Checkpoint 2 – Vacuum Sewer Systems for Flat, Flood-Prone Towns

1. Data Analysis

Vacuum sewer systems were identified in Checkpoint 1 as a promising alternative to gravity sewers and septic tanks for small communities with flat topography and frequent flooding. In this checkpoint the initial data analysis is based on case studies, published reports and grey literature about inflow and infiltration, project costs and operational experience. The sustainability pillars table from Checkpoint 1 guided the selection of evidence and the identification of social, environmental, economic and technical dimensions.

1.1 Data and sources

Case studies and reports. A technical presentation by Bilfinger Water Technologies summarised design and cost data for a vacuum sewer installation in Fujairah. The study reported that sealed vacuum pipes prevent undetected inflow of storm or ground water and can achieve substantial cost savings compared to gravity sewers. In the same case study capital expenditures for an 18 km network were compared: the gravity option (approximately €2.83 million) required deep trenches, manholes and multiple lift stations, whereas the vacuum network (approximately €1.68 million) relied on a central vacuum station and shallow pipes, saving about €1.15 million. A more recent case from Miles Crossing, Oregon described how a community replaced failing septic systems with a vacuum sewer system and employed a telemetry monitoring system to track valve activations. This allowed operators to detect anomalies during rain events, reduce inflow and infiltration, and optimise maintenance.

Literature and technical guidance. Engineering texts on vacuum sewer design explain that household wastewater is collected in small chambers with float-controlled valves and conveyed as plugs of air and wastewater through sealed mains to a central vacuum station. Unlike gravity sewers, the network does not require continuous slope and therefore uses shallow trenches that minimise disturbance to tree roots and utilities. Sealed pipes limit infiltration and exfiltration; however, valves and pumps are electromechanical and require preventive maintenance and trained operators. Remote monitoring technologies (e.g., telemetry systems) improve reliability and allow proactive maintenance.

1.2 Key trends and comparisons

- **Inflow and infiltration (I/I).** Traditional gravity sewers can experience significant infiltration during high groundwater and storm events. The vacuum sewer presentation notes that sealed vacuum pipes prevent undetected inflow and exfiltration, thereby protecting groundwater quality and preventing sewer overflows. The Miles Crossing case confirms that real-time monitoring of vacuum valves enables operators to locate unusual inflow events and rapidly remediate them.

- **Capital and life-cycle costs.** In flat terrain, gravity sewers rely on deep trenches, manholes and multiple lift stations; these elements increase construction costs and vulnerability to flooding. The Fujairah case shows that a vacuum network for an 18 km service area cost about €1.68 million versus €2.83 million for a gravity network, resulting in roughly 40 % savings. Although vacuum systems require a central station with pumps and control systems, the reduced excavation and elimination of manholes lower both capital and operating expenditures over the life cycle. Lower I/I also reduces treatment volumes and energy demand at downstream treatment plants.

- **Social and environmental dimensions.** Sealed mains prevent exfiltration of pathogens and nutrients during floods, improving public health. Shallow trenches minimise disruption to residents and landscapes and allow installation alongside water lines without requiring separate

trenches. Adoption requires community education and operator training to build familiarity with vacuum valves and station controls. Equity considerations include ensuring that small towns with limited tax bases have access to grants or low-interest financing to cover the fixed costs of vacuum stations.

- **Technical performance.** Vacuum networks eliminate the need for continuous slope and can follow flexible alignments, which is advantageous in built-up areas with utility conflicts. The system relies on electromechanical valves and vacuum pumps; preventive maintenance and standby power are necessary for reliable service. Remote monitoring systems provide real-time data on valve activations and enable operators to pinpoint and repair leaks or unauthorized connections.

1.3 Summary table

Table 1 summarises the sustainability pillars, key data sources and considerations used in this analysis. The table focuses on keywords and short phrases rather than sentences.

Pillar	Evidence / Data source	Key data or trends	Considerations
Environmental	– Flood-prone towns experience sewer overflows; – Septic tanks leak pathogens; – Vacuum pipes are sealed	– Vacuum prevents undetected inflow/exfiltration; – Shallow trenches reduce soil and root disturbance	– Monitor groundwater quality; – Assess resilience during floods; – Evaluate ecosystem impacts
Economic	– Case study: vacuum network (€1.68 M) vs gravity (€2.83 M); – Reports of 25–40 % cost savings	– Lower excavation and no manholes reduce CAPEX; – Reduced I/I lowers treatment OPEX	– Conduct life-cycle cost analysis; – Assess affordability for small towns; – Evaluate economies of scale
Social	– Vacuum systems protect public health by preventing sewage leaks; – Shallow trenches minimise disruption; – New technology requires education	– Improved health outcomes; – Reduced construction disturbance	– Community awareness and training; – Affordability for low-income communities; – Operator capacity development
Technical	– Components: collection chambers, interface valves, sealed mains, central station; – Remote monitoring	– No continuous slope required; – Sealed network reduces odours and infiltration; – Real-time telemetry detects anomalies	– Establish design and maintenance standards; – Provide operator certification; – Plan for backup power and scalability

1.4 Summary figure

Figure 1 compares the approximate capital cost of gravity and vacuum sewer systems for a small, flat service area based on the Fujairah case study. The gravity option includes deep trenches, manholes and multiple lift stations, while the vacuum option uses shallow, sealed pipes and a central vacuum station. The vacuum system's lower cost highlights the potential economic advantage of this technology in appropriate contexts.

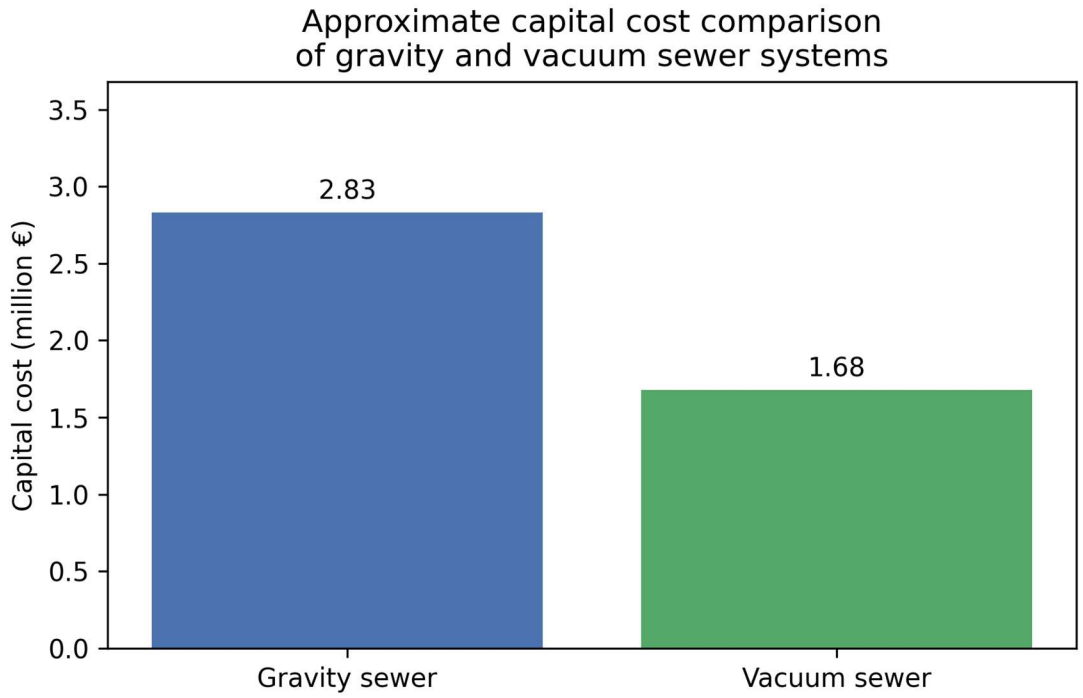


Figure 1 – Capital cost comparison of gravity and vacuum sewer systems

2. Preliminary Findings and Recommendations

Early insights. The data indicate that vacuum sewer systems address several sustainability challenges encountered by flat, flood-prone communities. Sealed mains and shallow trenches prevent inflow of stormwater and groundwater and reduce exfiltration of sewage, thereby protecting public health and the environment. Capital costs can be lower than gravity systems because deep excavation, manholes and multiple lift stations are eliminated; life-cycle analyses suggest that lower I/I leads to significant operational savings. Remote monitoring platforms enhance reliability and allow proactive maintenance.

Challenges and gaps. Despite these benefits, several barriers to adoption persist. Vacuum stations and interface valves introduce fixed capital costs and require electromechanical maintenance; communities need trained operators and reliable power supplies. There is a lack of standardized design and acceptance criteria for vacuum systems, which may limit engineer and regulator confidence. Small towns often lack the funding and technical capacity to pilot new technologies. Social acceptance may also be hindered by unfamiliarity with vacuum valves and concerns about reliability.

Implications for recommendations. These findings suggest that technical assistance and policy support are needed to scale vacuum sewer adoption. Life-cycle cost analyses should be integrated into funding criteria so that avoided I/I and excavation are recognized. Design and maintenance standards, operator training programs and modular, prefabricated station designs would reduce perceived risk. Targeted grants or set-asides for flood-prone small towns can overcome the financing barrier and promote equitable access. Demonstration projects with publicly available performance dashboards (for example, I/I reduction, energy use and operational uptime) can build community confidence and provide real-world data for decision makers.

3. Artifact Selection & Draft Concept

After considering several communication formats, I decided that my final artifact will be a **policy memo**. Below I explain my reasoning and outline the memo I plan to develop.

3.1 Why a policy memo?

I thought about other options such as an infographic, a short video or podcast, and an interactive cost-comparison tool. Each has merit: an infographic could engage the public visually, a video or podcast might tell a compelling story, and an interactive tool could let users explore cost scenarios. However, my goal is to influence decision makers—state water infrastructure authorities, municipal engineers and funding agencies—who operate in a policy environment and expect concise, evidence-based recommendations. A policy memo is a familiar format for them. By writing a memo, I can present technical and economic evidence succinctly, frame the problem and its urgency, and lay out clear actions they can take to support vacuum sewer adoption. The memo format also fits within the time and scope constraints of this course.

3.2 Outline of my policy memo

1. **Executive summary:** I will briefly state the issue of inflow and infiltration in conventional sewer systems and summarize why vacuum sewers are a suitable alternative for flat, flood-prone towns.
2. **Problem statement:** I will describe the specific challenges faced by these communities—such as sanitary sewer overflows, groundwater contamination and high capital costs associated with deep excavation and multiple lift stations.
3. **Evidence:** This section will compile data from the Fujairah and Miles Crossing case studies, including cost comparisons, reductions in inflow and infiltration, and operational experiences, along with insights from engineering literature.
4. **Recommendations:** I will propose actions such as adopting technology-neutral funding criteria, developing standardized design and operations guidance, creating operator training and certification programs, establishing grant set-asides for small, flood-prone towns, and supporting demonstration projects.
5. **Call to action:** I will conclude by urging the state water infrastructure authority to begin developing design guidance and to open a grant window for vacuum sewer projects within a specific timeframe (e.g., six months).

References

Flovac. (n.d.). *Shelter from the rain: Miles Crossing, Oregon, United States*. Flovac. Retrieved November 8, 2025, from https://flovac.com/miles-crossing-oregon-united-states/

Guertler, M. (2014). *Vacuum sewerage & water management systems*. In **Regional workshop on integrated resource management in Asian cities: The Urban Nexus** (Da Nang, Vietnam, June 25–27, 2014). Bilfinger Water Technologies.