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# HERE, THERE OR EVERYWHERE: A COMPARISON OF CENTRALISED AND DECENTRALISED DESALINATION SCHEMES

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# Here, there or everywhere: A comparison of centralised and decentralised desalination schemes

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## ABSTRACT

This paper seeks to highlight the potential differences between decentralised and centralised desalination schemes and identify the situations in which one is more suited than the other. The discussions presented are based on expectations for Australian projects, and the findings are based on recent work for our clients in Australia who are seeking answers to this question.

A key difference is that decentralised plants can in theory be located near end users (thereby reducing transfer requirements). Centralised schemes by their nature need to supply a larger consumer base and therefore some of these consumers will necessarily be far away, particularly for cities with large urban sprawl and lower density housing. Therefore centralised plants tend to be located a large distance away from most end users and require longer and larger delivery systems.

The following aspects should be considered when assessing decentralised desalination schemes versus centralised desalination schemes: availability of multiple sites within highly urbanised cities, value of land within each service area, the bathymetry of source waters, the level of management and oversight required to deliver a program of works, site and sea conditions at each plant site and the requirement for multiple approvals, applications and consultations with local government, utilities and community groups. Where these risks are either proven to not exist or are minor in comparison to a centralised desalination plant, then a decentralised scheme may be favorable. A cost estimate will be required for the particular scenario to establish the economic context as this can vary widely between sites.

## INTRODUCTION

Desalination plants are a reliable alternative source of potable water in rainfall dependent water supply areas. Ten to fifteen years ago, the increased efficiency and reduced costs of reverse osmosis-based seawater desalination plants reached a tipping point and they became viable options for water supply for major Australian coastal cities. This timing matched a period of drought in Australia, and several large reverse osmosis plants were constructed to supply the major cities of Perth, Sydney, Adelaide, Gold Coast and Melbourne. All of these were single plants in a centralised scheme, built to service coastal cities housing millions of people, with large infrastructure and delivery requirements.

This paper seeks to highlight the differences between decentralised and centralised desalination schemes and identify the situations in which one is more suited than the other. The discussions presented are based on expectations for Australian projects, and the findings are based on recent work for our clients in Australia who are seeking answers to this question.

In this study, reverse osmosis was the only desalination process considered. Other desalination technologies have not been considered.

### Decentralised desalination

Decentralised plants can in theory be located near end users (thereby reducing transfer requirements). While centralised schemes, which by their nature need to supply a larger consumer base and therefore some of these consumers will necessarily be far away, particularly for cities with large urban sprawl and lower density housing, are located a large distance away from most end users and require longer and larger delivery systems.

Potential advantages of a decentralised desalination scheme consisting of multiple smaller scale SWRO plants include shorter transfer requirements, smaller diameter intake and outfall requirements resulting in multiple construction approaches, and power is more readily available within the local network without augmentation.

Decentralised schemes can allow for easier staging and implementation as each plant can be installed and commissioned at a time as demand arises. Many of the large-scale plants built in Australia, in response to drought conditions were 'mothballed' after only a few years of operation and have only recently begun re-supply. A decentralised scheme can provide operational flexibility, with the ability to only operate a select few plants to suit small demands rather than a large plant with less flexibility to supply at significantly lower rates.

## CONCEPT DESIGN

To compare centralised and decentralised desalination in terms of economic, environmental, and social factors, a concept design for each scheme was prepared. Using an average population density in Australian cities of 35 people/ha [1], and assuming an average water usage rate of 140 L/person/day, the following concepts for decentralised and centralised plant were developed as shown in Table 1. The concept for a centralised solution is for one plant, while for a decentralised scheme this was assumed to be supplied via 10 smaller scale plants.

### Key components

The key components of a SWRO plant that can deliver potable water to the water supply network include a SWRO plant, intake and outfall infrastructure, a delivery connection and power supply. The key differences in these components for a centralised or decentralised desalination plant are detailed in this section, along with the basis for concept design.

#### *Seawater Reverse Osmosis Plant*

Using a typical plant availability rate of 92 % to account for down times for maintenance etc. the following plant production rates were estimated, as shown in Table 2.

| Parameter | Decentralised Scheme | Centralised Scheme |
|---|---|---|
| People serviced per plant | 100,000 | 1,000,000 |
| Area serviced per plant | 30 km2 | 285 km2 |
| Plant capacity | 5 GL/year | 50 GL/year |
| Distance to most end users | 6 km | 20 km |
| Number of plants | 10 | 1 |

*Table 1: Plant concepts*

| Parameter | Decentralised Scheme | Centralised Scheme |
|---|---|---|
| Plant availability | 92 % | 92 % |
| Plant production | 5 GL/year | 50 GL/year |
| Daily plant production | 15 ML/day | 150 ML/day |
| Number of plants | 10 | 1 |
| Storage | 24 hours | 4 hours |

*Table 2: Plant production rates*

A potential disadvantage of decentralised plants, which by their nature are located closer to end users, is that access to good quality raw water may be limited and if variable or low-quality raw water is to be sourced, this would require additional pretreatment. In comparison, a centralised plant, which is located some distance away from most end users can be easily re-located near a source of raw water that is of better quality and low variability and is unlikely to require additional pretreatment.

Another potential disadvantage for decentralised plants, given that product water will be piped directly into the supply or distribution network for direct supply to customers, is that larger onsite storages are required. For the concept design it is assumed that 24 hours of production will be stored on site. While for a centralised plant that has access to additional storages provided in the downstream network via network scale reservoirs and storages, only 4 hours of onsite storage was assumed in the concept design.

In terms of operational complexity, the delivery of desalinated water into the network from up to 10 sites, each with its own monitoring and control system, will increase the risk of a failure, as the risk of a failure in one of the many systems is higher than that of a single plant. However, the consequence of one system failing in a scheme with 10 supply sources is lower than one system in a scheme with only plant.

### *Intake and concentrate outfall*

For the concept design both centralised and decentralised plants are assumed to utilise open intakes as this is the most common method for large scale SWRO plants in Australia. Subsurface intakes such as vertical beach wells, infiltration galleries, and horizontal and slant wells were not considered as they are uncommon in Australia and have a significant environmental impact during construction [2]. The most common concentrate management method in Australia is ocean discharge and has been assumed for both centralised and decentralised schemes.

The intake and outfall are sized based on a recovery of 42 % (typical recovery achieved for Australian SWRO plants). It is common to size the outfall to accommodate the full intake flow for ease of operation on start-up and shutdown so that the all the raw water drawn can be recirculated back to the ocean. This has been assumed for both schemes in this study.

In terms of water depth at plant intake, the greater the depth the better quality and less variable the source water is likely to be. For decentralised plants located within 6 km of end users, access to deep water with favorable bathymetry is less likely and therefore the plant could be limited to drawing source water from a depth of 10-15 m. The ideal depth is around 25 m (typical intake depth for most large scale Australian SWRO plants) and a centralised plant located within 20 km of most end users is more likely to have access to water of sufficient depth within this distance.

The minimum distance to reach this depth is dependent on local bathymetry. For the concept design it has been assumed the length of the intake and outfall for a decentralised scheme is 1,500 m, while for a decentralised scheme 2,000 m has been adopted.

A tunnel solution has been adopted for most large desalination plants in Australia. Due to the practical limitations of a tunnel boring machine (TBM) size, the minimum safe and practical size of tunnels is about 2.8 m in diameter. If tunnels were implemented for a decentralised plant, the tunnels would be larger than required for hydraulic purposes. Tunnels are typically only cost effective for large plants, and it is the assumed approach for the centralised plant.

Based on community and regulatory expectations and experiences for desalination in Australia, jetty's, dredged channels and weir approaches are not considered suitable as they can have a significant impact on the environment and visual impact of the shoreline. Therefore, the possible alternatives for intake / outfall construction for decentralised plants include horizontal directional drilling (HDD) and pipe-jacking and pipes constructed using cut and cover techniques.

A summary of the intake and outfall concepts for each scheme is provided in Table 3.

| Parameter | Decentralised Scheme | Centralised Scheme |
|---|---|---|
| Recovery | 42 % | 42 % |
| Daily plant production | 15 ML/day | 150 ML/day |
| Intake / outfall volume | 40 / 24 ML/d | 375 / 225 ML/d |
| Ocean depth | 10-15 m | 25 m |
| Construction method | HDD / pipe jacking | TBM tunnel |
| Adopted intake / outfall size | DN 750 | 2.8 m |
| Intake / outfall length | 1,500 m | 2,000 m |

*Table 3: Intake and outfall concepts*

| Parameter | Decentralised Scheme | Centralised Scheme |
|---|---|---|
| Daily plant production | 15 ML/day | 150 ML/day |
| Delivery pipeline size | DN 350 | 1 m |
| Network connection point | DN500-600 distribution main | Large storage or reservoir |
| Delivery pipeline length | 500 m to 3 km | 15-20 km |

*Table 4: Delivery infrastructure*

| Parameter | Decentralised Scheme | Centralised Scheme |
|---|---|---|
| Daily plant production | 15 ML/day | 150 ML/day |
| Plant electrical load | 2.5 MW | 30 MW |
| Power connection point | Local power connection | Terminal station or sub-transmission loop |
| Power connection length | 3-6 km | 15-20 km |

*Table 5: Power supply*

| Parameter | Decentralised Scheme | Centralised Scheme |
|---|---|---|
| Plant production | 5 GL/year | 50 GL/year |
| Plant footprint | 4.5 ha | 15 ha |
| Number of plants | 10 | 1 |
| Total footprint | 45 ha | 15 ha |

*Table 6: Plant footprint*

*Delivery pipeline*

The delivery infrastructure required to transfer water from each plant will depend on the proximity to the identified connection points in the network. A decentralised plant with a lower production rate could connect directly into a distribution main, while a centralised plant with larger capacity would require connection to a large storage or reservoir in the network. The delivery pipeline concepts are provided in Table 4 on the previous page.

*Power supply*

Energy demand for a modern SWRO plant, with energy recovery, is around 3.5 kWh/m3. This excludes the power required for pumping the product water into the network, which can be significant in some installations, particularly with long delivery pipelines. A summary of the power supply concept is shown in Table 5 on the previous page.

The energy demand of a decentralised plant is equivalent to the electricity required to power approximately 2500 homes and is likely to strain the power available on the local network. This is therefore a constraint on the ability to install a SWRO plant in a given location. The opportunity for the plant to be turned off at peak load times is a potential mitigation measure.

**Plant siting**

There are a wide range of possible options for desalination plant locations. Each plant location would need to be connected to the nearest of the following key locations: source seawater, point for concentrate discharge, water supply connection point and terminal station for power supply. In some cases these can be conflicting as the closest point to source seawater might be the furthest from the water supply connection point. It is typical for proximity to source seawater to be the driving factor, due to the significance of intake infrastructure.

*Plant footprint*

To determine the footprint of a 5 GL/year and 50 GL/year SWRO plant, benchmarking of other Australian SWRO plants, including all ancillary and associated buildings, was used. An allowance for additional pre-treatment and on-site storage was added for decentralised plants.

The land required for each scheme is shown in Table 6 on the previous page. This excludes the lay down area required for construction and therefore the total land required is likely to be greater. The total land required for a centralised scheme is significantly lower than for a decentralised scheme, highlighting the economies of scale in plant sizing and land requirements.

*Siting considerations*

The key considerations for desalination plant siting include:

- Minimum site area as described in section 2.2.1. Noting that additional land is likely to be required for construction lay down area.
- Minimise the costs associated with pipelines to and from the sites. Only sites within 2 km of a seawater source were examined to reduce intake and outfall costs.
- Land use type excluding residential zones and preference for farmland or industrial.
- Seawater quality and bathymetry. Only sites that reach the minimum required depth at a length of less than 2 km from the shore were considered.
- Proximity to a suitable connection point in the water supply network.
- Environmental considerations, where possible (noise production and proximity to sensitive receptors, contamination, ecological impacts, cultural and heritage issues).

## RESULTS

The concept designs for the decentralised and centralised schemes were investigated in the context of large coastal Australian cities to enable comparison and represent some of the opportunities and challenges associated with each scheme.

**Social impacts**

Large Australian coastal cities typically have limited availability of land zoned for industrial or farming purposes, which is preferred for SWRO plants. The very nature of a decentralised scheme means that plants are located in close proximity to urban areas where larger parcels of land tend to be zoned for recreational, commercial or conservation purposes.

For any scheme, plant siting is critical to avoid areas of cultural or social significance and sensitive receptors, minimise construction phase impacts as well as considerations for land use and visual impact. In most instances a single site that manages these risks can be found, typically within regional or industrial areas. However, the availability of 10 sites in one city that are equally distributed with population requires are harder to find and are generally within areas zoned for recreation or commerce.

For a scheme, with plants located on recreationally or commercially zoned land, the following additional risks were identified:

- Impact on land use: The plant site would require the acquisition of multiple commercial lots, all containing operational businesses with the economic impacts of the closure of these businesses likely to be significant. Alternatively, the plant site would result in the removal of rare public open space in an area with ample development and urban areas. Acquisition of such land is likely to have significant social impacts.
- Value of land: Land in built up areas is typically valued higher than in less developed areas, due to demand for land in built up areas being greater. The extent of development in areas where decentralised desalination is being considered can have a significant impact on CAPEX and land availability. This impact is only expected to increase over time as many cities experience growing populations and competing land constraints.
- Lay-down area: Lay-down area adjacent to the plant site is typically required and in built up areas nearby recreational facilities will likely be required during the construction phase for this purpose. This would result in the temporary closure of these facilities and would require additional works to re-instate them before they are returned to their previous use.
- Visual impact: Decentralised plants are typically located adjacent to public open spaces or recreational facilities and therefore are likely to have a substantial visual impact. Some of these areas, which by their nature are in proximity to the coast also attract large numbers of tourists and are popular with many locals. Where intake pump stations are located close to the shore, these can have a significant visual impact on popular beaches.
- Proximity to sensitive receptors: The surrounding areas are likely to consist of schools, recreational facilities and residential premises. Noise mitigation methods will be required, both during construction and operation. The regular delivery of chemicals and supplies will also need to be managed to ensure the impact on the surrounding community is minimised.
- Construction phase impacts: The intake and concentrate pipelines are of significant sizes, and the construction of these pipes are likely to result in significant impacts to the local community, including the closure of roads for extended times.
- Community engagement: Any plant will require extensive engagement with local council and communities. For a program of 10 sites, the consultation process will require the engagement of up to 10 local councils, communities and stakeholder groups and thus 10 different communications strategies, compared with one for a centralised plant.

### Environmental factors

For any desalination plant the intake and outlet have the potential to impact upon the marine environment during both the construction and operational phases. There is also the risk in some cases that the intake may entrain marine organisms. A key concern is the impact from returning brine into the ocean environment.

Decentralised plants are more likely to be located on water bodies such as bays, inlets and the like which can have reduced turn-over of water compared to open oceans. This can increase the difficulty of managing the environmental impacts of concentrate discharge, and therefore sites near such water bodies are expected to require additional modelling to address both real and perceived risks as well as additional monitoring during operation to ensure compliance with regulatory limits.

With multiple sites, there is also an increased risk of variations to design or delays to works due to unknown or unforeseen issues (e.g. unexpected ground conditions, unknown buried services, presence of asbestos, ordinances or other hazardous materials). Each site will have its own individual challenges and as such each site will require its own specific design and environmental studies.

### Economics

Economics are presented below for an abstract concept to provide a representative result, noting that specific risks for individual projects are likely to change outcomes.

#### *Capital cost*

To estimate the cost of the decentralised and centralised schemes, benchmarking of the capital costs of other Australian SWRO plants and internal GHD cost databases were used to develop per unit base rates. The base rates were applied to the concepts described in section 2 to determine the approximate cost for an Australian context for each of the project components including marine, desalination plant, delivery power and land.

The costs presented are for direct costs only, to provide a general comparison between a decentralised and centralised scheme. The costs do not include the total cost that would be expected to be incurred for the development of an entire project.

As shown in Figure 1, for the concepts developed, the centralised scheme is expected to cost approximately $1.4 billion AUD, which is around $0.3 billion AUD less than the decentralised scheme, which is expected to cost approximately $1.7 billion AUD.

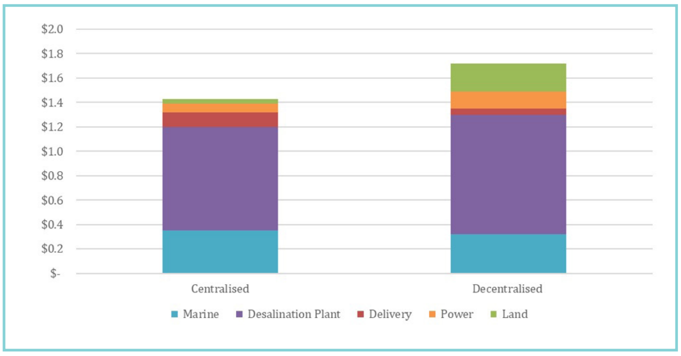


*Figure 1: Capital cost estimate ($billion AUD)*

These costs are consistent with other SWRO desalination projects when considering only the desalination plant component and accounting for project size and inflation [3].

The key aspects where a decentralised scheme provides cost savings compared to a centralised scheme are in the marine and delivery components. This is due to smaller intake and outfalls and shorter delivery pipelines.

Conversely, the key aspects where a decentralised scheme incurs greater costs compared to a centralised scheme are in the plant, power, and land components. All three are largely due to the economies of scale that are provided in a decentralised scheme that results in lower cost for these components.

Most notably the land component is expected to be an order of magnitude greater for the decentralised scheme due to the requirement for additional land and the implications of the value of land in highly urban areas compared to less developed areas; land in built up areas is typically valued higher than in less developed areas, due to demand for land in built up areas being greater. This cost component is highly sensitive to the local context and variation in land value; however, this impact is only expected to increase over time as many cities experience growing populations and competing land constraints.

#### *Operating cost*

To estimate the operating cost of the decentralised and centralised schemes, benchmarking of the operating costs of other Australian SWRO plants and internal GHD cost databases were used to develop per unit base rates for plant and power components, which were applied to the concepts described in section 2 to determine the approximate cost for an Australian context. The power costs assume that renewable energy is sourced from the grid.

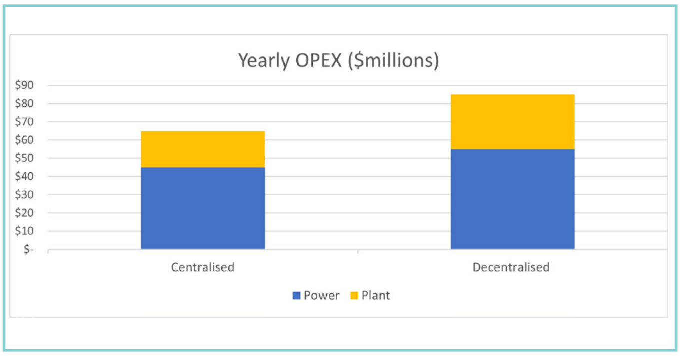


*Figure 2: Operating cost estimate ($million per year AUD)*

As shown in Figure 2, for the concepts developed, the centralised scheme is expected to cost approximately $65 million AUD per year, which is around $20 million AUD less than the decentralised scheme, which is expected to cost approximately $85 million AUD per year.

This aligns with the average cost of water produced by SWRO desalination plants of $1.1 USd/m3 [4], which for 50 GL equates to ~$90 million AUD per year.

The running costs for operating 10 facilities compared to one facility are higher for both power and plant components. The power requirements for a decentralised scheme are increased with reduced economies of scale, which is highlighted by the requirement for multiple delivery pipelines resulting in a cumulative length that is greater than for one larger pipeline (60 km in total for a decentralised scheme compared to 20 km for a centralised scheme).

The plant running costs of a centralised scheme are lower due to the economies of scale that are achieved with a single plant compared to multiple facilities each with their own requirements for ancillaries, staff, deliveries, and waste management.

## DISCUSSION

The concept developed has highlighted the differences between a decentralised and centralised scheme, with some general commentary on situations where one scheme would be more suitable than the other. The following section discusses the arguments for and against a decentralised scheme. These arguments can be viewed in terms of general and site-specific factors.

Table 7 on page 10 provides some discussion of the factors influencing a decision for a decentralised scheme.

Table 8 on page 10 provides some discussion of the factors influencing a decision against a decentralised scheme.

## CONCLUSION

In summary, the following key considerations should be given when considering decentralised desalination over a centralised scheme:

- Given the highly urbanised nature of cities, there can be limited availability of sites suitable to construct multiple plants. A number of available sites in large cities are commercial residences, public recreational facilities, or public conservation and resource zones. Many of the sites are likely to be near residential zones and other sensitive receivers. In addition, suitable locations may be concentrated in one area and end up becoming a single plant.
- The value of land within the area should be considered with effort made to reduce land procurement costs where possible. Due to the economies of scale for plant footprint, a decentralised scheme can require in the order of 3 times more land in total that a centralised scheme. Growing populations can mean fewer suitable sites are available in the future.
- The bathymetry of source water may mean that the areas suitable for locating an intake and outfall are limited. The location of multiple intake and outfall structures mean some may encroach on shipping lanes, major ports or recreational areas.
- A high level of management and oversight will be required in order to deliver the program of works, given the number of different sites and construction zones.
- Construction, commissioning, and operation of multiple plants will require resources spread across multiple sites, therefore introducing inefficiencies.
- There is added complexity in dealing with and responding to a variety of different site and sea conditions at each of the 10 sites. During construction there is an increased risk of variations to design or delays to works due to unknown or unforeseen issues. In addition, during operation with the increasing number of sites, there is an increased risk of damage due to vandalism or storms, or complications from a feedwater water quality issue.
- Multiple approvals, applications and consultations with local government, utilities and community groups will be required. Each site will have its own individual challenges and as such each site will require its own specific approach.

Where these risks are either proven to not exist or are minor in comparison to a centralised desalination plant, then a decentralised scheme may be favorable.

| Factor | Description |
|---|---|
| General | |
| Greater ability to match investment staging with supply/demand shortfall.<br>High uncertainty in supply/demand forecast. | A centralised project could also be staged to some degree. Key exceptions likely to be marine works, power supply and treated water transfer. |
| A view that many smaller assets provide more resiliency than a single large asset. | A natural disaster, for example wildfire/bushfire could impact on a region. There may be a lower likelihood that this type of event impacts across many regions and therefore spreading assets across many regions may have more resiliency in total. |
| A view that material technological improvement in desalination will appear in the near term | |
| A view that Government policy / community sentiment may change in the near term on alternatives to desalination. | A prime example of this in some jurisdictions in potable reuse. |
| Site specific | |
| Proximity to demand / distribution point in the water network | More suitable connection points at relatively smaller flows |
| Proximity to power supply | More suitable connection points at relatively smaller demands |
| A lack of large sites | |
| A site-specific opportunity that is aligned to a smaller sized project | E.g., an existing ocean outfall that could accommodate brine, a power station that already draws and discharge seawater for cooling |

*Table 7: Factors in favour of decentralised desalination*

| Factor | Description |
|---|---|
| General | |
| Regulatory approvals | Onerous and lengthy.<br>Would need to be completed for each site. |
| 'Not in my backyard' | May put multiple areas/regions offside (as opposed to one area/region). |
| Total land requirement | One large plant is likely to require less land than multiple small plants |
| Economies of scale | Efficiency gains (construction and operation) of a large facility. Prime examples include transfer pipelines and tunnels/marine structures where it is generally the case that cost is not linear to capacity. |
| Operational complexity | Network management for multiple connections more complex to manage and oversee (e.g., sampling and monitoring requirements). |
| Site specific | |
| A specific opportunity for one large site | E.g., an existing facility with sufficient space available for a single site. |
| Limited availability of multiple small sites. All suitable sites coalesce in one location | Suitable locations concentrated in one area and end up becoming a single plant. |

*Table 8: Factors against decentralised desalination*

## AUTHORS

**Rebecca Argento**

Rebecca is a Senior Process Engineer at GHD and has experience in desalination in the areas of feasibility investigations, concept, functional and detailed designs. Before joining GHD Rebecca worked at the Victorian Desalination Plant and has worked on numerous desalination projects around Australia.

**Nathan Peiper**

Nathan is a civil engineer with over 10 years' experience. His experience includes the analysis, design and documentation of water and wastewater treatment plants. Nathan has been the lead for complex detailed design works as well as long term strategic planning for water infrastructure.

**Greg Finlayson**

Greg is a known thought leader in the water industry and has a history of technical leadership in new technologies and their implementation, and for example he led the technical development of the Wonthaggi Desalination Plant, including development of the contract, and the EES and other approval processes.

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