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CONTAINMENT AND REMOVAL OF SEWAGE OVERFLOWS FROM IMPACTED SURFACE WATERS - SYDNEY WATER'S CURRENT PRACTICES AND OPTIMISATION OPPORTUNITIES

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EXECUTIVE SUMMARY

Overflows from sewers are a common occurrence that can pose significant risk to the environment and human health, damage the reputation of the water utility within the community, and lead to regulatory action. Effective methods to contain and remove sewage contamination from waterways can minimise these risks. This practical research project focused on helping Sydney Water to determine improvements that could be made to their current approach to managing sewage overflows, through a process of evaluation, benchmarking, literature review of best practice techniques and equipment, and field trials of those techniques and equipment deemed appropriate for Sydney Water's assets and area of operations.

Sydney Water's current practice follows a process of:

- Containment
- Pumping
- Flushing
- Aeration

These were evaluated through a combination of understanding and categorising the key waterways impacted by sewage overflow, and consultation with Sydney Water staff. The nature of the receiving environment has an impact on both the urgency of incident response and the methods used to contain and remove the overflow. Sydney Water's clean-up crews, network operators and project team members shared their experiences with the range of overflow management equipment and methods. Effectiveness of their current approach, equipment and methods used in the categorised receiving environments was evaluated by discussions and surveys with field crews and network operators. To assess how well Sydney Water's current methods met industry best practice, they were compared with six large water utilities (Australian and international), revealing Sydney Water's strong approach to pumping, flushing, and aeration. New approaches identified through the benchmarking process, like the use of stormwater mats for containment and dechlorination mats for flushing, were recommended for field trials.

A literature review was also conducted, which did not identify any new techniques for flushing or pumping, but several were identified in containment and aeration.

Field trials were conducted by Sydney Water on silt curtains (containment) and low-spray aerators (aeration). The field crews found silt curtains to be effective and easy to handle. The low-spray aerators were also found to be practical, easy to operate, and useful for smaller waterways or in a high-density bush area with difficult access. Environmental damage experienced with other aeration methods due to sediment disruption was minimised. Low-spray aeration was considered to be a more effective and safe method than Sydney Water's current bar aeration method.

While much of Sydney Water's current techniques and equipment was deemed to be well developed, this research and trials conducted did conclude that the current approach could be improved through the addition of silt curtains during the containment phase, and the implementation of low-spray surface aerators to increase dissolved oxygen levels in the receiving waterway. Embedding these findings into Sydney Water's standard response to sewage overflows may help address the risks posed by these events. The results of this research may be of interest to other utilities wanting to improve their sewage overflow clean-up approach, and to contractors / suppliers working alongside them.

KEY POINTS

- Sydney Water has well-developed sewage overflow containment and removal techniques.
- New approaches in containment and aeration were identified through benchmarking and literature review, with silt curtains and low-spray aerators proving practical in field trials. Other options were excluded due to utility concerns and safety issues.

ABSTRACT

Overflows from sewers are a common occurrence that can pose significant risk to the environment and human health, damage the reputation of the water utility within the community, and lead to regulatory action. Effective methods to contain and remove sewage contamination from waterways can minimise these risks. This practical research project focused on helping Sydney Water to determine improvements that could be made to their current approach to managing sewage overflows, through a process of evaluation, benchmarking, literature review of best practice techniques and equipment, and field trials of those techniques and equipment deemed appropriate for Sydney Water's assets and area of operations. While much of Sydney Water's current techniques and equipment was deemed to be well developed, the research and trials did conclude that the current approach could be improved through the addition of silt curtains during the containment phase, and the implementation of low-spray surface aerators to increase dissolved oxygen levels in the receiving waterway. Embedding these findings into Sydney Water's standard response to sewage overflows may help address the risks posed by these events. The results of this research may be of interest to other utilities wanting to improve their sewage overflow clean-up approach, and to contractors / suppliers working alongside them.

INTRODUCTION

Sydney Water's wastewater systems consist of:

- approximately 27,000 kilometres of wastewater pipes
- approximately 30 water resource recovery facilities, which treat over 1.3 billion litres of wastewater everyday
- 695 wastewater pumping stations

The number of dry weather sewage overflows (chokes) from Sydney Water's sewer mains due to blockages and breaks is highly variable year-on-year due to the strong impact of the prevailing climatic conditions. There were 11,220 dry weather overflows recorded across all of Sydney Water's Sewage Treatment Systems in the 2023-24 reporting period. In prolonged drought conditions, the annual total can exceed 20,000. The record low in prolonged wet conditions was 7,644 in 2022-23.

Each year the overflow from a small percentage of chokes impacts upon a waterway due to direct flow or indirectly due to entry to the stormwater drainage system. In 2023-24, there were 487 dry weather overflows that reached a waterway where there was less than 10mm of rain; see Figure 1.

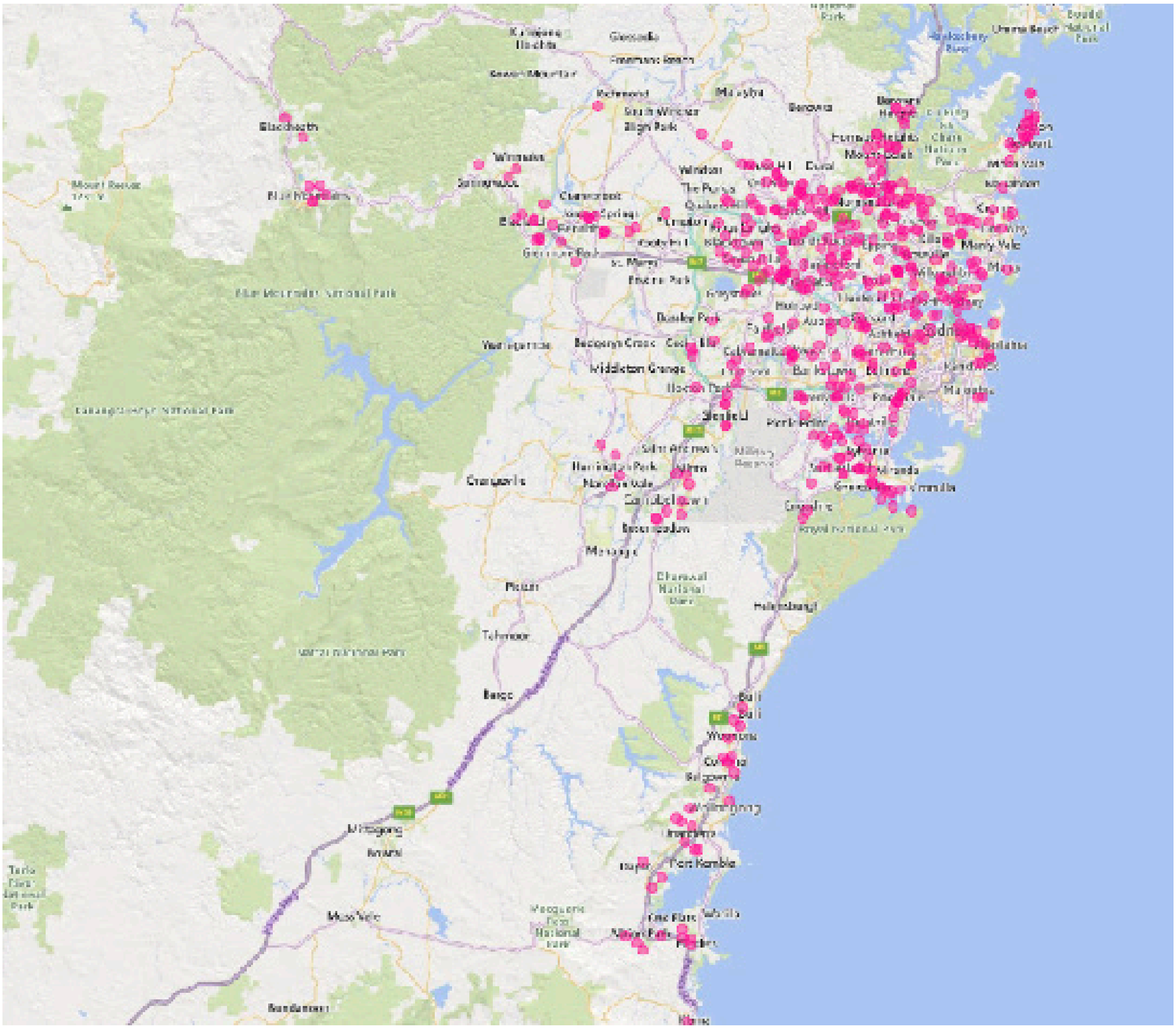

Figure 1: Location of dry weather sewage overflows (487) that reached a waterway in 2023-24

This project was funded through an enforceable undertaking by Sydney Water to the NSW Environment Protection Authority (EPA) following a discharge of untreated sewage from a Sydney Water rising main in Wollongong in 2020-2021. One key component of the undertaking was for Sydney Water to fund a practical research project to drive improvements in environmental performance.

Sydney Water subsequently partnered with Beca HunterH2O. The project was to conduct practical research into the optimisation of containment and removal of sewage overflows from impacted surface waters, aiming for effective and timely removal of sewage-contaminated waters by direct pumping to sewer mains or extraction using vacuum tankers. The project focused on helping Sydney Water to determine the improvements that could be made to their current approach to managing sewage overflows, through a process of evaluation, benchmarking, literature review of best practice techniques and equipment, and field trials of those techniques and equipment deemed appropriate for Sydney Water's assets and area of operations.

This research focused on sewage containment and clean-up of waterways, but excluded prevention, minimisation of overflows, and contaminated land remediation. The equipment and methods described in this paper are most applicable to sewage overflows that occur in dry weather due to blockages and breaks (chokes). Due to dilution and increased flow in waterways, usefulness and applicability decrease when there is wet weather (either causing the overflow or at the same time as a choke).

METHOD

A phased approach was adopted, with the assessment method used during each phase summarised below.

1. Reviewing current Sydney Water practices. The effectiveness of Sydney Water's current practices for the key sewage overflow to waterway categories identified in this project was evaluated via discussions with Sydney Water's clean-up contractors and project team members, and a survey completed by Sydney Water's clean-up contractors and Network Operators. The survey results detailed what equipment and methods were found to be practical and/or effective by the field crews.

2. Benchmarking against other utilities. Beca HunterH2O approached six large water utilities to benchmark Sydney Water's sewage overflow containment and removal methods against industry practice (noting the relatively small sample size of organisations surveyed). Meetings via MS Teams were held between the Beca HunterH2O project team and representatives from these major utilities familiar with their overflow containment and removal methods. Meetings typically involved the Beca HunterH2O team detailing Sydney Water's overflow containment and removal methods, with the major utility representatives identifying differences in their own responses. Focus was given to highlighting differences in the utility's approach to that adopted by Sydney Water.

3. Identifying new approaches and technologies. A literature review was conducted to identify any effective technologies not currently used by Sydney Water that could potentially improve its containment and removal of sewage overflows. Literature sources reviewed included technical publications, scientific journals, publicly available sewage overflow management response procedures from other utilities, and commercially available products. Where possible, suppliers were also approached. Technologies that are purely scientific or of an R&D nature were not captured given their lack of immediate applicability.

4. Field trials. Field trials were recommended to Sydney Water for a select number of approaches and technologies identified in items 2 and 3 above based on their:

- Practicality – Practicality of deployment and operation of the equipment by Sydney Water and their contractors; largely dependent on parameters such as size and weight. Practicality is essential for operator safety, as well as being able to deploy the equipment, especially when dealing with difficult terrain such as bushland, steep slopes, uneven ground, etc.; and
- Effectiveness – How well the equipment works at doing the job it is designed to do.

RESULTS

Interested readers can contact Sydney Water (tim.hill@sydneywater.com.au) for detailed research findings. Key outcomes are highlighted below.

Sydney Water's current approach and practice

Different receiving environments have varying sensitivities to sewage overflows. This impacts both the urgency of incident response and the methods used to contain and remove the overflow to minimise environmental and health impacts.

Key waterways within Sydney Water's areas of operations that have been historically affected by sewage overflows have been categorised as:

- Stormwater Canals
- Freshwater (Non-Tidal) Rivers, Creeks, and Ponds
- Wetlands
- Tidal Rivers and Estuaries
- Ocean/Beach

The four systems (or stages) of containment and clean-up used by Sydney Water are:

Containment. Sydney Water uses a variety of methods to physically contain or reduce the flow of sewage to receiving bodies, and to collect and remove wastewater materials from affected areas. These methods involve the use of sandbags, AquaSacs (AQUA·SAC®), Watergates, green fencing and booms.

Pumping. Sydney Water uses a variety of pumping and vacuum methods to transfer sewage overflows to sewer mains or transport by tankers elsewhere for disposal and minimise the risk of overflowing containment. Clean-up crews choose the most suitable size of pump (ranging from 2 inch to 6 inch, or 50.8 mm to 152.4 mm) to maintain effective containment and not exceed capacity requirements of the receiving network. Several pump types are used including diesel and petrol pumps, hydraulic pumps and electric pumps. These pumps can be skid mounted, as part of a quick response trailer or truck, or freeform without a skid. Pump weight and manual handling capabilities are important in determining their use, particularly in difficult-to-access areas. If pumping into a sewer access chamber (manhole), it is important to secure the pump pipe to prevent it from lifting out of the access chamber when pumping.

Flushing. Flushing is primarily performed to clean affected stormwater gutters/drains to ensure that all sewage waste is flushed and removed by clean-up crews, as well as to flush the affected land where the overflow occurred. Flushing can also be used to clean contaminated waterbodies. It is important that, prior to flushing, clean-up crews manually remove as much contaminated solid material as possible. Mains hydrants are typically used by Sydney Water for flushing purposes. Recently, Sydney Water has implemented Smart Hydrants fitted with a flowmeter to monitor the amount of water used for the flushing process. This data provides insight into the extent of water use for sewage overflows and aids in decision making as to whether alternate sources of water are required. When utilising mains water at clean-up sites for flushing, depending on the receiving environment's eco-aquatic sensitivity, it may be necessary to dechlorinate the water prior to it entering the natural environment. In general, if a site is deemed sensitive (e.g. a wetland, close to waterway), Sydney Water also follows a dechlorination process.

Aeration. Due to the biological and chemical oxygen demand of wastewater, sewage overflows can result in significant reduction in the dissolved oxygen (DO) concentration of waterways. As fish and other complex aquatic life forms require oxygen to survive, a lack of oxygen can result in the death of these animals. To reduce fish kills, aeration is used by Sydney Water where required. Aeration involves introducing air/oxygen to dissolve into the water column using a mechanical aerator. Currently, the main aeration method used by Sydney Water is diffused aeration via bar aerators.

It is essential that the containment and clean-up methods used are effective and practical. A summary of preferred containment and removal methods by Sydney Water's clean-up contractors and Network Operators is provided in Table 1. Sandbags, diesel and petrol pumps, hydrants/drip method dechlorination and aeration bars are among the most favoured methods.

Table 1: Preferred equipment (ticked ü) used by Sydney Water's clean-up contractors and Network Operators

Containment / Removal Method	Stormwater Canals	Natural Creeks and Ponds	Wetlands	Tidal Rivers / Estuaries
Containment				
Sandbags	✓	✓	✓	
AquaSacs (AET Flood Defence Limited, 2023) (A patented self-inflating sandbag comprising heavy-duty Jute sack and cotton liner and containing a water absorbent polymer)				
Watergates (Water Damage Defense, 2023) (PVC coated polyester barriers designed to act as flood protection and manufactured by MegaSecur)	✓	✓		✓
Green Fencing (A semi-permeable silt fence)			✓	
Booms (A containment method which is typically used to contain oil spills and floating debris)				✓
Pumping				
Diesel Skid Pumps				
Diesel Quick Response Trailer	✓			
Small Petrol Pumps (Bullfrog)	✓	✓	✓	✓
Hydraulic Pumps				
Electric Pumps				
Vacuum Truck	✓			✓

Containment / Removal Method	Stormwater Canals	Natural Creeks and Ponds	Wetlands	Tidal Rivers / Estuaries
Flushing				
Hydrants	✓	✓	✓	✓
Smart Hydrants (with flowmeter)	✓	✓	✓	✓
Drip Method (A dechlorination method where chemical addition is achieved by allowing a drum of <10% concentration of sodium ascorbate solution to slowly drip into the flow of flushing water)	✓	✓	✓	
Dechlorination Standpipes (Developed by Sydney Water to assist in the chemical dechlorination of mains water, this method works by installing a dechlorination standpipe at the water main and placing ascorbic acid tablets in the top of the pipe)	✓	✓		
Physical Dechlorination (Used for moderate sensitivity receiving environment by slowly allowing overland flow of mains water, this method works as chlorine is neutralised upon reacting with organic matter in its path or even sunlight)				
Physical Clean-up (brooms and rakes, mechanical sweeper trucks)	✓	✓		
Aeration				
Aeration Bars (Perforated tubes connected to an air compressor)	✓	✓	✓	✓
Pumps as Aerators		✓		
(Air entrained through the pumping process)				

Containment

- Sandbags were considered effective and practical.
- The perceived practicality of AquaSacs varied widely.
- Watergates were typically considered easy to use and effective.
- The perceived effectiveness and practicality of green fencing varied widely.
- The perceived effectiveness and practicality of booms varied widely.

Pumping

- Diesel and petrol skid pumps were generally considered practical and effective, with the exception of use in creeks, ponds and wetlands.
- Diesel quick response trailer pumps were generally considered practical and effective.
- Small petrol (bullfrog) pumps were generally considered practical and effective.
- Hydraulic pumps were generally considered effective; however, their perceived practicality was more varied.
- Most contractors had never used electric pumps.
- Vacuum trucks were considered very effective and practical for stormwater canals, with their perceived practicality and effectiveness more varied when used in other waterway categories.

Flushing

- Smart Hydrants were generally considered practical and effective; however, the response to their use in wetlands was more varied.
- The drip method of dechlorination was considered effective and practical in stormwater canals, creeks and ponds. The response to their use in wetlands and tidal/estuary waterways was more varied.
- The use of dechlorination standpipes was considered very practical and effective for stormwater canals, creeks, and ponds. The responses were more varied regarding their use in wetlands and tidal/estuary waterways.
- The perceived practicality and effectiveness of physical dechlorination varied greatly in responses.
- Physical clean-up methods were considered effective and practical in stormwater canals, creeks and rivers. The responses were more varied regarding their use in wetlands and tidal/estuary waterways.

Aeration

- Aeration bars were considered effective and practical, with the exception of use in wetlands, where the response was more varied.
- The use of pumps as aerators was varied in all waterway categories.

Benchmarking

The benchmarking results of Sydney Water's containment and removal methods against six large water utilities (Table 2) are presented in Table 3.

Overall, this study has found that Sydney Water generally has well-developed containment and removal methods, particularly in the Pumping, Flushing and Aeration categories. There were, however, a number of containment methods used by the other utilities that Sydney Water does not currently use; see Table 4.

Flushing and dechlorination techniques were similar between Sydney Water and the Australian and New Zealand utilities. All used potable water for flushing, and dechlorination was provided (when deemed necessary) using similar methods. UK utilities, however, had a different approach to flushing. With UK-1, flushing was primarily provided using wastewater treatment plant effluent to both save water and due to the lack of chorine content. UK-2 stated that they were not permitted to use chlorinated mains water for flushing.

Only two utilities surveyed had experience with aeration as a response to sewage overflows. Both had used pumps as aerators in contaminated waterbodies. While none of them had much experience with aeration, all had expressed interest and/or stated that aeration was a method they were actively looking into for implementation post sewage overflow.

Table 2: Summary of major water utilities benchmarked against

Utility Tag	Organisation Type	Location	Approximate Service Population
UK-1	Environmental Consultancy	United Kingdom	N/A
UK-2	Water Utility	United Kingdom	2.5 million
NZ	Water Utility	New Zealand	1.5 million
AU-1	Water Utility	Australia	0.5 million
AU-2	Water Utility	Australia	2 million
AU-3	Water Utility	Australia	1.5 million

Table 3: Summary of containment and removal techniques identified during benchmarking

Containment and Removal Methods	Sydney Water	Major Consul-tancy A (UK-1)	Major Utility B (UK-2)	Major Utility C (NZ)	Major Utility D (AU-1)	Major Utility E (AU-2)	Major Utility F (AU-3)
Contaminent							
Sandbags	✓	✓[1]	✓	✓	✓	✓	✓
AquaSacs	✓	✓[1]	✓	X[2]	X[2]	X[2]	X
Watergates	✓	✓[1]	X[2]	X	X[2]	✓[2]	X
Green Fencing	✓	✓[1]	X	✓	X	✓	✓
Booms	✓	✓[1]	✓	X	X[2]	✓	X
Pumping							
Diesel Skid Pumps (4-6 inch)	✓	✓[1]	✓[3]	✓	✓	✓[3]	✓[3]
Diesel Quick Response Trailer	✓	✓[1]	✓[3]	✓[1]	X	X	✓[3]
Small Petrol Pumps (2 inch)	✓	✓[1]	✓[3]	✓	✓	✓[3]	✓[3]
Hydraulic Pumps	✓	✓[1]	✓[3]	✓[1]	X	✓[3]	✓[3]
Electric Pumps	✓	✓[1]	✓[3]	✓	X	✓[3]	✓[3]
Vacuum/Combo Truck	✓	✓[1]	✓[3]	✓	✓	✓[3]	✓[3]
Flushing							
Hydrants/Mains Water	✓	?	X	✓	✓	✓	✓
Smart Hydrants (with flowmeter)	✓	?	X	X	X	X	X
Drip Method/IBC Dosing	✓	?	X	✓	X	X	X
Dechlorination Standpipes	✓	?	X	✓	X	X	✓
Physical Dechlorination	✓	?	X	✓	✓	✓	✓
Physical Clean-up	✓	?	✓	✓	✓	✓	✓
Hosing (e.g., via combo truck)	✓	?	✓	?	✓	X	✓
Aeration							
Aeration Bars	✓	X	X	X	X	X	X
Pumps as Aerators	✓	X	X	X	✓	X	✓

Key: ✓ - used X - used ? - used
Notes: 1. Not specified but was said to be similar to Sydney Water's practice.
2. Have in inventory, or have experience with the equipment/method, but currently do not use.
3. Equipment is hired

Literature review

The literature review did not identify any new approaches or techniques in the Pumping or Flushing category. However, several new approaches and techniques were identified in the Containment and Aeration categories; see Table 4.

There was very little information on containment methods in technical publications or scientific journals. A variety of methods were found in publicly available sewage overflow management response procedures from other utilities.

Several aeration methods were found in the literature that potentially have practical applications but are not currently used by Sydney Water. These were based on published reviews of aeration methods for hypoxic/anoxic rivers, literature on wastewater and dam/pond aerators, field trials in the Murray-Darling River system, as well as research into commercially available products.

Methods recommended to Sydney Water for consideration for field trials based on the benchmarking and literature review included:

- Stormwater Mats **(Containment)** (ERTEC Environmental Systems)
- Silt Curtains **(Containment)** (Texas Boom Company, 2023)
- Dechlorination Mats **(Flushing)**
- Venturi Aerators **(Aeration)** (Baldwin et al., 2021)
- Fountain Aerators (Low Spray) **(Aeration)** (Water Quality Solutions, 2023)

Sydney Water ultimately selected silt curtains and low-spray aerators for field trials. Stormwater mats were discounted by Sydney Water due to concerns about the mats not staying in position during incident response. Discussions with the Venturi aerator supplier and Sydney Water concluded that the Venturi attachments were not suitable for use with Sydney Water's existing pumps as the configuration was too complicated and impractical during incident response. Additionally, Sydney Water's and their contractor's preference was to replace dechlorination mats with sacks. Sydney Water plans to trial dechlorination sacks in line with the Dechlorination Standpipe Attachment developed by their Water Quality team.

Field trials

The initial field trials were conducted in the Botany Wetlands Canal in February 2024. This canal had a depth of approximately 1.5 m and a width of approximately 12 m. It is located approximately 4 km east-northeast of Sydney Airport and 2 km south-southwest of Randwick Racecourse. The Botany Wetlands is located on Sydney Water owned land. It receives stormwater run-off from a large urban catchment in Sydney's eastern suburbs, extending from Queens Park to Botany Bay. There were no sewage overflow incidents in the canal at the time of the trial. The site was chosen based on its good accessibility and generally low DO levels in this waterbody due to the relatively stagnant nature of the canal. The low-spray aerators were further trialled by the Network Operators on several real incident occasions elsewhere.

Silt Curtains. Sydney Water conducted trials of silt curtains as a containment measure; see Figure 2. Positive feedback was reported from operators and contractors regarding deployability and effectiveness, noting that their light weight made for good manual handling for deployment and retrieval.

Figure 2: Silt curtain being trialled at Botany Wetlands Canal, Sydney

Aerators. A low-spray surface aerator with a nominal oxygen transfer rate (OTR) of 1 kgO2/h was taken to field trials; see Figures 3 and 4. The low-spray aerator was compared to Sydney Water's bar aerators (diffused aeration), which had been used by Sydney Water during a number of overflow events where aeration was required.

While the aerator bars are light and were successfully deployed during the field trials, unlike the surface aerator, the bar aerator required the towing of its associated compressor which weighed approximately 900 kg, as compared to a small portable generator of approximately 60 kg used for the surface aerator trial. Thus, although likely effective when towing capability and good site access are available, the current diffused aeration setup used by Sydney Water is not suitable for sites with poor access, which are commonly encountered by Sydney Water.

The field trials highlighted the improved utility of the trialled surface aerator over Sydney Water's current diffused aeration method. Specifically:

- The low-spray surface aerator was found to be very practical and easy to operate.
- Sydney Water noted that the surface aerator would have high utility, particularly for smaller waterways and hard-to-reach areas, when compared to the existing diffused aeration configuration.
- The trialled bar aerator (diffused aeration – single bar) demonstrated a high risk of environmental damage when used at the bottom of the waterway. During the Botany Wetlands Canal trial, there was a significant increase of >10 NTU in turbidity at the aeration zone in the bottom diffused aeration configuration. This was attributed to the disruption of sediments in the canal, likely due to uncontrolled movement of the aerator bar. Sydney Water crews also reported bad ambient odours during the diffused aeration trials.
- Using the surface aerator reduced the risk of environmental damage. It was observed during the Botany Wetlands Canal trial that there was no increase in water turbidity, indicating that sediment disturbance was minimal.

Figure 3: Surface aerator being trialled at Botany Wetlands Canal, Sydney

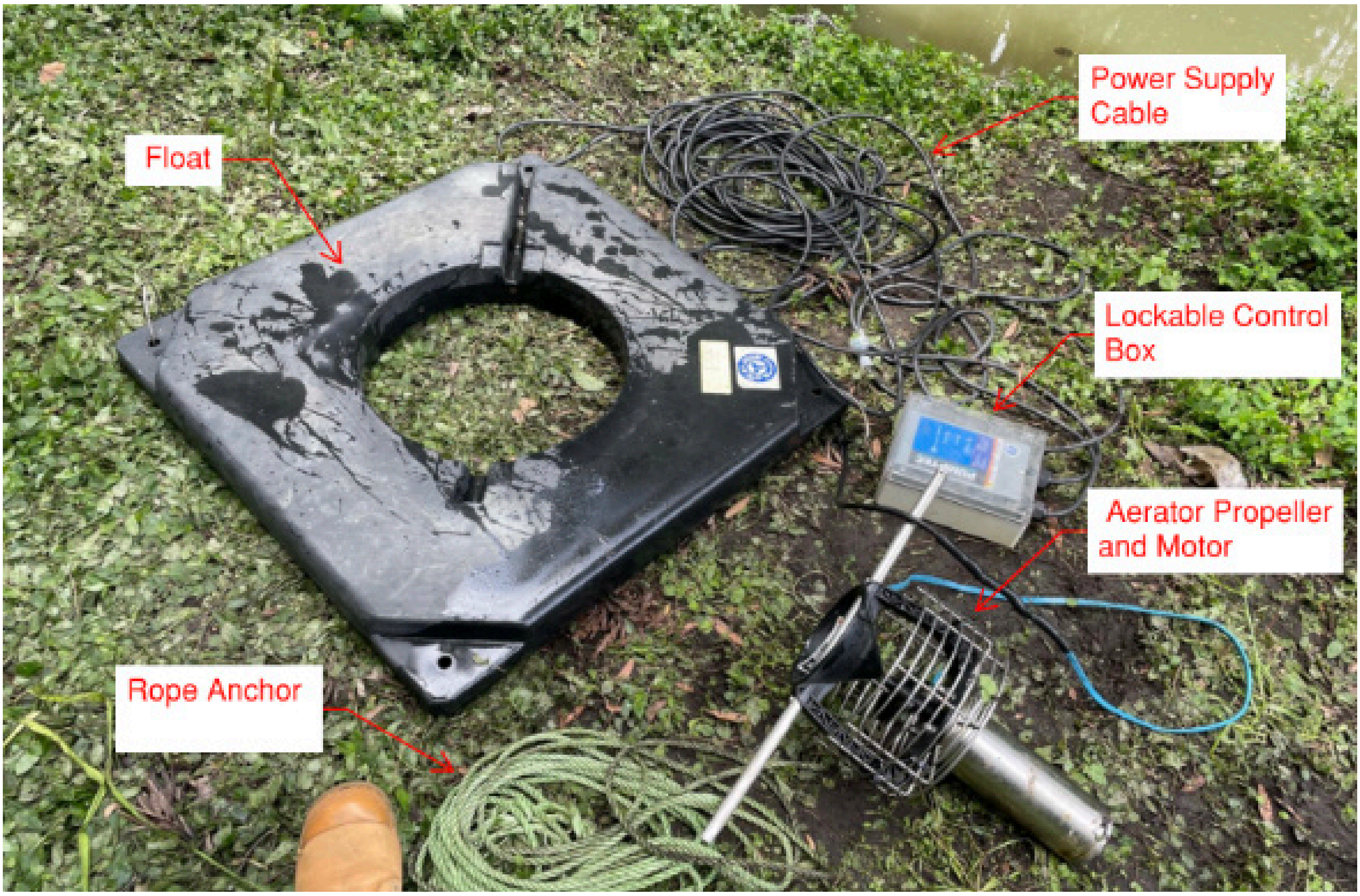

Figure 4: Surface aerator disassembled

The initial field trial results were, unfortunately, not useable for aeration effectiveness assessment due to storms causing a significant increase in baseline DO close to saturation. Therefore, a desktop study was undertaken to compare the oxygen transfer rates of various surface aerator and diffused aeration configurations. Subsequent trials by the Network Operators on several real incident occasions elsewhere found low-spray aeration to be a more effective and safe method than Sydney Water's current bar aeration method to replenish depleted oxygen and restore waterways as part of the environmental clean-up process. The improved Work Health and Safety (WHS) and effectiveness of the low-spray aerators when deploying the equipment in a high-density bush area with difficult access were particularly welcomed by the field crews.

DISCUSSION

Benchmarking

Differences in approach can either result in more or less opportunity for sewage overflow containment and removal depending on how utilities structure their sewage overflow approach. Thus, it is important to note that this paper does not necessarily make comment on the effectiveness of different containment and removal methods as this is inherently impacted by the procedures, resourcing, training and/or communication used by different utilities, as well as climatic conditions that render natural dilution, such as the case in the UK. Furthermore, a water utility that uses a wide variety of methods does not necessarily see better performance in terms of mitigating the negative impacts of sewage overflows. As mentioned earlier, our focus was to identify differences in the utility's approach to that adopted by Sydney Water.

Evaluation of containment and clean-up methods

The long list of approaches and technologies identified during benchmarking and literature review, which Sydney Water has not used before, was evaluated at a high-level (see Table 4). A shortlist of suitable options was then produced. Further details on shortlisted options (e.g. weight, cost, availability) were then obtained by going to the market. A select number of methods were then recommended to Sydney Water for field trial consideration.

Table 4: Long list of methods identified through benchmarking and literature review

Stage/Method	Brief Description	High-Level Assessment	Consid-ered for Shortlist
Containment			
Inflatable Dams	Rubber structures that can be used as a barrier to prevent water flow. Require inflation.	Effective in limiting the flow of water. However, they are very similar to Watergates, which are currently used by Sydney Water. Additionally, Watergates do not require inflation.	No
Skimmer Vessels	Boats that collect floating debris via conveyor belts or nets. Require ancillary equipment for offloading, disposal, and transportation over land.	Good potential for clean-up of floatable waste. However, they are expensive and not easily portable.	No
Pneumatic Plugs (AU-1)	Pneumatic plugs that can be used to block stormwater pipes to prevent contamination of the stormwater system.	Good potential to limit contamination of stormwater systems. However, deployment may be difficult and there must be no flow in the stormwater pipe when being deployed. Sydney Water has experience with similar plugs but does not currently use them due to safety concerns.	No
Stormwater Mats (AU-3)	Semi-permeable mats that prevent the flow of solids into stormwater systems.	Good potential to limit contamination of stormwater systems.	Yes
Earth Berms (UK-2)	The method of creating earth berms (e.g. using shovels, Bobcats, etc.) to divert and pool sewage overflows.	Well-constructed and positioned earth berms have potential to effectively divert and contain flows. However, their construction can be difficult and time-consuming. Similar results could be achieved with simpler containment methods (e.g. sandbags).	No
Hay Bales/Coir Logs (AU-2, AU-3)	Alternatives to sandbags. Used as a barrier to contain sewage overflows.	Both hay bales and coir logs can effectively be used to contain sewage overflows. However, they are practically very similar to sandbags used by Sydney Water and provide no notable advantage.	No
Silt Curtains	Similar to a containment boom. Silt curtains, however, typically are much deeper. Curtains can extend close to the bottom of the waterbody. Modular units can be connected to form longer lengths. Units are typically 15 – 20 m in length.	Can effectively contain surface flows. Had been used effectively by Sydney Water in the past.	Yes

Stage/Method	Brief Description	High-Level Assessment	Consid-ered for Shortlist
Ponding using Excavators + Tarpaulin (AU-3)	Very similar to earth berms as a containment method, discussed above. Ponds are constructed and lined with tarpaulin to contain sewage overflow.	As with earth berms, ponding may provide effective containment. However, their construction can be difficult and time-consuming. Similar results could be achieved with simpler containment methods (e.g. sandbags).	No
Pipe Wrap at Overflow Point (UK-1)	Containment of sewage overflow by wrapping overflowing damaged pipe at the source of the overflow.	Wrapping while sewage overflow is ongoing would be an unacceptable WHS risk due to contact with sewage.	No
Steel Mesh (NZ)	Steel-mesh cover that prevents the flow of solids into stormwater systems.	Good potential to limit contamination of stormwater systems. However, they are practically very similar to stormwater mats, which are more portable and considered a better option.	No
Stream Drying (NZ, AU-1, AU-2)	Stream drying is the process of completely removing contaminated water from a stream through both pumping and natural processes like evaporation, before refilling the stream with uncontaminated water.	Not recommended by the NZ water utility spoken to during benchmarking. While they may be useful in some circumstances, it is not recommended as a primary method of containment.	No
Pumping			
Nil	There are no new pumping methods identified as part of this study.		
Flushing			
Dechlorination Mats (NZ, AU-3)	Dechlorination mats are flat bags with pockets for dechlorination tablets. These are placed downstream of the potable water stream and upstream of the contaminated waterbody.	Potential to provide improved mixing of sodium ascorbate (or other dechlorination chemicals) and improved dechlorination.	Yes
IBC Dosing (NZ)	Very similar to the drip method used by Sydney Water. The intermediate bulk container (IBC) method involves batching a solution with a high concentration of sodium thiosulphate (or can be alternative dechlorinating agents) and discharging it directly into the stream.	Very similar to the drip method used by Sydney Water. Bulkier than existing drip method.	No
Dechlorination Tablets in Silt Bags (AU-1, AU-2)	Similar to the dechlorination mats. Dechlorination tablets are placed in the semi-permeable silt bags to provide dechlorination.	Very similar to the dechlorination mats, that appear to be more effective.	No
Recycled Water Flushing Truck (UK-2)	A vacuum/flushing truck that recycles contaminated overflow for flushing purposes. While this water is filtered, it is not disinfected.	As the recycled water is not treated / disinfected, it is considered a WHS risk, thus not considered further.	No

Stage/Method	Brief Description	High-Level Assessment	Considered for Shortlist
Aeration			
Surface Aeration			
Venturi System	Pump-as-aerator setup with a Venturi attachment to improve aeration.	Field trials by others have shown Venturi systems can improve DO in hypoxic and anoxic waterways in the Murray-Darling River system. Potential use in response to sewage overflows. Low efficiency but high oxygen transfer.	Yes
Water Fountains	Aeration via pumping and spraying low DO water to allow for air entrainment, providing localised areas of increased DO.	Potential for use in response to sewage overflows. Must be low spray drift to eliminate WHS risk.	Yes
Paddle Wheels	Aeration is provided as the top 20 cm of water is splashed by rotating paddles on a floating pontoon, allowing oxygen to be entrained.	Potential for use in response to sewage overflows. However, more recommended as a preventative measure for stratification-driven hypoxia. More effective alternatives available for response to sewage overflows, such as Venturi and low-spray fountain aerators. Significant splashing poses a WHS risk, thus not considered further.	No
Surface Bubble Aerators	Bubbles are injected into the contaminated water to provide aeration.	Potential for use in response to sewage overflows Have found use in response to hypoxia in the Murray-Darling River system.	Yes
Surface High Speed Aerators	Provide aeration simply through mechanical mixing by disturbing surface waters and allowing for air entrainment.	Potential for use in response to sewage overflows. Commonly used in wastewater treatment for aeration.	Yes
Subsurface Aeration			
Solar Bubble-Plume Diffusers	Designed to prevent stratification and aerate the hypolimnion (lower layer of water) by maintaining a vertical flow pattern which allows water from depths to be oxygenated via exposure to the surface.	More suited as a preventative measure against stratification driven hypoxia. Field trials by others in the Murray-Darling River system showed the solar bubble-plume diffusers did not effectively increase DO in hypoxic waterways, thus not considered further.	No

Stage/Method	Brief Description	High-Level Assessment	Considered for Shortlist
Aeration			
Suburface Aeration			
Nanobubbles (Ultra-Fine)	Ultra-fine bubble aerators produce <1µm bubbles with very large surface area to volume ratios to provide aeration.	Field trials by others showed promise, improving DO in hypoxic waterways. However, this was achieved over days.	Yes
Microbubbles	Microbubble aerators produce 10-100µm bubbles with large surface area to volume ratios.	Very similar to ultra-fine bubble aeration.	Yes
Fine Bubbles	Fine bubble aerators use slits/ pores ≤2mm. The bar aerators used by Sydney Water are in this category.	The bar aerators used by Sydney Water are fine bubble aerators. However, Sydney Water has expressed interest in smaller, easier to use units. Small, portable options available on market. High standard aeration efficiency (SAE) values.	Yes
Mega Aerator	This aerator produces milli-bubbles (less than 1mm but greater than 1µm) and is designed for large bodies of water, as well as smaller polluted bodies of water with low DO levels. Various models exist with oxygen transfer rates ranging from 6.3 to 127 kgO_2/h.	A large milli-bubble aerator that may potentially be able to improve DO in sewage affected waterways. Appears to have recently been discontinued, thus not considered further.	No
Propellers/ Aspirators	Downward-facing propellers work by aspirating air and propelling oxygenated surface waters to oxygenate deeper levels and undo stratification of waterbodies.	Good oxygen transfer rates and mixing. However, downward facing propellers will likely disturb sediments. Not considered further due to risks in shallow waterways.	No
Chemical Aeration			
Calcium Peroxide	A slow-acting (weeks to months) calcium salt that is used in aquaculture to maintain oxygen levels. It works through offsetting sediment oxygen demand, as the salt dissolves and reacts slowly, accumulating on the surface of sediment.	Due to its slow-acting nature and no immediate DO increase to the water phase, it is not considered effective for addressing sewage overflow-driven DO depletion. Also, efficacy, regulatory approvals, cost and safety require further research, thus not considered further.	No
Sodium Percarbonate	A fast-acting (minutes to hours) chemical that produces peroxide, which decomposes to form oxygen.	Has potential to improve DO for emergency aeration. However, potential significant environmental risks are associated with the use of sodium percarbonate, thus not considered further.	No

Shortlisting of aeration methods

A decision tree (Figure 5) based on pragmatic “Pass-Fail” steps was developed and used to aid in the shortlisting and recommendation of aeration options since there were multiple aeration options to be considered. The steps adopted are as follows:

- **Contamination:** The aerator must not pose a WHS risk and/or environmental damage concern.
- **Portability:** Sydney Water indicated a preference for all aerators recommended for field trial to be able to be operated by no more than two people, as larger units were considered to have little utilisation by Sydney Water (especially when dealing with difficult terrain such as bushland, steep slopes, uneven ground, etc.) despite benefits of increased oxygen transfer. A limit of <50 kg was set, with a preference of <40 kg. Any aeration equipment requiring cranage was not considered further as Sydney Water’s experience was that the frequency of large clean-up jobs was low, and if necessary, multiple units of the portable aerators could be used.
- **Power:** It is essential that power demands can be met with portable equipment.
- **Deployability:** It is essential that an aerator can be set up by no more than two people.
- **Effectiveness:** It is essential that the aeration system can raise DO levels quickly (i.e. high specific oxygen transfer rates or SOTRs) compared to similarly sized aeration methods.

It is worth pointing out that while larger aerators were not considered for field trial, primarily due to their limited portability and deployability, they may provide significant value during a very large (albeit relatively rare) overflow event. However, WHS risks must be considered when using large, high-speed surface aerators, as despite being low-spray, there would likely be an increased risk of aerosol generation given the large amount of surface disruption they cause.

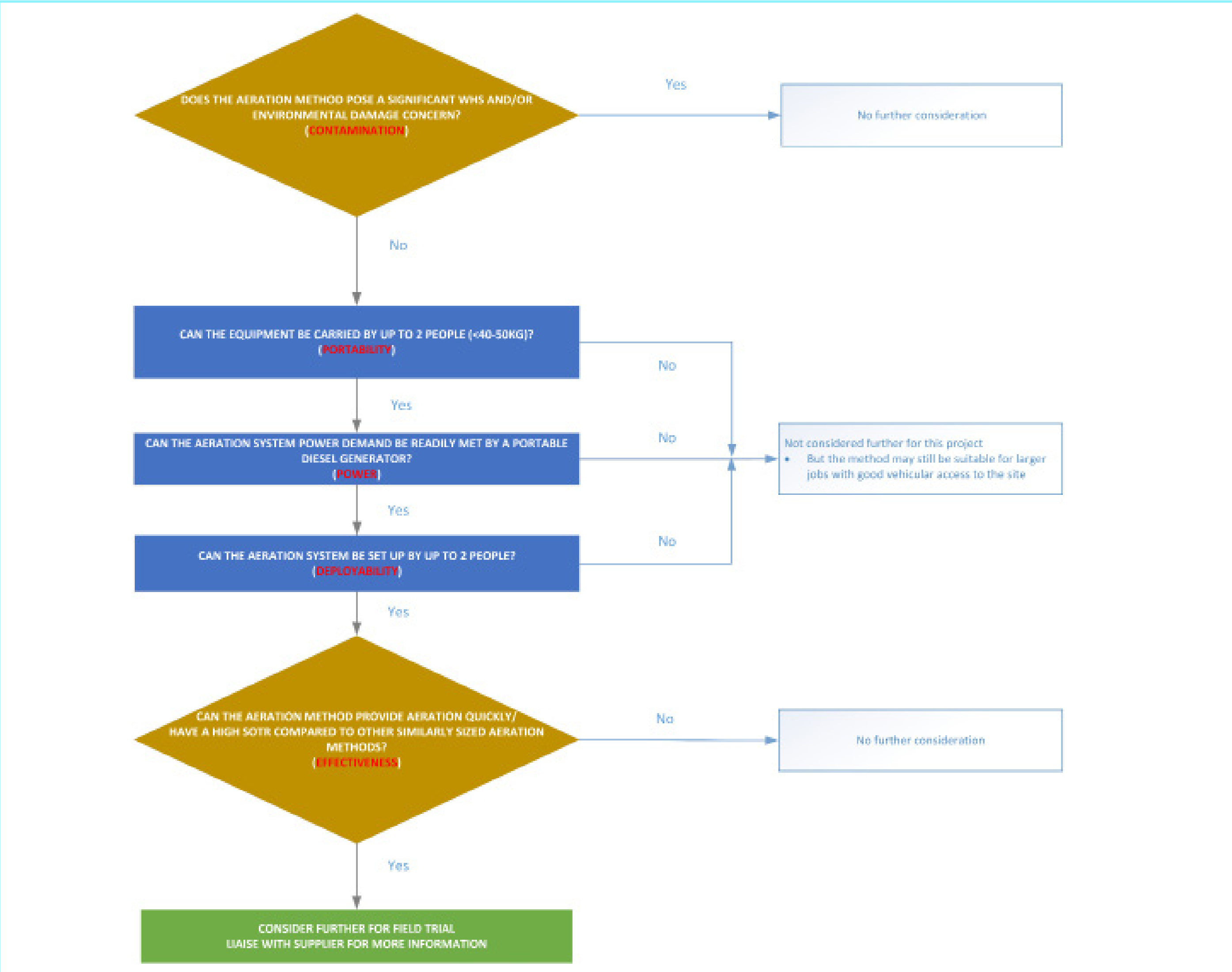

Figure 5: Aeration decision tree

Industry benefits

Whilst other utilities may have different approaches to managing sewage overflows to waterways, the results of this research will be of interest to those wanting to improve their sewage overflow clean-up approach. Utilities and their contractors / suppliers working alongside them could start by categorising their waterways and then learning from Sydney Water's experience.

CONCLUSION

A process of evaluation, benchmarking, literature review of best practice techniques and equipment, and field trials of those techniques and equipment deemed appropriate for Sydney Water's assets and area of operations was adopted to help Sydney Water to determine improvements that could be made to their current systems (Containment, Pumping, Flushing and Aeration) in managing sewage overflows.

Whilst much of Sydney Water's current techniques and equipment was deemed to be well developed, this research and Sydney Water's field trials did conclude that the current approach could be improved through the addition of silt curtains during the containment phase, and the implementation of low-spray surface aerators to increase dissolved oxygen levels in the receiving waterway.

The results of this research could be used by other utilities when they are looking at options to improve response in their particular context.

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