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Stormwater Management Framework and Good Practice Guidelines for Meat Processing Plants

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EXECUTIVE SUMMARY

These guidelines are the third and final deliverable in a project focused on the management of stormwater in Australian meat processing facilities. The guidelines consolidate and build on the outcomes of the first two stages which include an industry survey of nine facilities; a literature review on current stormwater management compliance requirements for meat processing plants; a review of management practices and technologies that are available to the industry; and lastly, a techno-economic assessment of five commercially available technologies to assist processors to improve stormwater management.

These guidelines have been prepared specifically for use by meat processors and are designed to assist them meet the growing challenges faced by the industry. The guidelines will help processors examine their existing storm water management strategies to determine:

- if they are effectively separating and collecting 'clean', 'dirty' and 'contaminated' stormwater runoff streams and diverting as much runoff as possible away from the plant's WWTS, and
- if existing treatment methods are effectively designed, operated and maintained.

The guidelines provide information on possible alternatives or additions to the treatment train to improve the removal of both particulate and soluble pollutants and the management of intense rainfall events. Emphasis has been placed on low impact technologies that help to preserve and restore natural hydrologic processes. These guidelines have been divided into six main sections which provide:

- the types and load of pollutants typically found in stormwater runoff from meat processing plants and strategies utilised to treat, reuse and dispose of runoff.
- a series of worksheets to help determine **what** current strategies are employed to separate and collect, manage and treat runoff and identify possible opportunities for improvement.
- a series of worksheets to help determine if the current technologies used to **separate and collect** stormwater runoff are **working effectively** and identify opportunities for improvement.
- a series of worksheets to assist meat processors determine if the current technologies used to **treat** stormwater are **working effectively** and identify opportunities for improvement.
- information on treatment technologies in terms of their pollutant removal effectiveness, site requirements and costs to assist meat processors compare and consider alternative treatment technologies or possible additions to existing treatment trains.
- give an indication of the financial benefits of directing runoff away from wastewater treatment systems (WWTS).

There is no one-size-fits-all solution for stormwater management or treatment. A tailored on-site solution is required. In this regard, best practice can be considered as that which has a no worsening effect on the receiving environment. The information provided will help processors identify where possible improvements can be made. In many instances, the services of an expert in stormwater design and management will be required.

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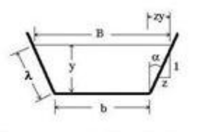
DEFINITIONS

TERM	DEFINITION OR ABBREVIATION
Annual Exceedance Probability (AEP)	The probability that a given rainfall total accumulated over a given duration will be exceeded in any one year. E.g. 1% AEP is equivalent to a 1 in 100-year event
Average Recurrence Interval (ARI)	An expression of the likelihood of occurrence E.g. average number of years, between flood events as large as or larger than the design flood event - a 100-year ARI flood will occur on average once every 100-years.
Source	Any building, structure, facility, or installation from which there is or could be a discharge of runoff.
Contaminant	A physical, chemical, biological or radiological substance or matter in the water and is at high enough levels to have a negative effect on human health or on the health of animals or plants.
Clean or uncontaminated runoff	Sources of clean runoff, green spaces or other impervious surfaces that do not come in contact with low levels of containments such as dirt or meat processing contaminants. Clean or uncontaminated water is not usually treated by meat processing plants before being release to water ways, stormwater drains or reuse.
Dirty contaminated runoff	Water from precipitation that has flowed over surfaces with low levels sediment and organic. Sources of dirty water include stock holding pens. Dirty runoff requires on site stormwater or wastewater treatment or collection for reuse.
Contaminated runoff	Water from precipitation that has flowed over surfaces and become contaminated with nutrients organic debris and meat tissue or other animal products including excreta, fats and oils, heavy metals, pathogenic viruses and bacteria, sediment, chemicals from wash down and truck washing and hydrocarbons. Sources of contaminated water include wastewater treatment areas, stock, truck washing, impervious surfaces in contact with meat products, composting or solid waste storage areas, poorly managed treated wastewater irrigation and fuel/chemical storage areas. Contaminated runoff requires on site stormwater or wastewater treatment or collection by a service provider.
Emergent plants	Emergent plants are rooted in soil that is periodically submerged but their leaves and stems extend out of the water.
Ephemeral plants	Ephemeral plants have a short life cycle. They take advantage of short periods of low water.
H:V	Horizontal:Vertical dimension of a slope or channel side e.g. z:1 in diagram below.  Trapezoidal Cross Section
Hydrology	The science dealing with water on the land, or under the earth's surface, its properties, laws, geographical distribution, etc

TERM	DEFINITION OR ABBREVIATION
Hydrological soil Type A	Group A is sand, loamy sand or sandy loam types of soils. It has low runoff potential and high infiltration rates even when thoroughly wetted. They consist chiefly of deep, well to excessively drained sands or gravels and have a high rate of water transmission.
Hydrological soil Type B	Group B is silt loam or loam. It has a moderate infiltration rate when thoroughly wetted and consists chiefly or moderately deep to deep, moderately well to well drained soils with moderately fine to moderately coarse textures.
Hydrological soil Type C	Group C soils are sandy clay loam. They have low infiltration rates when thoroughly wetted and consist chiefly of soils with a layer that impedes downward movement of water and soils with moderately fine to fine structure.
Hydrological soil Type D	Group D soils are clay loam, silty clay loam, sandy clay, silty clay or clay. This HSG has the highest runoff potential. They have very low infiltration rates when thoroughly wetted and consist chiefly of clay soils with a high swelling potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface and shallow soils over nearly impervious material.
Littoral	Pertaining to the shore of a basin or pond.
Macrophyte plant	A macrophyte is an aquatic plant that grows in or near water and is either emergent, submergent, or floating.
Non-point source / diffuse runoff	Non-point source (or diffuse) runoff originates over a large land area without a single point of origin.
Point source runoff	Originate from a single point.
Perennial plants	Plant that lives for more than two years.
Runoff	Precipitation that flows over land as surface water instead of being absorbed into groundwater or evaporating.
Runon	Runoff that flows from another property or area.
Stormwater	Stormwater is water from a precipitation or snow event that infiltrates into the soil, is held on the surface and evaporates, or becomes a runoff flow.
SWTS	Stormwater treatment system
WSUD	Water sensitive urban design
WWTP / WWTS	Wastewater treatment plant/ Waste water treatment system

1.0 BACKGROUND

1.1 Project description

The objective of this project is to review current methods of stormwater runoff management undertaken in abattoirs in Australia and identify best practices for the management of water runoff from abattoirs both in Australia and internationally. Poorly managed runoff can have a significant detrimental environmental impact on nearby surface water bodies and create flooding, amenity and odour issues for meat processing plants. Surface flows may also negatively impact on neighbouring properties. A well-managed facility should firstly prevent or minimise contamination of stormwater runoff and secondly, effectively manage and treat it to prevent contamination of downstream catchment areas. Where practical, runoff can also be utilised as an additional water resource for meat processors.

Phase one of the project included an industry survey of nine facilities (7 abattoirs, 1 hide processor and 1 renderer) to gain an understanding of how facilities are currently managing their runoff and a literature review that focused on current stormwater management compliance requirements for meat processing plants. It also provided a review of current and relevant management practices and technologies that are available both in Australia and internationally.

The second phase of the project undertook a techno-economic assessment of five commercially available technologies to assist processors to improve their stormwater management. On the basis of the survey results, it was decided that the techno-economic evaluation should focus on best practice management stormwater treatment technologies that will assist meat processors to:

- improve the quality of water discharged to receiving environments
- enable step improvement on currently employed technologies
- improve sludge management
- reduce the amount of hard infrastructure needed to convey and treat stormwater
- cope with the uncertainty in the timing and intensity of rainfall events
- encourage reuse of high volume, low nutrient runoff.

The selected technologies were high efficiency sediment basins, trafficable solids trap, denitrifying bioreactors, constructed wetlands and cartridge filters. The assessments included, where available, an indication of capital and operational cost of treatment methods/technologies. Each of these technologies have application to the meat industry within their own limitations. The use of the technology should consider the water quality of the runoff and the required quality of the discharge water.

There is no one-size-fits-all solution for stormwater management or treatment. A tailored on-site solution is required. In this regard, best practice can be considered as that which has a no worsening effect on the receiving environment. This phase of the project presents a framework to assist meat processors to identify a stormwater treatment train that is most appropriate for their site-specific requirements as well as assess their existing treatment system. It provides information to assess whether existing systems are working effectively and defines what is considered good practice in their management and operation. In addition, two case studies are presented which demonstrate the use of the framework and highlight how two meat processors are currently managing runoff at their respective sites.

1.2 Stormwater management challenges facing meat processors

Managing stormwater runoff and minimizing impacts on receiving environments can be complex. Some of the challenges faced by meat processors in managing site stormwater include:

- aging infrastructure, often built when the facility was initially constructed, that is requiring more frequent maintenance. Additions to the plant, such as increased impervious areas, may render existing stormwater infrastructure inadequate for flow volumes and intensities.
- climate change and the associated uncertainty in the timing and intensity of rainfall events making existing infrastructure inadequate to handle increased flows or velocities.
- low priority or lack of funds for the retrofitting or replacement of stormwater assets.
- lack of data on water quality runoff before and after any onsite water treatment.
- limited research of the impacts, if any, of stormwater discharges from meat processing plants into waterbodies or stormwater drains in relation to aquatic and human health.
- tightening of water runoff quality standards.
- potential for uncontrolled discharges due to increases in frequency and intensity of events. This has already contributed to tightening of stormwater regulation in some instances.

Greater attention is being paid to the impact of increased frequency of extreme weather events, flooding and the potential negative impact on site infrastructure and receiving bodies (Walsh, 2012). The site design of many meat processing facilities is based on historical climate conditions and existing infrastructure is often difficult and costly to upgrade or adapt in order to accommodate changing climate patterns. Given that climate models show an expected increase in the frequency of heavy rainfall events, (IPCC, 2012) the impact of these changes should be considered in the selection of stormwater pollution control strategies (Charlesworth, 2010). Climate resilient solutions include:

- applying integrated stormwater quality models in combination with analysis of climate change scenarios (Hathaway, 2014)
- pipe upsizing
- underground storage, and
- biofiltration methods

The removal of dissolved pollutants may receive greater attention in the future. In the past, regulation has largely focused on controlling volumetric discharges and a limited number, if any, of individual parameters. For many meat processing plants stormwater treatment of clean runoff streams has largely focused on the settling of suspended solids and the removal of particulate fractions of pollutants. The focus on individual parameters may increase the adoption of tertiary treatment technologies.

The use of green infrastructure (i.e. natural vegetative cover) has become an integral component of adaptation planning with respect to stormwater management (Gaffin, 2012). Benefits include its ability to be integrated with conventional drainage systems and the costs of green infrastructure relative to conventional infrastructure. For example, Moore et al found bio-infiltration with a substantial upgrade to pipes and storage chambers moderate both flooding and adaptation costs even when implemented over a relatively modest (10 %) portion of the watershed (Moore, 2016). Other benefits can include reduced energy use and recharging of groundwater.

1.3 Stormwater management planning

To achieve best practice in stormwater management it is important to have plans which describe how a system is designed and operated, including defining specific responsibilities and tasks required for maintaining the system. A stormwater management plan should include:

- plans and documentation of the stormwater management system (maps, water flows, information on treatment devices)
- defined water quality objectives (based on environmental values of the receiving environment)
- an assessment of the source of runoff and threats to receiving environment including identification of pollutants
- a description of the system and how stormwater is managed
- defined responsibilities and frequencies for operation and maintenance

Further information on pollutants, water quality objectives and stormwater management and treatment systems at meat processing sites is provided in the following sections.

2.0 HOW TO USE THESE GUIDELINES

These guidelines have been prepared specifically for use by meat processors and are designed to assist them meet the growing challenges faced by the industry. The guidelines will help meat processors examine their existing storm water management strategies to determine:

- if they are effectively separating and collecting 'clean', 'dirty' and 'contaminated' stormwater runoff streams and diverting as much runoff as possible away from the plant's WWTS, and
- if existing treatment methods are effectively designed, operated and maintained.

The guidelines also provide information on possible alternatives or additions to the treatment train to improve the removal of both particulate and soluble pollutants and/or the management of intense rainfall events. Emphasis has been placed on low impact technologies that help to preserve and restore natural hydrologic processes.

Opportunities identified (particularly design aspects) may require further assistance and advice of engineering consultants.

These guidelines have been divided into six main sections.

- Section 3: Defines the types and load of pollutants typically found in stormwater runoff from meat processing plants and strategies utilised to treat, reuse and dispose of stormwater runoff.
- Section 4: Provides a series of worksheets to help determine ***what*** current strategies are employed to separate and collect, manage and treat stormwater runoff and identify possible opportunities for improvement.
- Section 5: Provides a series of worksheets to help determine if the current technologies used to *separate and collect* stormwater runoff are ***working effectively*** and identify opportunities for improvement.
- Section 6: Provides a series of worksheets to assist meat processors determine if the current technologies used to ***treat*** stormwater are ***working effectively*** and identify opportunities for improvement.
- Section 7: Provides a table of stormwater treatment technologies in terms of their pollutant removal effectiveness, site requirements and costs to assist meat processors compare and consider alternative treatment technologies or possible additions to existing treatment trains.
- Section 8: This section gives an indication of the financial benefits of directing stormwater away from a wastewater treatment system (WWTS).

Figure 1 shows the Stormwater Management Framework which can be used to assess stormwater management at meat processing sites. The framework provides an overview of the sources of stormwater, management and design aspects, potential treatment technologies and opportunities for improvement.

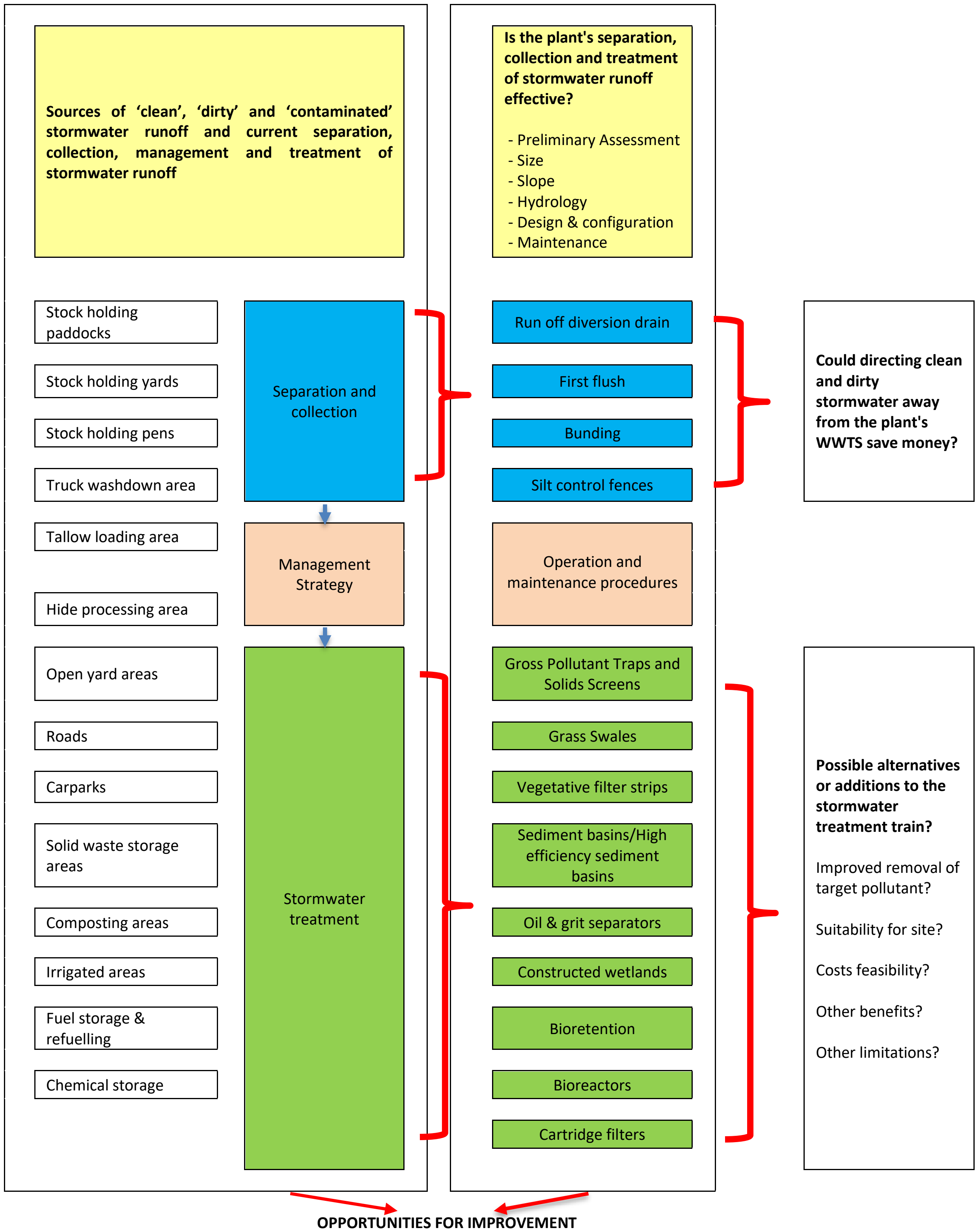


Figure 1: Framework for assessing stormwater management at meat processing sites

Reference documents

The following key reference documents were used to develop the design, operation and maintenance aspects provided in the various worksheets. Additional references are included at the end of this document.

- Brisbane City Council. (2006). Draft Water Sensitive Urban Design Engineering Guidelines.
- Catchment and Creeks Pty Ltd. (2012). Erosion and Sediment Control: A Field Guide for Construction Managers.
- Maine Government. (2017). Maine Stormwater Best Practices Manual. Maine Department of Environmental Protection
- Massachusetts Department of Energy and Environmental Affairs. (2008). Volume 2 Chapter 2: Structural BMP Specifications for the Massachusetts Stormwater Handbook.
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- WA Government - Department of Water. (2007). Stormwater Management Manual for Western Australia - Structural Controls.

3.0 POLLUTANTS AND STRATEGIES CONSIDERED IN THIS STORMWATER TREATMENT FRAMEWORK

3.1 Pollutants typically found in runoff from meat processing plants

As stormwater runoff moves across impervious surfaces it can become 'dirty' or 'contaminated' with a variety of pollutants. The following is a brief description of these groups of pollutants, including typical sources.

Gross pollutants

Gross pollutants such as litter and organic debris including natural vegetation, manure, oils and grease as well as coarse sediment are typically removed using *primary treatment* methods such as screens or filters. They are generally considered low risk.

Table 1: Sources of gross pollutants from meat processing plants (MLA & AMPC, 2003)

Pollutant	Source
Course sediment	Stock yards and pens, truck wash down areas and areas irrigated areas
Organic debris	Stock yards, pens and loading ramps
Litter	Carparks and roads, open areas, loading docks

Suspended matter

Suspended matter can include solidified oils and fine sediment which are typically removed using *secondary treatment* methods such as sedimentation or the skimming of surfaces to remove floating materials.

Table 2: Sources of suspended matter from meat processing plants (MLA & AMPC, 2003)

Pollutant	Source
Fine sediment	Stock yards and pens, truck wash down areas and areas irrigated with treated wastewater
Oils	Truck wash areas, roads and carparks, workshops and tallow loading areas

Dissolved pollutants

Dissolved materials include nitrogen and phosphorous, heavy metals, pathogenic bacteria and organic pollutants such as hydrocarbons and are typically removed using *tertiary treatment* methods utilising biological processes such as biofiltration, wetlands or chemical treatment such precipitators and flocculants to remove phosphorous and metals.

Table 3: Sources of dissolved materials from meat processing plants (MLA & AMPC, 2003)

Pollutant	Source
Phosphorous	Stock yards and pens, solid waste storage areas and areas irrigated with treated wastewater
Nitrogen	Stock yards and pens and areas irrigated with treated wastewater
Organic pollutants	Stock yards and pens and solid waste storage areas
Chemicals	Chemical storage areas and truck wash area
Pathogens	Stock yards and pens, open areas, truck wash areas, solid waste storage areas and areas irrigated with treated wastewater
Salt	Stock yards and pens, hide salting and drying areas, salt storage areas

3.2 Typical pollutant load of stormwater runoff from meat processing plants

Very little literature is available on the quality of stormwater runoff from meat processing plants. Table 4 summarises ranges for key water quality parameter, for both wet and dry weather, where available. The data presents an exhaustive review of Australian and worldwide stormwater quality monitoring studies (Fletcher, 2004).

Table 4: Water quality characteristics of stormwater runoff

	TOTAL SUSPENDED SOLIDS (TSS) (mg/l)		OIL AND GREASE (mg/l)		TOTAL PHOSPHORUS (TP) (mg/l)		TOTAL NITROGEN (TP) (mg/l)		FAECAL COLIFORMS (FC) (mg/l)	
Source	**Wet weather**	**Dry weather**	**Wet weather**	**Dry weather**	**Wet weather**	**Dry weather**	**Wet weather**	**Dry weather**	**Wet weather**	**Dry weather**
Rural	20-400 Typical 90	5-40 Typical 14	3-100 Typical 17		0.08-0.6 Typical 0.22	0.02-0.2 Typical 0.06	0.7-6 Typical 2	0.4-2 Typical 0.9	20-20 000 Typical 600	3-3000 Typical 100
Roads	90-800 Typical 270				0.15-1.5 Typical 0.5		1-5 Typical 2.2		1700 - 30 000 Typical 7000	
Roofs	5-90 Typical 20				0.06 - 0.3 Typical 0.13		0.7-6 Typical 2		6-600 Typical 60	

3.3 Water quality objectives

State based environmental water quality conditions generally define the water quality objectives for stormwater runoff (CSIRO, 1999). This is combined with specific requirements as defined in individual site environmental licenses. For further information on legislative requirements and examples of license conditions, refer to Milestone 2 of this project - Survey and Literature Review. Table 5 provides an example of water quality objectives which has been adapted from (CSIRO, 1999). These show an indication of best practice performance objectives for urban environments. This information is currently unavailable for meat processing sites.

Table 5: Water quality objectives of stormwater runoff. Adapted from (CSIRO, 1999)

POLLUTANT	RECEIVING WATER OBJECTIVE	CURRENT BEST PRACTICE PERFORMANCE OBJECTIVE (URBAN)	CURRENT BEST PRACTICE PERFORMANCE OBJECTIVE (INDUSTRIAL/MEAT PROCESSING SITE)
Suspended solids (SS)	Comply with SEPP (e.g. not exceed 90th percentile of 80 mg/L)[1]	80% retention of the typical urban annual load	TBD[4]
Total phosphorous (TP)	Comply with SEPP (e.g. base flow concentration not to exceed 0.08 mg/L)[2]	45% retention of the typical urban annual load	TBD
Total nitrogen (TN)	Comply with SEPP (e.g. base flow concentration not to exceed 0.9 mg/L	45% retention of the typical urban annual load	TBD
Litter	Comply with SEPP (e.g. no litter in waterways)[3]	70% reduction of typical urban annual load	TBD
Flows	Maintain flows at pre-development levels	Maintain discharges for the 1.5 year ARI pre-development levels	TBD

[1]An example using SEPP (Waters of Victoria 1988), general surface waters segment.

[2] SEPP Schedule F7—Yarra Catchment—urban waterways for the Yarra River main stream.

[3] Litter is defined as anthropogenic material larger than five millimetres.

[4] To be determined

3.4 Treatment, re-use or disposal strategies utilised by meat processors.

A stormwater treatment train is a sequence of treatment methods that seek to achieve an acceptable quality of water runoff or discharge.

Treatment trains generally include primary, secondary and tertiary treatment with each level having a greater removal efficiency with respect to particle size and targeting specific types of pollutant.

Table 6 summarizes the various stormwater treatment, re-use or disposal strategy utilised by meat processing plants.

Table 6: Stormwater treatment, re-use or disposal strategy utilised by meat processing plants.

SOURCES	FIRST FLUSH COLLECTION	FULLY RETAINED	DIRECTED TO SWT	DIRECTED TO WWTP	CAPTURED AND REUSE
Holding paddocks			♦ Diversion Banks (clean runoff) Grass swale & Vegetative Strip (S) Sediment basin (S) Constructed wetland/Bio-retention Basin (T) Holding pond for reuse (T)		♦ Clean runoff upslope of paddock to well vegetated areas or storage dam
Holding yards	♦ Only for covered & sealed yards		♦ Diversion Banks (clean runoff) Grass swale & Vegetative Strip (S) Sediment basin (S) Constructed wetland/Bio-retention Basin/Bioreactor (T)		♦ Holding pond for reuse after treatment e.g. irrigation
Holding pens				♦ Solids Screen (P)	
Truck washdown	♦ Solids Screen (P) If the area has no roof		♦ (After first flush if the area has no roof) Gross Pollutant Trap (P) Grit and oil separator (S) Cartridge filter (T)	♦ If covered - minimal amount	
Tallow loading	♦ If the area has no roof		♦ (After first flush if the area has no roof) Gross Pollutant Trap (P) Grit and oil separator (S) Cartridge filter (T)	♦ Roofed areas - minimal amount	
Hide processing				♦ Evap. Ponds	
Open yards			♦ *Yards unlikely to be contaminated* Swales for conveying to stormwater drainage network		
			♦ *Workshop maintenance areas* Gross Pollutant Trap (P) Grit and oil separator (S) Cartridge filter (T)	♦ Yards where liquid or solid waste are handled	

SOURCES	FIRST FLUSH COLLECTION	FULLY RETAINED	DIRECTED TO SWT	DIRECTED TO WWTP	CAPTURED AND REUSE
Roads	♦ Sealed roads		♦ *Contaminated roads with piped drainage* Gross Pollutant Trap (P) Oi and-grit separator (S) Cartilage filter (T) *Contaminated roads with open drainage* Screens or grates (P) Grass swales & vegetative strips Sediment basin (S) Bio-retention basins (T)		♦ Holding pond for reuse after treatment (e.g. irrigation)
			♦ *Uncontaminated roads with piped drainage* Gross Pollutant Trap (P) Oi and-grit separator (S) *Uncontaminated roads with open drainage* Grass swales & vegetative strips (S)		♦ Roads in areas where contamination is unlikely can be directed to stormwater dams or well vegetated areas
Carparks	♦ Sealed carparks		♦ *Sealed Carpark with piped drainage* Gross Pollutant Trap (P) Oi and-grit separator (S) Cartridge filter /Bio-retention Basin (T)		♦ Clean runoff upslope of paddock to well vegetated areas or storage dam
			Unsealed carparks Gross Pollutant Trap (P) Vegetative strip & swale downslope (S) Bio-retention Basin (T)		♦ Clean runoff upslope of paddock to well vegetated areas or storage dam
Solid waste storage				♦ Solids Screen	
Composting				♦ Solids Screen	
Irrigated					♦ Runoff from tailings dam irrigated to pasture or vegetative filter strip
Fuel storage & refueling		♦ Containment to prevent stormwater contamination			
Chemical storage		♦ Containment to prevent stormwater contamination			

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4.0 MANAGEMENT OF RUNOFF FROM SOURCES

The section provides a series of worksheets to assist meat processors determine what current strategies are employed to separate and collect, manage and treat stormwater runoff and identify possible opportunities for improvement.

4.1 Stock holding paddocks

Collection and separation		Management & Design		Treatment		Reuse	
Diversion banks to divert clean runoff upslope of paddock to well vegetated areas or storage dam	☐	Not intensively stocked and rotational grazing practiced	☐	Secondary treatment by grass swale used to convey or divert water	☐	Collect dirty runoff in a storage dam for reuse e.g. irrigation	☐
Paddock runoff directed to SWTS	☐	Stock not held in paddocks for long duration	☐	Secondary treatment by vegetative filter strips along edge of drainage lines	☐		
		Good grass cover	☐	Secondary treatment by vegetative filter strips on paddock boundary	☐		
		Stock are excluded from drain lines to prevent damage and grazing	☐	Secondary treatment in sediment basin	☐		
		Vegetative filter strips on the paddock boundary are fenced preventing grazing and trampling by stock	☐	Tertiary treatment in a constructed wetland or bioreactor.	☐		
		Contour banks are used to slow down the velocity of runoff	☐	Tertiary treatment in a bio-retention basin	☐		
		Regularly inspections and maintenance undertaken on diversion banks and drains.	☐				
		Silt control fences are used downslope as a temporary measure when poor cover	☐				

4.2 Stock holding yards

Collection and separation		Management & Design		Treatment		Reuse	
Diversion banks up-slope of holding yards divert dirty runoff around the yards to well vegetated area or storage dam for reuse	☐	Dry cleaning is undertaken where possible to reduce or avoid holding yard hose downs.	☐	Secondary treatment by grass swale	☐	Treated dirty runoff collected for reuse e.g. holding pond for irrigation	☐
Storm water runoff from yards directed to SWTS via a solids screen	☐	Stock not held for long duration	☐	Secondary treatment by vegetative filter strips along edge of drainage lines	☐	Clean roof runoff reused for areas that do not require potable water including stock initial wash, irrigation of paddocks or gardens.	☐
First flush collection of dirty runoff, via a solids screen, in pit or dam off sealed yards only (holding period 5 days)	☐	Limited receival of very dirty stock.	☐	Secondary treatment by vegetative filter strips on yard boundary	☐		
Clean runoff collected from roof in tank or dam, directed to SWTS or redirected to off-site drainage line	☐	Regularly inspections and maintenance is undertaken on drains.	☐	Primary treatment in sediment basin	☐		
First flush collection of roof runoff before storage	☐			Tertiary treatment in a constructed wetland or bioreactor.	☐		
Gradient slopes in the yard's direct dirty runoff to perimeter channel or spoon drains rather than across the yard	☐			Tertiary treatment in a bioreactor	☐		
Yards sealed to prevent excess soil loss in runoff (reinforced turf, concrete or plastic with large voids)	☐			Tertiary treatment in a bio-retention basin	☐		
Roof to limit direct rainfall into the yards	☐						
Clean roof runoff separated from holding yard runoff	☐						
Holding yards are well separated from holding pen's contaminated runoff.	☐						

4.3 Stock holding pens

Collection and separation		Management & Design		Treatment		Reuse	
Diversion banks up-slope of holding pens divert stormwater runoff around the pens	☐	Screening of all hose water and stormwater runoff to remove manure	☐	As covered, stormwater runoff from this area is minimal and directed to the plant's WWTS.	☐	Clean roof runoff reused for areas that do not require potable water including stock initial wash, irrigation of paddocks or gardens.	☐
Runoff directed to the plant's WWTS.	☐	Dry cleaning is undertaken where possible to reduce or avoid holding pen hose downs.	☐				
Clean runoff collected from roof in tank or dam, directed to SWTS or redirected to off-site drainage line	☐	Sufficient head room underneath mesh floors to allow machinery to remove manure.	☐				
First flush collection of roof runoff before storage	☐	Pen floors compacted to a standard which ensures effluent does not infiltrate and contaminate groundwater	☐				
Bunding used to prevent hose water runoff from moving onto other operational areas.	☐	Roof has one-metre overhang for every three metres of height above the bund to prevent rain blowing in to the wash bay or walls or skirts.	☐				
		Mesh floor where possible to allow manure to fall through to dry collection area beneath.	☐				

4.4 Truck washdown areas

Collection and separation		Management & Design		Treatment		Reuse	
Stormwater runoff from this area is minimal as covered and directed to system used to treat washdown water	☐	Excluding the washing of vehicles at the plant has been considered.	☐	As covered stormwater runoff from this area is minimal and directed to the washdown WWTS.	☐	Where practical, roof runoff reused for truck washdown or other operations not requiring potable water.	☐
Diversion system in stormwater pit automatically diverts wash down and first flush from uncovered hardstand areas for treatment. The remainder flows to storm water drains.	☐	Sediment weirs in channels or silt basket regularly inspected and cleaned regularly	☐	Secondary treatment of first flush in washdown WWTS.	☐		
Clean runoff collected from roof in tank or dam, directed to SWTS or redirected to off-site drainage line	☐	Oil separator regularly maintained - sediment cleared and oil/grease collection container emptied.	☐	Secondary treatment of first flush in washdown by an oil and grit separator	☐		
First flush collection of roof runoff before storage	☐	First flush sump or dam emptied within 5 days	☐	Tertiary treatment of first flush in a cartridge filter	☐		
Washing area bunded (roll over bunds at the entry and exit points) to divert washdown and stormwater runoff to collection sump.	☐	Roof has one-metre overhang for every three metres of height above the bund to prevent rain blowing in to the wash bay or walls or skirts.	☐				
Stormwater inlet pit fitted with gross pollutant and sediment traps (grated screen and weirs in channels/silt baskets)	☐	Floor surface material has low permeability to assist in water collection and to reduce the absorption of chemicals	☐				
Roof to limit direct rainfall into the washdown area	☐	Regularly inspections and maintenance is undertaken on drains.	☐				
Stormwater drain can be isolated with a cut-off valve when trucks are being washed.	☐						
The cut off valve is kept closed at all times except after the first flush has been collected.	☐						
Washdown area graded to drain.	☐						

4.5 Tallow loading areas

Collection and separation		Management & Design		Treatment		Reuse	
Stormwater runoff from this area is minimal as covered and directed to the plant's WWTS.	☐	Good work practices reduce spills in tallow loading areas	☐	As covered stormwater runoff from this area is minimal and directed to the washdown WWTS.	☐	Where practical, roof runoff reused for operations not requiring potable water.	☐
Diversion system in stormwater pit automatically diverts any wash down water, spills and first flush water from uncovered areas to the plant's WWTS. The remainder flows to storm water drains.	☐	Procedure in place to ensure any spills are removed promptly.	☐	Treatment of first flush in plant's WWTS	☐		
Clean runoff collected from roof in tank or dam, directed to SWTS or redirected to off-site drainage line	☐	First flush sump or dam emptied within 5 days	☐				
First flush collection of roof runoff before storage	☐						
Roll-over bunds to prevent any stormwater or spills flowing to other operational or vehicle movement areas.	☐						
Loading area graded to drains.	☐						
Stormwater drain can be isolated with a cut-off valve when tallow is being loaded onto tankers.	☐						
The cut off valve is kept closed at all times except after the first flush has been collected and remaining stormwater needs to be release to stormwater drains.	☐						
Area covered to limit direct rainfall into the tallow loading area	☐						
Stormwater inlet pit fitted with gross pollutant trap (grated screen)	☐						

4.6 Hide processing areas

Collection and separation		Management & Design		Treatment		Reuse	
Any brine fluid captured in the hide salting areas is stored separately in a sealed plastic tank before treatment or disposal	☐	Dry cleaning is used rather than hose down to reduce brine generation	☐	Brine is converted to salts through the use of evaporation ponds or similar technologies	☐	Where practical, roof runoff reused for operations not requiring potable water	☐
Brine is not disposed into the plants' WWTP	☐	Brine is not diluted so as to keep volumes low	☐				
Clean runoff collected from roof in tank or dam, directed to SWTS or redirected to off-site drainage line	☐	Contracting hide salting off-site has been considered	☐				
First flush collection of roof runoff before storage	☐						
Roll-over bunds to prevent any stormwater or spills flowing to other operational or vehicle movement areas.	☐						
Salted hides are stored in a bunded area	☐						
Areas using chemicals for wool removal are bunded and separated from hide salting areas	☐						

4.7 Open yard areas

Collection and separation		Management & Design		Treatment		Reuse	
Any runoff from yards frequently used by vehicles to move by-products and wastes is directed into the WWTP.	☐	Wastes are not transported across yards that do not drain to the plant's WWTS.	☐	Stormwater runoff from areas where liquid or solid waste is handled is directed to the plant's WWTS.	☐	Where practical, roof runoff reused for operations not requiring potable water.	☐
Any runoff from yards where contamination is unlikely is directed into the stormwater drainage system for disposal.	☐	Oil separators on inlet pits where stormwater is piped are regularly maintained - sediment cleared and oil collection container emptied.	☐	Secondary treatment by oil and grit separator, in maintenance workshop areas	☐		
Roll over bunds line waste transport corridors and direct any stormwater to the plant's WWTP.	☐	All bins used to transport waste are fully enclosed.	☐				
Stormwater inlet pit fitted with gross pollutant trap	☐	Staff moving liquid and solid waste are careful to avoid spills and remove the bulk of solid material using dry cleaning methods	☐				
		Yards used for transporting wastes between buildings are roofed to minimise contamination of stormwater runoff.	☐				

4.8 Roads

Collection and separation		Management & Design		Treatment		Reuse	
Stormwater runoff is from roads in areas where contamination is unlikely so directed into paddocks with good grass cover and pervious soils.	☐	Oil separators on inlet pits where stormwater is piped are regularly maintained - sediment cleared and oil collection container emptied.	☐	Screens on road drainage where transport trucks are frequently bringing in sediment and manure and runoff is contaminated	☐	Treated runoff collected for reuse e.g. holding pond for irrigation	☐
Runoff from roads frequently used by trucks transporting livestock (bringing manure and sediment onto the site) is directed to SWT before entering any offsite drainage line.	☐	Regularly inspections and maintenance is undertaken on drains.	☐	Secondary treatment of road runoff by oil and grit separator for roads where drainage is piped.	☐		
Collection of first flush to capture dust and oil from a sealed road surfaces	☐			Secondary treatment in sediment basin of contaminated runoff from roads frequently bringing in sediment and manure	☐		
Drainage from kerbs and guttering or preferably grass swale runs adjacent to roads	☐			Secondary treatment by grass swales running adjacent to the road or conveying uncontaminated stormwater to paddocks	☐		
				Secondary treatment by vegetative filter strips along edge of drainage lines	☐		
				Tertiary treatment by bio-retention basins	☐		

4.9 Carparks

Collection and separation		Management & Design		Treatment		Reuse
Diversion banks up-slope of car parks to divert runoff around the car park to well vegetated area or storage dam for reuse	☐	Oil separator regularly maintained - sediment cleared and oil/grease collection container emptied.	☐	Secondary treatment of runoff from sealed parking areas with piped stormwater drainage with an oil and grit separator	☐	
Runoff from sealed parking areas is piped to stormwater drainage or SWTS.	☐	Contour banks on steep slopes of the unsealed carpark are used to disperse runoff and reduce it's velocity fto avoid scouring.	☐	Tertiary treatment of runoff from sealed carpark with piped drainage with a cartridge filter	☐	
Runoff from unsealed parking areas directed to grass buffer areas down-slope or directed to paddocks with good grass cover and pervious soils.	☐	Regularly inspections and maintenance is undertaken on diversion banks and drains.	☐	Secondary treatment of runoff from sealed parking areas with no piped drainage by grass swale	☐	
Stormwater inlet pits are grated to trap coarse litter	☐			Secondary treatment of runoff from sealed parking areas with no piped drainage by vegetative filter strips along edge of drainage lines	☐	
				Secondary treatment of runoff from sealed parking areas with no piped drainage by vegetative filter strips on carpark boundary	☐	
				Tertiary treatment by biorention basins	☐	

4.10 Solid waste storage areas

Collection and separation		Management & Design		Treatment		Reuse
Stormwater runoff from this area is very minimal as covered and directed to the plant's WWTS.	☐	Good work practices reduce spills in solid waste storage areas	☐	As covered, stormwater runoff from this area is minimal and directed to the washdown WWTS.	☐	
Bunding prevents runoff flowing to other operational or vehicle movement areas.	☐	Procedure in place to ensure any spills are removed promptly.	☐			
Covered to limit direct rainfall into the solid waste storage area	☐					
Area graded to drains.	☐					

4.11 Composting Areas

Collection and separation	Management & Design	Treatment	Reuse
Stormwater runoff from this area is very minimal as covered and directed to the plant's WWTS. ☐	Good work practices reduce spills in solid waste storage areas ☐	Leachate treated by the plant's WWTP ☐	Where practical, reused for areas that do not require potable water e.g. irrigation of paddocks or gardens. ☐
Diversion banks up-slope of composting areas to divert runoff around the area to well vegetated area or storage dam for reuse and to prevent water run-on. ☐	Procedure in place to ensure any spills are removed promptly. ☐	Secondary treatment by grass buffer strip between composting area and any waterway (to capture any pollutants that have blown outside the composting area) ☐	
Underdrainage in composting areas collects leachate ☐	Vertical composting units (VCU's) used to contain possible pollutants as the area is susceptible to groundwater contamination. ☐		
Bunding prevents run-on and runoff flowing to other operational or vehicle movement areas. ☐	Facilities located on gently sloping land with grades between 1 in 10 and 1 in 200. ☐		
Cover prevents rainfall collecting in the solid waste storage area ☐	The soil type able to support composting operations e.g. allows some infiltration but does not become waterlogged e.g. loam or clay (sandy soils may require additional management measures) ☐		
	Appropriate vertical separation distance from the base of the infrastructure to the maximum groundwater level (e.g. at least 2 m) ☐		
	Facilities is located outside the 1 in 100 year flood level ☐		
	Stockpile shaped to stop water from gathering in ponds on the pile surface and windrows run parallel to the slope of the ground to avoid water collecting on the upside of the piles. ☐		

4.12 Irrigated area

Collection and separation		Management & Design		Treatment		Reuse	
Diversion drains up-slope of irrigation areas divert stormwater runoff around irrigated area to well vegetated area or storage dams for reuse and to prevent water run-on.	☐	Contour banks are used on steep irrigated slopes to disperse runoff and reduce its velocity so as to reduce scouring and erosion.	☐	Secondary treatment by vegetative filter strip on the down-slope boundary of the irrigation area.	☐	Runoff collected in the tailing dam is irrigated to pasture or the vegetative filter strip.	☐
Contaminated stormwater that has flowed across irrigated areas is directed towards a vegetative filter strip, woodlot or tailings dam.	☐	Irrigation areas have been located so stormwater follows the natural slope of the land away from these areas.	☐	Secondary treatment of runoff directed to woodlot	☐		
		Regularly inspections and maintenance is undertaken on diversion banks, tailings dams and drains.	☐	Tertiary treatment of runoff in constructed wetland (instead of a tailings dam)	☐		
		Irrigation scheduling and monitoring of soil and ground water to minimise risk of overloading the soil surface with nutrients and to minimise runoff	☐	Tertiary treatment of runoff in bioreactor	☐		

4.13 Fuel storage & refuelling

Collection and separation		Management & Design		Treatment		Reuse
Fuel storage area has an impervious bund and an impervious floor within the bunded area	☐	The re-fuelling of vehicles is undertaken in bunded areas or in areas where a spill can be managed.	☐	After rainfall, all bunds are emptied and the sump pumped out for disposal by a liquid waste treatment facility or to sewer with a trade waste approval	☐	
Bund has been designed to hold 100% - 133% (includes fire water) of the capacity of the largest tank or container plus additional volume for rainwater accumulation (e.g. capacity to cope with a one-in-twenty-year 24-hour storm).	☐	Good work practices reduce spills in fuel storage areas e.g. regularly inspect valves, pumps, pipes and hoses and undertake preventive maintenance	☐			
Fuel storage areas roofed to limit direct rainfall into the fuel storage area (ensure it will not hinder firefighting operations.	☐	Procedure is in place on cleaning spills and how to stop substances entering the environment once they have escaped	☐			
Floor graded in such a way that liquids are collect in a sump. There is no access to the stormwater system within the bund.	☐	Equipment for cleaning up spills is readily available in the fuel storage area.	☐			

4.14 Chemical Storage

Collection and separation		Management & Design		Treatment		Reuse
Chemical storage area has an impervious bund and an impervious floor within the bunded area	☐	The decanting of chemicals is undertaken in bunded areas or in areas where a spill can be managed.	☐	After rainfall, all bunds are emptied and the sump pumped out for disposal by a liquid waste treatment facility or to sewer with a trade waste approval	☐	
Bund has been designed to hold 110% of the capacity of the largest tank or container plus additional volume for rainwater accumulation (e.g. capacity to cope with a one-in-twenty-year 24-hour storm	☐	Good work practices reduce spills in chemical storage areas e.g. regularly inspect valves, pumps, pipes and hoses and undertake preventive maintenance	☐			
The material is in drums and other small containers so the bunded area is at least 25% of the total volume of the stored products.	☐	Procedure is in place on cleaning spills and how to stop substances entering the environment including directing away from biological stormwater controls such as wetlands and filter strips.	☐			
Fuel storage areas roofed to limit direct rainfall into the fuel storage area (ensure it will not hinder firefighting operations.	☐	Equipment for cleaning up chemical spills is readily available in the fuel storage area.	☐			
Floor graded in such a way that liquids are collect in a sump. There is no access to the stormwater system within the bund.	☐					

5.0 GOOD PRACTICE IN STORMWATER SEPARATION AND COLLECTION

This section provides a series of worksheets to assist meat processors determine if the current technologies used to separate and collect stormwater runoff are working effectively and identify opportunities for improvement. Opportunities identified (particularly design aspects) may require the further assistance and advice of engineering consultants.

The principles of best practice stormwater management are to avoid, segregate, reuse (where possible), treat and dispose.

Avoidance

Avoidance strategies preventing contact between stormwater runoff and sources of contaminants include (U.S. EPA Office of Water, 2006):

- Diversion of 'clean' runoff from areas of possible contamination e.g. contour banks and roofing with guttering and downpipes for reuse
- Isolating contaminated areas e.g. solid waste or chemical storage in roofed and well-sealed bunds
- Vegetation cover over stockyards
- Training employees in spill prevention, control, proper storage, handling and transportation techniques and educate staff to be aware of stormwater pollution.
- Training and ensuring staff implement efficient wash-down practices e.g. low flow, high pressure hoses and dry cleaning.
- Identifying and assessing stormwater contamination risks and developing management plans and procedures to manage these risks.

Segregation

Separation strategies avoid unnecessary contamination and treatment. Stormwater should be separated into:

- 'clean' runoff from relatively clean surfaces such as roofs. Although the volume may be small it can reduce the total volume effluent being sent to the Wastewater Treatment System (WWTS). This can be the period when effluent is most difficult to dispose of due to constraints on irrigation imposed by antecedent rainfall.
- 'dirty' runoff is stormwater runoff that has become degraded through contact with soils
- 'contaminated' runoff that has been in contact with manure, urine, processing products or wastes, fuels or chemicals.

Table 7: Segregation strategies for meat processing plants

Strategy	Application
Diversion drain	Holding paddocks and yards, open areas, workshops, roads and carparks and solid waste storage areas
Bunding	Holding pens and pre-processing race, truck wash-down area, processing areas, solid waste storage areas and fuel and chemical storage
Roofing	Holding pens and pre-processing race, processing areas, solid waste storage areas and fuel and chemical storage
First flush capture	Holding pens and pre-processing race, truck wash-down area, product and tallow loading dock, workshop, roads & carparks, roofs with potential stack contamination.
Contour banks	Holding paddocks and roads and car parks

5.1 Runoff diversion drains

Runoff diversion drains are located immediately upslope to divert 'clean' upslope runoff away from 'dirty' or 'contaminated' area. They reduce slope lengths and should move water to stable outlets at a nonerosive velocity. They may also be used for flood control as a flood bypass channel or floodway.

They consist of a ridge or channel or a combination ridge and channel and constructed across sloping land or at the top or bottom of a steep slopes.

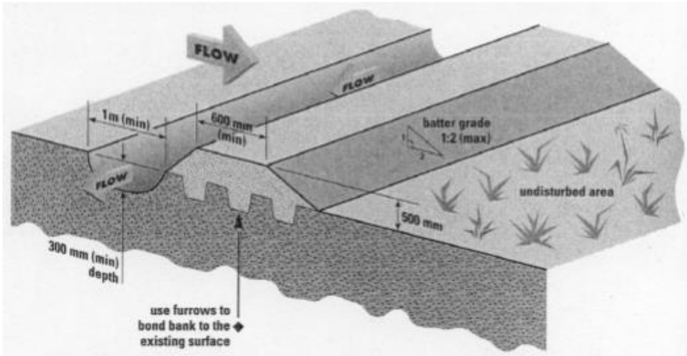


Figure 2: Typical Diversion Drain Design (Institution of Engineers Australia, 1996)

GOOD PRACTICE

PRELIMINARY ASSESSMENT	The scouring resistance of the soil is well understood. Battered embankments to direct flow on non-dispersive soils can be made from an excavated channel. Embankments to direct flows on erosible soils however should not be made from disturb sub-surface soil i.e. construct bank from soil brought on site.	☐
	The discharge velocities required from the drains into downstream treatment systems e.g. wetlands, sediment basins are well understood at the design stage.	☐
SIZE	Site specific	
SLOPE	Can be used on slope ranges between 1.5% and 15%.	☐
HYDROLOGY	Diversion drains have been designed to convey large flows (up to a 20-year average recurrence interval [ARI] storm) (MLA & AMPC, 2003).	☐
	Where the failure of a diversion drain would have serious consequences downstream an ARI of 50 years was used to design diversion drain (Institution of Engineers Australia, 1996).	☐
	The velocity in diversion drains does not exceed 0.6 m/s for bare earth drains (MLA & AMPC, 2003).	☐
	The velocity in diversion drain does not exceed 2.0 m/s for well grassed drains (MLA & AMPC, 2003).	☐
	Diverted stormwater does not cause damage downstream.	☐

DESIGN & CONFIGURATION	Drains are capable of diverting runoff around operational areas during large storms without overflowing or accumulating sediment.	☐
	Drain beds with high velocities (in excess of 2m/s) are reinforced with (Catchment and Creeks Pty Ltd, 2012): • erosion blankets made of synthetic geotextile fabrics or natural fibres (for temporary erosion control). • jute or coir mesh (temporary protection for low to medium velocities) as biodegradable and safe for wildlife. Placed over mulch layer or sprayed with anionic bitumen emulsion (1-3L/m^2). • erosion control mat containing much layer reinforced with synthetic mesh (risk for wildlife) or biodegradable mesh (temporary protection for low to medium velocities). • turf reinforced mats (high velocity, permanent drains). • cellular confinement systems (pockets filled with rocks or vegetation (low to medium velocities). • angular, fractured rock lining (high velocity, permanent drains, especially stormwater outlets). Geotextile or rock filter layer if voids are not filled with soil and pocket planted.	☐
	Any reinforcement has been installed well (Catchment and Creeks Pty Ltd, 2012): • erosion control mesh or mats are well anchored, stapled firmly in place and mats higher in the channel overlap mats lower in the channel by at least 300mm. • mesh is rolled firmly into the prepared surface. • rocks placed level or just below the surrounding land surface to allow free entry into the drain.	☐
	The drains have stable outlets i.e. no erosion occurs at the drain discharge point: • vegetated outlets. • grade stabilization structures or storm sewers. • open channels with adequate capacity and depth. • stable area e.g. woodlot.	☐
	Level spreaders are used at discharge points to evenly spread the water and to reduce erosion. The spreaders are excavated into the soil and the downstream lip of edge is level with the surrounding land surface.	☐
	The banks have been designed by a person experienced in hydraulic design. Desired design discharge (e.g. 1.5m/s) used to determine the configuration needed by considering (Catchment and Creek Pty Ltd (a), 2010): • the shape of the drain and the surface of the drain. • the maximum velocity allowable in the drain for the given surface. e.g. for grassed diversion drains this is 2m/s. • the maximum allowable depth for the drain (is based on the maximum velocity determined above). • the results of a manning roughness formula that predicts the velocity of water flow based on the velocity, slope, and channel conditions. • the height of freeboard based on the embankment types (e.g. 500mm for earth banks).	☐

Also considered:

- what was required to ensure the discharge from the outlet does not cause erosion.
- ensured the spacing of the diversion banks has been based on the slope, the susceptibility of the soil to erosion and the intensity of storms.

MAINTENANCE	Banks have uniform and complete grass cover (low growing, stoloniferous grasses used).	☐
	Grass strand length of 50mm is maintained in channels conveying medium to high flows and 20-50mm in channels conveying low flows (Catchment and Creek Pty Ltd (b)).	☐
	Grass clippings from mowing are removed.	☐
	Excess sediment or debris is removed promptly so as not to reduce the hydraulic efficiency of the drain.	☐
	Regular inspection of drains is undertaken to identify any damage or erosion. Any damage is immediately repaired by laying turf or seeding.	☐

5.2 First Flush (FF) pits or dams

First flush systems collect initial runoff flows and then allow subsequent runoff to overflow into downstream treatment systems, waterways or the stormwater drainage network. This limits the transfer of contaminants in stormwater runoff that may have built up between storm events.

Figure 3 provides an example of a first flush system.

Figure 3: First flush pond with overflow (Courtesy of TEYS Beenleigh)

GOOD PRACTICE

PRELIMINARY ASSESSMENT	All areas in the plant have been segregated into 'clean', 'dirty' and 'contaminated' stormwater areas. These areas have been mapped (and even marked on the ground surface) to assist in training staff on water management on site as well as being a day-to-day reminder.	☐
SIZE	The volume of the FF collection pit or basin is able to capture most of the pollutant load expected from the contaminated area (predetermined by government authority (e.g. first 20mm of 24 hours) or first 10-20 mm rainfall over the catchment area (MLA & AMPC, 2003). E.g. 10m x 20m area required to capture 20mm of rainfall in 24 hours requires a first flush capacity of 4000 Litres. 10m x 20m x 0.02L = 4m^3 or 4000 Litres (Brisbane City Council, 2014)	☐
	The pits or dams have additional volume to accommodate the accumulation of sediment on the bottom. (usually an additional 30% of the required capacity) (NSW EPA, 2013).	☐
	Contaminated areas are of minimum size. This has included roofing all areas where contamination of the stormwater is likely.	☐
SLOPE	The slope of the catchment area and drains direct contaminated water to the collection pit or dam.	☐
HYDROLOGY	The first flush device, collection pit or dam has been designed or selected to accommodate a specific flow based on the desired volume to be captured and considered the impact of debris/suspended solids traps	☐

DESIGN & CONFIGURATION

First flush systems are effective and have been properly designed and installed. ☐

A weir diverts runoff to the general stormwater system via a bypass channel when the first flush collection pit or dam is full. The distance between the collected first flush water and the bypass channel is large enough to avoid entrainment of the captured first flush stormwater in bypass flows. Figure 4 shows an image of first flush collection pit (NSW EPA, 2013) ☐

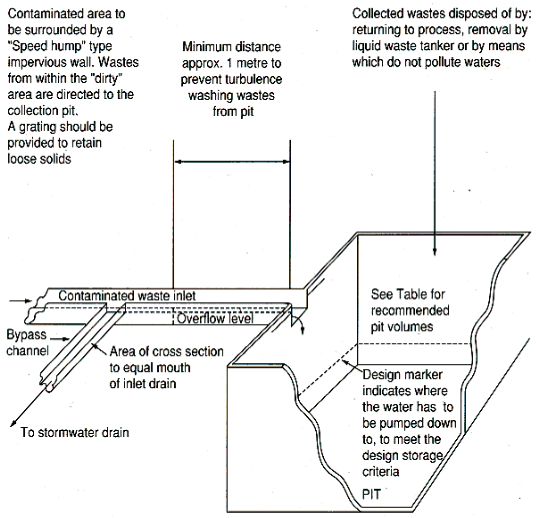


Figure 4: Image of first flush collection pit

First flush roof runoff is directed to a downpipe first flush diverter. Usually a separate chamber that is sealed off with a floating ball when full so only the clean stormwater runoff flows to storage. Figure 5 shows an image of downpipe with first flush device (Australian Government, 2013) and cross-section of first flush device (Rainwater Harvesting Ltd Ptd, 2017) ☐

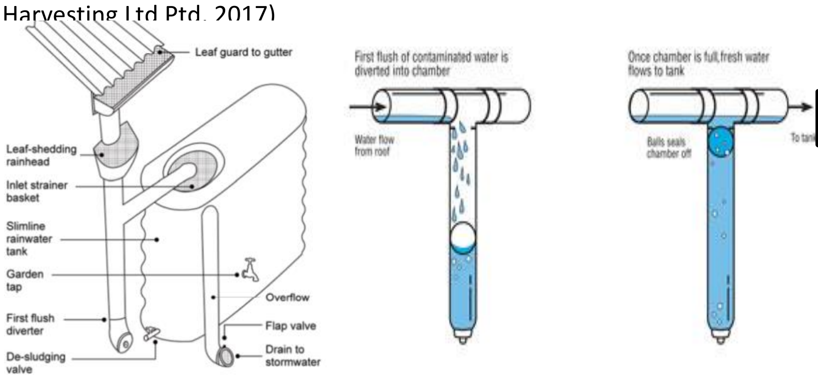


Figure 5: Image of downpipe with first flush device and cross-section of first flush device

Bunds or walls contain and direct contaminated water to the first flush collection pit or dam. Uncontaminated water from 'clean' or 'dirty' areas do not flow to the first-flush system (thereby keeping the required volume of the pit to a minimum). ☐

	Stormwater passes through a suitable device(s) e.g. grate/screen, silt trap, gross pollutant trap to remove large solids before entering the pit.	☐
	A rain gauge can detect rainfall and automatically close outlet to stormwater drainage system.	☐
MAINTENANCE	The contents of the first flush pit or dam is emptied prior to the next significant storm event (usually within 5-10 days but depends on local weather conditions).	☐
	The contaminated first flush is treated at the source (oil and grit separator and discharged, sent to the plant's WWTP or is collected by a liquid waste provider).	☐
	The contaminated first flush is disposed to sewer in accordance with a Trade Waste Agreement with the local sewerage authority. All necessary pre-treatment is undertaken.	☐
	Ponds and collection pits have a guide-stick, a painted line or a float valve to indicate how much free capacity is required at all times to ensure that there is sufficient spare capacity to capture the required volume of contaminated or dirty water for each rainfall event.	☐
	The site is well maintained and clean e.g. regularly swept to reduce the extent of contaminated run-off.	☐

5.3 Bunding

A bund is an impervious embankment constructed of concrete, earth or other suitable material that provides a barrier to retain a liquid. Bunds prevent run-on into contaminated areas, direct stormwater runoff from contaminated or dirty areas to a collection point for treatment or disposal and prevent contaminated or dirty stormwater from flowing into clean areas.

	GOOD PRACTICE	
PRELIMINARY ASSESSMENT	All areas in the plant have been segregated into clean, dirty and contaminated water areas. These areas are mapped (and even marked on the ground surface) to assist in training staff on water management on site as well as being a day-to-day reminder.	☐
SIZE	Fuel and chemical storage tanks are located on hard stand areas with associated perimeter bunding. Bund has been designed to hold 100% of the capacity of the largest tank or container (or 133% including fire water for flammable liquids) plus additional volume for rainwater accumulation (e.g. capacity to cope with a one-in-twenty-year 24-hour storm) (Keane, 2016).	☐
	Chemical storage drums are located on hard stand areas with associated perimeter bunding. Bund has been designed to hold at least 25% of the total volume of the stored products (Keane, 2016) .	☐
SLOPE	Floor within bunded compounds are graded and drain to a stormwater treatment system or disposal.	☐
HYDROLOGY	Bunds comply with the relevant Australian Standard	☐
DESIGN & CONFIGURATION	All surfaces exposed to incoming organics, final product, contaminated material storage areas and active composting pads which have the potential to produce leachate and contaminated runoff are bunded and graded sufficiently to prevent run-on and run-off of surface water.	☐
	Roll over bunds or ramps are used where vehicle access is required.	☐
	The floor of the bund compound is compatible with liquids to be contained.	☐
	Roofs cover bunded compounds to minimise stormwater entry	☐
MAINTENANCE	Stormwater is not allowed to accumulate in bunds thereby reducing their effective volume.	☐
	Bunds are not damaged e.g. not cracked due to weather erosion, movement or damage from mobile plant.	☐
	Joins of the bund to the floor or pipes through the bund or floor are well sealed	☐
	Bund upgrade have been undertaken if necessary to ensure bund is fit for its current usage.	☐

5.4 Silt control fences

A temporary sediment control technique used to capture sediment from areas of disturbed soils e.g. for drains with poor ground cover or areas that have been recently disturbed. The temporary sediment barrier made of a porous fabric. A single 30.5 m run of silt fence may hold 50 tons of sediment in place (US EPA, 2012).

GOOD PRACTICE

PRELIMINARY ASSESSMENT	The site's contours have been examined to determine the proper fence placement.	☐
SIZE	A reasonable rule-of -thumb for the proper length of silt fence is 30.5 metres of silt fence per 929 square metres of disturbed area (US EPA, 2012).	☐
SLOPE	The fencing may be used on gentle to very steep slopes.	☐
HYDROLOGY	The drainage area above the fence does not exceed a quarter of an acre. If water flows over the top of a fence during a normal rainfall this indicates the drainage area is too large and will cause undercutting, washouts, and fence failures.	☐
DESIGN & CONFIGURATION	Fencing is securely staked into the ground (up to 200 mm depth) to prevent scouring under the fencing (MLA & AMPC, 2003).	☐
	Posts are driven 600 mm into the ground with 3 m maximum spacing between posts (MLA & AMPC, 2003).	☐
	The fence height is no greater than 700 mm (MLA & AMPC, 2003).	☐
	The bottom of each end of the fence is higher than the top of the middle of the fence so unusually heavy rain flows over the top not the end where it would cause erosion.	☐
	J-hooks have been used (which have ends turning up the slope) to break up long fence runs. Figure 6 shows an image of J-hooks (US EPA, 2012).	☐

Figure 6: J-hooks to break up long fence runs

	Fences have been properly placed based on the site's contours.	☐
	A heavy porous filter fabric that will not tear when attached to the posts has been used.	☐

	Tight soil has been compacted around both sides of the silt fence to obviate the need for wire or chain link reinforced fencing. This compaction also minimizes water finding its way under the fence	☐
	The fabric is correctly attached to the posts (three plastic ties per steel post or several staples per wooden post with a wood lath to overlay the fabric) (U.S. EPA Office of Water, 2006).	☐
MAINTENANCE	Inspect after runoff events to determine if they are full or damaged.	☐
	Sediment deposits from behind the fence are removed when they reach half the height of the fence. If the fence is clogged a new silt fence above or below it to collect additional sediment	☐

6.0 GOOD PRACTICE IN THE TREATMENT OF STORMWATER

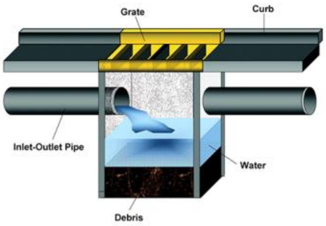
This section provides a series of worksheets to assist meat processors determine if the current technologies used to ***treat*** stormwater are working effectively and identify opportunities for improvement. Opportunities identified (particularly design aspects) may require the further assistance and advice of engineering consultants.

6.1 Primary Treatment - Gross Pollutant Traps (GPTs) and Solids Screens

Gross pollutant traps and solids screens prevent solids (typically greater than 5 mm) such as manure, organic debris, litter and coarse sediment from blocking stormwater systems. They provide limited removal of medium to fine sediment and dissolved pollutants.

They are relatively inexpensive and are a common component of conveyance drainage networks.

GPTs are important as they protect the integrity of the downstream treatments from overloading and clogging.

Type of gross pollutant traps	Target pollutants and efficiency
Screens **(Printers National Environmental Assistance Centre, 2017)** 	Gross pollutants (High) Coarse sediment (Low)
Catch basins/chamber **(EdenFlo, 2017)**  	Gross pollutants (Moderate) Coarse sediment (Moderate) Medium sediment (Low)
Pit traps **(Ecosol, Ecosol Litter Basket, 2017)** 	Gross pollutants (Moderate) Coarse sediment (Low) Oils and Grease Moderate-High if oil socks or pillows are incorporated into trap.

	GOOD PRACTICE	
PRELIMINARY ASSESSMENT	Areas that regularly block, or areas where litter is generated, have been identified for GPTs or solids screens.	☐
	GPTs and screens are located where access for inspection and maintenance is easy but also complementary to other treatment measures.	☐
	There is a good understanding of the volume and quality of stormwater runoff, depth and slopes relative to other components of the stormwater system and equipment available for cleaning.	☐
SIZE	Gross pollutant traps have a relatively small lateral footprint	☐
	Screen opening size captures coarse solids (typically 20 – 50- mm) and is correctly sized so as not to require frequent cleaning (MLA & AMPC, 2003).	☐
SLOPE	GPTs are not located on steep grades or mild slopes where head losses would cause local flooding.	☐
HYDROLOGY	Catchment area of 0.1-1 ha for GPTs	☐
	Designed to treat a minimum design flow of a 1 in 3 month ARI, with bypass arrangement to accommodate flows up to the 100 year ARI flow without creating any flooding (South Australian Department of Planning and Local Government , 2010).	☐
DESIGN CONFIGURATION	GPTs have a high flow bypass system.	☐
	GPTs operate effectively and design does not cause resuspension of captured contaminants during flows in excess of the design ARI.	☐
	A low flow treatment system has been installed after all GPTs where collected debris is continuously wet and is being transformed from a relatively innocuous state to highly bio-available form.	☐
	Pits are not too shallow and provide sufficient pollutant storage.	☐
MAINTENANCE	GPTs and screens are regularly cleaned, especially after storm events so localized flooding does not occur and pollutants are not remobilised.	☐

6.2 Secondary Treatment – Sedimentation Basins

Sedimentation basins detain sediment in stormwater and regulate flow during typical and high flow conditions. They promote the settling of sediments by temporary detention and flow reduction. Drainage ways and downpipes are commonly direct towards basins that are made up of inlet/forebay and outlet structures and a detention pond (to allow finer particles such as clays and silts time to settle. Sediment systems include:

- Sediment basins (which are generally temporarily filled and utilised for early treatment by removing coarse particles immediately following a storm)
- Sediment basins with retention ponds (which allow for removal of finer particles and generally operate for several days after a storm)

High efficiency sediment basins (HES) have a comparatively smaller footprint than traditional sediment basins and higher removal efficiency of fine and colloidal sediment. They feature an automated dosing system and mixing fore bay cell which can reduce overall detention time from 5 days to 1 hour compared with traditional sediment basins.

GOOD PRACTICE

PRELIMINARY ASSESSMENT

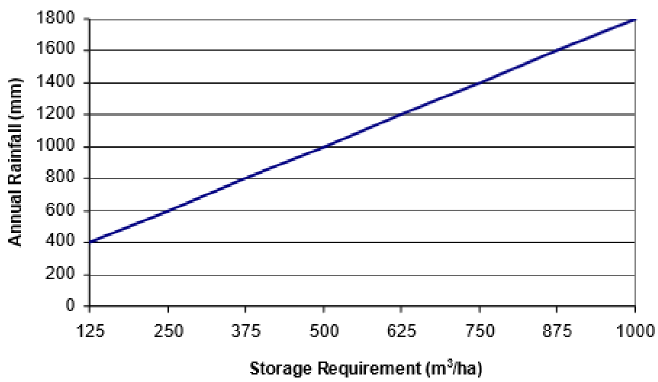
A comprehensive flood routing method was used to size and configure the basin and outlet pipes, spillways, etc. based on topographical and soil survey of the site, targeted sediment size, estimated design flows and access for maintenance ☐

SLOPE

The slope of the catchment area directs contaminated water to the basin.

SIZE

The basin has been designed according to the design particle size (MLA & AMPC, 2003)



☐

The table above shows the sedimentation zone storage required per hectare for a site containing soils with greater than 33% of particles less than 0.02 mm (silts and clays). A basin has been designed to treat coarse soils (more than 67% of particles greater than 0.02 mm) would have a volume approximately 50% of what s indicated in the table above.

The basin length to width ratio is at least 3:1 where the basin only has a single inflow point ☐

The basin length to width ratio is 2:1 where the basin has multiple inflow points and baffles are used. ☐

The volume of a detention pool ensures desilting is only required approximately every 5 years - additional sediment accumulation volume has been added to the total sedimentation volume (typically 30%) ☐

HYDROLOGY

The basin has a spillway that can safely convey the 20 year ARI peak flow from the catchment (MLA & AMPC, 2003). ☐

Estimate design flows e.g. Rational Method design procedure for small areas or a runoff routing model for large catchments greater than 50 hectares (Brisbane City Council, 2006). ☐

DESIGN

The basin has been designed for sediment deposition of predominantly coarse particles (more than 67% of particles greater than 0.02 mm) - flow passes through the basin (MLA & AMPC, 2003). ☐

The basin has been designed to also capture fine soils (more than 33% of particles smaller than 0.02 mm) runoff - captured and retained for several days - drawn down within at least 5 days after a rainfall event occurring (i.e. through irrigation) (MLA & AMPC, 2003). ☐

The basin is accessible for maintenance. Ramps are provided to or into the basin if necessary. ☐

The sedimentation basin is constructed with a hard bottom that enables machinery access and helps the excavator operator know when they have reached the base of the basin when desilting. (HES are constructed with concrete to allow for easier cleaning) ☐

Where the outlet feeds on to another treatment system e.g. a wetland or bio-retention basin it consists of two outlet structures. A control outlet (overflow pit/ pipe or weir) and a spillway outlet (which will discharge water to a bypass channel when the flows is above the designed operation flow. ☐

Where the outlet only discharges to a conveyance system (swale or piped system) there is only one outlet that can handle flood flows. ☐

The shallow marsh (to a depth of 0.2 m) and ephemeral marsh zone (to 0.2 m above water level) around the edge of the basin is suitably vegetated (not floating or submerged macrophytes) to reduce erosion and strengthen the bank (Brisbane City Council, 2006). ☐

The batter slopes to the water edge and into the basin are vegetated (soft treatment) ☐

The batter slopes to the water edge and into the basin are lined with rocks (hard treatment) ☐

	There is dense planting of the littoral zones to reduce scouring and erosion to the basin batters and restrict access to the open water (70-80% cover is achieved after two growing seasons) (South Australian Department of Planning and Local Government , 2010).	☐
MAINTENANCE	Sediment levels are monitored regularly with a measuring post reference against the top water level to identify depth of sediment accumulation	☐
	Forebay is de-silted as required and sludge disposed of in approved method	☐
	Detention basin is drained and de-silted as required and sludge disposed of in approved method. Conventional sediment basin should be cleaned out every 2 – 5 years while a HES should be cleaned out every 2 or 3 months reducing any anaerobic sludge production and related odour issues	☐
	Routine inspection to identify damage to vegetation, erosion or debris build up, especially after storm events	☐
	Litter and debris removed promptly	☐
	Terrestrial and aquatic invasive weeds controlled	☐
	Basin vegetation is watered during establishment and as required. Dead plants replaced.	☐

6.3 Secondary Treatment - Grass Swales

Grass Swales (essentially grass-lined channels) are sometime used an alternative to a concrete channel, kerb and guttering or pipes for runoff conveyance. Their main role is to convey runoff however they also pre-treat runoff and reduce the rate of flow across a site. The removal efficiency varies between swales as it is a function of runoff flow rates, grass density and particle size and density (WA Government - Department of Water, 2007).

	GOOD PRACTICE	
PRELIMINARY ASSESSMENT	Soils are suitable (and amended if necessary) for maintaining good grass cover. A or B hydrologic group soils are the most effective for infiltration (Maine Government, 2017).	☐
	There is sufficient space to enable a flatter cross-section for mower manoeuvrability.	☐
	The type of grass lining for swale has been selected based on soils and hydrologic conditions at the site	☐
	The slopes were not greater than >4% but <1% as swales can become waterlogged if they are unable to drain effectively.	☐
SIZE	Width and length was driven largely by available space. The greater the width and length, the greater the conveyance and treatment capacity. Swale widths greater than 2.5 m have structural measures such as flow spreader banks to ensure uniform spread of flow (MLA & AMPC, 2003).	☐
SLOPE	On steep slopes swales are parallel to natural contours.	☐
	Longitudinal slope of grass swale is generally in the range of 2 -4% to promote uniform flow conditions. A steeper longitudinal slope provides an effective drain, but could increase erosion risk and reduce treatment efficiency (MLA & AMPC, 2003).	☐
HYDROLOGY	Catchments up to 2 hectares	☐
	Maximum flow velocity is less than 0.3 m/s for the 1 year ARI event to aid in sedimentation and a maximum velocity of 1.0 m/s for the 20 year ARI event (MLA & AMPC, 2003)	☐
	A high flow bypass installed if velocities in excess of 2.0 m/s are anticipated. NB. A well-designed grass swale can safely convey this velocity for short durations (MLA & AMPC, 2003).	☐
	For small simplistic catchments, the Rational Method is suitable for peak flow estimation. For large complex catchments, hydrologic/hydraulic models may be more suitable (WA Government - Department of Water, 2007)	☐

DESIGN / CONFIGURATION

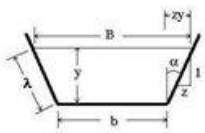
Geometry is designed to minimise sharp corners using parabolic or trapezoidal designs. A V-shaped swale is not recommended (University of Illonois, College of Agricultural, Consumer and Environmental Sciences, n.d.). ☐

The width of the flat bottom of a trapezoidal channel is at least 3 times the channel depth. The width of non-trapezoidal channels is similar to the depth (Maine Government, 2017). ☐

Concrete dish drain in the middle of the swale or under-drains are installed where longitudinal slopes are less than 2% (MLA & AMPC, 2003) ☐

Where the longitudinal slope exceeds 4%, check dams along swales distribute flows evenly across the swale as well as reduce velocities (WA Government - Department of Water, 2007). The riffles maximise the retention time within the swale, further decreasing the velocities and better promoting particulate settling. Riffles are typically low level (e.g. 100 mm) porous rock weirs that are constructed across the base of a swale. Image of riffles (Axler, 2009) ☐

Channel side slopes do not exceed 3 :1 (Horizontal:Vertical) ☐



Trapezoidal Cross Section

Flow velocities along a swale are kept sufficiently low to avoid scouring of vegetation and collected pollutants. ☐

Pre-treatment for swales include litter traps at point source inlets and buffer strips parallel to the top of the banks to pre-treat sheet flows entering the swale. ☐

Plant species selected can tolerate periodic inundation and design velocities ☐

Rock beaching and/or dense vegetation at inlet point of point source entrances into swales (such as from overland flow from a kerb or from a pipe system) to dissipate the energy of the flow to minimise erosion potential. ☐

MAINTENANCE	Swales are inspected after storms to ensure rainwater has drained and that there is no erosion	☐
	Swales are mown regularly. Mown grass height is 5-10cms taller than the maximum flow depth of the design water quality storm (Maine Government, 2017).	☐
	Frequent inspections are carried out in first few months to ensure vegetative cover is establishing well. If not swale reseeded or alternative plant species investigated.	☐
	All grass clippings are removed. The mower is adjusted to a height that avoids scalping of the edges and side slopes. No mowing occurs immediately after a rain event	☐
	Built up sediment and debris is removed from in and around the swale to avoid the transportation of resuspended sediments during periods of high flow and to prevent a damming effect from sand bars.	☐
	Swale is not fertilised	☐
	Damaged areas within the channel are repaired e.g. ruts or holes	☐
	Swales is inspected regularly for ponding, as it can become a nuisance due to mosquitoes breeding in standing water if obstructions develop (e.g. debris accumulation, invasive vegetation) and/or slopes of swales are too flat and inadequately maintained, allowing water to pool for more than four days.	☐
	The buffer strip is periodically aerated (by rototilling or other) to restore infiltration capacity (can do when reseeding prior to any significant rainfall).	☐
	Traffic movements along the swales be prevented as it causes rutting and hardens the surface to provide preferential flow paths that do not allow infiltration.	☐

6.4 Secondary Treatment – Vegetated Filter Strips

Vegetative filter strips, are broad, sloped grassed or vegetated areas that treat shallow overland flow (Figure 7). They are also used as a buffer between an operational area and waterways or drains. They remove significant proportions of sediment as well as dissolved pollutants through plant uptake, microbial breakdown and soil infiltration.

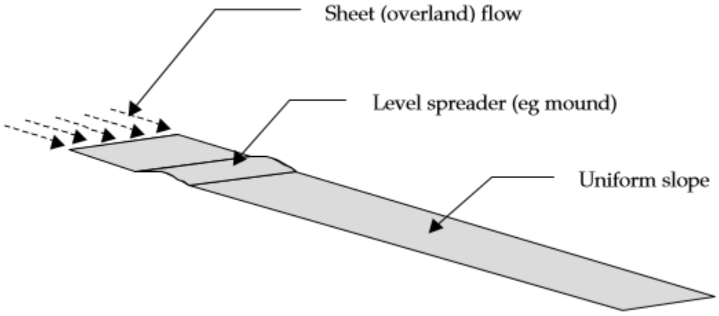


Figure 7: Vegetative Filter Strip (NSW EPA, 1997)

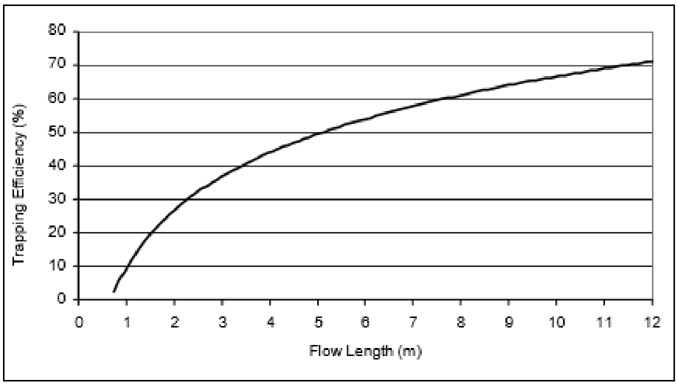
GOOD PRACTICE

PRELIMINARY ASSESSMENT

Good understanding of soils (very sandy or heavy clay soils can reduce nutrient removal efficiency of strips), slope proposed cover type and contributing drainage area. ☐

SIZE

The length of the strip ensures adequate sediment removal.
>10 m - to aid in removing sediment and associated phosphorous
>30 m - for significant soluble pollutant removal (MLA & AMPC, 2003)



☐

Figure 8: Sediment trapping efficiency of Vegetative Filter Strips of varying lengths.

SLOPE

Not suitable for areas with steep slopes (>10%) (MLA & AMPC, 2003). ☐

Longitudinal slope up to 10%, although ideal conditions are slopes between 1% and 5% (MLA & AMPC, 2003). ☐

HYDROLOGY

Maximum flow velocity of 0.3 m/s to optimise sediment removal (MLA & AMPC, 2003). ☐

Design flow depth of 12 mm has been adopted (MLA & AMPC, 2003).

DESIGN CONFIGURATION	Strip disperses flows so as to achieve maximum effectiveness. Use a gravel or earth bund, curb stop or flow distribution trench if necessary.	☐
	Grasses and plants are indigenous and suitable for the local soils and climate. Grasses show good regrowth are dormancy and cutting. Non-clumping grasses with fibrous roots such Kikuyu work well.	☐
	The edge of the filter strip is level with drainage areas.	☐
MAINTENANCE	Strips are inspected after storm events and any unevenly deposited sediment accumulations removed.	☐
	Any erosion or gullies are attended to promptly.	☐
	Replanting or reseeding is undertaken if necessary and plant species changed if they are not establishing well.	☐
	Grass strips are mown and clippings removed.	☐
	Level spreaders are inspected regularly.	☐

6.5 Secondary Treatment – Oil and Grit Separators

Oil and Grit Separators (OGS) remove course sediment and floating oil, grease, gasoline, light petroleum products and other floating liquids from stormwater runoff. A wide variety of proprietary devices that have been developed in recent years which are modifications of the traditional OGS that typically target coarse solids and large oil droplets.

GOOD PRACTICE

PRELIMINARY ASSESSMENT	Located where readily accessible for maintenance and inspection and accessible for vacuum trucks or other oil- and grit-removal equipment.	☐
SIZE	-	
SLOPE	-	
HYDROLOGY	Individual separators should serve impervious areas of no more than 1 acre.	☐
DESIGN CONFIGURATION	The treatment of oil is undertaken close to its source to retain the oil in a floatable, non-emulsified form e.g. truck washdown bays, maintenance workshop and car parks	☐
	Third party performance testing has been undertaken on purchased and installed systems to ensure they met the claimed designed specifications to the manufacturer.	☐
	The OGS are installed in locations accessible to such vacuum trucks	☐
	Bypass configurations operate effectively	☐
	Site has traditional gravity separators - three or four chambers system where sediment and particulate matter settle, debris is screened and free surface oils float to the top and are separated. These conventional OGS are <u>not usually efficient for removing oil droplets</u> with diameters smaller than 150 microns.	☐
	Site has parallel plate or coalescing plate separators. These use the same principles as conventional gravity separators but incorporate an array of closely spaced parallel plates to increase the surface settling area so the overall size of the unit to be reduced. Depending on the type of plate used these systems can be expected to remove oil droplets less than a 150 micron.	☐
	Site uses separators that use rotary and shear forces to augment gravitational forces where greater treatable flow rate are required. These units are compact, have low headloss (as they have large, clear openings and no internal restriction) and no pollutant re-entrainment. Can remove 68% to 99% of settleable solids, including large proportions of fine particles (less than 100 microns).	☐
MAINTENANCE	Remove trapped materials between storm events	☐

6.6 Tertiary Treatment - Constructed surface wetlands

Constructed wetlands are a treatment option for the removal of fine sediment, nitrogen, phosphorus, organic matter, pathogens and heavy metals. Constructed wetlands are designed to mimic natural wetlands and use retention, settling adsorption, biological uptake processes and filtration to remove sediment and contaminants from stormwater. They can also encourage UV disinfection depending on the water residence time, provide valuable habitat and can have significant aesthetic value. They are also an important flood prevention measure. Thus, if constructed and maintained well they can operate as a low maintenance, self-sufficient flood control device.

	GOOD PRACTICE	
PRELIMINARY ASSESSMENT	The initial assessment of the viability of a wetland included: • Topographical survey to identify any constraints that may impact the wetland design. • Groundwater monitoring for a sufficiently long enough period to establish water table fluctuations and seasonal changes, groundwater levels (especially where shallow groundwater is present), water quality, groundwater contours and flow directions. • Geotechnical survey to establish soil horizons and properties of the soil (soils have sufficient water retention characteristics to promote plant growth, particularly during the dry season). • Soil investigations and management plans developed if in acid sulphate soils are present as defined by regulator. • Surface water hydrology monitoring of stormwater inflows undertaken to determine flows and water quality • Vegetation survey to identify existing native vegetation species that could be incorporated into the wetland design.	☐
SIZE	2 - 4% of catchment area for optimum high nutrient removal, particularly nitrogen removal. Large wetlands are more efficient at removing sediment and the nutrients attached to sediment while wetlands with alternating depths are more suitable for removing dissolved nutrients.	☐
	If CW is only 2% of the catchment area it has adequate depth, a biological pre-treatment such as a vegetative filter strip and sufficiently long hydraulic residence time to retain sediment and associated phosphorous.	☐
	If CW is only 2% of the catchment area floating macrophytes such as duckweed are used (can remove 6.1 kg/ha/y of TN and 0.8 kg/ha/y of TP, which is approximately three times greater than that of emergent macrophytes).	☐
	Has been sized according to the water quality required and to mitigate peak flows from large rainfall events.	☐
SLOPE	On slope 4:1 to 5:1 (H:V)	☐
HYDROLOGY	Hydrologic calculations (water balance) has been performed to verify CW able to receive and retain enough flow from rain, runoff, and groundwater to ensure long-term viability.	☐
	There is a drainage area of at least 10 acres or a water source that is able to sustain a constant inflow.	☐

Soil testing has been undertaken to determine suitability. Hydrologic soil groups C and D are suitable. If hydrologic soil groups A and B then a clay or synthetic liner has been installed if necessary. ☐

Soil permeability has been tested to ensure that excessive infiltration will not cause the CW to dry out. If there is excess infiltration a compacted subsoil or impermeable liner has been installed. ☐

DESIGN & CONFIGURATION

CW located off-line to the natural drainage line or water course and with a spillway so large flows can bypass it without damaging it. ☐

Existing site contours were used where possible in construction and the CW incorporated into the natural hydrology and drainage lines of the site. Efforts were made not to remove existing vegetation. ☐

The CW is located more than 200 m from residential areas to provide the lowest risk from mosquitoes and midges. ☐

Organic soils used for CW planting as encourage CW plant growth, act as a good sink for pollutants and good water holding capacities. ☐

Wetlands has different zones of vegetation - Open water plants emergent (low marsh plants and high marsh plants), ephemeral plants and buffer plants (area outside of maximum water surface elevation) ☐

Good variety as monoculture planting carries risk from pests and disease ☐

The emergent vegetation comprises 50-80% of the normal water surface area. ☐

Chosen species are robust, native non-invasive, perennial plants that establish quickly. ☐

Chosen species for zone are suitable tolerant of a range of water depths and inundation periods. ☐

Plants have been planted to a density (usually 4 plants/m2 in channel and basin areas) that reduces weed competition and maintenance costs. ☐

Plants are in perpendicular rows to the flow path with each row offset from the previous to reduce short-circuiting and to create flow paths. ☐

Plants were given sufficient time to establish themselves before the WC becomes fully operational. ☐

Buffer vegetation enhances habitat value and wetland health - trees, shrubs, and native ground covers. ☐

Suitable length to width ratio (at least 3:1 or flow pathway through the CWs has been maximized). ☐

Suitable depths
e.g. sedimentation zone - at least 1.5 m deep
shallow water macrophyte area - 0.3 – 0.5 m deep
open water outlet zone - at least 1.5 m deep. ☐

Forebay or sediment basin captures all inflows and effectively removes all coarse sediment while reducing excessive sediment accumulation and erosion by inflow. ☐

Forebay or sediment basin contains at least 10 -15% of the total permanent pool volume ☐

Forebay is at least as deep as other open water areas ☐

Forebay is separated from the rest of the wetland by a berm or gabion wall ☐

The flows exiting the forebay is nonerosive to the deeper pond and don't resuspend of previously collected sediment. ☐

There is no vegetation in the forebay ☐

Forebay bottom has been hardened to facilitate sediment removal. ☐

The forebays has permanent vertical markers to indicate sediment depth. ☐

The CW has varying depths throughout to improve plant diversity and health. ☐

Are areas of open water zone (around 35 to 40% of the total surface area) that prevent short-circuiting. ☐

Outlet control devices is in open water areas (around 5% of the total surface area) to prevent clogging and easy drainage for maintenance. ☐

Outlet devices large enough to protected it from clogging and multistage and allows the water surface to be varied (depending on season, accumulation sediment, treatment levels required or mosquito control). ☐

Outlet is accessible. ☐

CW is lined with a less permeable layer such as clay if necessary to reduce groundwater interactions ☐

Shoreline slopes are 1:6 to 1:8 for wider ranges of zones for plant growth and have no depressions that may pool water or inhibit drainage ☐

MAINTENANCE

- [ ] A maintenance plan has been developed
- [ ] The use of fertilisers and pesticides is restricted.
- [ ] Inlet and outlets are inspected for signs of clogging and unclogged promptly if necessary.
- [ ] Any valves or pumps are inspected and maintained according to the manufacturers recommendations.
- [ ] Inspections include looking for dead spots and monitoring for mosquito larvae and taking necessary mosquito control if necessary.
- [ ] Inspections are conducted at least twice a year (and after major storm events) to ensure banks are not eroding, plants are healthy and there is not an excessive deposit of sediment.
- [ ] The access road to the wetland is well maintained.
- [ ] Invasion or environmental weeds are controlled.
- [ ] Accumulated sediment in the forebay or sediment basin is removed when it exceeds 10% of the available volume.
- [ ] Accumulated sediment is removed from the main basin as required - often only needed after 20 years and carefully disposed of (i.e. may contain heavy metals, hydrocarbons etc).
- [ ] Harvesting of wetland vegetation may be necessary so as to encourage soluble nutrient removal (best done in the dry season to allow regrowth before the wet season and after the bird breeding season).
- [ ] Any dead wetland plants are replaced with the same or similar species
- [ ] Records are kept of maintenance activities.
- [ ] Monitoring of surface water levels, flow pathways and groundwater levels is undertaken to determine if the WC hydrology matches design assessment.
- [ ] Monitoring of in and out flows of suspended solids and nutrients (during low flow and high flow periods).
- [ ] CW is allowed to periodically dry out to promote nutrient removal and biomass decomposition.

6.7 Tertiary Treatment - Bio-retention swales and basins

Bioretention swales and basins are used to treat both low and larger flows. The water moves through several layers which provide different levels of filtration. Vegetation and shallow depressions (basins) or embankments (swales) are used to restrict the flow of a fraction or all stormwater runoff. Particulates settle out via sedimentation while the captured stormwater slowly percolates through filtration media which is more permeable than the site's soil (mechanical straining) (Payne, 2015). Dissolved material may also bind with the filter media (sorption) while soil and plant microbes, plant uptake and adsorption (Davis, 2009).

Filtered water then travels through a transition layer to an underdrain of perforated pipe, sand or gravel which conveys the filtered runoff to stormwater drains or waterbodies (Nylen, 2015). Bioretention systems include:

- Bioretention basins - shallow depression with biofiltration trench.
- Bioretention swales - vegetated drainage channels with biofiltration trench.

In meat processing plants bioretention systems are typically designed to treat runoff from downpipes, parking lots and roads. Basins, and to some extent swales, can be used for flood storage although it is not their primary purpose.

GOOD PRACTICE

PRELIMINARY ASSESSMENT	The bioretention system's design suits the needs the locations local climate, geology, topography and groundwater - MUSIC model of the surrounding catchment and 'treatment train' can be used to developed an initial estimate of the bioretention dimensions	☐
SIZE	The system is correctly sized - oversizing will mean inflows cannot sustain vegetation while under sizing will result in clogging and increased maintenance requirements.	☐
SLOPE	-	
HYDROLOGY	Water velocities are no greater than 1m/s due to the likelihood of scouring.	☐
	Designed to capture and retain runoff from storms up to the three-month ARI.	☐
	Able to convey stormwater runoff from storm larger than the design 3-month ARI by conveying the water along the swale or via an overflow into a piped drainage system.	☐

DESIGN & CONFIGURATION

A system is lined to increase the period of the submerged zone (recommended for climates where periods between flows is greater than three weeks). ☐

A raised outlet has been included in the design to create a submerged zone in the lower biofilter layers. This submerged zone increases moisture availability, to sustain plant and microbial communities, and biofilter function and improve nitrogen and pathogen removal. ☐

The best filter media has been chosen (low clay content and low organic matter will maximise filtration while minimise nutrient leaching). Typically, the selected saturated hydraulic conductivity of the filter media is one to two orders of magnitude greater than that of the native surrounding soil. See Table below (Gold Coast city Council, 2007) ☐

Typical Permeability of Different Soil Types

Soil Type	Typical Particle Size (mm)	Permeability (m/day)
Gravel	2	850
Coarse Sand	1	85
Sand	0.7	8.5
Sandy Loam	0.45	4.5
Sandy Clay	0.01	1.0

The infiltration medium in the base of the swale or basin drains after a storm event in 24-48 hrs. ☐

The filter media, transition layer and drainage layer (gravel) is of adequate depth. ☐

The hydraulic design of the swale or basin ensures stormwater flows are distribute evenly across the entire system. ☐

The system has adequate sediment pre-treatment and other controls to minimise clogging. ☐

The swale or basin has appropriate plant species and planting layout - species with an extensive root structure will improved pathogenic microbial removal and nitrogen removal. Plants need to be able to survive in the biofilter environment of sandy soils, prolonged drying and intermittent inundation. Vegetation guidelines and explanatory background science have also been produced by Monash University. ☐

Overflow bypass channel is located near the inflow zone to prevent high flows passing over the surface of the filter media. ☐

Rock beaching is used to dissipate the energy of concentrated inflow to avoid scouring. ☐

MAINTENANCE	Routine inspection to identify any areas of increased sediment deposition, scouring, rill erosion of batters from lateral inflows, and clogging (boggy)	☐
	Monitor inflow systems and overflow pits for scouring and litter build up	☐
	Sediment that is smothering the bio-retention basin vegetation is removed promptly	☐
	Adopting high planting densities and use a biodegradable erosion control mat if necessary on batters to control weeds and maintenance requirements.	☐
	Removal of accumulated sediment from as required.	☐
	If the surface continues to be boggy tilling the basin surface or removal of the surface layer.	☐
	Regular watering while vegetation is establishing	☐
	Dead plants are removed and replaced with plants of equivalent size and species	☐
	Plants are pruned to stimulate growth and diseased vegetation removed.	☐

6.8 Tertiary Treatment – Bioreactors

Excess nitrogen in runoff can cause algal growth, fish kills and degradation of downstream waterway. Nitrogen sources from meat processing sites include manure and urine from areas such as cattle holding yards and plant debris. Bioreactors are an emerging technology that can treat and reduce nitrogen in groundwater and surface runoff through denitrifying bacteria (Figure 9).

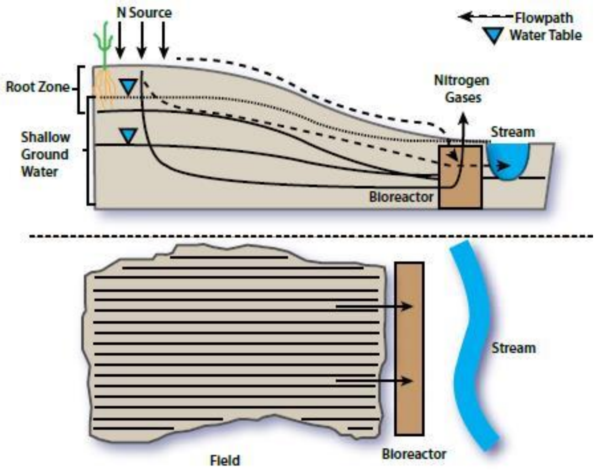


Figure 9: Schematic of a Bioreactor Wall (Lassiter, 2013)

Denitrifying bioreactors are primarily used for nitrogen removal but are also capable of some phosphorus removal. They require upstream primary and sometimes secondary treatment to remove sediment. Bioreactors can be used in conjunction with primary treatment and a high efficiency sediment pond to remove coarse and fine sediment respectively to prevent blockage.

Bioreactors have been used successfully in the agricultural sector with proven application in dairy, poultry, sugar cane and banana production (Eadie, 2016).They are also suitable for treatment of runoff from meat processing facilities. (Lassiter, 2013) They are relatively simple and cheap to install and are generally maintenance free.

Bioreactors are generally placed in the groundwater downstream of a holding pond to remove nitrogen before it reaches the waterways.

GOOD PRACTICE

PRELIMINARY ASSESSMENT	Site-specific conditions that were recognized including the range of temperatures, flow rates, discharge points, nitrate concentrations and nitrate removal goals.	☐
SIZE	Bioreactor footprints are typically less than 0.5% of the drainage area.	☐
HYDROLOGY	The hydraulic conductivity of the carbon source is about the same as the surrounding aquifer. The carbon source material and size of particles impacts the saturation hydraulic conductivity. Lower hydraulic conductivity compared with surrounding aquifer will cause the water to bypass the bioreactor and higher hydraulic can cause upwelling which pulls and treats deeper groundwater which has not been impacted by the processing runoff.	☐

DESIGN CONFIGURATION	Bioreactor walls are excavated into the shallow groundwater table perpendicular to the direction of groundwater flow to allow horizontal flow. It is backfilled with organic material and covered by top soil. It could be used downstream of holding tanks, high efficiency sediment pond or other ponds to reduce nitrogen levels in groundwater (They are limited to the upper 1-2m of groundwater).	☐
	Bioreactor beds are excavated lined basins that are backfilled with organic material and covered by nitrate rich top soil. Groundwater is either pumped into the bed or flows into it using steep topography to provide the hydraulic head. Re-expressed groundwater passes vertically through the media.	☐
	The flowrate to reactor beds is controlled to maintain an anaerobic environment, which makes this design more complex than the bioreactor wall.	☐
	Bioreactor use baffles to allow for variable media such as biochar/woodchip mixes with a zeolite barrier. Zeolites/soil can be used as a barrier wall at the end of the bioreactor to ensure ammonia and/or reactive phosphorus passing through the traditional woodchip is adsorbed onto the media.	☐
	Consideration was given to the selection of the carbon source e.g. corn cobs and green waste are readily available but have a shorter lifespan than woodchip. In addition, removal rates increase as temperature increases.	☐
MAINTENANCE	Any grass growing on the bioreactor is mowed.	☐
	Woodchip is replaced when required which can be once every 15-20 years.	☐

6.9 Tertiary Treatment – Cartridge Filters

Cartridge filters are an option which provide combined primary, secondary and tertiary treatment method in a single unit (**Figure 10**). They are capable of removing sediment, nutrients, heavy metals and oils and grease. Cartridge filters are good for constrained spaces and are suitable for catchments of around 1-2 ha that have runoff with relatively 'light' contaminant loads e.g. carparks, truck wash bays, chemical storage and maintenance workshops. They remove fine solids, and colloidal bound and dissolved contaminants. They are not a suitable for heavy sediment areas such as holding yards unless there is pre-treatment to remove the coarse solids. They may be an alternative solution to first flush systems for relatively uncontaminated areas, particularly for isolated areas that are a long way from the first flush system. This could reduce piping requirements.

Figure 10: Ecosol filter with the StormDMT filter (Ecosol, 2017)

GOOD PRACTICE

PRELIMINARY ASSESSMENT	Suitable for carparks, truck wash bays, chemical storage and maintenance workshops	☐
SIZE	Modules are in the order of 1-2 metres in diameter and several meters in height.	☐
HYDROLOGY	Capable of treating flows in the order of 7 through to 100 L/s	☐
DESIGN CONFIGURATION	Easy access for cleaning and maintenance.	☐
MAINTENANCE	Filter is inspected every couple of months	☐
	The primary treatment chamber litter basket, secondary treatment chamber forebay and free floating hydrocarbon chamber cleaned out after every major event	☐
	The tertiary treatment cartridge replaced at the frequency recommended by the manufacturer	☐
	Removable hydrocarbon baffles have the filter media replaced every 12 months or immediately after any spill.	☐
	Unit is backwashed as required	☐

7.0 ALTERNATIVE OR ADDITIONAL TREATMENT?

This section provides information on stormwater treatment technologies in terms of their pollutant removal effectiveness, site requirements and costs to assist meat processors compare and consider alternative treatment technologies or possible additions to existing treatment trains.

There is a linear relationship between the level of treatment and particle size, i.e. the smaller the contaminate particle size the greater level of treatment required, as shown in Figure 11.

Table 8 shows typical pollutant removal efficiencies for key stormwater treatment processes. Table 9 shows the costs, benefits and limitations of various treatment methods.

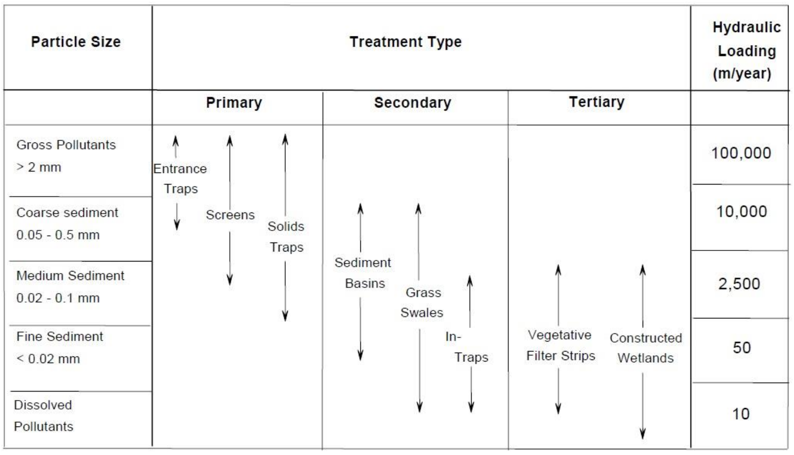


Figure 11: Linear relationship between contaminate particle size and level of treatment required for its effective removal (Perrens Consultants, 2003)

Table 8: Typical pollutant removal efficiencies for key stormwater treatment processes (Fletcher, 2004).

	Litter	Organic Debris	Coarse Sediment 0.05-0.1mm	Total Suspended Solids	Oil and Grease	Total Nitrogen	Total Phosphorous	Metals	Pathogens
Gross Pollutant Trap	10%-30%		10-25%	0-10%	0-10%	Negligible	Negligible	Negligible	Unknown
Sediment Basins	Very high (>95%)		Very high (>95%)	50-80 %	>75%.	20-60%	50-75%	40-70%	
High Efficiency Sediment Basins				80-90% [1]		70-90% [1]	70-90% [1]		
Grass Swales and Vegetative Strips	Very high (>90%)		Very high (>90%)	60-80%	No data	25-40%	30-50%	20-60%	
Oil and Grit Separators				48% 61%* [4]				21-36% 42-52%* [4]	42% 50%* [4]
Extended Detention pond	Very high (>95%)		Very high (>95%)	60-85 %	>75%	30-70%	50-80%	50-85%	40- 90% [2]
Constructed Wetlands	Very high (>95%)		Very high (>95%)	65-95%	>75%	40-80%	60-85%	55-95%	Up to 75%[2]
Biorention Swales or Basins	100%		95-100%	85% (65-99)	>75%	64% (50-70)	70% (40-80)	85% (50-95)	
Bioreactors						50%[3]	32%[3]		
Cartridge Filters				80-92% [4]		45-55% [4]	65-71% [4]		

[1] (Robson, n.d.). [2] (Massachuett Department of Energy and Environmental Affairs, 2008). [3] (Lassiter, 2013). [4] Three Chamber OGS (chamber size 52 m^3) * Manhole OGS with Bypass (Henry, 1999)

Table 9: Costs, benefits and limitations of treatment methods

TREATMENT	COSTS	BENEFITS	LIMITATIONS
Gross Pollutant Traps and Solids Screens	(Lake Macquarie City Council , 2003) **SUPPLY AND INSTALL:** Inlet protectors: $500-$1,000 Catch basins: $2,000-$10,000 Pit Traps: $1,000-$5,000 **MAINTENANCE:** Inlet protectors: $500-$1,000 per year Catch basins/chamber: $4,000 - $8,000 per year Pit Traps: $1,000 - $5,000 per year	• Retain manure, litter and coarse sediment • Reduces contact time of solids like manure with water (reducing leeching) • Reduces sludge build up in downstream treatment systems improving their removal efficiency and reducing maintenance costs • Small footprint and largely hidden from sight	• Limited removal of fine sediment and dissolved pollutants • Requires regular clean out for best performance (e.g. after each storm event) • Often must be designed to facilitate onsite vehicles. • Material will need to be removed by a street sweeper, vacuum truck or hand
Grass Swales	(WA Government - Department of Water, 2007) **CONSTRUCTION:** $30/metre length of swale ($10m² for seeded swale or $18m2 turfed) Additional $30/m for the construction of the subsoil drain for grades less than 2% (excavation, perforated pipe, gravel and sand backfill and geofabric surround) (South Australian Department of Planning and Local Government , 2010) **MAINTENANCE:** $3.13/ m²	• Retains gross pollutants, coarse sediments and some nutrient removal • Retards flow velocities Lower capital costs than traditional piped systems • Can create beneficial habitat • Aesthetically appealing • Retains particulate pollutants close to source	• Limited removal of fine sediment and dissolved pollutants • More land area required than kerb and gutter • Areas with steep slopes may limit the use of swales • Gullies and natural channels should be avoided if they would be difficult stabilize • It is recommended that the water table is at least 1m below the swale. • Shade can limit grass growth
Vegetative Filter Strips	(URS , 2003) **CONSTRUCTION:** (depends on the surface area and type of vegetation) Strip that was graded, compacted, scarifies, top soiled and seeded with grasses) - $10 - $15/m². 20 to $50/m². with planted ground cover and native grasses. **MAINTENANCE**: $2.5/m²	• Retain sediment, some soluble nutrients and hydrocarbons. • Reduces peak storm water flows • Visually unobtrusive • Relatively inexpensive and require much less maintenance than wetlands • Aesthetically pleasing • Habitat to increase biodiversity on site	• Land area required • The ability of the strip to disperse flows will determine its effectiveness • Not suitable heavily shaded areas • Not suitable for areas with steep slopes (>10%) • Very sandy or heavy clay soils can reduce nutrient removal efficiency.
Sedimentation Basins	(Taylor A. W., 2002) **CONSTRUCTION**: $50,000 **MAINTENANCE**: 6% of construction cost annually	• Retains sediment size typically 125 µm or larger and fine sediment if designed to do so. • Control or regulation of flows entering the downstream treatment system. • Storage for reuse on site.	• Limited removal of dissolved pollutants • Areas containing a high proportion of clays will require high capacity basins and possibly flocculant dosing. • Large footprint

TREATMENT	COSTS	BENEFITS	LIMITATIONS
High Efficiency Sedimentation Basins	(Eadie, 2016) **CONSTRUCTION**: Up to 3 ha: $10,000 3-15 ha: $90,000 15-100 ha: $300,000 **MAINTENANCE**: Small: $2,000 Medium: $20,000 Large: $100,000	• Reduced footprint compared with traditional sediment basins. • Reduced coagulant used due to better mixing during application. • Automatic application of coagulant removing the need to manually dose during rain events. • Real-time data logging to ensure compliance and to pick up non-compliance more quickly. • Capacity to remove fine sediment prior to tertiary treatment. • Ease and frequency of cleaning compared with traditional ponds • Simple to operate. • Short lead in time – establishment and installation is approximately 1 month.	• Not designed for coarse sediment so may require primary treatment e.g. runoff from cattle yards. • Basic systems (i.e. no incorporation of macrophytes) do not remove dissolved nutrients so additional treatment may be required. • Retrofitting a HES into an existing sediment basin may be problematic due to the specific layout and size to provide the best outcome. • Can release soluble nutrients back into the water channel if the sediments become anoxic between rainfall events.
Oil and grit separator	(Lake Macquarie City Council , 2003) Rocla Downstream defender: ~$12,000 to $36,000 capital Maintenance cost of ~$20 per ha per month (suction cleaning).	• New generation OGS - removal of particles as small as 100 microns. - use less space and cost less than traditional wet or dry basins. - are more effective at removing hydrocarbons - Maintenance costs are typically less than with traditional settling basins. • They improve the efficiency and maintenance requirements of downstream treatment technology.	• Traditional OGS do not treat dissolved pollutants • Regular maintenance is required to maintain performance • High capital costs may be associated with commercial products • Some systems have standing pools of water that could cause mosquito issues
Constructed Surface Wetlands	(Weber, 2001) **CONSTRUCTION**: Varys greatly depending on the configuration, location and site conditions, volumes and flow rate and target pollutants Approximately $500 000 to $750 000 per wetland hectare. (Taylor A. , 2005) **MAINTENANCE**: 2% of construction costs annually	• Medium to fine particulate and some soluble nutrients. • Flood retardation • Storage for wet weather or reuse. • UV disinfection through long hydraulic residence times. • Can be retrofitted into existing treatment systems to provide tertiary treatment of both effluent and/or stormwater. • Aquatic and terrestrial habitat.	• Not suited to very flat or steep terrain • Large footprint • Not suitable for very sandy soils or shallow bedrock • Not suitable for areas with a frequently high groundwater table

TREATMENT	COSTS	BENEFITS	LIMITATIONS
Bioretention Swales and Basins	(Taylor A. , 2005) **CONSTRUCTION**: 1m wide, 1m deep infiltration trench in Sydney - $138/m. This cost includes excavation, installation of geofabric liner, installation of perforated pipe, installation of gravel layer, installation of filter layer, application of top-soil, application of grass seed, application of fertiliser and watering **MAINTENANCE**: 5-20% of construction cost	• Able to remove dissolved pollutants in runoff • Can replace pipe drainage • Existing grass swales can be easily retrofitted. • Can treat low flows while conveying larger flows.	• Not suitable for areas with high groundwater tables. • Requires complete vegetation cover to allow clogging • Larger footprint than a wetland
Bioreactor	**CAPITAL**: $US200/ acre (Lassiter, 2013) $US203-454/ha (Christianson, 2013) **MAINTENANCE**: $US309-637/ha (Christianson, 2013)	• Simple design with low ongoing costs and maintenance requirements. • Reduced footprint compared with wetlands for nitrogen removal so suitable for space constrained sites. • Suitable for shallow aquifers. • Suitable for small catchments (1-5ha). • Effective nitrogen removal. • Bioreactor wall design is good for flat topography while the bioreactor bed is good where there is elevation and a hydraulic head can be achieved without pumping.	• Upstream sediment removal is required as bioreactors do not handle too much sediment. • The rate of flow needs to be controlled or the anaerobic conditions will not be maintained. Bioreactor wall design intercepts the groundwater but for bioreactor beds the flow needs to be controlled either through gradient or pumping which adds to the costs. • Substantial nitrate can bypass bioreactors in deep aquifers. • Can produce greenhouse gases due the decomposition of organic matter. • Can have loss of dissolved carbon during the start-up period. • Possible generation of low levels of hydrogen sulphide gas due to anaerobic conditions. This can be managed by balancing the nitrogen load and retention time.
Filter Cartridges	**CAPITAL**: AUD $20,000 - $105,000 depending on size **MAINTAINENCE**: In order of AUD $10,000 - $15,000 per year for cleanouts and media replacement	• Good for confined or small areas. • Capable of tertiary treatment. • Could install several in different locations on site. • Potential for retrofitting as well as new build. • Can treat between 1.5L/s to 100L/s depending on the product. • Fully self-contained units for quick on-site installation.	• High maintenance costs • Maintenance requirements may increase during high flow events or if the areas are heavily contaminated. • They are unlikely to handle the high organic loads from areas such as cattle yards without significant primary treatment.

8.0 SAVINGS FROM DIVERTING STORMWATER FROM WASTEWATER TREATMENT SYSTEMS

This section gives an indication of the financial benefits of directing stormwater away from wastewater treatment systems (WWTS). Some meat processing plants divert 'clean' or 'dirty' stormwater to their plant's wastewater treatment plant. This may be due to space restrictions or the location of the WWTS. However, best practice is to segregate and then treat, and if desirable and feasible reuse as much stormwater as possible. This may reduce the likely hood of a license breach due to uncontrolled releases as well as reduce the cost of treating stormwater in the plant's WWTS.

By sending stormwater through the wastewater treatment system there are additional impacts and costs through:

- Discharge fees for additional water
- Pumping costs
- Change in composition of wastewater and unpredictable changes to wastewater treatment requirements/inflows.
- Additional chemical additive costs
- Difficulty in disposing of wastewater discharge with additional stormwater runoff particularly for irrigation due to constraints on irrigation imposed by antecedent rainfall.

The addition of stormwater to the wastewater treatment system brings additional costs. These costs should be weighed against the costs of managing a separate stormwater system and the additional considerations. **Table 10** provides an estimate of the cost of treating 1 kL of wastewater through the wastewater treatment system.

Table 10: Estimated wastewater treatment costs

Item	Estimated cost per kL of wastewater
Wastewater power	$0.29
Wastewater treatment	$2.00
Discharge costs to sewer	$1.06
Total costs	$3.35

Table 11 gives an indication of costs of treating a portion of the Annual Average Rainfall for sites located in various regions in Australia. Costs are based on a site where 50% of the footprint is covered by impervious surfaces (roof tops, roads etc) so that 50% of the annual rainfall is directed the site wastewater treatment plant. This should be compared with costs to treat runoff in a separate stormwater treatment system which may also include additives, pumping and labour costs. In this case, it is likely that there would be no discharge costs as the water would be discharged to the stormwater system or waterway. In this example, the costs of treating stormwater in the wastewater treatment ranges between $9,200 (Adelaide) and $20,300 (Sydney region) per hectare per year.

Table 11: Estimated cost to treat portion of the Annual Average Rainfall per ha catchment in WWTS

Location	Depth of Rainfall (mm) per annum (BOM, 2016)	Total Volume of runoff (kL/ha/yr)	Cost to treat 50% of average annual rainfall $/ha/yr*
Adelaide	551	5,510	$9,229
Brisbane	1149	11,488	$19,242
Canberra	636	6,360	$10,653
Hobart	494	4,940	$8,275
Melbourne	648	6,480	$10,854
Perth	868	8,680	$14,539
Sydney	1216	12,160	$20,368
Toowoomba	952	9,520	$15,946
Wagga Wagga	572	5,720	$9,581

9.0 CASE STUDIES

Stormwater management at Teys Beenleigh, Queensland

Teys Australia is a red meat processing and cattle feeding company operated by the Teys family under a 50/50 joint venture between the Teys family and Cargill. The company operates six beef processing facilities along the eastern seaboard of Australia and supply high quality red meat products to the international and domestic markets.

Background and drivers of best practice

Prior to 2013 Teys Beenleigh directed its clean and contaminated stormwater into a stormwater pond on the eastern side of the property (see Figure 12). From here, this water was pumped to the plants trade waste discharge pond.

Figure 12: Eastern stormwater pond at Teys Beenleigh

A significant rainfall event in 2013 resulted in the pond overflowing and the implementation of a Department of Environmental and Heritage Protection (DEHP) approved Transitional Environmental Program (TEP). The five-year TEP follows DEHP's stormwater management hierarchy of control mechanisms of firstly preserving existing elements of the natural stormwater system and then those that manage the quantity and quality of stormwater, at or near the source of potential contaminants. This also includes changing flow by using stabilisation or avoidance principles and/or erosion controls. If these measures are insufficient the DEHP requires structural measures to be undertaken to improve water quality and control runoff to capture mobilised pollutants and mitigate geomorphic stream damage. As a last line of control, the receiving water must be managed to avoid any residual impacts from stormwater pollutants or flows.

Site assessment and planning

Teys Beenleigh sought the assistance of an external consultancy firm who were familiar with both their site and stormwater management. Modelling of flow paths and expected volumes of runoff were undertaken using specialised software. Teys' own mapping identified areas generating clean and contaminated runoff. See Figure 13 for flow modelling map.

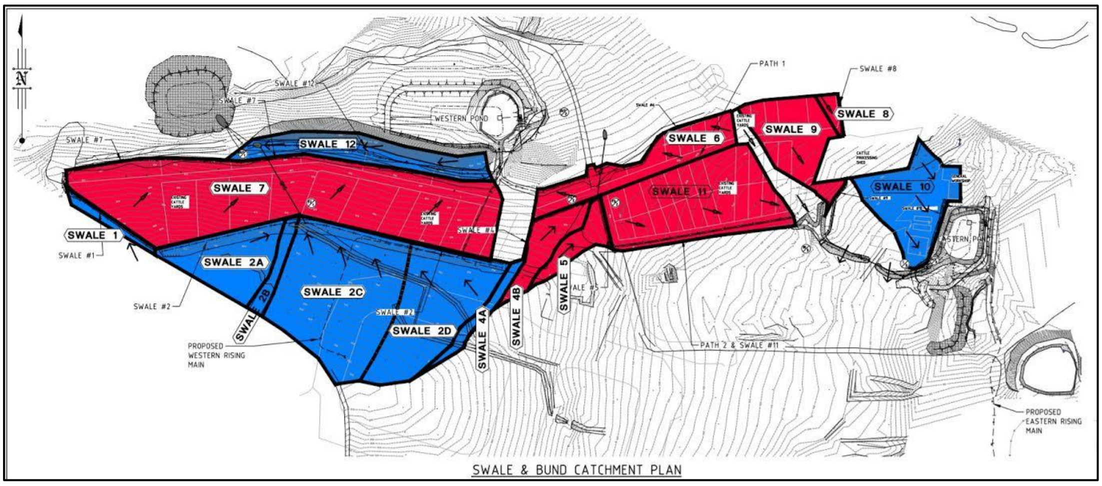


Figure 13: Clean and dirty runoff flows from Beenleigh cattle holding yards and pens

Runoff segregation and treatment

Contaminated water from the plant's holding pens are directed to the existing stormwater pond on the eastern side of the property. To meet the DEHP requirement that all constructed infrastructure be built to withstand a one in twenty Average Recurrence Interval (ARI) storm event in a 24-hour period, the existing pond capacity needed to be significantly increased.

The stormwater collected in the eastern pond is pumped to a series of decommissioned anaerobic lagoons, no longer used as the result of the site's decision to construct a state-of-the-art Covered Anaerobic Lagoon (CAL) wastewater treatment system. The decommissioned anaerobic ponds will not only capture any mobilised pollutants in the runoff but also greatly increase the stormwater holding capacity of the eastern stormwater catchment (see Figure 14).

Treated stormwater from the decommissioned lagoons is then directed to a holding pond before being discharged to sewer. Sewerage water quality requirements met include COD, TSS and TKN levels.

Contaminated runoff from the stock holding yards is directed to a newly constructed pond on the western side of the property which also meets the required ARI of 1 in 20. Contaminated stormwater in the pond will be sent to the sites wastewater treatment system (see Figure 15). Course material such as grit and manure are captured by rock checks and other removal mechanisms prior to entering the pond.

Figure 14: Decommissioned anaerobic ponds to treat stormwater runoff (to the south) and holding pond for treated runoff prior to release to sewer

Segregated clean water is conveyed by grass swales and underground drains (see Figure 13) to outlets flowing into the adjacent creek. The outlet has large 'Rip Rap' rock to reduce erosion.

Figure 15: Site wastewater treatment system - covered anaerobic lagoon and Biolac® used for the removal of nitrogen.

Stormwater segregation infrastructure

Newly constructed drainage work sought to use green infrastructure where possible. Segregating both clean and contaminated streams has involved the construction of multiple grass swales. Newly excavated swales were stabilised with a hydro-mulching emulsion of green dyed wood fibres and a propriety binder mixture (see Figure 16).

Figure 16: Hydro-mulching

Guttering and downpipes were also installed on the western maintenance workshop to divert clean runoff away from the eastern contaminated stormwater pond and directly to the adjacent creek.

Hard infrastructure installed as part of the TEP included underground pipe work to direct potentially contaminated stormwater from the plant's undercover yards to the primary treatment system and always from the eastern contaminated stormwater pond.

Areas such as the plant's truck wash hard stand area and tallow loading dock direct potentially contaminated stormwater to the plant's primary treatment system.

Avoidance of stormwater contamination runoff

While most of the plant's fuel and chemical storage areas are roofed and bunded, the need for hard infrastructure to avoid potential stormwater contamination from spills was complicated by the rapid expansion of the site. Instead of investing in hard infrastructure such as bunds and sumps, Teys has invested in portable dangerous goods containers. The off the shelf containers meet all the requirements of housing dangerous goods with the added flexibility of being portable (see Figure 17).

Figure 17: Portable dangerous goods containers

Spill kits are readily accessible and their use is currently undergoing revision as part of a plant update of the Standard Operating Procedures.

Monitoring

Teys Beenleigh currently undertakes groundwater, surface water and water quality monitoring of its Waste Water Treatment Plant, including:

- Weekly and monthly monitoring of the Waste Water Treatment Plant.
- Quarterly monitoring of the groundwater.
- Monthly monitoring of surface water.

By July 2017 Teys Beenleigh's stormwater management system will be fully operational and is an excellent example of best practice of runoff avoidance, segregation and treatment.

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