Safety in facilities design guidelines

DP-11

Ver. 1

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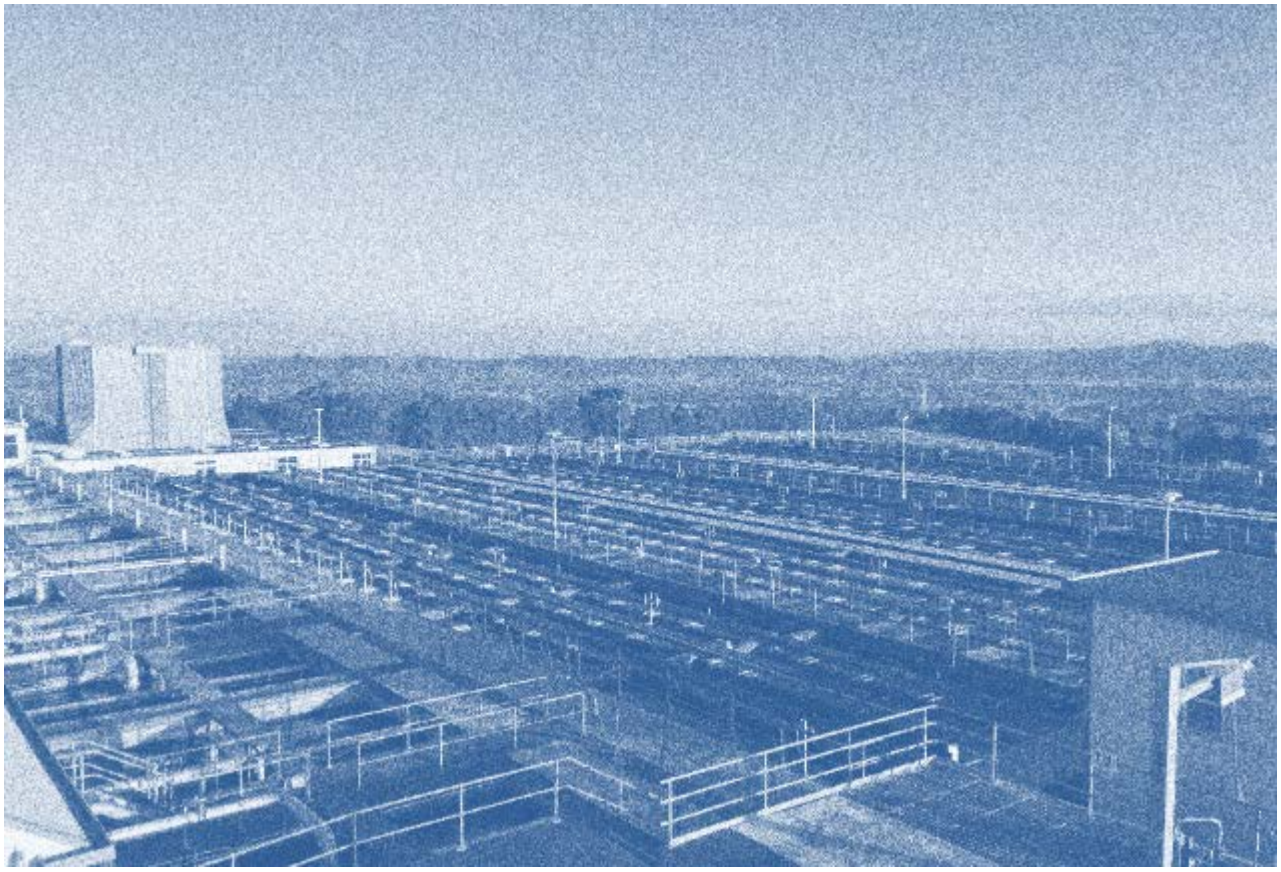

Revision	Description	Released by	Date
0.1	Working draft	J de Villiers	25/03/2020
1	First release. No changes	J de Villiers	15/6/2020

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Definitions and abbreviations

CSE	Confined space entry
dbA	Decibels with weighing "A" for human perceived loudness
HVAC	Heating and ventilation air conditioning
kg	kilogram
LED	Light emitting diode
MCC	Motor control centre
MSD	Materials safety data sheet
SCADA	Supervisory control and data acquisition system (networked control system)
VSD	Variable speed drive

1. Introduction

This guide describes provide a summary of good design practices for operability and safety at Watercare facilities, and is an extension to the Watercare Safety in Design guidelines (DP-10). These practices are intended to guide designers in the layout and features and the relationship of elements within facilities.

2. Accessibility

2.1 Confined spaces

Improved accessibility at facilities has multiple benefits that range from reducing workplace hazards to higher worker efficiencies for both construction and maintenance.

Traditional design approaches have equipment located in confined spaces. This ranges from penstocks and isolation valves located in liquid-filled channels, to chemical injection points into a pipe at the bottom of an access chamber. Under current safety codes these are designated as confined equipment spaces. Access, regardless of intent or duration, requires the following:

- All workers have up-to-date CSE training certified by a third party
- A certified extraction team with appropriate equipment support needs to attend the entry
- A plan for each entry, including a hazard assessment and contingency planning, needs to be prepared, submitted, and reviewed prior to the CSE being approved.

The objective is to eliminate confined equipment spaces in process facilities wherever possible.

2.2 Identify restricted areas or areas requiring special permits or training

Signage is required to indicate areas where there is excessive noise or chemicals are stored. These areas may be separated from general areas by soundproof doors or other permanent barrier. Special permits or equipment/training may be required for entry into these areas.

Additionally, access may be controlled through security systems requiring keypad codes, swipe or proximity cards.

2.3 Ladders and stairways

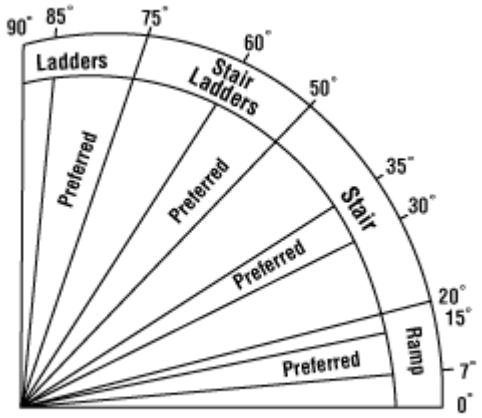
Fixed ladders have long been used as a compact and inexpensive method of accessing two levels. Worker injuries have led to restrictions on ladders that include:

- Mandatory three points of continuous contact: two hands plus one foot (this precludes a worker carrying a toolbox).
- Safety cages.
- Multiple intermediate platforms.
- Mandatory fall protection training.

Despite these changes, fixed ladders remain a potential worker hazard. Multiple attachment points between the ladder rail and the wall make three-point contact difficult. In addition flat bar rails are uncomfortable for hands under tension: workers tend to grab the steps with their hands rather than slide their hands on the rails. Safety cages are often considered more psychological than physical. Fall protection (with a lanyard) while climbing a ladder is often considered impractical by workers.

The objective in facility design is to eliminate the use of fixed ladders, particularly in dry areas, such as for pits, chambers, equipment platforms and chemical storage tanks.

Where stairways are installed in lieu of ladders they should be at an angle of no more than 50° but ideally no more than 35°. Handrails shall comply with Watercare's standard details for (1) restricted areas and (2) those areas open to the public. Ramps should be considered where heavy equipment is installed. If ramps are not feasible then appropriate lifting arrangements shall be considered. Scissor lifts may be a good option where space permits.



Slope and Type of Structure

2.4 Design of vehicle access ways and manoeuvring areas

Facilities requiring truck access shall have adequate access areas for vehicles entering and leaving the site. This may include turn-around space and building access appropriate for the facility i.e. where pumps are periodically overhauled off-site there will be access right up to appropriately sized doors with consideration to lifting equipment used. Fencing and bollards may be used to limit these areas or avoid unintended access (reversing into walls, installed equipment or driving off retaining walls).

3. Workplace Safety

3.1 Noise levels

Ambient noise levels above 85dbA require signage advising the entrant to wear hearing protection. When properly worn, this reduces the risk of damage to hearing. However hearing protection by its nature inhibits communications between workers. This increases the time, cost and safety risk of on-site maintenance personnel. Without good verbal communications, safety alerts are compromised.

The objective is to procure equipment with a maximum noise level of 80dbA. This will keep ambient noise levels below 82dbA without intensive acoustic treatment of the room. Noise enclosures are not preferred as they inhibit maintenance and inspection.

3.2 Chemical contact and chemical fumes

The traditional approach has been to equip workers with protective clothing when performing maintenance on chemical feed equipment. To manage fume hazards by dilution through ventilation, and/or by exhausting the fumes to the exterior away from personnel. There are several concerns with this approach:

- Protective equipment (such as for strong acids) is bulky and movement-restrictive. This makes maintenance less efficient.

- Dilution is no longer considered as a preferred approach to treatment of chemical fumes. In part due to the lack of understanding of low exposures on humans and the environment, and in part due to the increased energy consumption.

Where chemicals are used, consideration must be given to the handling, storage use (mixing or dosing) and disposal (packaging, containers and residues) of the chemicals, as well as safety facilities such as emergency showers, eye wash stations and MSD information.

The objective is to contain fumes within the chemical storage system, and to scrub any fumes prior to discharge to the environment. Where chemical metering equipment is to be taken out of service for maintenance, a purging system should be provided to flush the chemical out of the equipment prior to maintenance.

3.3 Minimizing rooms and maximising sightlines

Increasing the number of rooms within a process facility has significant capital cost implications:

- Room-based access and egress needs for code compliance.
- Separate systems for HVAC, electrics and lighting.
- Increased footprint to accommodate pathways blocked by walls.

There are compelling reasons to house certain equipment in their own room, such as security and electrical safety. However many process functions can be housed in a single larger room so long as noise, fumes, and safety are controlled. Larger rooms are inherently safer due to better visual sightlines and lower in cost due to shared services.

The objective is to reduce walls and door access by addressing the objectives noted previously to create larger, light filled spaces which are easier to manoeuvre within during construction and operation.

3.4 Fire Safety

Fire safety considerations are to be part of the design:

- Access and egress routes.
- Illuminated signage.
- Maximum fire cell area.
- Need for sprinkler/inert gas in switch-rooms.
- Smoke detection and manual call point system.
- Fire alarm panel location.

Managing fire alarms at Watercare facilities:

- Buildings as defined by the Building Act must be equipped with an acceptable early warning system.
- Facilities not classed as buildings under the Building Act will be assessed based on operational and financial risk.
- Small sites that are of low risk and not housed in a building or significant structure – typically just a standalone control panel, will not be specifically monitored for fire. It is considered that loss of SCADA transmission will trigger a call-out in any event.

3.5 Hazard exposure management and identification

3.5.1 Guards

All rotating, moving or oscillating items shall be fully guarded to comply with the relevant standards and Health and Safety at Work Act. Guards shall be fabricated with inspection ports or shall be fitted with expanded metal sections to allow inspection without having to remove the guards.

All guards shall be designed and fitted with location pins or other suitable devices to ensure the correct positioning of the guard and provide positive fixing. Guards shall not be readily removable.

Grilles, bars or mesh shall be provided behind inspection ports where moving equipment may be reached. Alternatively, interlocks shall be provided to stop equipment in the event that covers are opened. Wherever practicable, maintenance access should be achieved by external access points without the need to remove guards.

3.5.2 Safety signs

Safety signs shall be in a visible location on all approach angles to the equipment. All written signs shall be in English.

Hazards around equipment must be identified. Labelling and identification of equipment, services and the like at facilities (NZS 5807 - Code of Practice for Industrial Identification by Colour, Wording and Other Coding.)

All equipment shall be provided with permanently fixed nameplates or labels. The equipment weight shall be indicated on the nameplate for major equipment items.

3.5.3 Safety interlocks

All mechanical equipment must have lockable devices installed (i.e. switches, valve locks) which allow for physical locking of the equipment where stored energy may cause harm. Mechanical safety interlock devices shall be installed and tested in accordance with the product supplier's requirements.

3.5.4 Protection barriers

Protection barriers shall be installed where moving equipment and vehicles are in regular operation. Barriers include:

- Bollards around building corners and entrances.
- Fencing and chains to restrict operators, other vehicles or equipment entering the operation area.
- Light beams.
- Pressure pads.
- Speed humps.
- Cargo restraints and barriers.

3.5.5 Lifting equipment

Lifting devices shall be painted safety yellow (BS5252 – 08 E51) and the load capacity clearly visible and readable from the nearest normal working platform or floor.

Lifting equipment shall be certified. Adequate space allowance shall be provided where mobile lifting plant is needed to operate.

3.5.6 Layers of protection assessment (LOPA)

The LOPA method is to determine the safety integrity level (SIL) of elements and functions within a Safety instrument systems. This is in addition to any HAZOP and CHAZOP.

Layers of protection categories:

Independent protection layers (IPL's) are devices, systems or actions capable of preventing an undesired consequence. The probability of failure on demand (PFD) of and IPL is determined as described by IEC 61511.

According to the calculated SIL, risk reduction factors are related as defined by IEC 61508 as follows:

SIL	**Probability of failure on demand (PFD)** Scale 0 – 1 0 – Control fully effective 1 – Control not effective	**Risk reduction factor (RRF)**
1	0.1 – 0.01	10- 100
2	0.01 - 0.001	100 - 1000
3	0.001 - 0.0001	1000 – 10,000
4	0.0001 - 0.00001	10,000 – 100,000

Where the RRF is between 1 and 10, SIL-A is assigned as a transitional level to potentially assign a specific risk reduction level. This decision is a process specific decision by Watercare as it is outside the scope of IEC 61511 and does not require any safety instrument systems.

PFD's for IPL's:

IPL – Independent protection layer	**PFD – Probability of failure on demand**
Inspection and testing	Considered effect on

IPL – Independent protection layer	PFD – Probability of failure on demand
	individual IPL's to the related PFD
Basic process control system	0.1
Critical alarms and operator response	0.2 – 0.5
Safety instrument function (sensor, logic solver) – interlocks	0.001 – 0.1 (based on SIL)
Secondary containment	0.01 – 0.1 (Based on bund condition)
Level control	0.1
Pressure control	0.1
Pressure relief devices	0.01 – 0.1 (based on device and service conditions)
Gas detection	0.1
Emergency response (e.g. evacuation)	0.1 – 0.8 (based on individual situations)
Preventative maintenance	0.1
Material selection e.g. double seals, higher corrosion protection	0.001 - 0.01

4. Improved constructability, operability and maintainability

4.1 Ergonomic design of pipework

Valve hand-wheels and valve spindles shall be positioned so that they can be operated (manually or with actuator) without potential for injury. Positioning of lifting points shall consider use of appropriate craneage.

4.2 Manhole covers and lids

Where covers and lids are not hinged consideration shall be given to the maximum weight (20kg) for manual lifting or tools required for removal. Assessment of the need for manhole safety grilles shall be undertaken. Some larger hatch covers will require the provision of barriers when open (e.g. McBerns style lids). Standard Watercare design for hatches include securable struts to hold the cover open.

4.3 Flooring systems

Consideration of the need for non-slip floor coatings and stair treads. Avoid abrupt changes in floor level or gaps in gratings. Gratings must be secured with proprietary fixings.

4.4 Vertical removal of heavy equipment

In process areas, it is preferable that equipment weighing more than 15kg should be located such that it can be installed/removed vertically. Overhead lifting devices, such as bridge cranes or monorails should be able to transfer equipment to a loading dock or truck. Where floor-based devices such as trolley hoists would be used, the facility should have a simple pathway to move the removed component to a loading dock or truck bed.

This approach to facility design will improve both the constructability as well as maintenance. Valves (and other moving process equipment) heavier than 15kg should only be installed in horizontal piping.

Where craneage and anchor points are provided consideration must be given to how they are certified/ inspected periodically.

4.5 Reliable and maintainable lightning

Every light fixture should be accessible (for bulb replacement, cleaning, and aiming) by a maintenance worker using a standard 2.5m stepladder, resting on a solid floor. Ceiling lights should be limited to skylights. Where a travelling bridge crane is installed over a large process equipment area, the motorised hoist trolley should be equipped with an LED spotlight to illuminate the area below the hoist whenever the crane hoist is powered. LED-type bulbs should be used in all fixtures where available.

4.6 Working at height

Consider elimination (i.e. hinged poles for lowering radio aerial) or safe means of access. Examples include replacement of lighting elements, ventilation ducting and cable tray, monorail trolleys and gantry cranes, radio and lightning conductors, roof repairs and maintenance.

5. Energy footprint approaches in an era of rapid technological change

There are multiple regulations, codes, standards, and manuals of practice that dictate or influence the design of facilities. At issue is the effort required to keep these standards current during periods of rapid technological change. Most of these documents are highly collaborative in their development, and many require multiple layers of review before issuing. Updates are often facing obsolescence soon after acceptance. This is particularly true in terms of building layout, and in energy consumption.

5.1 Power management

In sites where high voltage transformers are installed signage and locked gates will restrict access to authorised personnel. Where switch gear with high voltage bus bars are installed then signage and fixed panels will limit access. Appropriate spacing around switchboards and MCCs for future maintenance shall be provided.

Provision of emergency stops at local control centres shall be provided.

Energised equipment (electric, pneumatic, hydraulic) need to be provided with means of de-energising and/or isolation.

Radiation sources (UV, microwave and laser) needs to be isolated from frequently accessed areas.

The wide availability of thyristor-type variable speed drives has led to their increased use. It is not uncommon to see multiple-pump facilities with every pump being controlled by a VSD. Even in cases where minimum flow rates are always greater than that of a single pump and head variations are minimal. Under these conditions, fixed speed pumps offer at least a 5% improvement in wire-to-water efficiency. In addition, fixed speed units are lower in cost, have longer life expectancies, and the electrics do not require air conditioned environments. Where there are multiple operating pumps or blowers in a facility, attempts should be made to minimise the use of VSD's.

5.2 Illumination

Also refer to section 3.2.

As process plant technologies have evolved, the staffing levels of process areas have been declining. Modern SCADA systems allow process control and monitoring from remote locations such that occupancy levels are steadily reducing. Equipment maintenance has become more predictable so that both minor and major maintenance can be scheduled in advance, and usually can be carried out in daylight hours. This provides opportunities to reduce the expenditure on lighting:

- The use of natural lighting (in particular skylights) can often provide sufficient lighting levels for safe access during daylight hours. This can allow supplementary access lights to be controlled by photocell, and task lighting to be activated either manually/timer or by motion sensors.
- Lighting levels in rarely used enclosed areas (such as an emergency exit corridor) is often provided at office-type lumen levels. It may be appropriate to reduce these levels to the minimum required for safety.
- Office area illumination levels were developed in the era of paper and pencils on tables. The transition to flat panels, projectors and whiteboards, renders direct overhead lighting somewhat inappropriate. Lighting in these areas should be diffused and have adjustable intensities to suit usage.

5.3 Ventilation

Design guides for ventilation rates are often intended to control fume levels by dilution (with fresh air) and dispersion (to the outside) environment. Modern technologies have developed lower volatility chemistry, superior odour containment and simple fume extraction systems. In addition, analytical equipment to detect fumes and trigger ventilation systems have become much more advanced in recent years. It is recommended that ventilation systems be modulated based on hazard and occupancy, and be capable of operating at low flow rates regardless of stipulated minimums in design guides and practices.

6. Welfare Facilities

Welfare facilities should include:

- Toilet and washroom facilities are typically required for larger pump stations and treatment plants.
- Decontamination facilities of personnel and equipment.
- Water supplies in Wastewater facilities are required to have backflow preventers that require annual certification.
- In areas with process water or recycled water supplies these shall be marked as non-potable.
- Where chemicals are stored and handled a safety shower or eyewash station is required.
- In some cases a lunchroom, laboratory or office may be required.

6.1 Toilets and washroom facilities

Depending on the facility type, the hours personnel spend at the facility and the operational practices or activities undertaken at the site, the following items should be considered:

- Lockers or storage areas for storing personal items.
- Gender appropriate toilet facilities.
- Shower facilities that allows personnel to clean and not distribute potential contaminants.
- Soap or wash solutions with cleaning cloths and towels for drying.
- Labelling of facilities.

- Bins or containers to dispose of waste material such as paper hand towels.

6.2 Decontamination facilities

Decontamination protects workers from hazardous substances that may contaminate and eventually permeate the protective clothing, respiratory equipment, tools, vehicles, and other equipment used on site; it protects all site personnel by minimizing the transfer of harmful materials into clean areas; it helps prevent mixing of incompatible chemicals; and it protects the community by preventing uncontrolled transportation of contaminants from the site.

Decontamination zones should be provided in contamination reduction zones which are areas between the exclusion zone (contaminated area) and the support zone (clean area).

Decontamination measures include but are not limited to:

a) Prevention – appropriate clothing, encasement, protection monitoring, air scrubbing and work practices.
b) Removal – appropriate containment and removal stations setup that may include clothing disposal, decontamination solutions, scrubbing implements, breathing equipment, washing and rinsing facilities, towels and replacement garments.
c) Testing – Reliability test on decontamination methods should be performed periodically to ensure effectiveness. These tests may include visual observation, sampling and laboratory analysis.

6.3 Water supplies

Water supplies should be to Watercare's connection standards to provide clean and safe water for consumption and cleaning. Process water must be kept separate from drinking or personnel washing facilities.

6.4 Safety showers

Safety shower should have an appropriate design to meet AS4775 and of materials suitable to the installation environment to prevent corrosion or function deterioration.

The layout should consider:

- Sited in suitable, accessible locations.
- Staff awareness of equipment location and with appropriate signage.

6.5 Personnel spaces and support zones

The location of personnel spaces such as lunchrooms, break rooms and control rooms must be considered in conjunction with the macro environmental influences such as but not limited to:

- Air quality and temperature.
- Wind direction and the potential direction of gasses.
- Distance and location from chemical storage.
- Lightning.
- Noise and vibration levels location of chemical or the direction of gasses.
- Prevention from direct entry to support zones from exclusion zones without passing through the decontamination zone.

The area layouts must be optimised for the particular purpose such as to provide for, but not limited to:

- Suitable seating areas and work platforms.

- Storage and change facilities.
- Areas for food preparation/heating with wash-up facilities.