MEMBRANE LINERS AND FLOATING COVERS FOR EXISTING OPEN WATER STORAGE BASINS: WHY? AND HOW?

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ABSTRACT

Several issues require careful consideration for the successful installation of membrane liners and/or floating covers to existing open water storage basins. For example: Membrane material type and colour; subgrade treatment for puncture protection and underdrainage; modification of existing inlet, outlet and overflow pipes/structures; maintenance of supplies to consumers during the installation and allowances for future operations and maintenance.

This paper discusses the key issues which require consideration in the implementation of water quality improvement projects using membrane liners and floating covers via the design and construct project delivery mode. Alternative means of addressing the key issues are given by reference to several recent projects.

KEYWORDS

Membrane, Liner, Floating Cover, Water Quality, Water Storages, Implementation

1.0 INTRODUCTION

The Victorian Government has been driving improvements in water quality and customer service in recent years. Water stored in open service basins is vulnerable to faecal contamination, dust and other airborne contaminants and sometimes algal blooms.

Three main solutions are available to authorities wishing to cover storages to avoid contamination and algal blooms without increasing chemical inputs:

- Replace the open basin with a roofed storage tank;
- Install a fixed roof over the basin;
- Install a floating (synthetic membrane) cover over the basin.

Floating covers have emerged over the last several years as generally the most cost-effective means of addressing the above problems. Unlined basins are usually lined prior to covering.

2.0 WHY?

2.1 Floating Covers

The use of floating covers in lieu of fixed covers has increased in recent years primarily due to their significantly lower capital and net present costs compared to fixed covers. This is clearly demonstrated by the cost of covering the 9ML Timboon Basin via various alternatives (refer Table 1 below, which is based on tendered prices as at September, 1997).

Net present value analyses undertaken for several projects indicate that floating covers are substantially more economical than fixed covers (after allowing for increased operations and maintenance costs and a shorter design life, eg 20 years compared with 40 years for a fixed cover).

Table 1: *Cost Rates for Timboon Basin (Floating Cover Only)*

Alternative	$ per m^2
Floating cover	$38 to $49
Fixed cover (Steel cladding)	$93 to $172
Fixed cover (Aluminium cladding)	$124 to $142

Based on an area of 3600 m2, being the area within the upstream (internal) embankment crest edges.

Other factors which favour floating covers, relative to fixed covers, include:
1. No need to investigate bearing capacity of foundation.
2. No need to include additional load transfer components, eg: column footings.
3. Less intrusive visually, eg: no extension above embankment crest level.
4. Stormwater runoff from the cover is discharged to the drainage system slowly, ie. the cover acts as a retarding basin.
5. Ability to install cover by floating on in some circumstances (allowing basin to remain in service).

There are, however, several disadvantages associated with floating covers, including:
1. Difficult access for visual monitoring, inspection, cleaning etc.
2. Keeping the top of the cover clean & free of ponded water.
3. Cover drainage is reliant on pumping.
4. Vulnerability to vandalism.
5. Higher maintenance costs - specialised cleaning and repair contractors required.

2.2 Membrane Liners

For basins with existing concrete lining, any existing concrete lining proposed to remain should be inspected for slab movement, joint condition, surface condition etc. Any problems with existing lining should be rectified prior to covering. Such rectification may or may not include the addition of a membrane liner (depending on perceived water quality risks, condition of existing lining, opportunities for increasing top water level and cost).

For basins without existing concrete lining, surfaces must be prepared to a standard suitable to accept a membrane or concrete liner. A membrane liner is often selected due to its impermeability, relative ease & speed of installation and cost.

3.0 HOW ?

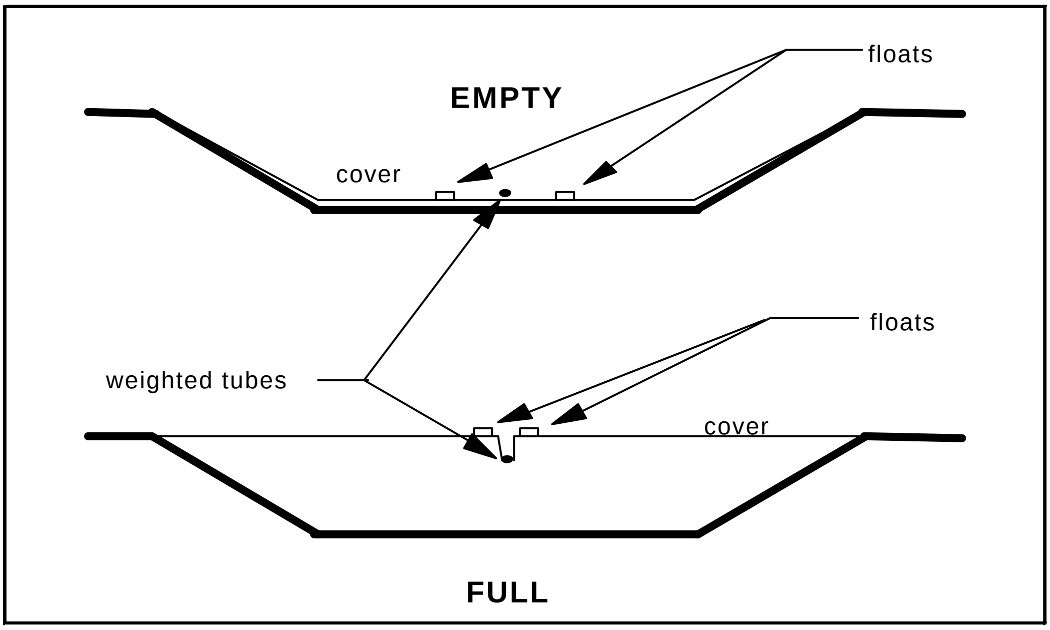
After a brief overview of the design principle of floating covers, key implementation aspects will be discussed.

3.1 Design Principle

Gerber (1984) provided an overview of the historical development and current best practice (as at 1984) of floating cover designs. The example projects discussed later in this paper all have a ‘defined sump reservoir cover’ design basis, which is illustrated in Figure 1 below.

Sufficient cover material is installed so that it will lay flat against the embankment walls and floor when the basin is empty. Excess cover material is ‘taken up’ when water is introduced to the storage by weighted (usually wet sand or cement grout) tubes. The tubes keep the cover tight at all water depths and define surface drainage sumps. The depth of the drainage sumps increases as the stored water level increases (to ‘take up’ additional membrane).

Figure 1. ***Defined Sump Reservoir Cover***



3.2 Standards

The American standard, NSF 54 (NSF International, 1991) outlines materials and testing requirements for a range of materials, eg: High Density Polyethylene (HDPE), Hypalon, PVC etc. NSF 54 also gives some guidelines for installation, however, it only gives general indications of chemical and puncture resistance requirements. It does not contain any requirements relating to permeability.

Approval for use with potable water is usually demonstrated via the provision of test certificates to Australian Standard AS 4020 or the American NSF 61 standard.

3.3 Membrane material type

Selection of an appropriate membrane material type is influenced by membrane function and location (eg: cover, floor liner or embankment liner), water quality & maintenance considerations and project budget.

A brief summary of the current main material options for liners and floating covers:

- High Density Polyethylene (HDPE). HDPE is lighter than water and will float if punctured, is jointed via fusion welding and has good chemical and UV resistance. However, it does not conform well to surface irregularities, tends to move and creep when placed on slopes and is relatively stiff and brittle (ie prone to stress cracking).
- Hypalon is a form of polyethylene (Chlorosulfonated PE, or CSPE) which is heavier than water (ie it will sink if punctured or cut) but which weathers well. It is usually jointed using chemical adhesives (this has water quality implications).
- Polypropylene has excellent materials properties, for example it is lighter than water (so it will float if cut or punctured), has good thermal and dimensional stability (ie minimal creep) and is jointed via fusion welding. Whilst a little more expensive than HDPE, it has been the preferred cover/liner material for many authorities in the last few years.

- Reinforced membranes (such as reinforced polypropylene and CSPE-R (reinforced Hypalon)) consist of an open weave reinforcing fabric (or ‘scrim’), typically a polyester mesh, which is ‘sandwiched’ by the plain (‘unreinforced’, or ‘unsupported’) membrane plies.
- As unreinforced membranes (eg: HDPE, unreinforced polypropylene) exhibit greater elongation than reinforced membranes, they have greater ability to conform to irregular surfaces and cater for settlements than reinforced membranes (NSF 54, 1991). However, unreinforced membranes can exhibit creep when laid on slopes.

3.4 Membrane Colour

Darker materials absorb more heat from sunlight and so get hotter than lighter coloured materials. Anecdotal evidence suggests that the difference in temperature of water under dark coloured covers compared to light coloured covers is quite small. There is a need to ensure minimal sunlight penetration (to avoid algal growth). In the absence of any comprehensive data, cover topside and underside colours should be selected on aesthetic and operations & maintenance considerations.

3.5 Subgrade Treatment

Liners need to be supported on appropriately prepared subgrade. The need to satisfy the liner manufacturer’s installation requirements for the liner is critical. For example, Nylex (1997) require the subgrade under its ‘Millennium’ Polypropylene membrane liners to be:

- ‘ … a regular surface free of sharp irregular or abrupt changes in line and level and jagged or fractured rock projections’; and
- ‘…of suitable fine soils or crushed materials with a maximum particle size of 8 mm for reinforced flexible membrane liner material and 16 mm for unreinforced flexible membrane liner material’.
- ‘… flat within tolerances of +/- 100 mm over any 5 metres’.

The Nylex specification does also, however, state that the Superintendent ‘may authorise the use of a geotextile underlay’ as an alternative to the above standards. There is a need to ensure that any alternative subgrade treatment will not void the manufacturer’s warranty.

There is also a need to provide a drainage path under membrane liners to allow for the hydrostatic relief and removal of groundwater during basin drawdown or emptying (to prevent the liner from lifting). Discharge of the underdrainage to a witness point (eg. a pit, rather than a buried connection) is useful as it allows monitoring of flows.

3.6 Existing pipes/structures

Modification of existing inlet / outlet / overflow / scour pipes or structures will usually be required to ensure no fouling / puncturing of membranes, as these often project into the space which is to be enclosed. The exact modifications will be a function of the existing arrangements. Elevated walkways are usually removed entirely, with future access to valves via ‘access hatches’.

3.7 Other issues

Membrane attachment: To existing concrete liner if one exists and is in good condition, otherwise, a new edge beam is constructed. The cover (and liner) are generally fixed by the use of stainless steel battens, a gasket and anchor bolts.

Seaming of panels is critical to the fitness for purpose of the completed liner and/or cover. Comprehensive Quality Assurance requirements should be in place (eg: 100% vacuum or air lance testing of all factory and field seams), together with destructive testing of samples (preferably by the Principal or Superintendent). Tests should include tensile strength and peel strength.

Cover drainage: Some level of 'ponding' of stormwater on the cover is to be expected, given the design basis of the cover drainage system. Whilst it is important to keep the cover clean to ensure that sumps do not accumulate undesirable material, this may be difficult in practice, as access to the sumps is usually somewhat restricted, particularly at higher stored water levels.

Warranty: It is important to follow the manufacturer's warranty application process, eg for Nylex, the completion and submission of a 'proposed use form' early in the project.

3.8 Future Operations and Maintenance

Inspection, cleaning of top surface and repair of floating covers can all be undertaken from 'topside', however, inspection, cleaning and repair of internal surfaces must be done from within the storage. Two main options exist: Divers or 'Drain and Inflate'. Appurtenances on the cover need to reflect the proposed future inspection, cleaning and repair methods.

Provision for instrumentation needs to be considered, eg: inclined conduits (to house level transmitters) strapped onto lining or stilling wells.

Security, including protection from vandalism is an important consideration. South East Water Limited increased the security level at each of its five membrane covered storages by installing a weldmesh security fence around the sites.

4.0 EXAMPLES OF RECENT PROJECTS

4.1 Projects

The five projects listed in Table 2 below have been selected to illustrate how the key implementation issues discussed above can be addressed.

Table 2: ***Case Studies***

Project (& Capacity)	Year Covered	L x W x D approx *	Existing internal surfaces
Timboon Basin (9 ML)	1998	60 x 60 x 4.5	Concrete lined floor and batters
Wonthaggi Low Level Basin (11 ML)	1998	72 x 63 x 4.0	Concrete lined floor and batters
San Remo Basin (23 ML)	1999	127 x 81 x 4.0	Clay floor; Rock beached earth batters
Tyabb Reservoir (318 ML)	1999	300 x 210 x 5.0	Concrete floor; Rock beached earth batters
Yarram Basin (3.4 ML)	2000	58 x 46 x 3.0	Mortared Rock Lining

* Length and Width of internal embankment crest edge. Depth from floor to crest.

4.2 Means of Addressing Key Implementation Issues

The means of addressing the issues discussed above are outlined in Tables 3 and 4 (overleaf).

Table 3: ***Membrane Material and Colour***

PROJECT	LINER	FLOATING COVER
Timboon Basin (9 ML)	Existing concrete liner	1.1 mm RPP tan on white
Wonthaggi Low Level Basin (11 ML)	1.14 RPP tan on white	1.14 RPP tan on white
San Remo Basin (23 ML)	1.1 mm RPP green on black	1.35 mm RPP green on black
Tyabb Storage (318 ML)	1.1 mm RPP/UPP* black	1.1 mm RPP tan on white
Yarram Basin (3.4 ML)	1.1 mm RPP tan on white	1.1 mm RPP tan on white

Where RPP = Reinforced Polypropylene and UPP = Unreinforced Polypropylene. * A cross shaped section of liner over the existing concrete floor was UPP (used to accommodate expansion / movement).

4.3 Operations & Maintenance

Reported O&M advantages and disadvantages are listed in Table 5 below.

Table 5: ***Operations & Maintenance experience***

Basin	Advantages	Disadvantages
Timboon Basin	Reduction in water quality complaints No interruptions to supply due to algae	Algae in surface water blocks pump well screen. Currently have a leak in the cover (location unknown - need to inflate to find). Access to valves not as convenient
Wonthaggi Low Level Basin	Clear water	Having to keep cover clean (to avoid / reduce weed growth) Visual monitoring difficult.
San Remo Basin	Previously no T& O in source water, yet T&O in the basin. This no longer occurs.	Pine needles blocking pump well and pump.
Tyabb Reservoir	Some chlorinators downstream of the reservoir have been turned off or had set point reduced.*	Cover drainage pumps blocking. Foresee some problems with internal cleaning.

* Water is dosed at 1 mg/L on inlet and has a residual of 0.4 mg/L under normal demand conditions at the outlet.

South East Water Limited ('SEWL'), which has five basins with floating covers (two with Hypalon and three with RPP) installed in 1994 and 1995, undertook a comprehensive microbiological sampling and testing program at the basins during 1997 and 1998.

SEWL found that:

- The licence requirements for the health parameters 'Faecal Coliforms' and 'Total Coliforms' were met each year in the five water quality zones.
- The basin outlet sample results for these parameters were comparable with zone results.
- Pseudomonas Aeruginosa was found in each water body, ie from within each basin.
- Water at depth and along flow lines gave better microbiological results in the water bodies.
- Temperatures in the water bodies varied with depth with about a 2^0C temperature drop from the surface to a depth of 3m.

Table 4: ***Means of Addressing Various Key Implementation Issues***

PROJECT	SUBGRADE TREATMENT	EXISTING PIPES / STRUCTURES	MAINTENANCE OF SUPPLIES DURING INSTALLATION
Timboon	Not applicable; existing concrete liner was retained.	Access hatch positioned over outlet and scour valves. Open inlet chamber covered with steel plate/covers. Top of existing overflow pit was flush with existing concrete lined batter.	The cover was prefabricated and 'floated on'. This enabled the basin to be kept on line (for all but a few hours when vacuuming occurring near outlet).
Wonthaggi	Smoothing of any sharp edges on existing concrete liner plus geotextile.	Inlet structure removed and pipe trimmed to be flush with batter. Liner sealed around existing outlet and scour nozzles within existing sump. Overflow pipe trimmed to be flush with batter	High Level Basin (7 ML approx) brought back into service; installed temporary chlorinator (and pumps for supply to standpipe).
San Remo	Most rock beaching removed, hollows infilled with clay/cement stabilised sand. Alternative subgrade treatment agreed to by manufacturer, ie the use of a thick 'cushion' type geotextile over remaining beaching and in-situ rock projections greater than the specified 8 mm height.	Existing inlet pipe removed and trimmed flush with batter. Outlet riser pipe removed, screen reinstalled on bottom tee (access hatch over). Overflow weir pit replaced by recessed chute with stainless steel support bars for cover	The 3 ML Almurta basin was temporarily brought back into service (compared with 23 ML San Remo Basin); chlorination arrangements were modified and telemetry links added.
Tyabb	A thick 'cushion' geotextile was placed on top of the existing concrete floor lining. Rock beaching was rolled into batters. A multi-layer geotextile / geogrid was installed over walls. Prior lab testing to verify proposed treatment had required puncture resistance.	Four new inlets to encourage circulation, finished flush with batters. Recessed chute for outlet, flush with batters. Overflow structure was extended upwards; weir slots maintained at existing level. Liner sealed below slots, cover sealed above slots (all around)	A cross connection of a 600 mm pipe to a 1050 mm pipe was installed prior to works (ie reservoir bypassed during works). Was only feasible in winter/spring.
Yarram	Cement-stabilised sand filling of hollows; geotextile over existing mortared rock lining plus underdrainage.	Inlet valve/float valve relocated outside of basin. New outlet installed flush with embankment. New recessed overflow pit.	The basin is one of two on site - it was merely bypassed.

SEWL has maintained chlorine dosing at all basins at some point upstream of the inlet to ensure good microbiological performance and has been able to delete downstream chlorinators in three zones.

Westernport Water has chlorine dosing upstream of the San Remo Basin (on the outlet to the Ian Bartlett Purification Plant). Very low levels of Pseudomonas Aeruginosa have been detected in some samples from San Remo Basin. Westernport Water is implementing a chlorine dosing system immediately upstream of the basin, to maintain a desired chlorine residual at all times within the basin. It is anticipated that chlorine dosing levels downstream of the basin will be able to be reduced after the new system is implemented.

South West Water has advised that since the commissioning of a chlorination system upstream of the Timboon Basin in November, 1999, no Pseudomonas Aeruginosa has been detected.

5.0 CONCLUSIONS

Recent experience with the implementation of membrane liners and floating covers for existing open water storages leads to the following conclusions which should be carefully considered prior to, and during, the implementation of such technology:

- Whilst membrane liners and covers are usually selected in preference to fixed covers etc, based on lowest capital and net present costs, disadvantages exist in terms of increased operator attendance and operating and maintenance costs.
- Current best available membrane material with some track record is reinforced polypropylene (with perhaps unreinforced polypropylene for floor lining).
- In the absence of any comprehensive data, cover topside colour selection should be based on aesthetics and operations & maintenance considerations.
- Existing inlet, outlet, overflow and scour arrangements should be reviewed and any opportunities for enhancements seized, particularly any to improve water circulation.
- Ensure that subgrade preparation is undertaken to a standard which complies with the liner manufacturer's specified parameters (eg. height of projections, changes of grade etc).
- Ensure that the contractor follows the manufacturer's administrative procedures for provision of warranty.
- Provide an edge anchor beam (proud of embankment crest level) for attachment of cover and liner and exclusion of potential contaminants.
- Principal or Superintendent to take destructive samples of liner and cover, for independent testing.

6.0 ACKNOWLEDGEMENTS

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