VACUUM, STEP, PRESSURE SEWER, GRAVITY, HYBRID - WHICH TECHNOLOGY TO USE?

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ABSTRACT

A significant number of wastewater reticulation technologies are available; each with varying attributes, costs and benefits. Assessment of these technologies is simplified when considering greenfield areas where generally only the network and trunk assets needs to be considered. However, when considering reticulation of existing communities, the specific attributes and costs of connecting individual existing properties can add an additional layer of complexity to the assessment. The costs and risks associated with the physical connection of each property have the ability to add significant cost to a project and mean an alternative reticulation technology may provide the least cost solution.

This paper considers how the attributes of existing properties can impact upon the preferred reticulation technology through cost, risk and practicality. A methodology is presented to facilitate the quantitative assessment of each individual property in the catchment and how this assessment can be used to optimise the selection of the final wastewater reticulation technology and network configuration.

KEYWORDS

Vacuum, Pressure Sewer, STEP, Wastewater Reticulation, Reticulation Technologies, Quantitative Assessment, Property Attributes, Property Connection Costs.

1 INTRODUCTION

The attributes of alternative wastewater reticulation technologies are becoming well understood. Advances in standards, systems and technologies are giving alternative technologies a big lift in reliability and reductions in cost, both in capital and in operational and maintenance costs. Technologies such as pressure sewer systems are becoming wildly accepted and are seeing significantly more communities reticulated with this technology. Additionally, vacuum sewer systems are being seen as a viable alternative and are becoming more common in applications throughout New Zealand. A number of other reticulation options are available, including septic tank effluent pumping (STEP), gravity systems, including traditional gravity and “modern” gravity systems such as low I&I systems such as “NuSewer” and “Leak Tight” sewer in Brisbane and Sydney respectively.

With all reticulation technologies the attributes are well understood for the public network. Track record of installation gives a foundation for reliable cost estimates to assist in the selection of technologies and for the determining of budgets to reticulate communities. However, there is a significant difference in costs, risks and associated attributes between greenfield land development and reticulating existing communities and existing properties.

Greenfield land development avoids a number of factors that reticulation of existing communities must consider. Primarily greenfield development networks are laid at the same time as other services, meaning service clashes and avoidance are not a factor, reinstatement costs are not significant as utilities are laid prior to surface treatment, and traffic management costs and constraints do not apply. One of the most significant factors is the connection of new properties. On property works are carried out prior to or in conjunction with house and foundation construction and prior to surface treatment and landscaping.

Providing reticulation to existing communities requires the connection of existing properties to the public network. Generally properties in existing communities will be serviced by on site treatment systems or septic tanks. A number of factors influence the ease and cost of connecting existing properties. These include access to the property, the location of existing drainage in relation to the new network, existing services, ground conditions, the proximity of the dwelling or other structures to the works, slope or fall, and extent of reinstatement requirements.

The extent of works required to connect existing dwellings can heavily influence the preferred reticulation option. Insufficient analysis of the cost of on property works can pose a significant risk to project budgets and overall project success. Careful analysis of the extent of works, risks and costs of physically connecting each dwelling is required at early stages in the project inception. This specifically includes at the options assessment stage, to facilitate the correct selection of reticulation technology, and at the budget determination stage, to ensure an adequate appraisal and understanding of the project costs is established prior to embarking on the project.

This paper outlines and documents a methodology successfully used to assess the costs and risks of connecting dwellings in existing communities being serviced by wastewater reticulation.

2 ATTRIBUTES OF WASTEWATER RETICULATION TECHNOLOGIES

The attributes of various wastewater reticulation technologies are generally well understood. To understand the implications of each technology, the attributes are summarized below, to provide a basis for further consideration of the technologies, the relative merits and constraints

2.1.1 VACUUM SYSTEMS

A vacuum wastewater system consists of a central vacuum pump station inducing flow into the network from ‘vacuum pits’ located in the road reserve in close proximity to each property. Typically between one and four properties are connected to each vacuum pit. When wastewater reaches a certain level in the pit, a vacuum valve is actuated, sucking the accumulated wastewater into the reticulation. The reticulation itself is typically in the order of 150mm NB pipe, and is laid comparatively shallow with a saw tooth type long section. The saw tooth long section has long runs of slightly falling grade, with a short (1 foot) lift section, often in series, to match ground contours. Due to the saw tooth configuration, reticulation must be laid predominantly by open trenching.

Vacuum systems are restricted in their ability to ‘lift’ wastewater, i.e. the vacuum pit can be 4m below the maximum elevation of the pipe. Systems typically have 4m of lift. Some systems have been designed with up to 10m of lift. These systems are described as being technically more sensitive, and while operate perfectly effectively, are less robust in their ability to provide trouble free operation.

Vacuum systems can draw flow from up to 2,000m away and can therefore service and area of 4,000m diameter from a single vacuum pump station. This gives significant advantages in being able to service significant populations with a single pump station. Scales of economy can be achieved with provision of services such as stand by generator, SCADA and land and access aspects such as security and landscaping of facilities.

Vacuum systems are well suited to:

- Flat catchments
- High water table or poor ground conditions such as sands or silts
- Large catchments or catchments with high property densities

Vacuum system constraints are:

- An inability to lift flow greater than minor elevation changes

- Are not well suited to small catchment populations

Property connections to a vacuum system can be considered to be the same as a gravity connection, with a gravity lateral coming out from the dwelling to a valve pit in the road reserve.

2.1.2 SEPTIC TANK EFFLUENT PUMPING (STEP) SYSTEMS

A STEP system requires septic tanks on all properties, with a small pump installed to pump tank effluent via a public reticulation system to a central treatment and disposal point (WWTP). Solids are retained on site and require periodic manual pump out with vacuum loader trucks. The reticulation system is for all intents and purposes the same as a pressure sewer system, with small bore PE pipe laid to ground contours at shallow depths.

STEP systems are well suited to smaller or low density catchments and those that require a wastewater treatment facility along with the reticulation. Examples of generally suitable catchments for STEP systems are clusters of lifestyle blocks, semi rural villages and communities and holiday communities.

Property connections for STEP systems are heavily influenced by the need for a large tank (generally between 4 m^3 and 6 m^3) to be installed on the property. Sufficient space, access and suitable ground conditions (i.e. flat or gently sloping) are required for the installation of a STEP tank. In addition, a power supply connection is required to the dwelling to provide single phase power to drive the discharge pump.

STEP discharge pumps are generally small single phase centrifugal pumps, very similar in design to water bore pumps. Multi stage pumps are readily available to provide significant head capabilities at required flow rates. Head capabilities in the order of 120 m are viable with multi stage centrifugal STEP pumps. This can provide significant benefits for hydraulic constraints in the public reticulation.

2.1.3 PRESSURE SEWER SYSTEMS

Pressure sewer systems are noted for being well suited to areas of high water table, flat or flow lying ground or steep and rocky ground. Primarily these attributes are due to the public reticulation being of small bore polyethylene pipe; and due to being a pressure system, the ability of the network to be laid to ground contours and not to grade.

Upon consideration of the ability to service existing dwellings, pressure sewer offers the greatest technical ability to physically service dwellings. This is as the discharge line is pumped, so grade is not an issue, the discharge line is very small, typically 40 mm OD PE, and that the units are relatively small and can be installed in areas of difficult access, lack of available space or in areas of high risk such as steep slopes or retaining walls. It has been known for pressure sewer tanks to be installed above ground or mounted to retaining walls on very steep and challenging properties.

It should be noted however that approximately 75% of the cost of a pressure sewer system construction in an existing catchment is in the on property equipment and installation. Mechanical and electrical assets are required on every property in the catchment. Additionally a maintenance liability is created, where at the end of the asset life, every pump in the catchment will require replacement. These costs and needs for future O&M requirements need to be balanced with the technical capabilities of the technology to service difficult properties, and also to provide the overall greatest benefit to communities regarding capital cost, O&M cost and risk.

2.1.4 GRAVITY SYSTEMS

Gravity wastewater reticulation is by far the most common method of reticulating wastewater in New Zealand. Traditional gravity wastewater systems generally consist of concrete or PVC pipes with concrete manholes used to change grade or pipe alignments. Traditional gravity wastewater systems can be viewed generally as simple and reliable but are often prone to inflow and infiltration problems. In severe situations these can lead to loss of service, wastewater overflows and environmental or public health risks.

Modern specifications and materials are bringing about cost and performance advances in gravity systems. Two leading examples of this is “NuSewer” and “Leak Tight” sewer by Brisbane Water and Sydney Water respectively. The adoption of polyethylene pipe fittings means that gravity systems can be sealed effectively against groundwater and resilient to ground movement which would otherwise lead to pipe cracking and failure. This gives modern gravity systems significantly enhanced performance with regards to inflow and infiltration.

The prevalence of modern maintenance equipment has greatly simplified gravity network maintenance and repairs. This combined with the flexible properties of polyethylene pipe mean that manholes are no longer required to change grade and alignment. Modern maintenance equipment such as CCTV, vacuum loaders, jet washing trucks, root cutters, etc. mean that personnel no longer need to physically climb into manholes to carry out maintenance tasks. Maintenance shafts can be constructed in place of manholes at regular intervals in the network. Maintenance shafts are generally the same diameter as the sewer line (i.e. 150 NB) made of plastic pipe materials such as polyethylene and are cheaper and quicker to construct and maintain than traditional concrete manholes.

Property connections for gravity systems rely on fall from the dwelling to the network main. This often leads to gravity network mains being laid in private property along the back of sections or other difficult to access locations to achieve fall and be able to service all dwellings. Private laterals must be trenched from the dwelling to the network main. This can be expensive and disruptive for existing established dwellings. Often the attributes of the existing dwellings and catchment are not conducive to gravity reticulation and is a primary reason as to why the catchment has not be reticulated previously.

2.1.5 HYBRID SYSTEMS

Hybrid systems refer to a mix of wastewater reticulation technologies used to service a catchment. This is most common where a gravity system is combined with pressure sewer to optimise the cost and benefit to the community of providing wastewater reticulation. Hybrid systems stem from a sound understanding of the costs and constraints of physically connecting each dwelling. A simple example is a gravity main running along a street, where dwellings on one side of the street are above the road (and gravity main) and dwellings on the other side of the street are below the road (and gravity main).

The methodology presented within this paper is an effective way of assessing and quantifying attributes of properties to optimise the design of hybrid networks. The methodology focuses on the attributes of each dwelling to determine the most effective network reticulation for that dwelling.

3 PROPERTY CONNECTION COSTS

The ability and thus cost to physically service a house by various options has been identified as the fundamental driver to establish the preferred reticulation technology. As such a methodology was established that focused on the attributes of each individual property and how that property may be serviced by each wastewater option.

A property assessment is carried out to form the foundation of the assessment, allowing network selection to be based on the most efficient means of physically connecting to each dwelling. Refer to Figure 1 below for a pyramid schematic of the assessment methodology. This shows the property assessment forming the foundation of the process, giving rise to the network selection based on the most efficient means of connecting each dwelling. This all leads to the optimum solution, which best meets the needs of the community.

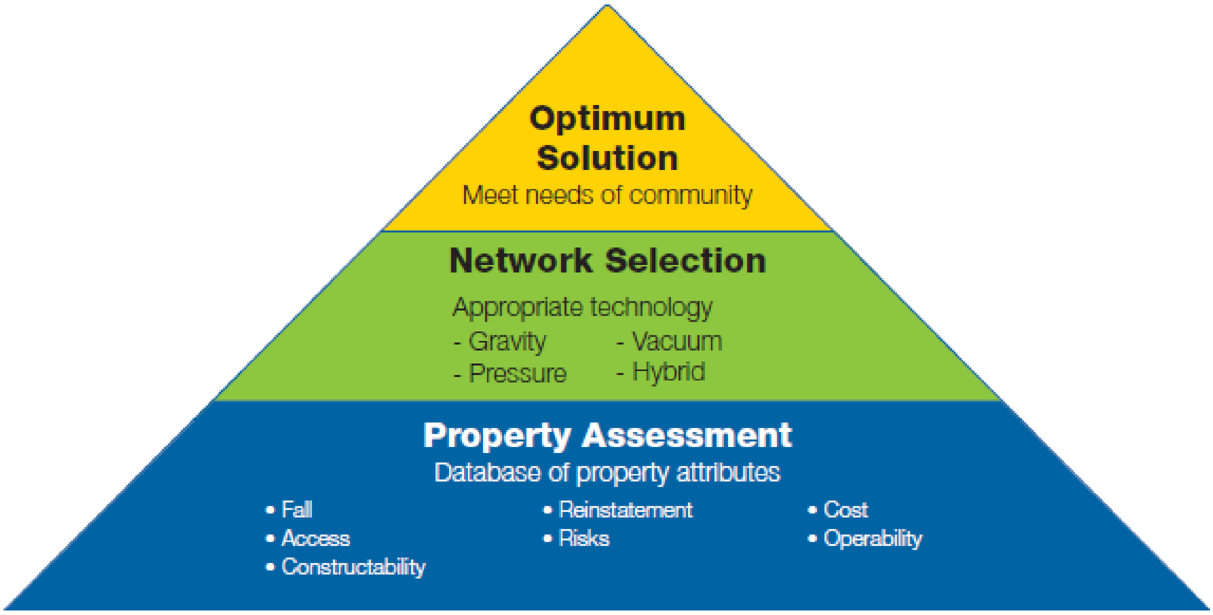

Figure 1 Assessment Methodology Basis

3.1 PROPERTY ASSESSMENT

The property assessment creates a database of property attributes that can then be analysed quantitatively for the optimum connection method. Attributes are gathered via three avenues:

- Property owner questionnaire
- Desktop assessment using existing GIS information, i.e. aerial photos, contours and property parcel outlines
- Physical onsite assessment of each property (generally from road frontage or driveway)

A number of attributes are recorded into the database and assessed through the optioneering process. These include both quantitative and qualitative attributes such as the distance of the house to the road boundary (quantitative) and the ability for machinery to access the area of property where work was likely to be carried out (qualitative assessment).

A list of recorded and assessed attributes is given below:

1. Property relative to street level (above or below the road, or flat)
2. Distance from house to road boundary
3. Distance from existing septic tank (if existing) to road boundary
4. Existing disposal system type
5. Age of existing disposal system
6. Trafficable boundary kit likely to be required (for pressure sewer, a cost factor)
7. Trafficable pump unit tank likely to be required (for pressure sewer, a cost factor)
8. Engineering risks present (retaining walls, canter-levered structures, steep banks or active slips etc)
9. Property access conditions, ranging from easy machine access to foot access only
10. Likely reinstatement requirements

The above attributes are assessed and have costs applied to them either directly or via cost factors for each connection type, either the installation of a pressure sewer pump unit, or a gravity lateral to the network reticulation (either traditional gravity network, a hybrid network or vacuum valve pit).

3.1.1 PROPERTY ATTRIBUTE CRITERIA, COST FACTORS AND IMPLICATIONS

The criteria for each attribute, cost factors and design implications are detailed below:

Property relative to street level:

Assessed from contour plans and confirmed by site inspection. Can the property be serviced by a gravity lateral connection, Yes or No.

Distance from house to road boundary:

Measured using GIS tools from aerial photos, reviewed against distances given in questionnaire returns. Used to cost either pressure sewer service / STEP pipe length & cost, or gravity / vacuum lateral length and cost.

Distance from existing septic tank (if existing) to road boundary:

Taken from questionnaire returns and an estimation of the location of septic tanks from aerial photos.

Existing disposal system type:

Taken exclusively from questionnaire returns. Used to assess the viability of a STEP system i.e. modern well-constructed onsite treatment tanks may be suitable for adoption in a STEP system.

Age of existing disposal system:

Taken exclusively from questionnaire returns. Used to assess the viability of a STEP system and the possibilities of adopting existing on site tanks.

Trafficable boundary kit likely to be required:

Assessed by site inspection. The need for a trafficable boundary kit has a cost implication for a pressure sewer connection to the property being assessed. This also has future operational implications for staff access to boundary kits.

Trafficable pump unit tank likely to be required:

Assessed by site inspection. This has a direct cost implication for a pressure sewer connection and typically occurs where the properties' driveway is the only area that can be accessed by construction machinery.

Engineering risks present:

Assessed by site inspection. This attribute primarily assesses the risks associated with connecting the specific property. Primarily it is the existence of retaining walls or steep slopes on the section but include any attribute that would require additional consideration at the design phase prior to carrying out works such as geotechnical or structural engineering input. Also included is the need to excavate within the zone of influence of building foundations such as tall house foundation piles. A cost factor of 1.2 is applied to the total cost of connecting these properties, i.e. a 20% cost premium for that property due to the presence of an item deemed an 'engineering risk'. The cost factor is based on cost to address the risk, not the likelihood of the risk occurring.

Property access conditions:

Assessed by site inspection. This attribute has the most significant implications on connection cost. Four levels of access were determined:

1. Machine access – Unrestricted machine access to the property, specifically, likely location of the existing septic tank and site of a new pressure sewer unit / STEP tank or alignment of a gravity / vacuum lateral. Cost factor 1 – no impact on standard cost of work.

2. Machine access to front of property only – This typically results in the inclusion of a trafficable pressure sewer or STEP tank as machinery can only access the driveway or car park. A cost factor of 1.1 is applied, i.e. 10% cost premium for connecting that property. Note a trafficable tank has a separate lump sum additional cost of $2,500 (approx. cost for a 1050 manhole to be used as a pump chamber).

3. No Machine Access – It is important to qualify the definition of 'No Machine Access'. This means that there is no easy machine access. It is anticipated that the work will still be carried out by mechanical excavators etc but that enabling works will be required to gain physical access with a machine. Examples of this are building a ramp over a retaining wall, removing a fence or hedge, or reinstating an established garden following driving a digger through it. A cost factor of 1.3 is applied for this category, i.e. a 30% cost premium on all work to connect that property.

4. Foot Access Only – This category is explicit, the only way to access the property, and the area of the existing septic tank or drainage, is by foot only. The properties typically have no parking and all access is via stairways either straight up or straight down steep banks. All equipment and construction materials including fill and aggregate would need to be packed in on foot. As such a cost factor of 1.8 is applied, i.e. an 80% cost premium on all work to connect that property. Note, only very topographically challenged catchments are expected to have this category of access.

Likely Reinstatement Requirements - Assessed by site inspection. This is based on an assessment of the likely location of a pressure sewer unit or STEP tank, location of existing septic tank and ground cover likely to be disturbed during connection of that property. Three reinstatement criteria were recorded, 'standard', 'fence / garden', and 'concrete / asphalt'. A lump sum cost was applied:

Standard reinstatement: $500

Fence / garden reinstatement: $2,500

Concrete / asphalt reinstatement: $2,500

3.1.2 DATABASE CONSTRUCTION

Following determination of attributes for each dwelling in the catchment, a database can be set up to record and document the attributes. This allows further interrogation and analysis of attributes in order to understand the impacts of attributes of dwellings on the selection of the optimum reticulation technology for the catchment.

An assessment database makes it possible to quantify aspects of a catchment, even though those aspects may be based on a qualitative assessment. An example of this is the degree of difficulty of access to properties, or the presence of engineering risks. It may be that the catchment appears to be well suited to gravity reticulation, as all properties are above the road or likely alignment of gravity lines. However, it may transpire that there is significant engineering risk present in bringing dwelling laterals down to the public gravity network. This would be due to the presence of steep banks, retaining walls or geotechnical instability between dwellings and the gravity main alignment. Conversely, it may transpire that where properties are all above the road, the only viable alignments for gravity laterals are down the driveway. On steep sections driveways are often a concrete or similar structural construction. While it is possible and quite practical to lay a gravity lateral down the driveway, the additional cost in trenching and reinstatement may put an alternative technology into the most preferred solution.

3.1.3 APPLICATION OF UNIT RATES

Once the assessment database has been constructed units rates can be applied to items to determine estimated construction costs. Units rates relevant to the local area and consistent with local authority standards, specifications and requirements should be used. Generally, unit rates from recent competitive tendering process are most accurate for forming rough orders of cost or engineer's estimates. In all cases a first principles assessment and reality check of costs and rates is recommended prior to adjudging a particular reticulation technology as least cost.

In certain situations a first principles check may demonstrate an adjustment in unit rates is warranted, such as applying a cost to represent a risk factor or to adjust for known market conditions or technology availability. Often with new reticulation technologies there is a lack of applicable recent tendered rates in the local market to base unit rates on. In these cases a first principles approach must be relied upon as the sole basis for cost estimates. In these situations care must be taken to avoid successive factors of conservatism. Overly conservative rates will rule out new technologies based on a lack of knowledge and familiarity, rather than a sound basis of the attributes of the technology and the costs associated with supplying and constructing it.

3.1.4 COST BASED ASSESSMENT

Using the assessment database and careful application of unit rates, costs can be determined to service each dwelling in the catchment for each available and viable reticulation technology. These dwelling connection costs can then be combined with cost estimates for the reticulation works to give a total cost to the community for servicing that catchment with a particular technology. In addition, certain areas, streets or sub catchments may be shown to be clearly well suited to a particular but different reticulation technology, meaning a hybrid system is the optimum solution for that catchment.

By applying a cost based assessment to dwelling connections in addition to the cost of reticulation, a true picture of the cost of each reticulation technology can be determined at the planning stages of a project. This ensures that the best reticulation technology for that catchment is selected at the planning stage, and that reliable budget estimates are determined, again during the planning and project inception stages.

The property assessment methodology provides a robust means to determine overall project costs for providing wastewater reticulation to a community. It also provides a quantitative basis for the cost and risk based selection of alternative wastewater reticulation technologies.

4 CONCLUSIONS

- A significant number of wastewater reticulation technologies are available with varying configuration attributes, costs and benefits.
- When considering the reticulation of existing communities, the specific attributes and cost of connecting individual existing properties can add an additional layer of complexity to the assessment.
- The costs and risks associated with the physical connection of each property have the ability to add significant cost to a project and mean a different reticulation technology may provide the least cost solution.
- A methodology was presented that assesses the attributes of each property within the catchment and quantitatively determines the likely cost to service each property with a particular wastewater reticulation technology.
- The determination of costs to service each property can be combined with the cost of the network reticulation to give a total cost of a reticulation technology to the community.
- This quantitative cost assessment can then be used to determine the preferred reticulation technology as relevant to that catchment or community.

The property assessment methodology provides a robust means to determine overall project costs for providing wastewater reticulation to a community. It also provides a quantitative basis for the cost and risk based selection of alternative wastewater reticulation technologies.