Perth Water Supply Alternatives

Comparing Desalination and Deep Aquifer Extraction, with Implications for Wheatbelt Agricultural Water Security

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Executive Summary

This report compares the economics and feasibility of two water supply options for Perth: seawater desalination and deep Yarragadee aquifer extraction. Contrary to common assumptions that groundwater extraction is inherently cheaper than desalination, the analysis demonstrates that when full system costs are considered, Yarragadee extraction is substantially more expensive and less flexible than coastal desalination.

Key Findings: Perth Water Supply

- **Energy costs comparable:** Desalination requires 3-4 kWh/m³, deep Yarragadee extraction requires 2.5-4 kWh/m³ (lifting water 500-800m plus treatment). No significant energy advantage to groundwater.
- **Distribution costs prohibitive:** Yarragadee aquifer located 150-250km inland from Perth. Pipeline infrastructure costs AU$10-30 billion for full system, compared to <AU$1B for coastal desalination co-located with existing infrastructure.
- **Scalability constraints:** Yarragadee sustainable yield estimates 5-150 GL/year (uncertain). Desalination can scale incrementally as needed. Perth currently uses ~300 GL/year.
- **Flexibility advantage:** Desalination responds to demand within hours. Aquifer extraction requires years of planning, irreversible infrastructure investment, and decades to assess sustainability.
- **Environmental impacts:** Both have impacts. Desalination: localized brine discharge, energy consumption. Yarragadee: regional groundwater depletion, subsidence risk, uncertainty about connectivity to other aquifers.

Conclusion for Perth: Desalination is economically superior. Yarragadee should be maintained as strategic reserve for emergency use, not developed as primary supply.

Findings: Wheatbelt Agricultural Water

The collapse of dryland agriculture in Wheatbelt marginal zones (documented in companion report) raises questions about desalination as agricultural irrigation source. The analysis reveals:

- **Technically feasible but economically prohibitive:** Desalination costs AU$1-2/m³. Agricultural irrigation requires 3-5 ML/ha annually. Cost: AU$3,000-10,000/ha/year—far exceeding value of most dryland crops (wheat ~AU$500-1,500/ha gross revenue).
- **Distribution amplifies costs:** Wheatbelt is 100-300km inland. Pipeline infrastructure adds AU$15-45 billion capital cost for region-wide system, plus AU$500-2,000/ML pumping costs.
- **Energy requirements massive:** Irrigating 1 million hectares requires 3-5 billion m³/year. At 4 kWh/m³: 12-20 TWh annually (equivalent to 40-70% of WA's total electricity generation).

- **Viable only for high-value crops:** Horticulture (AU$10,000-50,000/ha revenue) can potentially justify costs. Broadacre grains cannot. Would require complete agricultural restructuring.
- **Strategic applications possible:** Small-scale desalination for critical high-value zones, livestock water supply, town water supply in areas where groundwater depleted. Not solution for mass dryland agriculture replacement.

Conclusion for Wheatbelt: Desalination is not a salvation for collapsing dryland agriculture. Costs are 2-5x gross crop revenue. Viable only for niche high-value horticulture requiring complete economic restructuring, or for small-scale strategic applications (towns, livestock). Mass irrigation of Wheatbelt via desalination is economically impossible.

Policy Recommendations

For Perth water supply:

- Continue investment in coastal desalination as primary climate-independent supply
- Maintain Yarragadee as strategic reserve (minimal extraction, emergency use only)
- Do not invest in large-scale Yarragadee distribution infrastructure

For Wheatbelt adaptation:

- Acknowledge desalination cannot replace dryland agriculture at scale
- Consider small-scale strategic desalination for towns and high-value horticulture clusters
- Focus adaptation strategies on managed retreat from marginal lands, not irrigation salvation
- Explore alternative economic development pathways independent of broadacre grain agriculture

The analysis demonstrates that neither Yarragadee extraction nor agricultural desalination offers economically viable alternatives to current trajectories. Perth's water security is best served by coastal desalination. Wheatbelt's agricultural crisis requires adaptation to reduced rainfall regime, not expensive technological fixes.

Part 1: Perth Water Supply Context

Historical Water Sources and Climate Change Impact

Perth's water supply has undergone dramatic transformation over the past 50 years in response to climate-driven rainfall decline:

Historical pattern (pre-1975):

- Surface water (dams): 80-90% of supply
- Shallow groundwater: 10-20% of supply
- Rainfall supporting system: 800-1000mm annually in catchments
- Dam inflows: ~300 GL/year average

Current situation (2020s):

- Surface water: <20% of supply (dams rarely fill)
- Shallow groundwater: ~25% of supply (declining sustainability)
- Desalination: ~55% of supply (two plants operational)
- Rainfall in catchments: 600-700mm (20-30% decline)
- Dam inflows: ~50-100 GL/year (67-83% decline)

This dramatic shift from rainfall-dependent to climate-independent sources was forced by circumstance. The question now is how to meet future demand growth (projected 400+ GL/year by 2040s) using climate-independent sources.

Current Supply Infrastructure

Source	Capacity (GL/yr)	Climate Dependence	Trend
Dams (surface water)	50-100 (variable)	Total	Declining
Gnangara groundwater	70-80	High	Stressed
Kwinana desalination	140	None	Stable
Binningup desalination	100	None	Stable
Total current	**~300**	—	—

Desalination now provides majority of Perth's water. The question is whether deep Yarragadee aquifer offers a better alternative for future expansion than additional desalination capacity.

Future Demand Projections

Water Corporation projections indicate substantial demand growth:

- 2025: ~320 GL/year
- 2030: ~350 GL/year (population growth ~2.5 million)
- 2040: ~400 GL/year (population growth ~3 million)
- 2050: ~450 GL/year (population growth ~3.5 million)

This requires an additional 100-150 GL/year of climate-independent supply by 2040s. The choice is between expanding desalination (~240 GL/year total capacity) or developing Yarragadee extraction.

Part 2: Desalination Technology and Economics

Reverse Osmosis Technology

Perth's desalination plants use reverse osmosis (RO), the dominant modern seawater desalination technology:

Process:

- Seawater intake (35,000-40,000 ppm salinity)
- Pre-treatment (filtration, coagulation)
- High-pressure pumps (55-70 bar)
- Reverse osmosis membranes (salt rejection >99.5%)
- Post-treatment (remineralization, disinfection)
- Product water (<500 ppm, potable quality)
- Brine discharge (60,000-70,000 ppm, ~50% recovery rate)

Energy consumption:

- Modern large-scale RO: 3-4 kWh/m³
- Energy recovery devices capture pressure from brine stream (reduces consumption ~30%)
- Perth plants use renewable energy (wind farms) for carbon neutrality

Capital and Operating Costs

Capital costs (based on Perth plants and global benchmarks):

- Plant construction: AU$1,500-2,500/m³/day capacity
- For 100 GL/year plant (274,000 m³/day): AU$400-700 million
- Intake/outfall infrastructure: AU$50-150 million
- Connection to distribution system: AU$50-200 million (if coastal location near existing infrastructure)
- **Total capital for 100 GL/year: AU$500 million - 1 billion**

Operating costs:

- Energy: AU$0.40-0.60/m³ (at 4 kWh/m³ × AU$0.10-0.15/kWh)
- Membrane replacement: AU$0.15-0.25/m³ (amortized, 5-7 year lifespan)
- Chemicals (pre/post treatment): AU$0.10-0.15/m³
- Labor and maintenance: AU$0.15-0.25/m³
- **Total operating cost: AU$0.80-1.25/m³**

Levelized cost of water (LCOW):

- Capital amortization (30 year, 5% discount): AU$0.35-0.70/m³
- Operating costs: AU$0.80-1.25/m³
- **Total LCOW: AU$1.15-1.95/m³ (or AU$1,150-1,950/ML)**

Environmental Considerations

Brine discharge:

- Concentration: 60,000-70,000 ppm (1.7-2x seawater salinity)
- Volume: ~50% of intake volume (50% recovery rate)
- Impact: Localized salinity increase within ~500m of outfall
- Mitigation: Outfall design for rapid dilution, monitoring programs

Marine intake:

- Impingement and entrainment of marine organisms
- Mitigation: Intake velocity limits (<0.15 m/s), screening systems

Energy/carbon footprint:

- 4 kWh/m³ × 100 GL/year = 400 GWh/year electricity
- At WA grid average (0.6 kg CO_2/kWh): ~240,000 tonnes CO_2/year
- Perth plants offset with renewable energy procurement (wind farms)

Environmental impacts are manageable with proper design and monitoring. The technology is mature and well-understood.

Operational Flexibility

Desalination offers significant operational advantages:

- **Rapid response:** Can ramp production up/down within hours to match demand
- **Scalability:** Can add capacity in 50-150 GL/year increments as needed
- **Predictability:** Output known with certainty, no sustainability questions
- **Climate independence:** Performance unaffected by droughts, climate change
- **Reversibility:** Can be decommissioned if no longer needed (sunk cost only)

Part 3: Yarragadee Aquifer Extraction

Aquifer Characteristics

The Yarragadee Formation is a deep confined aquifer underlying much of the Perth Basin:

Geological characteristics:

- Depth: 300-800m below surface in regions of interest
- Thickness: 500-2,000m (variable)
- Lithology: Sandstone, minor shale interbeds
- Hydraulic conductivity: 0.5-5 m/day (moderate permeability)
- Storage coefficient: 10^{-4} to 10^{-5} (confined aquifer)

Water quality:

- Salinity: 500-3,000 mg/L (variable, generally brackish)
- Requires treatment for potable use (desalination if >1,000 mg/L)
- Some zones have elevated fluoride (>1.5 mg/L)

Location relative to Perth:

- Primary extraction zones: 150-250km inland from Perth
- Shallower depths near coast but poorer quality (higher salinity)
- Best zones: Myalup-Wellington area (~180km south of Perth)

Sustainable Yield Estimates

CSIRO and Department of Water assessments indicate substantial uncertainty:

- **Recharge rate:** 5-20 GL/year (highly uncertain, depends on rainfall, connectivity)
- **Current allocation:** ~10 GL/year (small-scale agricultural and industrial use)
- **Conservative sustainable yield:** 15-30 GL/year (match recharge)
- **Aquifer mining scenario:** 50-150 GL/year for 30-50 years (then depleted)

Critical uncertainty: Connectivity between Yarragadee and other aquifers unknown. Large-scale extraction could induce flow from overlying shallow aquifers (which support surface ecosystems) or underlying aquifers (which may have poorer quality water).

Extraction Costs

Pumping energy:

- Lifting water from 500-800m depth
- Energy calculation: 0.0098 kWh/m³/m × 500-800m = 4.9-7.8 kWh/m³ (theoretical)
- Pump efficiency (~65%): 7.5-12 kWh/m³ actual
- Friction losses in bore: add 1-2 kWh/m³
- **Total pumping energy: 8.5-14 kWh/m³**

Water treatment:

- Brackish water RO (for 1,000-3,000 mg/L): 1-2.5 kWh/m³
- Fluoride removal if needed: 0.5-1 kWh/m³
- Disinfection and distribution prep: 0.2-0.5 kWh/m³
- **Total treatment: 1.7-4 kWh/m³**

Total energy for extraction + treatment:

- **10-18 kWh/m³ (substantially higher than seawater desalination's 3-4 kWh/m³)**
- This assumes efficient modern equipment; older estimates (2-4 kWh/m³) likely underestimated pumping energy

Distribution Infrastructure Costs

This is where Yarragadee economics collapse. The aquifer is 150-250km from Perth, requiring massive pipeline infrastructure:

Pipeline specifications (for 100 GL/year capacity):

- Flow rate: 3.2 m^3/s (11,500 m^3/hour continuous)
- Pipeline diameter: ~1.8-2.2m (to minimize friction losses)
- Length: 180-220km (Myalup-Wellington to Perth)
- Material: Steel or HDPE pressure-rated
- Pumping stations: Every 30-50km to maintain pressure

Capital cost estimates:

- Pipeline construction: AU$10-20 million/km (for 2m diameter)
- 200km pipeline: AU$2-4 billion
- Pumping stations (5-7 stations): AU$50-100 million each = AU$250-700 million
- Extraction bores (50-100 bores × AU$2-5 million each): AU$100-500 million
- Treatment facilities: AU$300-600 million
- Connection to Perth system: AU$200-500 million
- Land acquisition, approvals, contingency: AU$500 million - 1 billion
- **Total capital cost: AU$3.5-7.3 billion for 100 GL/year**

Compare to desalination: AU$0.5-1 billion for same capacity (100 GL/year). Yarragadee distribution infrastructure alone costs 7-15x more than entire desalination plant.

Additional pumping energy for transmission:

- Friction losses over 200km: ~100-150m head loss
- Additional energy: 1-1.5 kWh/m^3
- **Total energy (extraction + treatment + transmission): 11-19.5 kWh/m^3**

Levelized cost of water from Yarragadee:

- Capital amortization (30 year, 5%): AU$2.50-5.00/$m^3$
- Energy (11-19.5 kWh/m^3 × AU$0.10-0.15/kWh): AU$1.10-2.90/m^3
- Operations and maintenance: AU$0.40-0.80/$m^3$
- **Total LCOW: AU$4.00-8.70/$m^3$**

Yarragadee extraction is 2-6x more expensive than desalination when full system costs are included.

Environmental and Sustainability Risks

Unlike desalination (well-understood impacts), Yarragadee extraction carries substantial uncertainty:

- **Aquifer connectivity unknown:** May induce drawdown in overlying shallow aquifers that support surface ecosystems
- **Subsidence risk:** Large-scale extraction from confined aquifers can cause land subsidence (precedents: California Central Valley, Mexico City)
- **Salinity changes:** Extraction may draw higher-salinity water from depth or adjacent zones
- **Irreversibility:** Aquifer depletion requires centuries to reverse (recharge 5-20 GL/year, extraction 100+ GL/year = mining, not sustainable use)
- **Assessment timeline:** Decades to verify sustainability after extraction begins. By the time problems become apparent, irreversible damage may be done.

Part 4: Comparative Analysis for Perth Water Supply

Cost Comparison Summary

Parameter	Desalination	Yarragadee	Winner
Capital (100 GL/yr)	AU$0.5-1B	AU$3.5-7.3B	**Desal**
Energy (kWh/m³)	3-4	11-19.5	**Desal**
LCOW (AU$/m³)	1.15-1.95	4.00-8.70	**Desal**
Scalability	Unlimited	Limited (5-150 GL/yr)	**Desal**
Flexibility	Hours	Years	**Desal**
Sustainability	Known/manageable	Uncertain/risky	**Desal**
Reversibility	Yes	No	**Desal**

Desalination wins on every metric except political perception (groundwater 'feels' cheaper than it actually is).

The Distribution Cost Multiplier

The critical insight is that distribution infrastructure dominates total system cost for inland sources:

Component	Desalination	Yarragadee
Production facility	AU$500-700M	AU$400-1,100M
Distribution to Perth	AU$50-200M (co-located)	**AU$2.5-5B (200km pipeline)**
Total capital	**AU$0.5-1B**	**AU$3.5-7.3B**

Distribution infrastructure represents 70-85% of Yarragadee total cost, versus 5-20% for desalination. Location matters more than production technology.

Recommendation for Perth Water Supply

Based on economic analysis, desalination is clearly superior for Perth's urban water supply:

- **Continue investing in coastal desalination:** Lowest cost, fastest deployment, highest flexibility
- **Maintain Yarragadee as strategic reserve:** Minimal current extraction, available for emergency use if desalination facilities compromised
- **Do not invest in large-scale Yarragadee distribution infrastructure:** The AU$3-7B for pipelines delivers worse outcomes than AU$1B for additional desalination
- **Monitor Yarragadee research:** Improved understanding of aquifer connectivity and sustainability may alter assessment, but current uncertainty favors not committing irreversible infrastructure investment

The common assumption that groundwater extraction is inherently cheaper than desalination is false when full system costs (especially distribution) are included. Coastal desalination is Perth's most economical climate-independent water source.

Part 5: Desalination for Wheatbelt Agriculture

The forest collapse and agricultural crisis documented in the companion report raises questions about whether desalination could provide irrigation water to replace declining rainfall. This section analyzes the technical feasibility and economic viability of agricultural desalination for the Wheatbelt.

Water Requirements for Broadacre Agriculture

Irrigated broadacre cropping requires substantial water volumes:

Typical irrigation requirements:

- Wheat: 3-4 ML/ha annually (300-400mm supplemental)
- Canola: 4-5 ML/ha annually
- Barley: 3-4 ML/ha annually
- Lupins: 3-3.5 ML/ha annually

Wheatbelt irrigation scenario:

- Current Wheatbelt agricultural area: ~4 million hectares
- Marginal zones (<350mm rainfall): ~1 million hectares
- Water requirement to irrigate 1 million ha: 3-5 billion m³/year
- **This is 10-15x Perth's current total water consumption**

Desalination Costs for Agricultural Water

Production costs (coastal desalination):

- Capital for 3-5 billion m³/year capacity: AU$15-50 billion (30-50 plants × AU$0.5-1B each)
- Operating cost: AU$1.15-1.95/m³
- Annual operating cost for 3-5 billion m³: AU$3.5-10 billion/year

Distribution costs (coast to Wheatbelt):

- Distance: 100-300km inland
- Pipeline network: Trunk + distribution = ~5,000-10,000km total
- Capital cost estimate: AU$15-45 billion (varying pipe sizes, pumping stations)
- Pumping energy: 1-3 kWh/m³ (elevation gain plus friction)
- Distribution operating cost: AU$0.50-2.00/ML additional

Total water cost delivered to farm:

- Capital amortization: AU$2.00-6.50/m³
- Operating costs: AU$1.65-3.95/m³
- **Total: AU$3.65-10.45/m³ (or AU$3,650-10,450/ML)**

Per-hectare annual irrigation cost:

- At 3-5 ML/ha requirement × AU$3,650-10,450/ML:
- **AU$10,950-52,250/hectare/year water cost alone**

Economic Viability Assessment

Compare irrigation water costs to crop gross revenues:

Crop	Gross Revenue/ha	Water Cost/ha	Viability
Wheat	AU$500-1,500	AU$11,000-42,000	**Impossible**
Canola	AU$800-2,000	AU$15,000-52,000	**Impossible**

Crop	Gross Revenue/ha	Water Cost/ha	Viability
Cotton (hypothetical)	AU$3,000-5,000	AU$30,000-80,000	**Impossible**
Horticulture (high-value)	AU$20,000-100,000	AU$10,000-30,000	**Marginal**

Water costs exceed total gross revenue for broadacre crops by 5-50x. Only very high-value horticulture (vegetables, fruit, viticulture) could potentially support desalinated irrigation water, and even then only marginally.

Energy Requirements and Grid Constraints

Irrigating 1 million hectares with desalinated water creates massive energy demand:

Energy calculation:

- Water requirement: 3-5 billion m^3/year
- Desalination energy: 4 kWh/m^3
- Distribution pumping: 1-3 kWh/m^3
- Total: 5-7 kWh/m^3
- **Annual energy: 15-35 TWh**

Context:

- Western Australia total electricity generation: ~34 TWh/year (2023)
- **Agricultural irrigation would require 44-103% of WA's total current electricity generation**
- This is equivalent to ~15-35 GW installed renewable capacity (wind/solar with storage)
- Capital cost for renewable energy: AU$30-70 billion (at AU$2,000-2,500/kW installed)

The energy infrastructure required exceeds the entire existing WA electricity system. This is not a minor addition but a fundamental transformation of state energy supply.

Viable Niche Applications

While mass irrigation of Wheatbelt broadacre agriculture is economically impossible, some niche applications may be viable:

1. High-value horticulture clusters:

- Scale: 5,000-20,000 hectares (0.5-2% of marginal zone)
- Crops: Vegetables, fruit, viticulture (AU$20,000-100,000/ha revenue)
- Water requirement: 50-100 GL/year
- Cost: AU$2-6 billion capital + AU$0.2-1 billion/year operating
- Benefit: ~AU$400 million - 2 billion/year gross agricultural revenue
- *Assessment: Marginal viability, requires complete agricultural restructuring*

2. Town water supply:

- Small-scale desalination (~0.5-5 ML/day capacity)
- Serves populations 1,000-20,000 where groundwater depleted
- Cost: AU$5-20 million capital, AU$3-8/m^3 operating
- *Assessment: Economically feasible for town water (similar to current remote town costs)*

3. Livestock water:

- Requirements: 50-100 L/animal/day (cattle, sheep)
- Small-scale desalination or brackish groundwater treatment
- Cost: AU$2-6/m³ (smaller scale, higher per-unit cost)
- *Assessment: Viable for high-value livestock operations*

These niche applications serve <5% of the agricultural land area facing rainfall decline. They are adaptation strategies for residual populations and economic activities, not solutions for maintaining broadacre grain agriculture.

Conclusion: Desalination Is Not Agricultural Salvation

The analysis demonstrates that desalination cannot serve as salvation for collapsing dryland agriculture in the Wheatbelt. Water costs of AU$10,000-50,000/hectare/year vastly exceed the economic value of broadacre crops. The energy requirements approach or exceed total state electricity generation.

Mass irrigation via desalination represents economic impossibility, not just expensive option. The fundamental constraint is that water intensive enough to replace 150-200mm rainfall loss costs more than the crops are worth.

Strategic applications for towns, livestock, and niche high-value horticulture may be viable and should be pursued where appropriate. These represent adaptation strategies for residual economic activity, not mechanisms to maintain current agricultural systems.

The policy implication is stark: Wheatbelt adaptation must focus on managed retreat from marginal lands and economic restructuring, not on expensive technological fixes that cannot change underlying economics.

Conclusion

This report has analyzed two distinct water supply questions: Perth's urban supply choice between desalination and Yarragadee extraction, and the potential role of desalination in Wheatbelt agricultural adaptation. The conclusions differ substantially between these contexts.

Perth Water Supply: Desalination Wins

For Perth's urban water supply, coastal desalination is economically superior to deep Yarragadee aquifer extraction on every relevant metric:

- **Cost:** Desalination AU$1.15-1.95/m³ vs. Yarragadee AU$4.00-8.70/m³ (including distribution)
- **Capital:** AU$0.5-1B per 100 GL/year vs. AU$3.5-7.3B (infrastructure location matters more than technology)
- **Flexibility:** Hours to adjust production vs. years for aquifer development
- **Scalability:** Unlimited vs. constrained by uncertain sustainable yield
- **Risk:** Manageable environmental impacts vs. uncertain aquifer connectivity and potential irreversible depletion

Recommendation: Continue expanding coastal desalination as primary climate-independent supply. Maintain Yarragadee as strategic reserve for emergency use only. Do not invest in large-scale distribution infrastructure for Yarragadee extraction.

Wheatbelt Agriculture: Desalination Cannot Save

For Wheatbelt agricultural irrigation, desalination fails fundamental economic viability tests:

- **Economics:** Water costs AU$10,000-50,000/hectare/year exceed total crop gross revenue (AU$500-2,000/hectare)
- **Scale:** Irrigating 1 million hectares requires 3-5 billion m³/year (10-15x Perth's total consumption)
- **Energy:** 15-35 TWh annually equals 44-103% of WA's current total electricity generation
- **Capital:** AU$45-120 billion total system (desalination + distribution + energy infrastructure)

This is not expensive but feasible—it is economically impossible. Water costs 5-50x more than crops are worth.

Viable niche applications:

- Small-scale high-value horticulture (5,000-20,000 hectares, requires complete agricultural restructuring)
- Town water supply (populations 1,000-20,000 where groundwater depleted)
- Livestock water for high-value operations

Recommendation: Pursue strategic small-scale desalination for towns and niche agriculture where viable. Do not frame desalination as solution for broadacre agricultural collapse. Focus adaptation strategies on managed retreat, economic diversification, and social support for affected communities.

Synthesis: Different Problems Require Different Solutions

The contrasting conclusions reflect different economic contexts:

Perth urban water:

- High-value use: AU$2-4/m³ willingness to pay
- Coastal location: Minimal distribution costs

- Manageable scale: 300-450 GL/year total
- **Result: Desalination economically optimal**

Wheatbelt agricultural water:

- Low-value use: AU$0.10-0.50/$m^3$ maximum economic value
- Inland location: Massive distribution infrastructure required
- Enormous scale: 3-5 billion m^3/year for marginal zones alone
- **Result: Desalination economically impossible for broadacre crops**

The fundamental lesson: Expensive water (AU$1-10/$m^3$) works for high-value uses in favorable locations but cannot substitute for rainfall in low-value broadacre agriculture. Technology cannot overcome basic economics.

Perth should proceed confidently with desalination as its climate-independent water source. The Wheatbelt must adapt to reduced rainfall through agricultural transformation, managed retreat, and economic restructuring, not through irrigation salvation that cannot exist at economically viable costs.

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