+2 (where N>4)	N/A	Capacity must be sized to support critical process units	e.g. Mechanical PST, RAS pumps, WAS pumps, sludge pumps, extraction fans

Notes:

- 6×ADWF refers to peak flow rate through the process unit and should be replaced by suitable a value as determined by flow frequency analysis or network modelling. In absence of this information, 6×ADWF should be adopted.
- Minimum flow paths can be superseded by product outcomes and site-specific requirements
- Refer to Section 4.2.2.3 for definitions of redundancy (e.g. N+1) and oversizing (e.g. N-1)

4.6 Staging and future provisioning

4.6.1 Purpose of staging and future provisioning

Opportunities for staging and future provisioning should be identified during the planning process.

Staging is the step-wise installation of treatment capacity to meet ultimate treatment demand. Staging is an effective method to provide adaptive capital expenditure and to address future unknown problems.

Future provisioning refers to the construction of certain assets that allow for future capacity expansion minimal need for construction of additional assets and allowing easy interfacing with existing plant assets.

Staging and future provisioning allows treatment servicing the ability to respond to:

- Uncertainty in wastewater catchment growth rates
- Changes in regulation or product outcomes
- Changes or improvements in treatment technologies

Further, it also provides the ability to:

- Maintain normal plant operation with minimal interruption to plant performance
- Improve cost and contract administration efficiencies
- Potentially defer capital expenditure
- Simplify project scope

4.6.2 Examples of staging

4.6.2.1 Planning horizon and ultimate treatment capacity

Treatment asset and system configuration development should consider staging and the required timing of key servicing requirements. The first step is usually to identify the ultimate treatment demands and required capacity based on the chosen planning horizon.

The planning horizon for each project will be site-specific and must be documented in the Basis of Planning/Design Basis. In the absence of a project specific planning horizon, a minimum horizon of 30 years should be adopted.

Once the planning horizon has been identified, an exercise should be conducted to determine the ultimate treatment demands and the required treatment capacity to service this demand. This then informs the staging requirements to reach this ultimate state based on the timing of stages and demand profiles.

Staging consideration may in turn constrain the viable treatment options available to meet project outcomes.

4.6.2.2 Staging at brownfield sites

Staging of treatment upgrades at brownfield sites will be constrained by the servicing requirements of the existing plant. In options assessments for brownfield sites, high-level staging and sequencing plans for the required upgrades must be developed to provide a holistic comparison between options and will provide additional clarity on project scope and complexity.

4.6.2.3 Staging at greenfield sites

For new treatment facilities, the impacts on planned staging and the ability to adapt to higher and lower growth within the wastewater catchment or changes to influent wastewater composition may dictate the need to adopt modular treatment designs. This will in turn provide greater capacity in future provisioning to respond quickly to changes within the catchment.

When assessing staging requirements, for both brownfield and greenfield sites, treatment capacity for both flow and ability to meet product outcomes must be considered in parallel.

4.6.2.4 Upgrade intervals

Generally, major process upgrades should be spaced by a minimum of 7 years to avoid too frequent disruptions to plant operations. Upgrades occurring too frequently can be cost inefficient, whereas too infrequent upgrades may result in inefficient capital expenditure.

4.6.2.5 Modularity of processes

Modularity gives flexibility of future plant operation during periods where process units need to be taken offline for maintenance. Staging and timing of major maintenance activities can be more easily planned to minimise the effect on the ability of the WWTP to meet its product outcomes objectives with modular plant designs. Some examples of process equipment with high modularity include:

- Membrane treatment systems – often supplied in discrete units (racks or cassettes)
- Mechanical equipment – screening equipment, pumps, thickening and dewatering units
- Media filters

Modular treatment infrastructure can also provide flexibility for asset renewal programs. Assets that can be installed progressively will have a staggered end of their design lives, allowing for spread of capital expenditure on renewals with minimal disruption to a plant’s ability to meet product outcomes. For this benefit of modularity to be realised, civil and structural components of the treatment infrastructure will need to be constructed to allow for increasing capacity over time (future provisioning).

Modularity should also be considered when sizing first stage builds of treatment process units. For example, bioreactor tanks may be built to half the volume of subsequent upgrade tanks to ensure impact on product outcomes is mitigated during maintenance periods. The process unit staging may be as follows:

- Stage 1: 4 off 5 ML/d ADWF bioreactors for a total capacity of 20 ML/d – only 25% capacity offline during maintenance
- Stage 2: additional 2 off 10 ML/d ADWF bioreactors for a total plant capacity of 40 ML/d – existing tanks now represent 12.5% of total capacity and new tanks 25% each, therefore maximum of 25% offline during maintenance

4.6.2.6 Staging case study

An example of the application of staging is listed below and shown graphically in Figure 4-38:

- Future point #1 (FP1): the plant upgrades comprise a major project involving installation of a new bioreactor, inlet works upgrade and solids stream processing to the required capacity at the ultimate planning horizon.

- After the FP1 upgrades, the plant treatment capacity may be limited by a process unit with high flexibility for modularity and staging such as filtration which only has the capacity up to future point #2 (FP2).
- At FP2, a smaller project including filter upgrades and installation of an additional chemical storage and dosing capacity

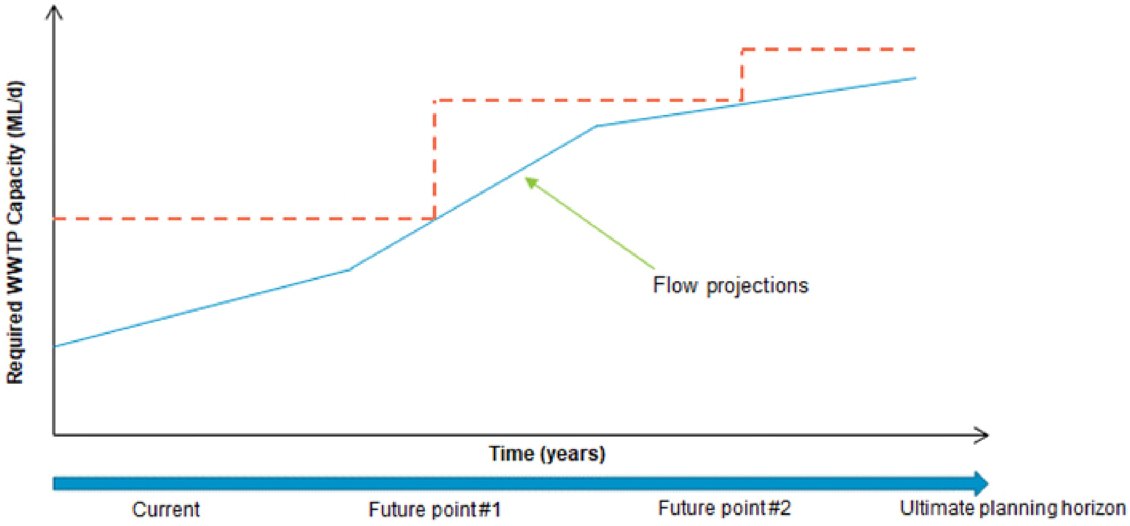


Figure 4-38 Example growth servicing upgrade staging graph

Table 4-59 Upgrades staging example

Planning horizon	Upgrades	Capacity limiting process unit(s) after upgrade
Current	N/A	Inlet works and bioreactor capacity
Future point #1	New bioreactor, inlet works upgrade and solids stream treatment	Filtration and chemical dosing
Future point #2	Filtration and chemical dosing system upgrade	All process units have the same capacity

4.6.3 Examples of future provisioning

4.6.3.1 Common assets

When sizing common assets, a view to the requirements at the ultimate planning horizon should be taken. This approach is most applicable to assets such as:

- Inlet works
- Buildings housing process and mechanical equipment
- Flow splitting chambers
- Electrical infrastructure – power supply, switch rooms, blank/spare cabinets etc.

4.6.3.2 Site allowances

High-level site layouts over the planning horizon should be developed in the options assessments planning phase to provide an understanding of staging and future provisioning impacts on footprint availability. Also, this exercise ensures that selected treatment technologies are compatible with the long-term capacity requirements.

When planning site layouts, ensure that space is provided for future assets, examples include:

- For raw wastewater secondary treatment systems (i.e. direct fed, no primary treatment). Ensure allowance in site footprint for future installation of primary treatment.
- Allowance for additional tanks (primary settling tanks, bioreactors, clarifiers etc.)
- Allowance in equipment buildings for additional mechanical or electrical units

5. Assessment of Cost, Time and Risk

5.1 Cost estimation

5.1.1 General approach

The level of costing confidence must be suitable for the activity and intent of cost development through project gateways. The general approach to cost estimation is shown below.

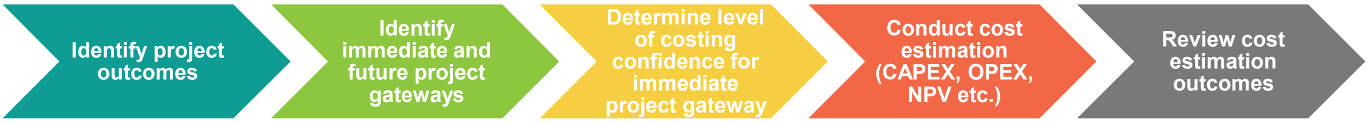


Figure 5-1 General approach for cost estimation

When conducting cost estimation, it should be noted that the level of costing accuracy is affected by the following:

- Scope identification – identified scope is reflective of what is required (and delivered)
- Quantity surveying – scale of delivered scope is reflective of what is required (and delivered); subset of scope
- Unit rates – unit rate costs are representative of actual delivery costs

5.1.2 Common scope items

When conducting cost estimates, it is important to consider not only the key process units in question but also to the common scope items which are often missed during planning projects. The purpose of considering common scope items is to reduce the scope variability and therefore cost variability as the project passes through the various delivery gateways. An example of such is provided in Figure 5-2 which illustrates the scope change and cost variation across various project gateways.

Common scope items relate to the cost requirements of auxiliary cost items required to ensure delivery of the project. These auxiliary cost items can be civil, mechanical, or electrical assets; or alternatively, overheads, preliminary activities or site preparation tasks that are required before delivery and installation of the new asset.

Examples of these common scope items include the following:

- Overheads and standard allowances (refer to Section 5.1.3.3):
  - Contractor overheads
  - Sydney Water overheads
- Common site services (power, control, water, air, access), consider:
  - Existing capacity of common services
  - Specification of common services and suitability for new assets/processes
  - Connection to common services
- Temporary works and unit cut overs at existing sites
- Process commissioning requirements

- Decommissioning of obsolete equipment and structures (including demolition and rubble disposal/recycle)
- Additional required effort (rock excavation, mine subsidence, structural modifications)
- Cost (or time) impact of site conditions and constraints (e.g. geotechnical, environmental, heritage, access)
- Cost of land acquisition

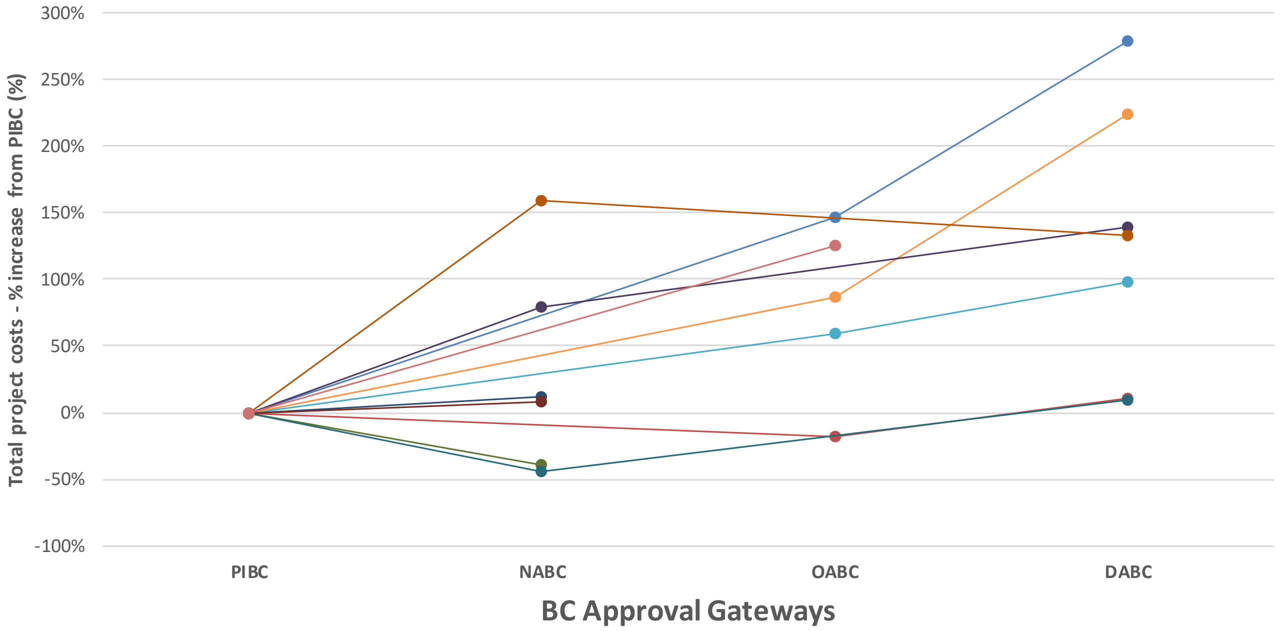


Figure 5-2 Impact of scope change through project life cycle

It should be noted that all scope items cannot be defined upfront; however, contingencies can be included to make allowances for typically experienced common scope items. The following should be considered when developing common scope items and contingencies:

- Learn from works at existing sites – common scope items and scale of effort
- Highlight scope areas which should be investigated (and quantified) in future project stages
- Consider making options assessment phase a more detailed step in project delivery, i.e. broad effort for numerous options or more focused effort on limited few options or a preferred option.

Common areas where project scope has traditionally led to increased cost estimates across the project approval gateways are captured in Table 5-1 below.

It is often difficult to assess the extent of the impact of these scope items. However, efforts should be made to include cost allowances for them, or at least mark these items as a cost risk. There are three methods that can be utilised:

- The first involves applying blanket cost contingency factor onto the cost estimate. Depending on the accuracy of the line items in the cost estimation, this can vary from 30% to 50%.
- Lump sum allowances for line items that have not been cost estimated
- An alternative, method for cost allowance is to assign a discrete percentage factor of each identified scope item to a known or calculated cost item. An overall cost contingency can still be applied to the total project cost, this is to cover for unknown or missed scope items. However, the overall cost contingency factor can be lowered.

For the latter, taking control and instrumentation as an example: an equipment quotation of $100,000 has been provided by an equipment supplier. Upon assessing the scope of supply, instruments have been offered but installation and integration with existing SCADA is not included. Therefore, a +15% factor is be applied as scope allowance and thus a total cost of $115,000 is assigned for this equipment item. This methodology is then continued through the various cost line items.

Table 5-1 Common scope allowances

Scope Item	Comments
Geotechnical and ground conditions	Ground conditions necessitating higher ground stabilisation efforts (e.g. piling), including any additional geotechnical investigation and land surveying
Environmental	Contaminated material or soil requiring specialised disposal Site revegetation and rehabilitation
Civil modifications of existing assets	Modifications, extensions or demolition of existing civil infrastructure required as a result of upgrades. Examples include concrete cut-outs for new pipes and structures, relaying or relocation of underground services, demolition and rubble removal.
Electrical	MV upgrades or upgrades to power supply, installation of cable ducts and cabling systems, upgrade of electrical cabinets.
Control, and instrumentation	Installation of instruments and integration with existing SCADA
Site services and ancillary equipment	Any potential upgrades to site services or ancillary process equipment which may be difficult to scope in early planning work, e.g. power supply, chemical systems, firefighting systems, reclaimed effluent supply, compressed air etc.
Brownfield site project allowances	Allowance to capture potential complexities in project delivery relating to cutovers, need to use temporary equipment during construction and increases in project schedule due to brownfield upgrade complexity
Digital components in design	Allowance for BIM and 3D modelling which may not be captured under a traditional “design” allowance

5.1.3 Net Present Value (NPV)

5.1.3.1 Standard rates

NPV assessment should be conducted using Sydney Water Econ 8 which is the standard NPV assessment template. Standard financial rates include the following:

- Discount Rate: 5.3%
- Inflation: 2.5% (‘economy wide’, and also for project and labour costs)
- Labour capitalisation: 6.4% (on infrastructure projects) or 10.7% capital uplift allowance (for DM Integrated Projects)

Note that these financial rates are updated regularly.

5.1.3.2 Assessment period

When conducting an NPV assessment the assessment period must be selected such that it accurately captures the value of the options. This must therefore include future equipment replacement costs or significant associated costs which occur at set intervals depending on the type equipment (e.g. membrane replacement every 15 years or digester cleanout out every 10 years)

In most scenarios, the following assessment periods can be utilised:

- Medium term assessment: 15 or 20 years
- Long term assessment: 25 or 30 years

5.1.3.3 NPV items

The following NPV items should be considered for NPV assessment tasks, refer to the respective tables for reference rates or values:

- Operating expenditures
- Renewal and replacement
- Operator overheads

In addition to the standard items above, consider on a case-by-case:

- Avoided costs, especially compared to baseline servicing or do nothing
- Residual asset life, especially compared to baseline servicing or do nothing
- Incremental maintenance rates
- Maintenance categories / effort levels (ongoing preventative, periodic minor renewal, large-scale renewal)

Table 5-2 Renewal periods

Category	Renewal Period
General Mechanical	15 years
Electrical	15 years
Civil/structural	50 years
UF Membrane replacements	10 years (supplier dependent, can be 15)
RO Membrane replacement	5 to 7 years (supplier dependent)
Filter media	7 years
Reactor/digester cleanout	10 years
Other major maintenance activities	5 years

5.2 Recycled Water Pricing

5.2.1 IPART Review and Determination of Recycled Water Pricing

A link to general IPART resources can be found here: IPART External Link 1.

IPART has established a pricing framework for public water utilities' recycled water schemes. IPART's framework allows the costs of a public utility's recycled water scheme to be recovered from general water and/or sewerage prices to its broader customer base when:

- it is the least cost way of delivering water and/or wastewater services, while complying with environmental and other regulatory requirements
- it avoids or reduces costs the broader customer base would normally pay (for example, expanding sewage treatment plants), or
- the utility's broader customer base is willing to pay for the external benefits the scheme generates.

Any residual costs of the recycled water scheme are then recovered from recycled water customers up to their willingness to pay and/or from developers via recycled water developer charges, subject IPART's pricing principles and developer charges determination.

The intent of IPART's framework is to recognise the system-wide benefits of recycled water, and ensures that recycling will be viable where the benefits it creates for customers exceeds its costs. This aims to provide incentives to get the right solutions in place to meet the demands of customers and the broader community.

5.2.2 July 2019 Review and Determination

The latest review was published in 2019 (IPART External Link 2). There are two key reports in this review:

1. "Review of pricing arrangements for recycled water and related services" (July 2019): IPART External Link 3; referred to as **IPART 2019 Document 1** herein; and
2. "Maximum prices for connecting to a recycled water system" (July 2019): IPART External Link 4, referred to **IPART 2019 Document 2** herein.

A summary of the IPART 2019 Document 1 and 2 is provided below.

IPART 2019 Document 1 details the following**:**

- IPART's form of price regulation, notably what services IPART must set prices for and how IPART will do this (Chapter 2)
- IPART's funding framework, which distinguishes between recycled water schemes that form part of a least-cost servicing solution and those that are higher-cost (Chapter 3)
- IPART's approach to treating avoided and deferred system (augmentation and network) costs that arise from recycled water schemes (Chapter 4).
- IPART's approach to treating external benefits that arise from recycled water schemes, including their identification, calculation and assessment ((Chapter 5).
- IPART's principles for pricing to recycled water customers (Chapter 6).
- IPART's methodology used to determine maximum recycled water developer charges (Chapter 7), also refer to IPART Document 2 below.

IPART 2019 Document 2 details the following:

This document details of allowable upfront charges from utilities paid by developers to recover part of the infrastructure costs incurred in servicing new developments. This document replaces IPART's Recycled Water Developer Charges, Determination no 8, 2006.

Note that as per the details in IPART 2019 Document 1, the allowable upfront charges can be charged as developer charges by Sydney Water in accordance with IPART, *Maximum prices for connecting, or upgrading a connection, to a water supply, sewerage, or drainage system: Sydney Water, Hunter Water, Central Coast Council - Final Determination, October 2018*; **and** IPART, *Maximum prices for connecting to a recycled water system – Sydney Water, Hunter Water and Central Coast Council – Final Determination, July 2019* (i.e. IPART 2019 Document 2).

Other important reference files include the following (External Link 5):

- Fact Sheet which outlines the key decisions on IPART's pricing framework for recycled water and related services.
- Template Spreadsheet is to assist utilities in applying IPART's methodology to calculate prices for connecting to a recycled water system (developer charges).

Funding framework (extracts from Fact Sheet)

The July 2019 IPART review has established three separate funding frameworks, as summarised in Figure 5-3:

- 1. Recycled water services supplied from 'least-cost' schemes.
- 2. Recycled water services supplied from 'higher-cost cost' schemes.
- 3. Stormwater harvesting and sewer mining services.

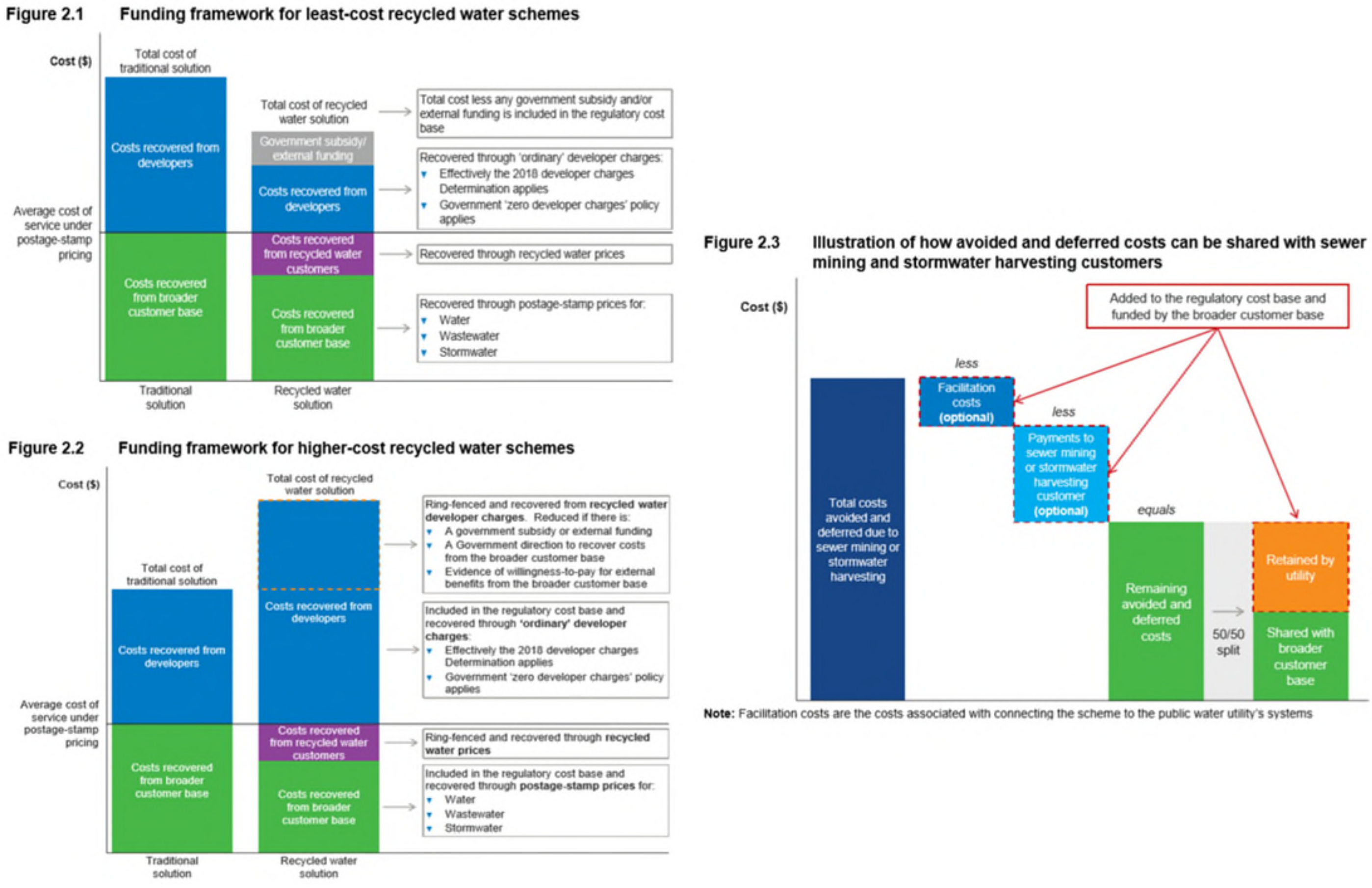


Figure 5-3 IPART Funding Framework for 2019 Review and Determination

5.3 Investment profiling

Wastewater treatment assets are large and complex. Building new facilities or modifying existing ones requires a high degree of planning and generally years in construction. Understanding when activities are required to be undertaken and how much those activities will cost is vital to forward planning. The following aspects are of key importance:

- Identifying planning triggers – working back from a future horizon at which the planned upgrades/assets are required informs the project milestones
- Quantifying cash flow requirements – forecasting and profiling future investment over a portfolio of projects to compile a robust forward budget forecast is vital to the business and is foundational in the development of pricing submissions

5.3.1 Project timeline

For an asset creation project, there are defined planning activities and approvals that are required prior to the construction and commissioning of the outcome. The project timeline is a schedule of activities with expected durations and required deadlines to enable the next phase of work to be initiated. This timeline will likely change over the evolution of asset creation project however it is important to estimate these early on to inform planning activities and cash flow requirements.

Table 5-3 summarises the indicative lead times for certain activities and different project types. These are intended to aid with formulation of project timelines and investment profiles in the early phase of an asset creation project. Value should be selected within the ranges, or even above the nominated as assessed based on the complexity, risk and scale of a project.

5.3.1.1 Planning timeline

The planning timeline comprises activities from need assessment to concept design. It may include discrete activities such as regulatory or treasury review. The timeline of the planning horizon varies significantly depending on the scope and complexity of a project, it will typically include the following key stages:

- **Needs assessment:** 1 to 6 months
- **Options study:** 2 to 8 months
- **Concept design:** 4 to 14 months
- **Approvals:** varies, approvals required after each of the above stages

5.3.1.2 Delivery timeline

The delivery timeline comprises activities from procurement to handover and includes the following stages:

- **Procurement**: 1 to 6 months (depending on procurement method)
- **Detailed design**: 3 to 18 months (depending on procurement method)
- **Construction**: 18 to 24 months as minimum, total length of construction is limited by the annual expenditure cap as determined by site restrictions and maximum construction activity that can occur at the site.
- **Commissioning**: 1 to 6 months depending on complexity and type of technology
- Process proving: 3 to 12 months. Note for recycled water systems, a minimum 12 months is required for process proving. This proving period will include validation against health requirements.

It should be noted that the above planning and delivery timelines do not account for any overlapping or fast-tracking, of which can be considered under special circumstances.

Table 5-3 Investment profiling typical lead times

Project Stage	Process renewal/upgrade no change to regulated streams <$100m (months)	Process renewal/upgrade no change to regulated streams >$100m (months)	Process renewal/upgrade with change to regulated streams or new facility <$100m (months)	Process renewal/upgrade with change to regulated streams or new facility >$100m (months)
Needs assessment	1	1	1	1
Servicing strategy	0 - 3	3 - 6	1 - 6	3 - 6
NABC approval	1	2	1	2
Options study	2 - 4	4 - 8	2 - 4	4 - 8
OABC approval	2	2	2	2
Concept design (Note: timeline affected by procurement method)	4 - 8	8 - 14	4 - 8	8 - 14
Environmental review (regulatory/MCOA)	No additional	No additional	2	2
DABC approval	2	3	2	3
Treasury review	N/A	3	N/A	3
Procurement to Handover	36 - 48	48 - 72	36 - 48	48 - 72
Minimum Time	**48 months (4 years)**	**74 months (6 years)**	**51 months (4 years)**	**76 months (6 years)**
Maximum Time	**69 months (6 years)**	**111 months (9 years)**	**73 months (6 years)**	**113 months (9 years)**

5.3.1.3 Additional considerations

Considerations should be given when detailing the planning and delivery timelines in terms of tendering and tendering/procurement:

- The market will require a minimum of 12 weeks for complex projects to tender if they are not involved in any earlier development of design.
- Tender evaluation is approximately 6-8 weeks, in parallel with contract negotiations. This does not account for insurance, commercial/contractual items that are outside of the framework i.e. disagreements on the terms and conditions of the contract framework.
- Recommendation to award is approximately 4 weeks post evaluation, to get to Contract Award.
- It will then take approximately 4 weeks to mobilise post contract award (i.e. the Contractor to set up design, complete paperwork (SWMS etc), any investigations etc).

5.3.1.4 Case study

A case study of the above project timeline is provided below. This case study is based on the Winmalee PRP and dewatering, dewatering programme, Hornsby Heights clarifier upgrade, Rouse Hill Growth Stage 1, LSCT, West Camden Biosolids (2012-2014), Hoxton Park (2010-2012), St Marys AWTP.

Stage	Process Timeline
Planning / Options / Concept Design	12 to 15 months
Funding Approval	4 to 6 months
Tendering & Award	4 to 6 months
Detailed Design / Procurement / Construction / Commissioning	24 to 30 months
Process Proving (Validation)	12 months
Total:	**56 - 69 months**

5.3.2 Activity cost

Funds are required not only for the material and labour to build the assets but also to undertake the planning and design of the assets. Allowances for each planning phase activity shall be estimated for inclusion in the total project cost and used to inform the investment profile.

Cost of planning and design activities will be dependent on the following:

- Scale of project – small scale project planning activities will be less in magnitude than large projects, but will make up a greater proportion of the total project cost
- Complexity of project – the greater the complexity of project the higher the associated planning and design costs
- Environmental approvals – new of modified environmental impact statements, especially those associated with new waterway discharges will required significantly greater effort than project working within existing EPL constraints
- Delivery mechanism – managing contractor delivery model will incur significant additional overheads throughout planning, design and delivery

5.4 Risk applicable to treatment assets

5.4.1 Sydney Water risk management framework

Sydney Water has a risk management framework (LINK) which standardises the risk management process across value streams. The risk management framework includes a risk matrix (LINK) which standardised the risk categories to be managed across Sydney Water projects. The current revision of the matrix (2019) considers the eight risks shown in Figure 5-4.

For wastewater treatment projects, it may be useful to consider risks through four distinct categories:

- Safety risks – conditions or circumstances with equipment or plant operations which could result in injury or illness of plant operators and site staff
- Servicing commitment risk – risk of not servicing committed development or schemes as previously stated
- Product risks – degradation of product quality below regulatory requirements, environmental commitments, or simply the quality range threshold for most efficient disposal

- Treatment failure risk – the exceedance of process unit operating or design parameters resulting in unstable operation or breakdown of process treatment pathways completely (risk of treatment failure is discussed further in Section 5.4.3)

Public health	• Exposure to unsafe product (acute, contaminant, chronic contaminant or hazardous material
Injury / Illness	• Harm to health and wellbeing (including psychological harm) of employees, contactors, members of public
Reputation	• Impact to SW brand and/or reputation in terms of stakeholders and customers and trust
Environment	• Adverse effect on flora, fauna, soil, waterways, heritage area, resources, air quality or Harm to natural and/or cultural heritage (including aboriginal objects and aboriginal places)
Compliance	• Breach of legal or regulatory compliance
Financial loss	• Financial losses or unrecoverable expenditure is incurred
Customer & Community	• Disruption to and/or cost associated with loss or damage to customer, community & developers
Performance	• Impact on achieving strategic initiative or Project performance impacts achieving program benefits and delivery • Project performance impacts achieving program benefits and delivery

Figure 5-4 Sydney Water risk matrix categories (revision 2019)

5.4.2 Application to wastewater treatment assets

The risk categories stipulated in the risk matrix are applicable to wastewater treatment assets and treatment facilities; however, most risk occurrences at treatment assets often trigger multiple risk categories; this is due to interconnections between the treatment assets which form the plant-wide system. Examples have been provided in Table 5-4.

Table 5-4 Examples of risk occurrences and risk categories

Treatment Example	Example of Risk Category
Inadequate chlorination of tertiary effluent	Public health, Injury / illness, Reputation
Injury / illness due to operations related activity	Injury / illness, Reputation, Financial loss
Insufficient of odour control	Reputation, Customer & Community
Wet weather bypass events resulting in discharge or partially treated effluent	Environment, Compliance, Financial loss
Ammonia breakthrough in secondary treatment	Compliance, Performance, Financial loss
Inefficient grit removal leading to higher frequency of reactor/digester cleanout	Financial loss, Performance
Greater biosolids production leading to more truck movements	Customer & Community, Reputation
Poor product outcome due to overloading of assets or processes	Performance, Compliance, Environment

5.4.3 Risk of treatment failure

The risk of treatment failure is due to a change in asset, process, or system conditions from a functional state to a non-functional state. The pathway to non-functionality, there exists intermediate stages where there is a deterioration in product outcomes. However, upon failure, the rate of impact and magnitude of consequence is ignorantly higher than a deteriorated product outcome, and restoration of functionality will require different management/mitigating measures compared to day-to-day product outcome impacts.

The risk of treatment failure cannot be explicitly categorised under any of the eight risk categories as the consequence of failure triggers all the risk categories. However, there is a strong interconnection between the risk of treatment failure with performance, environmental and compliance risks because upon a condition where an asset, process or system has failed, deterioration of plant performance and product streams can occur. These consequences then result in the triggering of compliance and environmental risks. For the latter, as an example, a process or asset failure can also lead to a change in product stream avenues such as emergency disposal or removal procedures. This further imparts reputational risks and financial losses.

5.4.3.1 Approach to assessing treatment failure

When assess the risk of treatment failure, it is important to consider four key aspects (summarised in Figure 5-5):

- **Area of failure** | type of asset, biological process, or treatment that has becomes non-functional
- **Timeline of failure** | time it takes for the asset, biological process, or treatment system to become non-functional
- **Consequence of failure** | impact of the non-functional asset, process or system on product streams and product outcomes, and all other risk categories as identified in the Sydney Water risk matrix.
- **Response to failure** | mechanisms available prevent failure, or return the asset, process or system to a functional state after is has failed

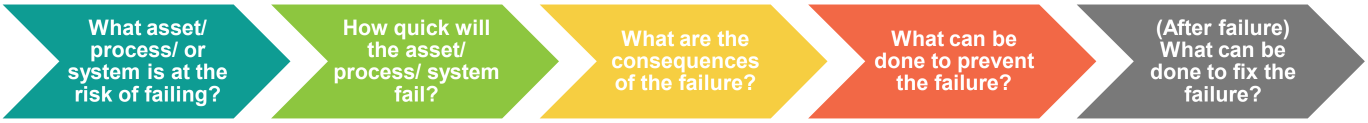


Figure 5-5 General approach for assessing risk of treatment failure

5.4.3.2 Area of failure

Treatment failure can occur across diverse assets and processes at a wastewater treatment plant. In general, treatment failure can be categorised under the following areas:

- Failure of a discrete asset (e.g. pump, instrument, gearbox or motor, valve, penstock)
- Failure of a biological process (e.g. anaerobic digestion, nitrifiers in activated sludge system)
- Failure of a combination of discrete asset and/or biological process resulting in the failure of a treatment pathway (e.g. liquid stream or solids stream)

5.4.3.3 Timeline of failure

Treatment failure can occur instantaneously or by accumulation (i.e. in a "*build-up*" or incremental manner).

5.4.3.3.1 Instantaneous failures

Instantaneous failures typically occur due to sudden or abnormal change in operating conditions, deterioration or damage to assets.

Instantaneous failures are more applicable to discrete civil, mechanical, and electrical assets which typically have a design condition or boundary and expected life-span and maintenance requirements. Examples include discrete assets such as process instrumentation, pumps, valves, pipework, water retaining structures, switchboards etc. However, instantaneous failures can also occur in biological systems with sensitive biological processes such as anaerobic digestion or emerging technologies (granular sludge, short-cut nitrogen etc.).

5.4.3.3.2 Accumulation failures

Accumulation failures typically occur due to a process or asset operating under a prolonged stressed condition. Under such condition, product outcomes deteriorate and there are greater operational efforts (e.g. chemicals, energy, maintenance etc.). Any further increase in loading or stress, or an abnormal event, can result the process or asset exceeding its critical point boundary and subsequently failure.

This failure timeline is more applicable to biological processes which can temporarily operate in stressed conditions (within reason) – but often with deteriorated product outcomes. However, due to the complexity of these processes and their interlocks with upstream and downstream systems, it is difficult to explicitly quantify their critical points and maximum length of stressed operation before failure.

Examples of accumulation failures include a build-up of sludge in the system (due to conditions preventing sludge removal in the liquids or solids streams), deterioration in biological conditions (e.g. loss of aerobic conditions due to insufficient aeration system), or prolonged system overloading due to influent loading conditions.

More importantly, in contrast to instantaneous failures, under stressed operation there is a window period in which the normal zone of operation can be restored. For example, with the build-up of sludge in the system, removal of the excess sludge by restoring and temporarily increasing the biosolids processing and outloading rate will return the system to normal operation

Further, it should be noted that whilst under stressed conditions, the transition from stress to failure can occur instantaneously, often due to the loss of a civil, mechanical, and electrical asset.

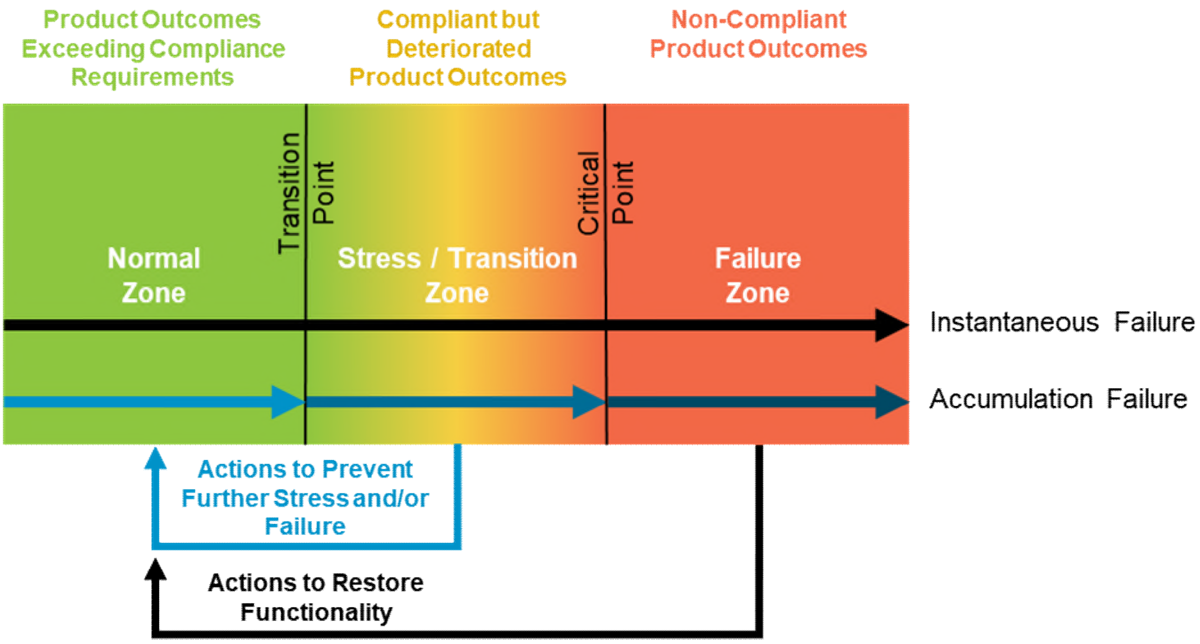


Figure 5-6 Timeline of process or asset failure

5.4.3.4 Consequence of failure

Irrespective of the timeframe, the consequence of process or asset failure is immediate. However, the severity of the consequence will depend on the process or asset that has failed **AND** the buffering ability of all interconnected processes or assets to absorb the effects of the non-functional process or asset. For example, a critical process can still function if a duty pump has failed and a standby pump is available to service the demand. However, upon failure of the standby pump, the entire process will be non-functional

It is important to emphasise that the interconnected processes or assets do not need to within the same product stream. A failure in the biosolids stream can cause product deterioration or failure in the liquid stream, and *vice versa*. Assessing this further, the failure in the biosolids stream can be caused by a failure in a single asset such as feed pump or thickening unit.

5.4.3.5 Response to failure

The level of response to failure is linked to the severity of the consequence of failure. Ideally proactive, planned maintenance and effective planning of capacity and operation can avoid failure. However, in the case of failure, examples of response mechanism include:

- Discrete asset failures can be addressed through repairs or substitution of the asset with a standby or critical spare (depending on the design and allowances in servicing availability).
- Process failures require high and immediate levels of response. For example, a sour digester will require a restart of the digestion process. This restart procedure involves decommissioning and re-commissioning of the process which is incurs financial losses and extended periods of digester shutdown.
- System failures also require high and immediate levels of response and can involve the restart or overhaul of multiple assets and/or processes.

5.4.3.6 Examples of process or asset failure pathways

There are multiple pathways which can cause process or asset failure. Inadequate response during the transition zone will result in triggering of failure pathways which is the sequence/route leading to a deterioration in product outcomes.

Examples of the common failure pathways observed in wastewater treatment plants are shown in Figure 5-7.

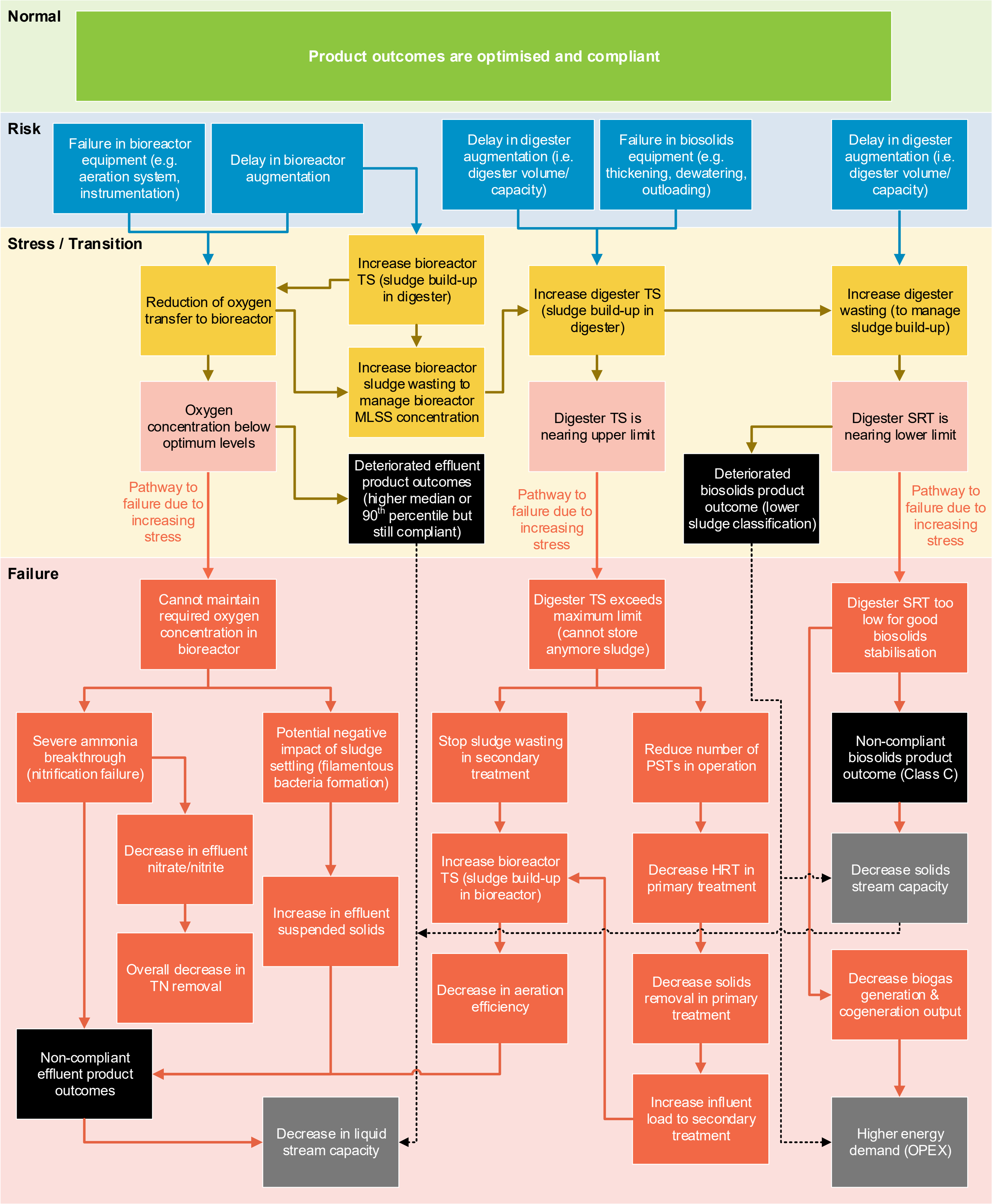


Figure 5-7 Treatment failure pathways

6. Discrete Planning Activities

Several planning activities occur on a periodic or as needed basis outside of the asset creation process. These are important activities in the overall asset management framework and often identify future needs which trigger asset creation projects.

A summary of the purpose and source references for the activity methodologies are provided.

6.1 Growth servicing assessments

Growth servicing assessments are conducted on the periodic (four to five year) basis. They are conduct simultaneous for network and treatment assets. Their purpose is the assess the current asset capacity against current and forecast demand profiles to assess the need for capacity augmentations.

They are a foundational artefact for the formulation of the forward growth program budgets and the associated forward prices submissions.

Recent iterations of growth servicing assessments are:

- 2014 Growth Servicing Strategies
- 2018 Growth Servicing Investment Plan

The most current methodology for growth servicing assessments is captured in the *Wastewater Treatment Growth Servicing Investment Plan, 2018*.

6.2 Process capability assessments

Process Capability Assessments are detail capacity and performance assessments which include a list of short- and medium-term investments and operational improvements. The assessments were a foundational artefact for Facility Blueprints, which have since been retitled System Plans.

The initial run of assessments was completed on all but three of Sydney Water's wastewater treatment plants across the period 2014 to 2018. As of 2019/20, a review of the procedure and methodology was being conducted to reformulate the PCA methodology, outcomes and outputs. Refer to the Treatment Planning Team in System and Asset Planning or Process Engineering Team in ETS for further updates on the PCA methodology.

6.3 Development applications

Ad hoc development applications (DA) should be assessed against the forecast demand profiles (i.e. as defined in GSIPs) and the treatment capacity of the receiving treatment plant(s). The 2018 GSIP methodology should be used in the assessment of DAs, unless more detailed information is available.

The following procedure is recommended:

1. Confirm differential demand relative to GSIP forecast – consult with network planners to confirm if DA forecast is within the GSIP forecast growth for the nominated precinct, quantify additional growth demand profile by subtracting previously allocated EP
2. Plot differential growth forecast – seek intermediate horizons to identify uptake (demand) profile and use linear interpolation between horizons
3. Compare GSIP and combined demand forecast trends (previous GSIP forecast plus differential forecast) to plant capacity lines – identify capacity shortfalls triggered by additional growth or planning horizons accelerated by the DA
4. Compile servicing summary – note capacity shortfalls and planned asset upgrades, and note impact of DA on planned investment timing and scale

6.4 Trade waste applications

Trade waste applications of significance shall be assessed against both the facility capacity and the forecast demand profiles (i.e. as defined in GSIPs) for the receiving treatment plant(s). As of 2019/20 a procedure was being developed for planning assessment of trade waste applications.

The procedure will:

- Provide review trigger load thresholds for each receiving treatment plant
- Compare proposed loads to forecast non-residential growth and the current facility capacity
- Nominate activities of concern which may infer increased impact to the receiving facility and network to ensure due consideration is given high risk customer categories when assessing proposed agreement

Refer to the Process Team in ETS for updates on this procedure.

7. Definitions

Term / Acronym	Definition
AWTP	Advanced water treatment process
ADWF	Average dry weather flow
BQS	Biosolids quality score
Campaign monitoring	Project specific monitoring program outside of the normal daily monitoring needs.
DO	Dissolved oxygen
Dry Weather Flow	Flow rate occurring during a dry weather period, typically defined as no rainfall occurring for 2-weeks
EKAMS	Effluent Knowledge and Management Systems
EP	Equivalent population
Flow-weighted composite	Collection of individual samples of a variable volume obtained at regular intervals. The volume of the individual samples is proportioned to the flow rate at the time of measurement of the individual samples.
Grab sample	Single fixed volume sample
GSIP	Growth Servicing Investment Plan
HLR	Hydraulic loading rate
HRT	Hydraulic retention time
IDAL	Intermittently decanted aerated lagoon
LMH	Membrane flux, litres per meter square per hour (L/m^2h)
LRV	Log removal value
MBR	Membrane bioreactor
MLE	Modified Ludzack-Ettinger
MDWF	Minimum dry weather flow
MLSS	Mixed liquor suspended solids
PCA	Process Capability Assessment.
PDMS	Plant Data Management System
PDWF	Peak dry weather flow
PWWF	Peak wet weather flow
RAS	Return activated sludge

RW	Recycled Water
SLR	Solids loading rate
SRT	Solids retention time
Time-weighted composite	Collection of individual samples of a fixed volume obtained at regular intervals. The individual samples are combined, and the combined sample is tested.
TS	Total solids
TSR	Total solids residue
WAS	Waste activated sludge

8. Governance

Role	Title
Group	Engineering and Technical Services, Asset Lifecycle
Owner	Engineering Manager
Authors	Ashley Smith (Lead Process Engineer)
Contributors & Reviewers	Alex Robertson (A/Lead Process Engineer), William Wu (Process Engineer), Hannah Lockie, Django Secombe, Castor Rajanayagam, Jason Sylvester, Louisa Vorreiter, Kandiah Vasanthan, Susan Kitching, Julian Briggs

8.1 Feedback and Updates

This guideline was developed with input from stakeholders and will continue to be refined with user input. For any feedback or suggested improvements to this guideline, send an email as follows:

Email address	WastewaterTreatmentAssetStandards@sydneywater.com.au
Subject	WWT0.1 Planning Guidelines: *Insert reference to section or topic*

This feedback capture email address is for informing the refinement of entire suite of wastewater treatment asset guidelines and standards (when fully developed).

Email account will be checked only periodically. Please do not expect an email reply.

8.2 Scheduled review

Proposed timetable for review of this guideline for improvement and to maintain currency is as follows:

Review #	Proposed timing
First review	February 2022 (18 months from first publish)
Second review	June 2024 (3 years from second publish)
Subsequent reviews	Every three to five years

Review of guidelines may be brought forward subject to criticality of improvement needs.

9. Appendices

Appendix 1 Basis of Planning Template

Refer to external Word Document.

Appendix 2 Methodologies for Input Data Collection and Analysis

A2.1 Collection of input data

Location	The monitoring location is an important consideration when requesting campaign monitoring. An incorrectly specified monitoring location will result in irrelevant data, or unnecessary manipulation of the data, for the generation of the influent specifications. When selecting a monitoring location (from HYDSTRA, EKAMS, or for campaign monitoring) consider the following: ▪ Type of data required (flow, concentration, mass) ▪ Number of samples or monitoring period ▪ Monitoring method (composite, grab, or online measurement) ▪ Risk of ragging or blockages of sampler ▪ Location of return streams to avoid “double counting” ▪ Location tanker discharge points ▪ Impact of the upstream and downstream processes and equipment on the sample such as continuous or batch processing, offline equipment or processes ▪ Time required to collect the specified number of samples ▪ Accessibility and safety risks in collecting the sample ▪ Alternative monitoring locations ▪ Mixing and hydraulic characteristics of the collection point, including water depth and conduit dimensions ▪ Any factors which can contaminate the sample or adversely affect the collection of the sample
Instrumentation and technology	Flow meters can experience hysteresis where the accuracy of the meter deteriorates overtime. This results in systematic errors in measurement and thus re-calibration is of the instrument is needed. Ensure that the flow meter is properly calibrated before the starting of the flow data collection. Flow meters have a measurement range. This range can be due to the design of the conduit in which it measures, for example the maximum water level in a Parshall flume; or from the sensitivity of the measurement instrument within the flow meter. Autosamplers have a sample/intake interval which can be adjusted. Consider the impact of the intake interval and the length of the intake tube required to reach the sampling location (see monitoring interval section below).

Manual sampling methods	Consider the impact and limitations of manual sampling methods when conducting campaign monitoring. Common sampling methods include the following: ▪ **Time-based**: The individual samples that make up the composite sample have equal volume. Therefore, the individual samples have an equal impact on the measurement of the composite sample. As a result, a time-based composite sample can be distorted by outliers. ▪ **Flow-weighted**: The individual samples that make up the composite sample have a volume that is proportioned to the flow rate at the time of their collection. As a result, a flow-weighted composite sample is less sensitive to outliers. Further, an accurate representation of the mass load can be obtained when multiplying the concentration of the flow-weighted composite sample with total volume. ▪ **Grab**: A sample that reflects the wastewater characteristics only at the point in time that the sample was collected. Grab samples are suitable for determining diurnal patterns but are unsuitable to be used for calculating mass loads. The number of grab samples and type of analysis conducted on the grab sample must be suitable for level of assessment or planning. ▪ Consider the value of installing online monitoring for long-term campaign monitoring programs.
Monitoring interval	The monitoring interval and period should reflect the inputs needed for the project. It is important to note that composite samples are affected by the sampling interval. In most scenarios, 15 minutes is recommended. The selection of the time interval should be evaluated according to the conditions of the sampling location. For example, the interval can be increased to 20 minutes if the distance between the intake point and the compositing equipment adversely affects the collection mechanism. For grab samples the time of the grab sample should take into consideration of the local conditions of the plant.

A2.2 Wastewater fractionation

Table 9-1 Example of a Table Representation of the Influent Fractionation Inputs

Parameter	Symbol	Example Value
Fraction of readily biodegradable COD that is VFA	F_{ac}	0.097
Fraction of total influent COD that is readily biodegradable	F_{bs}	0.232
Fraction of total influent COD that is soluble unbiodegradable	F_{us}	0.051
Fraction of total influent COD that is particulate unbiodegradable	F_{up}	0.180
Fraction of influent TKN that is free and saline ammonia	F_{na}	0.777
Fraction of influent TKN that unbiodegradable and soluble	F_{nous}	0.020
N content of the particulate unbiodegradable influent COD	F_{upn}	0.068
Fraction of slowly biodegradable COD that is particulate	F_{XSP}	0.750
Fraction of biodegradable organic TKN that is particulate	F_{nox}	0.626
Fraction of influent TP that is ortho-phosphate	F_{SPO4}	0.733
P content of the particulate unbiodegradable influent COD	F_{upP}	0.025
P content of the influent soluble unbiodegradable influent COD	F_{SPI}	0.067
Fraction of the biodegradable organic influent TP which is particulate	F_{XPB}	0.250

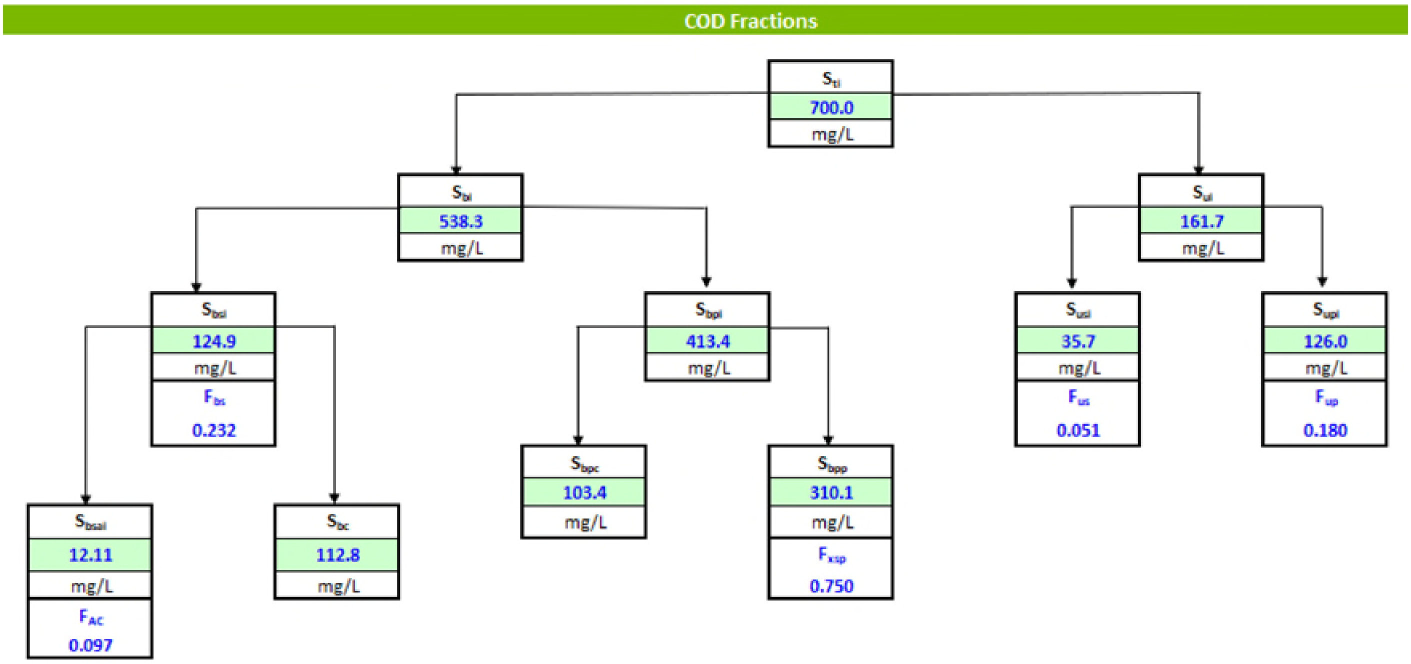


Table 9-2 Example of a Graphical Representation of the Influent Fractionation For COD

Appendix 3 Sludge Yield Calculations

Sludge yield calculations are based on the steady-state activated sludge model. This model is suitable for high-level activated sludge system sizing, and subsequent oxygen demand calculations (for if nitrogen specifications and internal reactor configuration is defined).

The steady-state model can also be used for cross-checking and validation of dynamic model outputs (e.g. BioWin). Further, during early stages of dynamic model creation, the steady-state model can be used to generate the starting sizing inputs for the system. This improves the overall efficiency of process modelling task as the low-detail, but governing parameters, are well-defined before detailed optimisation, system analysis, parameter calibration, and model tweaking. Sizing inputs include reactor volumes and sludge distribution, internal recycle rates, settling tank sizing (surface area), aeration system size etc.

Reference is made to the following resource: *Ekama (2008), Chapter 4, Biological Wastewater Treatment: Principles, Modelling and Design. Edited by M. Henze, M.C.M. van oosdrecht, G.A. Ekama and D. Brdjanovic. ISBN: 9781843391883. Published by IWA Publishing, London, UK*

The calculation procedure to determine system sludge mass is provided in equations 1 to 8 below. The definitions and standard literature values for the model parameters in these equations are provided in Table 9-3.

Note that these equations are only suitable for conventional activated sludge removal systems (e.g. MLE, 4-stage). They do not apply to biologically enhanced phosphorous removal (BEPR) systems as these BNR systems include additional biological colonies (i.e. phosphorous accumulating organisms) which necessitate a different activated sludge model and hence different calculation procedures.

Mass of volatile suspended solids (kgVSS) in activated sludge system = MX_v

$$MX_v = MX_{BHv} + MX_{EHv} + MX_{Iv} \quad (1)$$

$$MX_{BHv} = FS_{bi}\frac{Y_{Hv}SRT}{1+b_hSRT} = FS_{ti}(1-f_{us}-f_{up})\frac{Y_{Hv}SRT}{1+b_hSRT} \quad (2)$$

$$MX_{EHv} = f_h b_h MX_{BHv} SRT \quad (3)$$

$$MX_{Iv} = \frac{FX_{Ii}}{f_{cv}}SRT = FS_{ti}\frac{f_{up}}{f_{cv}}\mathrm{SRT} \quad (4)$$

Mass of total suspended solids (kgTSS) in activated sludge system = MX_t

$$MX_t = MX_v + MX_{IO} \quad (5)$$

$$MX_{IO} = FX_{IOi}SRT + f_{iOHO}MX_{BHv}\ (see\ note) \quad (6)$$

Unit sludge yield

$$Unit\ Sludge\ Yield = \frac{MX_v\ @\ Selected\ SRT}{FS_{ti}} \quad (7)$$

Active fraction of sludge with respect to VSS = f_{av}

$$f_{av} = \frac{MX_{BHv}}{MX_v} \quad (8)$$

Note: $f_{iOHO}MX_{BHv}$ term accounts for intracellular dissolved solids which precipitate from OHOs when a sludge sample is dried during the TSS test procedure. This ISS is a “virtual ISS mass” and should not be counted for reactor sizing. However, as this ISS mass has always been implicitly included in TSS results in the past, it should be retained when sizing secondary settling tanks with state-point analysis models as these design procedures were developed based on measured TSS results.

Table 9-3 Sludge yield model parameters

Symbol	Definition	Units	Standard Value
FS_{ti}	Influent Total COD Loading	kgCOD/d	Site specific
FS_{bi}	Influent Total Biodegradable COD	kgCOD/d	Fractionation specific
FX_{Ii}	Influent Unbiodegradable COD	kgCOD/d	Fractionation specific
f_{us}	Unbiodegradable soluble COD fraction	-	Fractionation specific
f_{up}	Unbiodegradable particulate COD fraction	-	Fractionation specific
f_h	Endogenous residue fraction	-	0.20
f_{cv}	COD to VSS ratio of sludge	kgVSS/kgCOD	1.48
f_{iOHO}	Precipitated ISS content of OHO's (biomass)	kgISS/kgVSS	0.15
Y_{Hv}	Specific yield coefficient	kgVSS/kgCOD	0.45
B_h	Endogenous respiration rate	/d	0.24 @ 20°C (B_{H20}) $B_{Ht} = B_{H20}\Theta^{(T-20)}$ where $\Theta = 1.024$
SRT	Solids retention time	D	Site specific
MX_V	Mass of volatile suspended solids	kgVSS	Site specific
MX_{IO}	Mass of inorganic suspended solids	kgISS	Site specific
MX_t	Mass of total suspended solids	kgTSS	Site specific
MX_{BHv}	Mass of activate OHO biomass	kgVSS	Site specific
MX_{EHv}	Mass of endogenous OHO biomass (non-activate biomass)	kgVSS	Site specific
MX_{Iv}	Mass of unbiodegradable organics VSS	kgVSS	Site specific