GRAVITY SEWER AND BEYOND

A Discussion of Sewage Collection Technologies and Costs

Objectives for Today's Discussion

- Sewer Collection System Options
- Some Technical Background on Alternative Collection Systems
- Installation Conditions Best Suited for Each System
- Comparison of Typical Lifetime Costs

Sewer Collection System Options

- Gravity Systems
- Low Pressure Sewer (Grinder Systems)
- Vacuum Sewer Systems

Gravity Sewer
Layout Characteristics

- Gravity sewer is typically under pavement
- 8-inch diameter and larger mains
- Typical minimum slope of 0.45 %
- Installed at a minimum of 3 ft deep and up to 20 ft+ deep below finished grade
- Manholes at all sewer intersections and approximately 350 feet apart on straight runs
- Discharge to a regional lift station

Gravity Sewer Installation Conditions

- Open cut installation only
  - Exceptions for large diameters (72” and up) where micro tunneling is an option
- Low groundwater table
- Little to no rock
- Deep runs require augmented open cut installation methods
  - Trench boxes
  - Shoring

Gravity Sewer Installation

Low-Pressure Sewer Layout Characteristics

- Small diameter pipes (2 – 4 inch)
- Pressure main installed in the ROW at minimal depth
- Each parcel has its own grinder pump station
  - Easements are recommended
  - Power is paid for by parcel owner (additional cost to resident)
- Pump stations will grind/chop solids and mix with liquid waste to form a slurry
- Flexibility in connecting to existing sewers

Low-Pressure Sewer Design Considerations

- Initial data gathering for planning
- Determine location and condition of existing septic tank systems
- Prepare a preliminary layout of pressure mains
- Determine valve locations
- Analyze alternative on-lot systems
- Determine most cost-effective generic type system and potential for phasing
- Determine design flows for present and build-out

Low-Pressure Sewer Design Considerations - cont

- Iterate pressure main design and perform hydraulic analysis
- Size wet wells for sufficient reserve capacity
- Pressure mains must accommodate full buildout flows but also provide cleansing velocity at current conditon
- Residential units typically have a designed peak flow of 15 gpm
- Minimum peak design velocity for grinder systems is 2.5 fps

Low-Pressure Sewer System Layout

Images by Crane Pumps

Low-Pressure Sewer
Pressure Main Installation Conditions

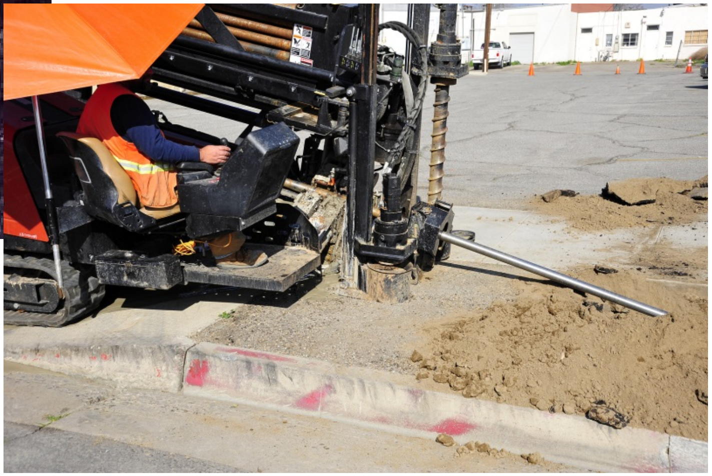
- Installed in ROW outside of roadway
- Installed with smaller/less impactful equipment
- Can accommodate hilly to flat terrain
- Installed via open cut or directional drill
- High ground water table and undesirable soil conditions are easier to overcome

Low-Pressure Sewer
Pump Station Installation Conditions

- Stations are typically owned by the utility and electricity is paid for by the owner
- Installed on private property (easements recommended)
- Installed with smaller equipment
- Installed via open cut
- Electric evaluation on each residence for connection
- Consider using septic tank for pump station

Low-Pressure Sewer Installation

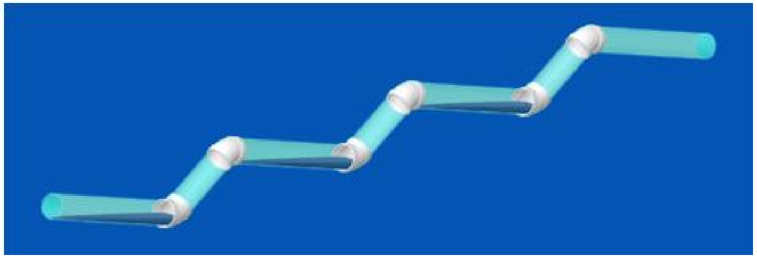
Force Main Pipe Installation



Images by Crane Pumps

Vacuum Sewer
Layout Characteristics

- Gravity Assisted Sewage Collection
- 3 Main Components
  - Valve Pits
  - Mains
  - Station



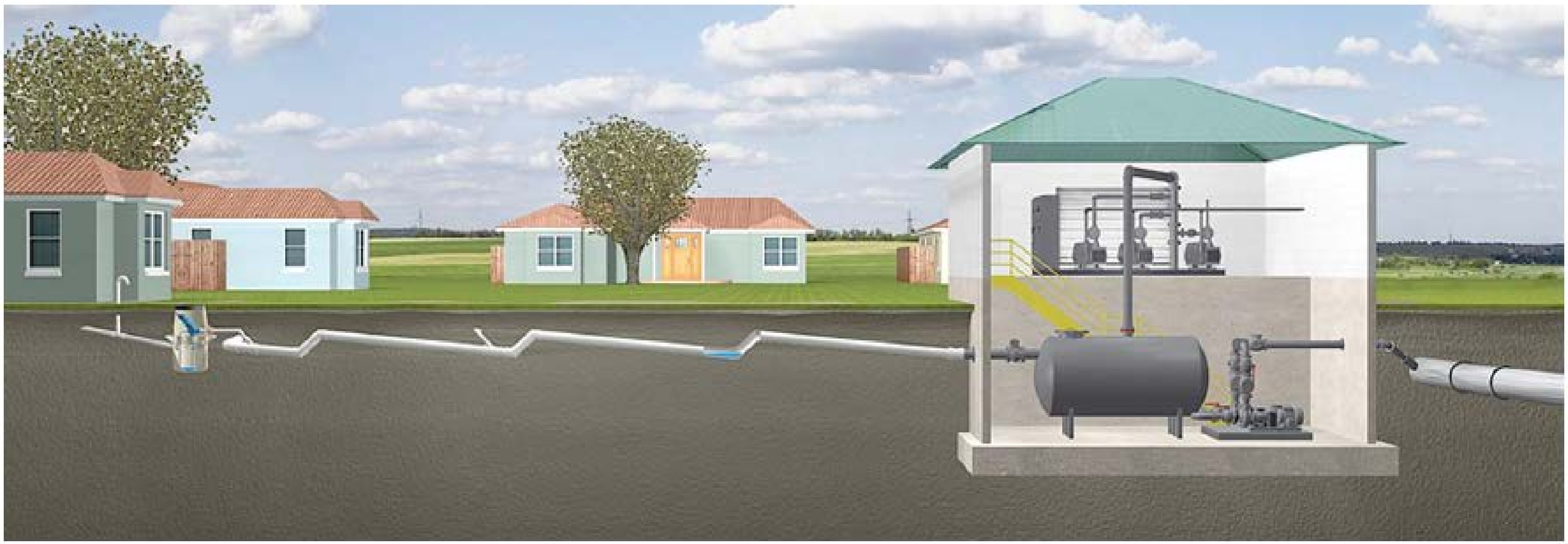
Vacuum Sewer Layout Characteristics

- High scouring velocities
- Elimination of the exposure to H_2S gas hazards
- Major leaks are detected immediately
- Reduced I&I
- The air/sewage mixture enters sewers at high velocity, and the air provides some pretreatment to the sewage inside the vacuum sewers

Vacuum Sewer Layout Characteristics

- Similar diameters to traditional forcemains (4–12 inch)
- Vacuum mains installed in row at depths of 3–6 ft below grade
- A minimum slope of 0.2% for downhill runs
- Follows hilly terrain using 1.0 ft – 1.5 ft lifts in the vacuum main
- Vacuum is maintained in the system by one station
- Residents connect to vacuum valve pits and no power required at the pits

Vacuum Sewer System Layout



AIRVAC Design Manual

Vacuum Sewer
Design Consideration – Mains

- First sized for adequate sewage flow and then sized to maintain proper vacuum levels throughout the system
- Laid out in runs; no looping of runs is permitted
- Each run is hydraulically analyzed to ensure proper flow in the pipe
- Minimum slope is 0.20% and must be held entering and exiting each lift
- Lifts are placed to maintain minimum pipe depth and facilitate proper function of the vacuum hydraulics

Vacuum Sewer Design Consideration – Mains and Valve Pits

- Flows on a natural downhill grade do not require lifts on slopes less than 2000 linear feet
- Hydraulic evaluations considerations
  - Diameter and length of pipe
  - Number of lifts
  - Number of valve pit connections
  - Elevation differences
- Valve pits are sized to allow for the service lateral to tie in as needed

Vacuum Sewer
Design Consideration – Stations

- Forcemain pumps are sized to meet traditional flow and total dynamic head characteristics and to meet the net positive suction head requirements to pull wastewater out of the vacuum tank
- Vacuum pumps are ideally positioned above the vacuum tank to prevent the introduction of any fluid to the vacuum pumps
- The vacuum tank is for full buildout plus any perceived development

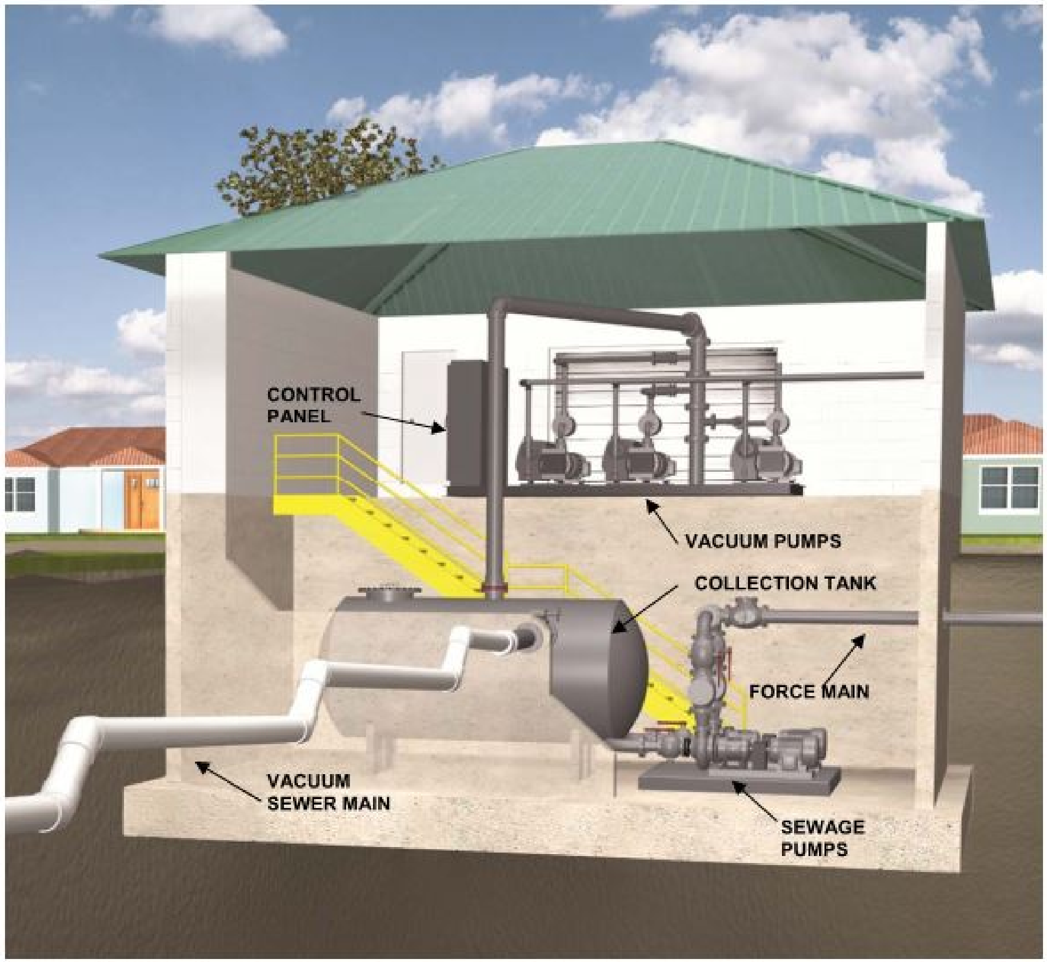
Vacuum Sewer
Vacuum Main Installation Conditions

- Installed in ROW outside of roadway
- Can accommodate hilly to flat terrain
- Installed via open cut only
- High ground water table and undesirable soil conditions are easier to overcome
- Similar flexibility during construction as forcemain

Vacuum Sewer
Vacuum Station Installation Conditions

- Vacuum stations are larger than traditional lift stations and require ¼ to ½ acres to construct
- Ideally stations are 2 stories to orient the vacuum pumps above the vacuum tank
- Water proofing is necessary for lower level

Typical Vacuum Station Layout



Typical Vacuum Sewer Main and Valve Pits

Vacuum Main Pipe Installation

Valve Pit O&M

Typical Vacuum Station

Vacuum Station Operation

Crystal River Vacuum Station

Sewer Collection System - Alternative Comparisons			
	Gravity Sewer	**Vacuum Sewer**	**Low-Pressure Grinder Sewer**
Power Requirements	Electricity required only at the Pump Station, and several pump stations may be required to service a single area.	Power is required only at the Pump Station. A single pump station is usually all that is required to cover a large area. Pumps only run on average 3 hours per day so power use is lower than alternative systems.	Grinder Pumps require power at each unit. This requires each home or business owner pay for the power. Existing houses may need to upgrade electrical mains and power board. Some pumps require constant power. Systems that require transfer pump stations will require high total power use.
Connections	No restrictions on connections.	Usually 2-4 homes are connected to a single collection valve pit, though larger flows from a gravity area can be accommodated into a multiple collection pit. Hotels, schools and high flow areas can be serviced by a buffer tank.	One pump is required per house. If the house is large or commercial flows are anticipated then a larger capacity pump may be required. Camping grounds and high flow situations are not recommended.
Leak Detection / Exfiltration	A broken pipe will go unnoticed for many months and the depth of the gravity lines will make detection difficult and expensive to repair.	Since vacuum is maintained within the mains at all times there is no chance of exfiltration of sewage.	As all pipework is under pressure then a break in the pipe may lead to large spills. Not suitable in environmentally sensitive areas.
Infiltration	Broken pipe can go unrepaired for long periods allowing stormwater to enter the system. This increases Treatment costs and power use.	Any leak in a vacuum main or valve pit will result in a vacuum drop which will register at the station immediately. Infiltration will occur until the leak is located but that is typically within 30-60 minutes of the vacuum drop being detected.	Infiltration is not common within a pressurized system.
Maintenance and Serviceability	High initial costs but low long-term O&M costs. Gravity sewer may require occasional jetting. Additional Maintenance would also include repair and coating of manholes. Access is typically not an issue as all infrastructure is located under roadways or within city property/utility easements.	Maintenance primarily involves replacement of the vacuum valves, and maintenance of the vacuum pumps. High scouring velocities in the system reduce risk of blockage. Most of the maintenance occurs at the vacuum station	Most maintenance requires the pump to be lifted out. An electrician is needed to be part of the service team. Access is difficult as all equipment is on the homeowner's property (utility easements are recommended).

Typical Lifetime Costs

- Gravity Sewer Systems
  - Higher capital costs
  - Lower O&M labor costs and lower equipment replacement costs
  - No moving parts - set it and forget it
- Low Pressure Sewer
  - Lowest capital costs of the three sewer systems
  - Higher O&M costs than Gravity Sewer
  - Grinder Pump selection is critical to reducing O&M labor and equipment replacement costs
- Vacuum sewer systems
  - Higher capital costs mainly due to the vacuum station
  - Vacuum main install costs are on par with FM costs
  - Valve pit costs are on par with manhole costs
  - O&M costs vary by owner depending on the age of the system and training of the operator
    - New technology is more reliable
    - Training operators is critical to keeping costs down

Typical Lifetime Costs

- The Net Present Worth (NPW) evaluation
  - Capital Costs (C) – Construction, Design, and Permitting
  - Annual O&M (O&M) – Labor cost to operate the system
  - Replacement Cost (R) – Equipment replacement over the life of the system
  - Salvage Value (S) – value of equipment at the end of serviceable life

$$NPW = C + (USPWF \times O\&M) + (SPPWF \times R) - (SPPWF \times S)$$

Example Project Cost Evaluation

- Gravity Sewer Systems
  - Capital Costs = $5,173,616
  - NPW = $4,842,240
- Low Pressure Systems
  - Capital Costs = $4,367,050
  - NPW = $5,364,024
- **Vacuum Sewer Systems**
  - Capital Costs = $4,709,530
  - **NPW = $4,385,263**

Sewer Collection System Summary

- Traditional Gravity Systems
  - Tried and true
  - Not usually the most cost effective in areas with high ground water, rock, or hilly terrain.
- Low Pressure Sewer (Grinder Systems)
  - Most economical capital costs but potentially the highest O&M costs
  - Very flexible for design and construction
  - Requires more homeowner by-in
- Vacuum Sewer Systems
  - Usually moderate to high capital costs
  - Relatively new to this area and requires special operator training
  - Flexible for design and construction
  - Greatly reduces I&I. Leaks are detected and identified quickly

QUESTIONS

Typical Lifetime Costs – Cont'd

- The Net Present Worth (NPW) evaluation
  - Uniform Series Present Worth Factor (USPWF) – Used to convert O&M costs to present day dollars.
    - Based on a discount rate (i) and life of the system (n).

$$\text{USPWF} = \frac{(1+i)^n}{i \times (1+i)^n}$$

  - Single Payment Present Worth Factor (SPPWF) – Converts the salvage value to present day dollars.
    - Based on a discount rate (i) and life of the system (n).

$$SPPWF = (1+i)^n$$

Capital Cost Estimates from Example Project

Gravity Sewer Project Costs				
DESCRIPTION	QTY	UNIT	UNIT COST	COST
Mobilization	1	Each	$20,000	$20,000
8" Gravity	22,535	LF	$28.00	$630,980
Manhole	76	Each	$3,200	$243,200
Lift Station	2	Each	$210,000	$420,000
6" Force Main	6,382	LF	$20.00	$127,640
Valve (FM)	9	Each	$1,800	$16,200
Road Repair	4.27	Mile	$500,000	$2,133,996
Land Acquisition	0.12	Acre	$180,000	$21,600
Septic Tank Abandonment	156	Each	$10,000	$1,560,000
Sewer Capital Cost Subtotal				**$5,173,616**
30% Contingency				$1,552,085
Design, Permitting and Const. Phase				$1,034,723
SEWER CAPITAL COST TOTAL				$7,760,424

Low-Pressure Grinder Sewer Capital Costs				
DESCRIPTION	QTY	UNIT	UNIT COST	COST
Mobilization	1	Each	$20,000	$20,000
2" Force Main	22,535	LF	$18.00	$405,630
Grinders	198	Each	$5,000	$990,000
Lift Station	1	Each	$210,000	$210,000
6" Force Main	2,752	LF	$20.00	$55,040
Valve (FM)	4	Each	$1,800	$7,200
2" Isolation Valve	208	Each	$1,200	$249,600
Road Repair	2.10	Mile	$375,000	$787,500
Land Acquisition	0.46	Acre	$180,000	$82,080
Septic Tank Abandonment	156	Each	$10,000	$1,560,000
Sewer Subtotal				**$4,367,050**
30% Contingency				$1,310,115
Design, Permitting and Const. Phase				$873,410
SEWER CAPITAL COST TOTAL				$6,550,575

Vacuum Sewer Capital Costs				
DESCRIPTION	QTY	UNIT	UNIT COST	COST
Mobilization	1	Each	$40,000	$40,000
4" Vac Main	17,944	LF	$19.00	$340,936
6" Vac Main	3,606	LF	$27.00	$97,362
8" Vac Main	2,652	LF	$34.00	$90,168
10" Vac Main	82	LF	$42.00	$3,444
Vac Station	1	Each	$1,000,000	$1,000,000
Valve Pit	89	Each	$4,900	$437,080
6" Force Main	2,752	LF	$20.00	$55,040
Valve (FM)	4	Each	$1,800	$7,200
Road Repair	4.27	Mile	$250,000	$1,067,500
Land Acquisition	0.06	Acre	$180,000	$10,800
Septic Tank Abandonment	156	EA	$10,000	$1,560,000
Sewer Subtotal				**$4,709,530**
30% Contingency				$1,412,859
Design, Permitting and Const. Phase				$941,906
SEWER CAPITAL COST TOTAL				$7,064,295

Gravity Sewer Net Present Worth

DESCRIPTION	QTY	UNIT	UNIT COST	COST	USPWF	SPPWF	R	S	O&M	NPW
Mobilization	1	Each	$20,000	$20,000	26.97					$20,000
8" Gravity	22,535	LF	$28.00	$630,980		0.71		$252,392.00		$452,905
Manhole	76	Each	$3,200	$243,200	26.97	0.71		$97,280.00		$174,564
Lift Station	2	Each	$210,000	$420,000	26.97	0.87	$108,000.00	$210,000.00	$1,805.00	$379,971
6" Force Main	6,400	LF	$20.00	$128,000	26.97	0.71		$51,200.00		$91,876
Valve (FM)	9	Each	$1,800	$16,200	26.97	0.71		$6,480.00		$11,628
Road Repair	4.27	Mile	$500,000	$2,133,996	26.97					$2,133,996
Land Acquisition	0.12	Acre	$180,000	$21,600	26.97	0.50		$8,640.00		$17,299
Septic Tank Abandonment	156	Each	$10,000	$1,560,000	26.97	0.71				$1,560,000
									Gravity Sewer Net Present Worth	**$4,842,240**

Low-Pressure Grinder Sewer Net Present Worth

DESCRIPTION	QTY	UNIT	UNIT COST	COST	USPWF	SPPWF	R	S	O&M	NPW
Mobilization	1	Each	$20,000	$20,000	26.97					$20,000
2" Force Main	22,535	LF	$18.00	$405,630	26.97	0.71		$162,252.00		$291,153
Grinders	198	Each	$5,000	$990,000	26.97	0.90	$1,089,000.00	$0.00	$10,021.97	$2,241,151
Lift Station	1	Each	$210,000	$210,000	26.97	0.87	$50,000.00	$105,000.00	$902.50	$186,507
6" Force Main	2,780	LF	$20.00	$55,600	26.97	0.71		$22,240.00		$39,909
Valve (FM)	4	Each	$1,800	$7,200	26.97	0.71		$2,880.00		$5,168
2" Isolation Valve	208	Each	$1,200	$249,600	26.97	0.71		$99,840.00		$179,158
Road Repair	2.10	Mile	$375,000	$787,500	26.97					$787,500
Land Acquisition	0.46	Acre	$180,000	$82,080	26.97	0.50		$57,456.00		$53,479
Septic Tank Abandonment	156	Each	$10,000	$1,560,000	26.97					$1,560,000
									Low Pressure Sewer Net Present Worth	**$5,364,024**

Vacuum Sewer Net Present Worth

DESCRIPTION	QTY	UNIT	UNIT COST	COST	USPWF	SPPWF	R	S	O&M	NPW
Mobilization	1	Each	$40,000	$40,000.00	26.97					$40,000
4" Vac Main	17,944	LF	$19.00	$340,936.00	26.97	0.71		$136,374.40		$244,717
6" Vac Main	3,606	LF	$27.00	$97,362.00	26.97	0.71		$68,153.40		$49,277
8" Vac Main	2,652	LF	$34.00	$90,168.00	26.97	0.71		$72,134.40		$39,274
10" Vac Main	82	LF	$42.00	$3,444.00	26.97	0.71		$1,377.60		$2,472
Vac Station	1	Each	$1,000,000	$1,000,000.00	26.97	0.87	$19,266.67	$500,000.00	$12,950.00	$931,188
Valve Pit	89	Each	$4,900	$437,080.00	26.97	0.90	$966.33	$0.00		$437,950
6" Force Main	2,780	LF	$20.00	$55,600.00	26.97	0.71		$77,840.00		$680
Valve (FM)	4.00	Each	$1,800	$7,200.00	26.97	0.71		$2,880.00		$5,168
Road Repair	4.27	Mile	$250,000	$1,067,500.00	26.97					$1,067,500
Land Acquisition	0.06	Acre	$180,000	$10,800.00	26.97	0.50		$7,560.00		$7,037
Septic Tank Abandonment	156	EA	$10,000	$1,560,000.00	26.97					$1,560,000
									Vacuum Sewer Net Present Worth	**$4,385,263**