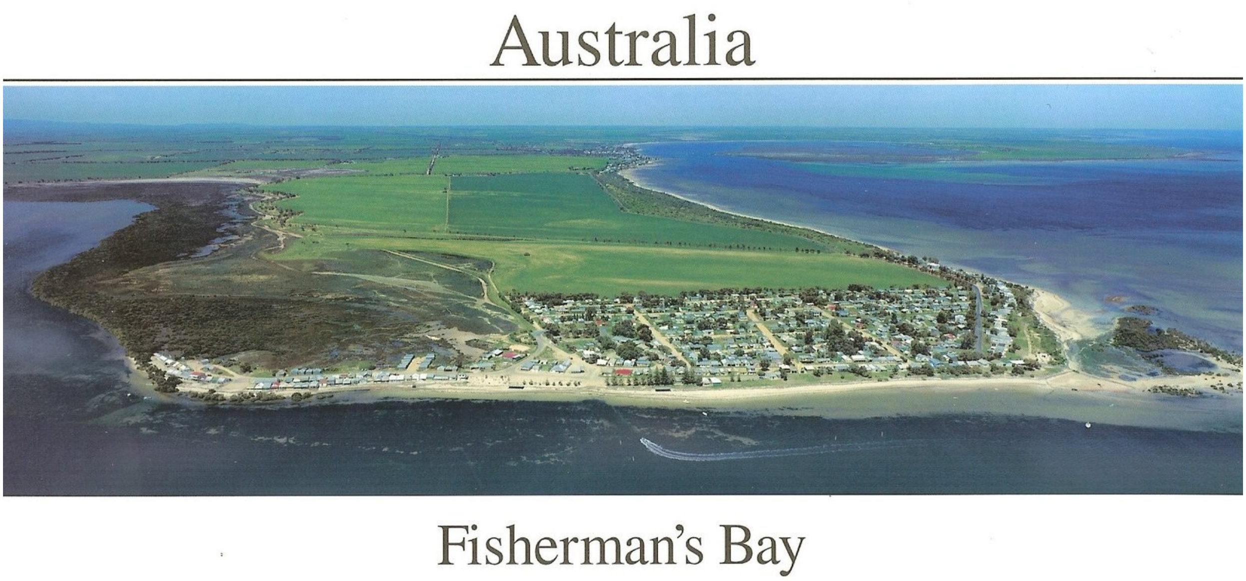
TECHNICAL WHITE PAPER

Energy Consumption and Whole-of-Life Cost Comparison:

Vacuum, Gravity, and Low-Pressure Sewer Systems



Fishermans Bay, South Australia — a flat coastal peninsula with water on three sides. Measured operational data from this system forms the evidence base for this paper.

Prepared by: Flovac Vacuum Sewerage Systems Pty Ltd

Date: June 2026 | Status: Issued for Engineering Review

> *This document presents a technical comparison of wastewater collection system energy consumption based on measured operational data from the Fishermans Bay Vacuum Sewer System, South Australia, supported by three independent engineering studies. It is intended for consulting engineers and local government bodies conducting options assessments.*

1. Executive Summary

This paper compares energy consumption and whole-of-life costs for three wastewater collection technologies: vacuum sewerage, gravity sewerage with pump stations, and low-pressure grinder pump systems. The comparison is based on measured operational data from an operating Australian vacuum system.

The primary case study is the Fishermans Bay Vacuum Sewer System, operated by the District Council of Barunga West in South Australia. The system serves 400 residential lots on a flat coastal peninsula, discharging to the Barunga West Sewage Treatment Plant at Port Broughton via a 7 km rising main. Eleven months of SCADA data from July 2025 to June 2026 provide the foundation for all energy calculations, with motor ratings confirmed from manufacturer datasheets for both pump types installed.

> *Every project is different. The figures in this paper are drawn from a specific site with specific conditions. They are presented as a validated evidence base, not a universal answer. Engineers should apply site-specific analysis to any options study.*

Key findings:

- Vacuum energy at Fishermans Bay: 7,400 kWh/yr confirmed from measured SCADA run hours and nameplate motor ratings. Cost: $2,220/yr at $0.30/kWh — $5.55 per dwelling per year.
- A gravity alternative requires three pump stations in cascade on this site. In high water table coastal environments, groundwater infiltration is a structural design constraint: pump stations must be sized for wet-weather flows 1.5 to 3 times dry-weather sewage flow. On a wet-weather design basis, gravity energy is 20 to 40 percent above vacuum.
- A low-pressure grinder pump system for 400 dwellings consumes approximately 48,000 kWh/yr, which is 6.5 times the vacuum figure. This energy is distributed across 400 individual property pumps and does not appear in the utility energy account.
- At scale the differences are more pronounced. A 2,000-dwelling LP system consumes approximately 240,000 kWh/yr compared with 37,000 kWh/yr for vacuum, a difference of more than $60,000/yr in energy cost alone. Where vacuum replaces multiple gravity pump stations, as at Pacific Harbour in Queensland where 18 gravity stations were replaced by a single vacuum station, the savings across energy, capital and maintenance are substantial.

2. Technology Overview

2.1 Vacuum Sewerage

In a vacuum sewerage system, wastewater collects in sealed chambers at each property. A pneumatically-operated interface valve opens when sufficient wastewater accumulates, drawing sewage and a controlled air slug into the reticulation under differential pressure. Sewage travels at high velocity in small-diameter pipes (DN90 to DN200) to a central vacuum pump station operating at -50 to -70 kPa. The station houses vacuum generation pumps and sewage delivery pumps that discharge to the treatment facility. Because the system is entirely sealed, groundwater cannot enter the reticulation. All energy is consumed at a single, metered, maintained location.

Flovac collection chamber with FV80 valve and SmartMC monitoring pillar.

The Fishermans Bay Vacuum Pump Station — all plant for 400 dwellings in one building.

2.2 Gravity Sewerage with Pump Stations

Gravity sewerage uses pipe grade to convey sewage to pump stations that lift the flow onward. On flat terrain, multiple pump stations in series are typically required, each needing a wet well, duty and standby pumps, a control panel, electrical connection and odour management. Gravity sewers are open to the ground environment. In sandy coastal soils with high seasonal water tables, which are common on the sites where vacuum sewerage is most often deployed, groundwater infiltrates through pipe joints and structural defects. This is a structural characteristic of the technology in these ground conditions, not a maintenance issue. Pump stations must be sized for peak wet-weather flows that may be 1.5 to 3 times the dry-weather sewage flow.

2.3 Low-Pressure (Grinder Pump) Systems

Low-pressure systems install a grinder pump at each property. Typical units such as the E/One Sentry (0.75 kW motor) consume between 60 and 240 kWh per dwelling per year, with a published midpoint of approximately 120 kWh/yr, cycling 20 to 40 times per day. This energy is charged to individual property owners rather than the scheme operator, and does not appear in utility energy accounts unless specifically aggregated across all properties.

3. Methodology and Data Sources

3.1 Vacuum Energy — Measured Data

Vacuum energy at Fishermans Bay is calculated from eleven months of SCADA cumulative run hour data (July 2025 to June 2026), annualised and applied to confirmed nameplate motor ratings. Both pump pairs operate in duty/assist configuration — only one of each pair runs at any time.

Equipment	Motor	Ann. Hrs	kWh/yr	Source
VP1 + VP2: Busch MINK MV 0502B (duty/assist)	7.5 kW	571 hrs	4,283	Manufacturer datasheet confirmed
SP1 + SP2: Grundfos SEV.80.80.110 (duty/assist)	11.0 kW	283 hrs	3,113	Manufacturer datasheet confirmed
Total annual energy			**7,396 kWh**	
Annual cost @ $0.30/kWh			**$2,219**	
Cost per dwelling per year			**$5.55**	

The sewage pump is sized for 12.32 L/s at 33.51 m TDH, reflecting the 7 km rising main to Port Broughton. At 7 km in DN150 HDPE, friction losses of approximately 28–30 m plus static head of 3–4 m produce the 33.51 m design figure, which is consistent with the Grundfos product selection.

3.2 Gravity Energy — Modelled Data

No gravity alternative exists at Fishermans Bay — the site was designed as vacuum from the outset. The gravity comparison is modelled on three pump stations in cascade. PS3 faces the same 7 km rising main to Port Broughton as the vacuum sewage pump and must therefore be sized comparably. PS1 and PS2 serve shorter internal rising mains with smaller flows.

Gravity Pump Station	Motor (est.)	Ann. Hrs	kWh/yr	Note
PS1: Upper catchment transfer	2.2 kW (est.)	approx. 700 hrs	approx. 1,540 kWh	Dry weather only
PS2: Mid catchment transfer	3.7 kW (est.)	approx. 700 hrs	approx. 2,590 kWh	Dry weather only
PS3: Long transfer to STP (7 km)	11 to 22 kW	283 to 550 hrs	3,100 to 6,500 kWh	Same rising main as vacuum
Total: dry weather basis			**approx. 7,230 kWh**	**Broadly comparable to vacuum**
Total: wet weather design basis			**9,000 to 10,500 kWh**	**20–40% above vacuum**

3.3 Low-Pressure Energy — Published Specifications

LP energy is calculated from E/One published specifications: 120 kWh/yr per dwelling at the midpoint of the published 60–240 kWh/yr range. For 400 dwellings: 400 × 120 = 48,000 kWh/yr. This is energy charged to property owners, not the scheme operator.

3.4 Supporting Independent Studies

- Wallbridge & Gilbert (2006), LGA South Australia: the breakeven point where vacuum becomes cost-competitive with pressure is 75–100 connections. Fishermans Bay at 101 pits exceeds this threshold.
- Arup (2011), Greenhills Beach (Kurnell): 30-year NPV comparison showing vacuum ($5.66M) outperforming pressure ($8.15M) by $2.49M. Result robust across all sensitivity analyses. Flovac explicitly acknowledged as vacuum system supplier and cost source.
- Florida DEP (FDEP) guidance on alternative collection systems identifies vacuum sewerage as the preferred technology in high water table, coastal, and flood-prone environments — precisely the site conditions where gravity requires multiple pump stations and infiltration management becomes a dominant design and energy constraint.

4. Case Study 1: Fishermans Bay, South Australia

4.1 Site Description

Fishermans Bay is a coastal residential settlement on the Yorke Peninsula, South Australia, administered by the District Council of Barunga West. The site is a flat sandy coastal peninsula, elevation 2.1 to 3.5 m AHD, with a seasonal high water table. The vacuum system serves 406 current lots via 101 monitored collection chambers, discharging via a 7 km rising main to the Barunga West Sewage Treatment Plant at Port Broughton. The system was commissioned in 2022 and is monitored in real time by the Flovac FMS platform.

All 101 Flovac collection chambers monitored in real time via the FMS platform. Each green marker reports valve status, activation count, alarm conditions, and sewage levels — per-property visibility unavailable in any gravity or low-pressure alternative.

4.2 System Configuration

- Two Busch MINK MV 0502B dry claw vacuum pumps — 7.5 kW, 400 m³/hr at 50 Hz — duty/assist
- Two Grundfos SEV.80.80.110.2.50B submersible sewage pumps — 11 kW, 12.32 L/s at 33.51 m TDH — duty/assist
- Stainless steel collection vessel, 7,260 litres
- 101 Flovac FV80 pneumatic interface valves across the reticulation
- Flovac Monitoring System (FMS) with per-pit real-time telemetry

Interior of the Fishermans Bay VPS showing one of the two Busch MINK MV 0502B vacuum pumps (foreground, label visible) and air-liquid separator (left). This pump and its standby partner, together with the two sewage pumps, represent the entire energy-consuming plant for 400 dwellings.

4.3 Measured Operating Data

- VP1 annualised run hours: 243 hrs/yr; VP2: 328 hrs/yr — combined duty/assist: 571 hrs/yr
- SP1 annualised run hours: 153 hrs/yr; SP2: 130 hrs/yr — combined duty/assist: 283 hrs/yr
- Annual flow: approximately 9,700 kL/yr
- February 2026 average daily flow: 19.6 m³/day (96 of 101 valves active)
- Peak flow period: January — consistent with coastal holiday community pattern
- Weekend average flow 31% above weekday, confirming seasonal holiday settlement character

4.4 Three-System Comparison — Fishermans Bay

Parameter	Vacuum (Actual)	Gravity (Modelled)	Low Pressure (Modelled)
Annual energy (kWh/yr)	**7,400**	9,000 to 10,500	48,000
Annual energy cost @ $0.30/kWh	**$2,220**	$2,700–$3,150	$14,400
Cost per dwelling per year	**$5.55**	$6.75–$7.88	$36.00
Number of pump units	**4 (centralised)**	6–8 (3 stations)	400+ (distributed)
Groundwater infiltration risk	**None — sealed**	High — sandy coastal soils	Moderate
Wet-weather flow uplift	**None**	Flow may double or more	Partial

Energy visibility	**Single metered point**	3 metered points	Distributed — not visible
Per-pit real-time monitoring	**Yes — FMS**	Pump station only	No

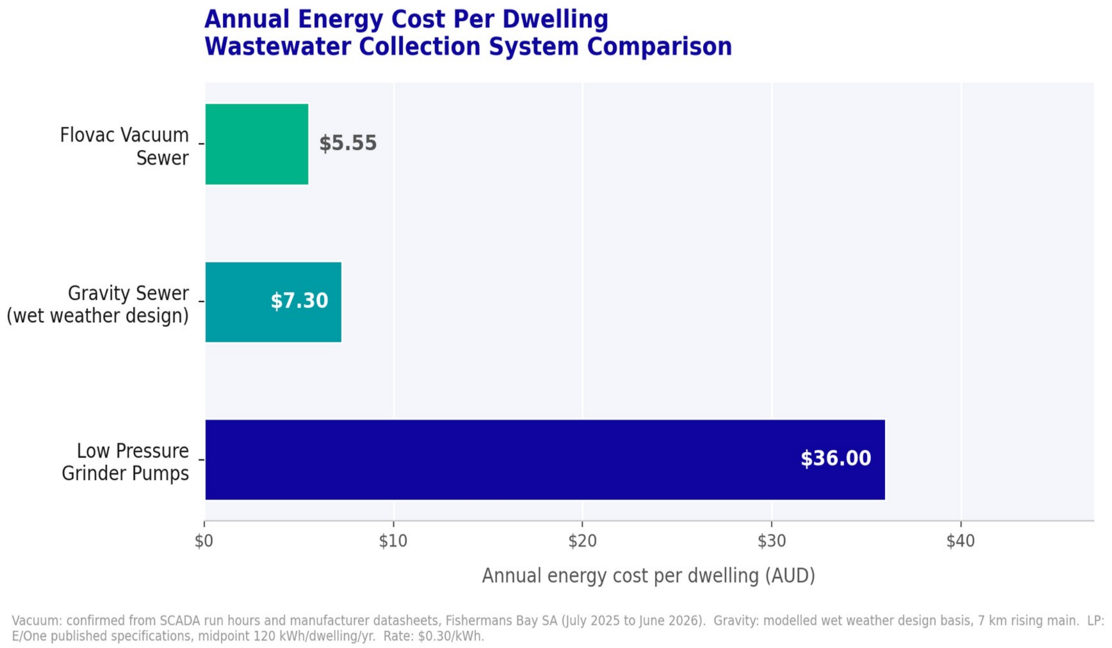


Figure 1: Annual energy cost per dwelling at current electricity rates of $0.30/kWh. Vacuum figure confirmed from SCADA data. Gravity reflects wet weather design basis. LP aggregates 400 distributed property pumps at published midpoint consumption.

> *The gravity figures reflect wet-weather design conditions required for this class of site. On a dry-weather basis only, gravity approaches vacuum on energy — but engineers cannot responsibly size to dry-weather flows alone on a high water table coastal site.*

5. Case Study 2: Large-System References

5.1 Pacific Harbour, Queensland — 18 Gravity Stations Replaced

Pacific Harbour demonstrates what vacuum sewerage delivers at scale. A single Flovac vacuum pump station replaced 18 gravity pump stations across the development, consolidating 36 or more duty/standby pump sets, 18 electrical connections, 18 wet wells and 18 odour management systems into a single facility with four pumps.

Pacific Harbour Vacuum Pump Station, Queensland — a single facility that replaced 18 gravity pump stations. All collection system energy, maintenance obligations, and operational monitoring consolidated into one location.

Even at modest run hours, 18 gravity pump stations with duty/assist configurations represent a substantial continuous installed electrical load. Vacuum consolidates this into one metered, managed location. The operational saving from eliminating 18 inspection sites and 36 or more pumps requiring maintenance is arguably greater than the energy saving alone.

5.2 Kurnell (Greenhills Beach), New South Wales

The Kurnell vacuum system (built 1989) covers 983 allotments, 420 valves, and 18 km of vacuum mains across four catchment areas. Actual measured power consumption is 80,604 kWh/yr, approximately 61 kWh/yr per allotment. Maintenance cost: $1.30/allotment/week. The 2011 Arup options report confirmed vacuum (Flovac) as the lowest-cost option on both capital and 30-year NPV, outperforming the pressure alternative by $2.49M over 30 years.

6. Scale Analysis: How the Differences Grow

6.1 Scaling the Fishermans Bay Baseline

The table below scales the Fishermans Bay confirmed energy baseline to larger systems. Vacuum energy scales approximately linearly with flow up to the point where additional pump units are required. LP energy scales exactly linearly, with each additional dwelling adding one more grinder pump. Gravity energy scales with flow and the number of pump stations required.

Scenario	Dwellings	Vacuum kWh/yr	Gravity kWh/yr	LP kWh/yr
Fishermans Bay (confirmed baseline)	400	7,400	approx. 9,750	48,000
Mid-size system	800	approx. 14,800	approx. 19,500	approx. 96,000
Large system	1,000	approx. 18,500	approx. 24,375	approx. 120,000
Large system	2,000	approx. 37,000	approx. 48,750	approx. 240,000
18 gravity stations replaced (Pacific Harbour scale)	**approx. 3,000+**	**approx. 55,500**	**approx. 130,000+**	**n/a**

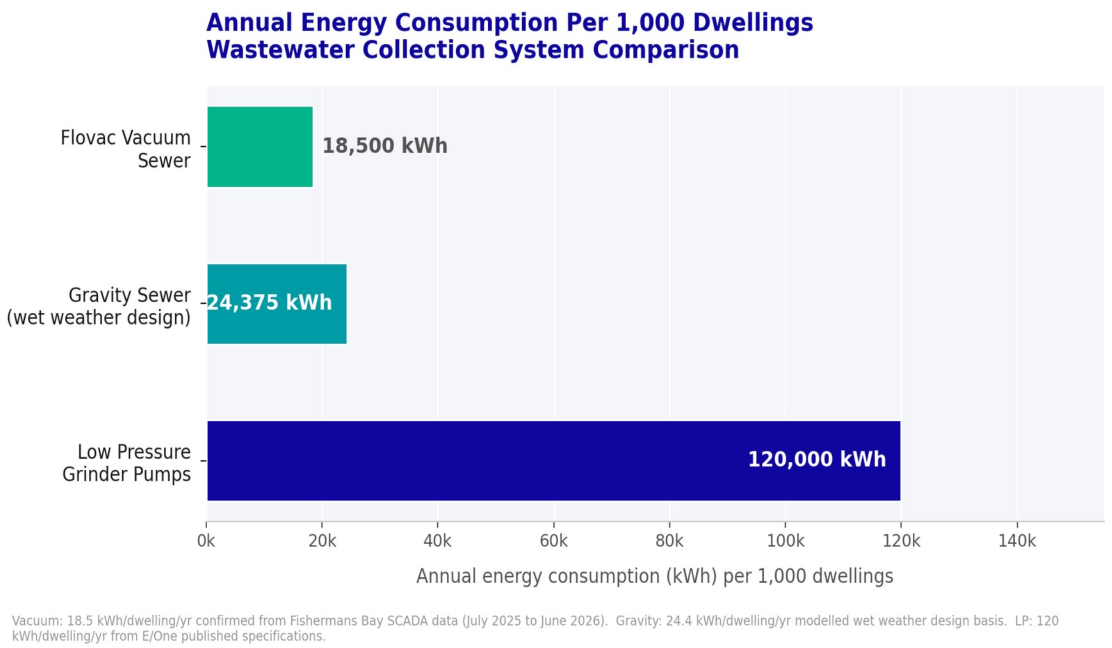


Figure 2: Annual energy consumption per 1,000 dwellings. LP energy of 120,000 kWh/yr is distributed across 1,000 individual electricity accounts and does not appear in the utility energy account.

6.2 Key Observations

- At 1,000 dwellings, an LP system consumes approximately 120,000 kWh/yr versus 18,500 kWh/yr for vacuum — a difference of over $30,000/yr in energy cost. Over a 30-year asset life that difference represents approximately $900,000 in energy costs from this factor alone.

- At 2,000 dwellings, the LP energy cost premium over vacuum exceeds $60,000/yr — roughly $30 per dwelling per year. Over 30 years that represents approximately $1.8M.
- The 18-station scenario illustrates a qualitatively different comparison. Replacing gravity infrastructure at this scale is not an incremental improvement — it is a restructuring of the entire operational model from distributed to centralised.
- Gravity infiltration effects compound at scale. A larger gravity system has more pipe surface through which groundwater infiltrates, increasing both pump station energy and treatment plant loading.

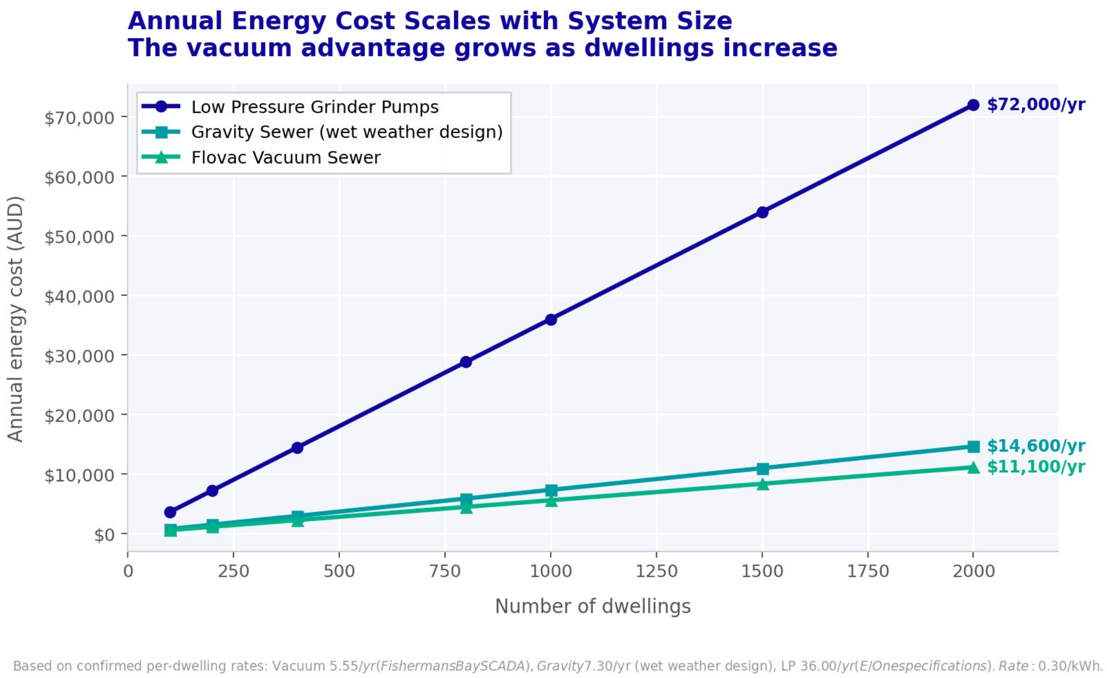


Figure 3: Annual energy cost grows with system size. The vacuum cost advantage over low-pressure systems exceeds $60,000/yr at 2,000 dwellings. All figures at $0.30/kWh.

6.3 Visibility and Governance

For LP systems the scale argument extends beyond energy cost to operational governance. A council managing a 2,000-dwelling LP scheme sees only centralised infrastructure energy in its accounts. The 240,000 kWh/yr consumed by 2,000 grinder pumps is spread across 2,000 individual electricity accounts and is not visible at the system level. Performance degradation or failing equipment generates no scheme-wide alarm.

Vacuum centralises all energy through a single metered point. The FMS platform calculates energy per cubic metre of wastewater transported in real time. Deteriorating performance, whether from a worn valve, an air leak or abnormal pump cycling, is visible before it becomes expensive.

7. Gravity Systems: The Infiltration Premium

7.1 Sizing for Wet-Weather Conditions

Options studies for coastal and low-lying sites must size gravity infrastructure for peak wet-weather flow, not dry-weather averages. In high water table coastal soils, groundwater infiltrates through pipe joints and structural defects throughout the gravity network. This is a characteristic of the technology in these ground conditions rather than a maintenance failure.

For the Fishermans Bay gravity modelled alternative, the measured dry-weather average flow is 19.6 m³/day. PS3 would need to be sized for wet-weather flows of 15 to 30 L/s rather than 12.32 L/s, increasing pump size, run hours, energy consumption and treatment plant loading.

Vacuum reticulation installation at shallow depth in sandy coastal soils typical of the Fishermans Bay site. In a gravity system, these same soils create a direct pathway for groundwater infiltration into the sewer network.

7.2 Vacuum: Structurally Immune to Infiltration

The vacuum system's energy consumption is unaffected by groundwater conditions. The Flovac valve opens only when triggered by accumulated sewage in the collection chamber sump. Groundwater cannot enter the sealed reticulation. The 9,700 kL/yr measured annual flow is entirely sewage — not a diluted mix requiring additional pumping and treatment.

> *In a gravity system on a high water table site, groundwater infiltration that doubles pump station throughput also doubles the hydraulic load at the treatment plant — increasing aeration and processing energy. The infiltration energy penalty falls on both collection and treatment.*

8. Conclusions and Decision Framework

8.1 Summary of Findings

- Vacuum sewerage delivers the lowest confirmed energy consumption for coastal, flat-terrain and high water table sites. At Fishermans Bay, 7,400 kWh/yr for 400 dwellings equates to $5.55 per dwelling per year, based on 11 months of measured SCADA data and manufacturer-confirmed motor ratings.
- Low-pressure grinder pump systems consume 6 to 7 times more energy than vacuum at equivalent dwelling counts. This energy is distributed across individual properties and does not appear in utility energy accounts. At 2,000 dwellings, the annual cost difference exceeds $60,000.
- Gravity systems are broadly comparable to vacuum on a dry-weather energy basis, but must be sized for wet-weather infiltration flows in the coastal and high water table environments where vacuum is most commonly deployed. On a design-condition basis, gravity energy consumption at this site is 20 to 40 percent above vacuum.
- Where vacuum replaces multiple gravity pump stations, as at Pacific Harbour, the whole-of-life advantages across energy, capital, maintenance and operational simplicity are substantial.

8.2 Decision Framework for Options Studies

- Aggregate all energy at the dwelling count — including distributed property pump energy for LP systems — before making any energy comparison.
- Use design-condition (wet weather) flows for gravity energy calculations on coastal and high water table sites, not dry-weather averages.
- The breakeven connection count for vacuum versus LP is 75 to 100 connections [2]. Most LP options studies are conducted for sites well above this threshold.
- Whole-of-life cost comparison should include maintenance obligations: the difference between 400 owner-maintained property pumps versus 4 centrally-maintained vacuum pumps is a significant operational cost factor over a 30-year asset life.
- Where reviewing an existing gravity network with multiple pump stations, evaluate vacuum replacement on consolidated infrastructure, reduced wet-weather capacity requirements, and eliminated infiltration load at the STP.

8.3 Limitations

- Fishermans Bay vacuum energy figures use nameplate motor ratings applied to measured run hours. Actual power draw at the operating point may differ slightly; site power metering would provide billing-grade accuracy.
- Gravity energy figures are modelled — no gravity alternative exists at this site. Modelling uses standard hydraulic practice and published flow data.
- LP energy is based on published manufacturer midpoint figures. Actual consumption varies with head, cycling frequency, and unit condition.
- Energy costs are calculated at $0.30/kWh. Actual tariffs vary by jurisdiction and supply arrangement.
- This document does not constitute a formal options study and should not be used as a substitute for site-specific hydraulic design.

9. References

Ref	Source	Description
[1]	Parsons Brinckerhoff (2003)	Fishermans Bay Sewage Disposal Option Study. District Council of Barunga West.
[2]	Wallbridge & Gilbert (2006)	Wastewater Collection Systems — Comparative Merits. LGA South Australia.
[3]	Arup (2011)	Greenhills Beach (Kurnell) Options Report. Australand / Sydney Water.
[4]	Florida DEP (FDEP)	Florida Department of Environmental Protection guidance on alternative wastewater collection systems. FDEP identifies vacuum sewerage as the preferred collection technology in high water table, coastal, and flood-prone environments where gravity sewerage requires multiple pump stations.
[5]	Flovac (2024)	Fishermans Bay VPS Operations and Maintenance Manual. Flovac Vacuum Sewerage Systems Pty Ltd.
[6]	Busch Vacuum Solutions (2021)	MINK MV 0502/0602 B Product Data Sheet. Australian edition.
[7]	Grundfos (2024)	SEV.80.80.110.2.50B Product Data Sheet. Grundfos Product Centre, 14/02/2024.
[8]	Flovac FMS (2025–2026)	Fishermans Bay SCADA monitoring data, July 2025 – June 2026.
[9]	Dawson, D. (Flovac)	Power Consumption Analysis; Power Use per Size of System. Internal spreadsheets.
[10]	E/One (ITT)	Sentry Series Grinder Pump published specifications.

About Flovac

Flovac is a specialist manufacturer and supplier of complete vacuum sewer systems. Flovac has worked with utilities, developers and engineers across Australia, New Zealand, the United States and Europe, delivering sewerage infrastructure on sites where conventional approaches are difficult, expensive or impractical.