Preliminary Evaluation of Cluster System Septic Tank Performance

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** Author's note: The data and results in report are very limited due to funding and time constraints. These data should not be used as design recommendations or to set policy. A longer-term study is needed to adequately answer the research questions.*

Background and Rationale

Onsite wastewater treatment systems are regulated under Minnesota Rule Chapter 7080 *Design and Operation Standards for Individual Sewage Treatment Systems* (Minnesota Pollution Control Agency, 2002). Chapter 7080 applies to wastewater treatment systems with design flows up to 10,000 gallons per day (or 30 homes) that discharge to a soil infiltration system. Treatment systems under 10,000 gpd are permitted at the county level. Onsite systems with design flows greater than 10,000 gpd (or serving more than 30 homes) are required to obtain a State Disposal Permit (SDS) through the Minnesota Pollution Control Agency (MPCA).

Over the last decade, the use of cluster systems has become increasingly popular in Minnesota. With cluster systems, sewage collection and treatment for a group of homes occurs at a single facility (i.e., community-level collection, treatment, and dispersal), as opposed to each dwelling (i.e., treatment and dispersal on each lot). Because Chapter 7080 was originally written for single-home treatment systems, issues such as groundwater mounding and nutrient impact to nearby waters are not clearly addressed in the rule, and the MPCA lacked technical guidance to evaluate larger wastewater systems (Wallace *et al*. 2005).

The MPCA has recognized the need for better guidance for cluster wastewater systems, and has responded accordingly. In 2004, they published a guidance document, *Design Guidance for Large Subsurface Wastewater Treatment Systems (LSTS)* (MPCA 2004), that identifies the standard process by which they will evaluate systems with design flows greater than 10,000 gpd or serving more than 30 homes. In addition, a new rule has been proposed (Chapter 7081) to establish guidance for systems that are larger than single-home but smaller than the 10,000 gpd NPDES threshold. The new categories are based on number of dwellings served and/or design flow, and are summarized in Table 1.

Table 1. Size categories for onsite sewage treatment systems in Minnesota.

Category	Number of Dwellings	Design Flow
Individual (ISTS)	5 or fewer	Less than 2,500 gpd
Mid-sized (MSTS)	6 – 30	2,500 – 10,000 gpd
Large (LSTS)	30 or more	Greater than 10,000 gpd

In the current version of 7080, the equation to size septic tanks on cluster systems is Tank Capacity = 1125 + 0.75Q, where Q is the maximum or peak system design flow in gallons per day (MPCA 2002). The LSTS Guidance Document and proposed Chapter 7081 require an increased septic tank capacity for new LSTS and Midsized Subsurface Wastewater Treatment Systems (MSTS) systems. The requirements for new LSTS and MSTS also take into account the type of collection system used. The septic tank capacity for a site that uses a gravity-flow collection system is determined by multiplying the average daily flow for the system by a factor of three. The septic tank capacity for a site that utilizes grinder pumps in the collection system is determined by multiplying the average daily flow for the system by a factor of four. This increase in required septic tank capacity is significant, and will likely have implications on the cost of cluster wastewater systems in the State of Minnesota.

The University of Minnesota Onsite Sewage Treatment Program performed a short-term investigation on the performance of septic tanks for MSTS and LSTS sites that were designed and installed before the release of the LSTS Guidance Document and Draft Chapter 7081. The required Chapter 7080 septic tank discharge criteria are 220 mg/L Biochemical Oxygen Demand (BOD) and 65 mg/L Total Suspended Solids (TSS) (MPCA, 2002). These criteria were set in the 1999 update of Chapter 7080 to assist designers in defining typical waste strength of domestic sewage prior to a soil treatment unit. If secondary treatment units are used prior to a soil treatment unit the values of BOD and TSS leaving the last septic tank may be higher then these criteria if the pretreatment unit can deal with a higher organic loading. The purpose of the study was to assess whether MSTS and LSTS tanks that were designed and installed before the increase in required capacity are capable of meeting the MPCA required discharge criteria for BOD and TSS.

Study Sites

Seventeen sites were included in this study, with design flows between 6,000 and 45,000 gpd. Six of the sites have gravity collection systems, six have grinder pump collection systems, one has a gravity collection system with a grinder pump lift station (and is classified as a grinder pump system), and four have Septic Tank Effluent Pumping (STEP) collection systems. Four sites were removed from the original list of 21 due to site inaccessibility or because they had STEP collection systems that fed into a recirculation tank where septic tank effluent was mixing with media filter effluent, as opposed to a single-purpose stilling tank. Site inaccessibility issues encountered included:

- Tank covers that were too heavy for person to lift or move (36” diameter, 4” thick concrete slabs without any sort of handle or crowbar notch);
- Tank covers that were not designed for operator access (plastic covers that were permanently fixed to the riser with long screws);
- Sites with bolted metal manhole covers that could not be unbolted;
- Access pathways without a gravel (or other well-drained) foundation.

Design engineers should be cognizant of site accessibility issues such as these when designing wastewater systems. The sites should have septic tank covers that facilitate operation and maintenance visits. Metal hatches (with a padlock), unbolted metal manhole covers, and bolted manhole covers (when regularly accessed) allow for reasonable tank accessibility. Sites should have an access path with a base of crushed gravel so maintenance can be performed year-round; access paths that do not have a well-drained, gravel foundation are hard to maneuver during wet (soggy) conditions.

Information on system design was obtained through contacting the design engineer or site operator, or through reviewing the MPCA or County permit. When available, the following information was documented: collection type, year of startup, design and average flow, number of homes, number of septic tanks, total tank capacity, presence of raw sewage manhole preceding septic tanks, presence of effluent filter/screen or filter/screen tanks, liquid depth of tanks, and date of last tank pumping. Some of the study sites had secondary treatment following the septic tanks; others discharged septic tank effluent directly into a soil treatment and dispersal system. All sites except one used soil infiltration for final treatment.

Design hydraulic retention time (HRT) was calculated when design flow and total tank capacity were both available. Actual flow data (based on average monthly flow) during the month(s) the system was sampled was used to calculate the HRT of the tanks during the study. When actual flow data was not available, estimates were made based on averages number of resident per home according to the 2000

US Census Bureau of 2.5 residents per dwelling and median residential usage of 60 gallons per day with a standard deviation of 40 gpd to equal 100 gpd (Mayer et al. 1999). Although this value may be slightly inflated, these systems also may have some I&I and exfiltration. Flows per home ranged from 14 gpd to 372 gpd. It should be noted that the HRT values reported are not accurate because they assume plug flow. To accurately estimate the HRT a flow dispersion test would be required which was not performed in this study. The actual HRT is quite likely to be very much shorter than the design HRT and certainly much less than the HRT computed based on flows and tank volumes because wide, rectangular tanks have a lot of 'dead' space such that calculated flow is far from true plug flow (R. Otis, personal communication, April 16, 2006).

Materials and Methods

Wastewater Quality

Wastewater from the septic tanks was tested for BOD and TSS. Three samples were taken during each site visit: one from the inlet of the first septic tank, one from the outlet of the first septic tank, and one from the outlet of the last septic tank. In general, sampling the wastewater entering the first septic tank is not useful because the values are often lower then the values leaving the first septic tank. This occurs because the wastewater entering the tank is a function of most recent domestic activity and large solids settle quickly. Influent wastewater characteristics may be helpful in identifying potential problems such as illegal discharges and system misuse.

Wastewater samples were pumped using a Cole Parmer peristaltic pump with silicon tubing. Samples were pumped, in order, from the influent of the first tank to the effluent of the last. To minimize cross-contamination, the pump tubing was purged before each sample was taken using wastewater from the tank being sampled. Samples were pumped from the wastewater surface inside the baffle of the tank, when there was one installed. During sampling, the end of the silicon tubing was placed as near to the wastewater surface in the tank as possible. The sides of the baffle were avoided so that the buildup on the baffle wall was not pumped into the sample. The samples were immediately placed on ice and sent to a Minnesota Department of Health certified laboratory for analysis. Because sludge/scum measurements often stir up solid material in the tank, samples for BOD and TSS were always taken prior to sludge/scum measurements in order to avoid contamination.

Due to equipment and budget constraints, it was not feasible to take composite samples at each site. To be consistent, all samples were taken using the method described above. This type of sampling (often referred to as "grab" sampling) is used by small-scale wastewater system operators in the state, and is generally an accepted method for sampling septic tanks. An adequate number of grab samples may be acceptable for effluent sampling, but they are less suitable for in and out comparisons. Sampling times should also be staggered to account for the residence times so the "same" wastewater is being sampled (R. Otis, personal communication, April 16, 2006).

During the study, one comparison was performed of 1-, 2-, and 4-hour composite samples at one site. Wastewater samples for the data in Table 2 were obtained using an ISCO Autosampler. Samples were collected once hourly for four hours. The two-hour composite sample comprised equal volumes from the first- and second-hour samples. Likewise, the four-hour sample comprised equal volumes from samples collected for hours 1, 2, 3, and 4. There was limited data collected so no statistically difference could be determined.

Table 2. Comparison of one-, two-, and four-hour composite septic tank samples.

	BOD		TSS	
	Effluent First Tank	Effluent Last Tank	Effluent First Tank	Effluent Last Tank
1-hour	195 mg/L	250 mg/L	56 mg/L	70 mg/L
2-hour composite	196 mg/L	250 mg/L	56 mg/L	56 mg/L
4-hour composite	200 mg/L	234 mg/L	48 mg/L	64 mg/L

The data in Table 2 demonstrate that, for the single system sampled, there was little variability between the one-, two-, and four-hour composites. However, the limitation of these data must be recognized. These data represent one sampling event, and the system from which the samples were taken was operating below design flow (Grinder Pump System #5). Replications of this exercise would be required before a conclusive statement could be made about the differences between grab and composite sampling.

Last date of Septic Tank Pumping

As part of the monitoring, the date of the last pumping was recorded. If sludge or scum layers get too thick, they can affect the performance of the septic tank.

Liquid Depth

Liquid depth in each tank was measured by visual inspection using a Sludge Judge II. Measurements were rounded to the nearest six inches and are reported in Appendix B.

Scum and Sludge Measurements

Scum thickness was estimated by visual inspection at the inlet of the first tank, outlet of the first tank, and outlet of the last septic tank of each system. If the scum layer covered the entire wastewater surface in the tank, a shovel was used to break through the layer in order to better assess the thickness. Estimations were rounded to the nearest inch and are reported in Appendix B.

Sludge depth was measured at the inlet of the first tank, outlet of the first tank, and outlet of the last septic tank of each system. All sludge measurements were performed using a Sludge Judge II (1¼″ outer diameter; manufactured by NASCO, Fort Atkinson, WI) and were rounded to the nearest inch (visual estimation). Sludge data for each system is reported in Appendix B.

Sludge Measuring Instruments

Sludge measurements varied significantly depending on the instrument used and the speed with which the instrument was lowered into the tank. Initially, a 1″ outer diameter Sludge Judge with a small check valve was used to measure the sludge. Then, the Sludge Judge II with a slightly larger diameter (1¼″ outer diameter) and a larger check valve was tested along with the Dipstick Pro (manufactured by Environmental Biotech Inc., Sarasota, FL). The Dipstick Pro has a ball valve and a larger diameter than either Sludge Judge instrument (1¼″ *inner* diameter). Figure 1 shows a close-up of the release valves on the three instruments.

Each of the three sludge measurement tools were compared side by side for systems with grinder pumps. The sludge produced from grinder pumps is typically very thick and difficult to measure as compared to the sludge in gravity systems.

Figure 1. Sludge Measuring Instruments.
(Left to right: Dipstick Pro, Sludge Judge II, Sludge Judge)

The 1″ Sludge Judge did not accept the entire wastewater/sludge profile when measuring thick, grinder-pump sludge. The evidence for this occurring was that the wastewater level measured by the instrument was 12 to 36 inches less than the actual wastewater level in the tank. When this happened, the 1″ Sludge Judge showed sludge measurements that were much lower than the other, larger-diameter instruments. Table 3 shows triplicate sludge measurements for each instrument (Sludge Judge, Sludge Judge II, and Dipstick Pro) from a site with thick sludge.

Table 3. Measurements in Thick (Grinder Pump) Sludge.

	Actual Measurement (triplicate, in inches)	Average Measurement (inches)
Sludge Judge (1″ OD)	8/10/10	9
Sludge Judge II (1¼″ OD)	14/24/24	20
Dipstick Pro (1¼″ ID)	22/27/30	26

The Sludge Judge (1″ OD) appears to underestimate the depth of the sludge. The Sludge Judge (1″ OD) appears to be more accurate when measuring the thin, well-degraded sludge that is normally found in the last tank of a series or gravity flow collection systems (Table 4).

Table 4. Measurements in Thin (Well-degraded) Sludge.

	Actual Measurement (triplicate, in inches)	Average Measurement (inches)
Sludge Judge (1″ OD)	6/8/8	7
Sludge Judge II (1¼″ OD)	8/3/10	7
Dipstick Pro (1¼″ ID)	8/10/12	10

Due to the thick-sludge/thin-sludge discrepancy with the Sludge Judge (1″ OD), the decision was made not to use it for the purposes of this study. The Sludge Judge II (1¼″ OD) was chosen instead of the Dipstick Pro because it was easier to use in the field. The Dipstick Pro was not as easy to use because two hands and a lot of pressure were needed to close the ball valve. On deeper tanks, this entails getting close to your work and occasionally employing an extra person with a hammer.

The most consistent sludge readings where achieved when the instrument was lowered into the tank slowly (at a rate of approximately one foot per second). Lowering any of the instruments into the tank faster than one foot per second resulted in sludge depths that were exaggerated by up to 18 inches. Despite the adoption of this "standardized" protocol, sludge measurements still varied significantly within a manhole; as a result, measurements were taken in triplicate at each location. In Appendix B, sludge triplicate measurements are reported, as opposed to averages, in order to convey this variability. Due to the variability in sludge measurements and the short duration of this study (3 months), it was not possible to determine sludge accumulation rates for the study sites.

Sludge characteristics (consistency, color, and shade) were recorded during sampling, using the descriptions listed in Table 5. It is worthwhile to note sludge color and consistency in septic tanks because it can be used as an indicator of the biological activity in the tank(s).

Table 5. Physical descriptors used to describe sludge.

	Descriptor	Description
Consistency (Thickness)	*Ch*	Chunky
	Thk	Thick
	Med	Medium
	Thn	Thin
Color	*Blk*	Black
	Brn	Brown
	Gr	Grey
Shade	*Dk*	Dark
	Lt	Light

Septic tanks that are achieving adequate anaerobic digestion typically have thin, black sludge in the last manhole (or inspection port) of the last tank in the series. If the sludge at this location is light in color and thick in consistency, anaerobic degradation is not occurring, and the system operator should take investigative action. This action would include sampling, taking measurements of pH and dissolved oxygen along with contacting homeowners regarding usage. Illegal discharge of chemicals, excessive use of caustic substances and/or excess sewage to septic tanks can upset the biological activity in a tank. Field data for each system is reported in Appendix B.

Flow Results and Discussion

The study sites are presented by type of collection system (gravity, grinder pump, or STEP). The median design flow for systems with gravity collection was 23,500 gpd, whereas the grinder pump systems were notably smaller, with a median design flow of 9,000 gpd. The median design flow for the four STEP systems was 8,750 gpd. Tables 6 and 7 summarize flow data and calculated HRTs for gravity and grinder pump systems, respectively.

Table 6. Flow and Hydraulic Retention Time (HRT) for Systems with Gravity Collection.

System	Design Flow (gpd)	Actual Flow[1] (gpd)	Tank Capacity (gallons)	Design HRT[2] (days)	Actual HRT[3] (days)
Gravity 1	10,000	8,437	20,000	2.0	2.4
Gravity 2	23,000	3,658	26,000	1.1	7.1
Gravity 3	24,000	15,508	30,000	1.3	1.9
Gravity 4	28,000	No flow device	45,000	1.6	--
Gravity 5	6,300	2,927	14,000	2.2	4.8
Gravity 6	44,875	21,227	40,000	0.9	1.9
Median	23,500	8,437	28,000	1.4	2.4

[1]Acutal flow based on average monthly flow(s) during the month(s) the systems were sampled for this study.
[2]Hydraulic Retention Time (HRT) was calculated using the following equation: HRT (days) = Tank Capacity (gallons)/ Flow (gpd)
[3]Actual HRT based on actual flow as identified in footnote 1.

Table 7. Flow and Hydraulic Retention Time (HRT) for Systems with Grinder Pumps.

System	Design Flow (gpd)	Actual Flow[1] (gpd)	Tank Capacity (gallons)	Design HRT[2] (days)	Actual HRT[3] (days)
Grinder 1	6,750	5,509	12,000	1.8	2.2
Grinder 2	43,000	8,726	70,000	1.6	8.0
Grinder 3	9,000	No flow device	10,000	1.1	--
Grinder 4	7,200	No flow device	7,000	1.0	--
Grinder 5	15,525	654	20,000	1.3	30.6
Grinder 6	8,625	3,610	20,000	2.3	5.5
Grinder 7	30,790	29,427	45,000	1.5	1.5
Median	9,000	5,509	20,000	1.5	5.5

[1]Acutal flow based on average monthly flow(s) during the month(s) the system was sampled for this study.
[2]Hydraulic Retention Time (HRT) was calculated using the following equation: HRT (days) = Tank Capacity (gallons)/ Flow (gpd)
[3]See Table 6.

The median design HRT was 1.4 days for gravity systems, and 1.5 days for grinder systems. There was one gravity system (Gravity 4) and two grinder pump systems (Grinder 3 and Grinder 4) that did not have a flow monitoring device installed, so it was not possible to calculate actual HRTs for these systems. Actual flow data were based on average monthly flow rates during the months that the system was sampled. For most systems, this included the months of September, October, and November, 2005. The median actual HRT was 2.4 days for gravity systems, and 5.5 days for grinder pump systems. Clearly, many of the systems included in this study were not running at or near design flow. This can be an issue with systems where the development is phased in (not all the homes are built at the start-up of the system), but may also be due to built-in safety factors in design flows.

Since actual flow and tank capacity data for the STEP systems were not available, the data presented in this study for STEP systems is very limited. The median design flow for STEP systems was 8,750 gpd. Remaining details for the STEP systems are located in Appendix B.

Figure 2 is a graphical presentation of the data in Table 6. The data is shown against the tank capacity equation from Chapter 7080 (Tank Capacity = 1125 + 0.75Q, where Q is the maximum system design flow, in gallons per day) (MPCA 2002). The proposed Chapter 7081 and LSTS Design Guidance document recommend a tank capacity three times the system average design flow for systems with gravity collection. This line is labeled "3Q". The smaller gravity systems in this study are generally designed with a higher tank volume-to-design flow ratio than the larger systems. The figure also shows that only one system (Gravity 1) is operating near design flow.

Figure 3 is a graphical presentation of the data in Table 7. The difference in Figure 3 versus Figure 2 is that the line labeled "4Q" denotes the proposed Chapter 7081 and LSTS Design Guidance document recommend a tank capacity equal to four times the average system design flow for systems with grinder pump (or pressurized) collection. Figure 3 shows that the distribution of grinder pump systems in this study is heavily weighted towards small systems. The figure also shows that only two systems (Grinder 1 and Grinder 7) are operating near design flow.

Figure 2. Tank Capacity versus Design Flow for Systems with Gravity Collection.

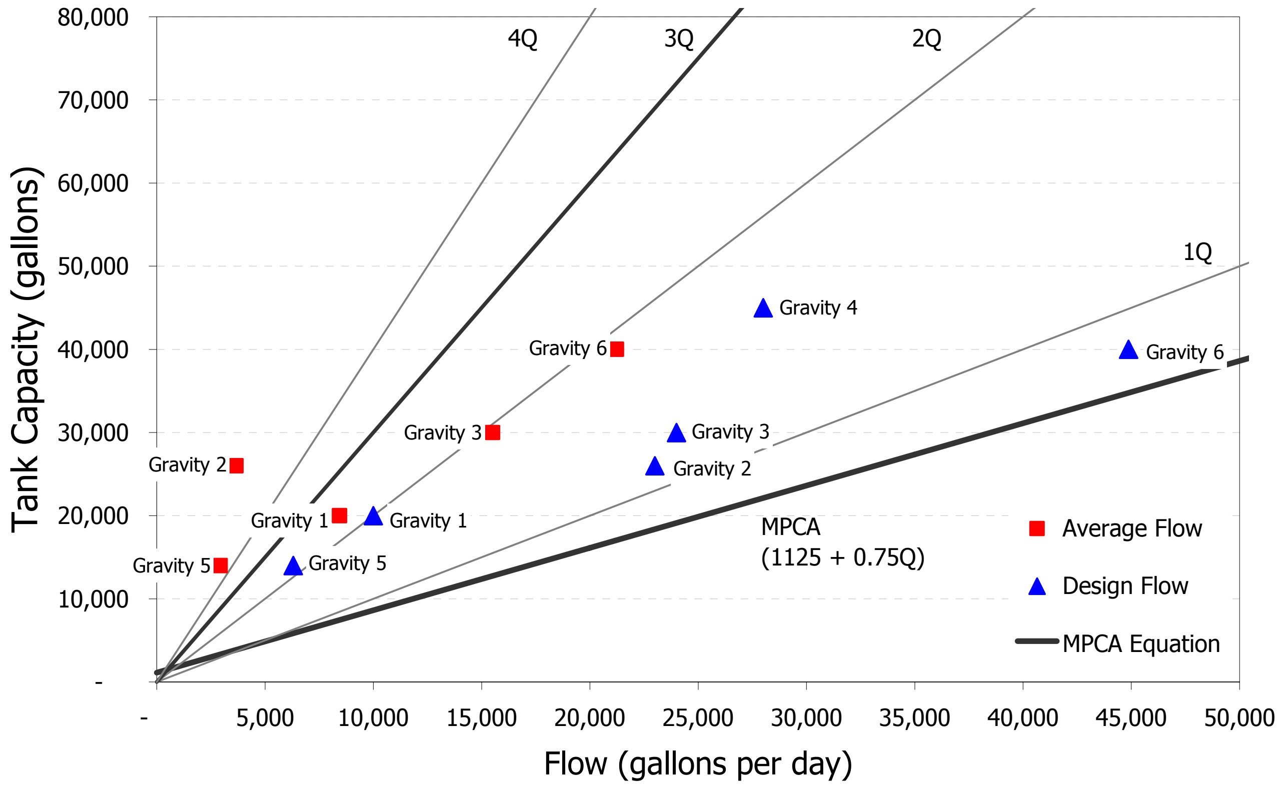
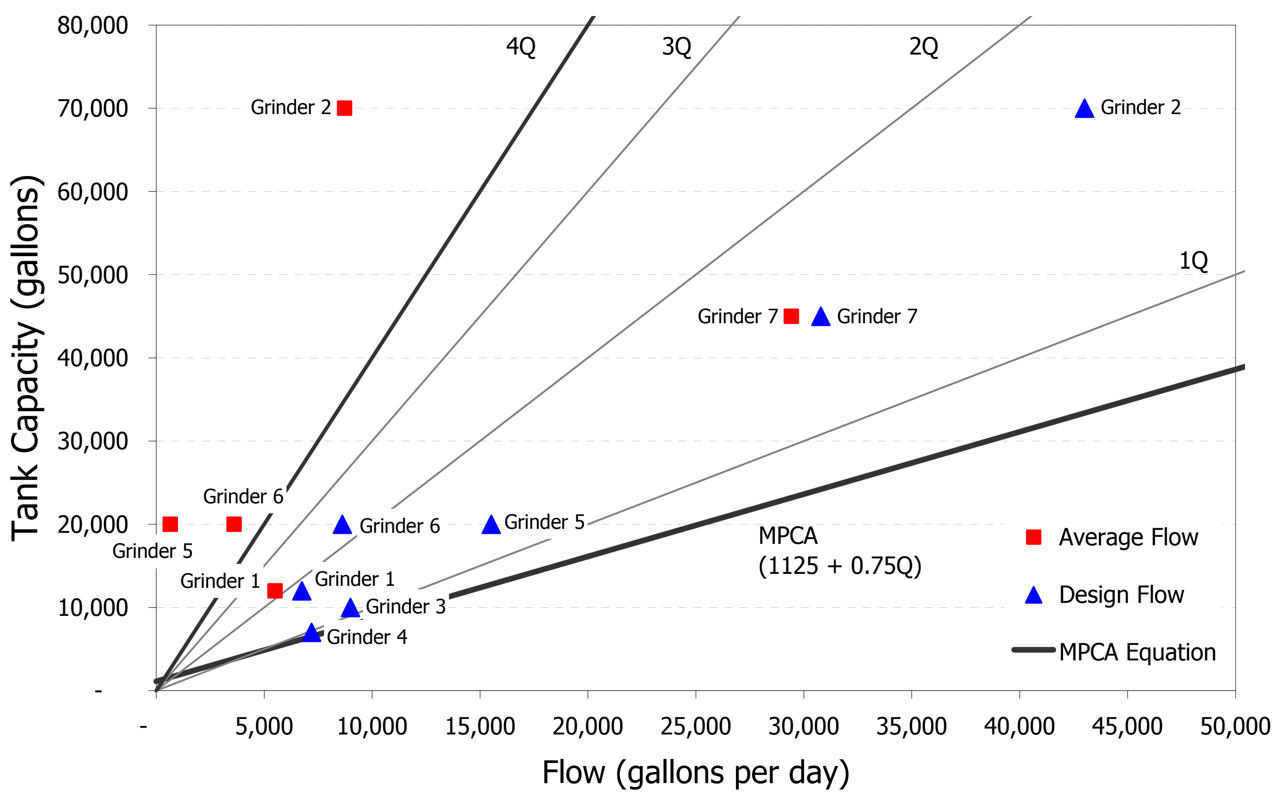


Figure 3. Tank Capacity versus Design Flow for Systems with Grinder Pumps.



Each system was sampled for BOD and TSS two or three times between September and December 2005. Table 8 presents the median effluent BOD and TSS data for gravity systems. The median BOD was 204 mg/L BOD (14 samples) and TSS was 58 mg/L TSS (13 samples). These data meet the MPCA recommended septic tank effluent concentrations of 220 mg/L BOD and 65 mg/L TSS. Data for systems where the effluent sample was drawn from a filter or filter tank were not included when calculating the median value because they could not be directly compared with the other (unfiltered) samples. A summary table of all BOD and TSS data for gravity systems is located in Appendix A, Table A1.

Table 8. Tank Performance for Systems with Gravity Collection.

	BOD Effluent Last Tank	**TSS** Effluent Last Tank
Median Value	204 mg/L	58 mg/L
Number of Samples	*14*	*13*

These results may have been easier to interpret if filtered and unfiltered BODs were to have been run. Septic tanks are designed to remove settleable solids. These solids accumulate in the sludge where the organics are broken down into soluble fatty acids, which enter the liquid phase and pass out of the tank. In effect, the tanks are producers of soluble BOD. This makes it hard to compare "in" and "out" data because the nature of the BOD can be quite different because of differences in the influent characteristics and the time since the last pumping (R. Otis, personal communication, April 16, 2006).

Table 9 presents the median effluent BOD and TSS data for grinder pump systems. The median effluent wastewater quality parameters for systems with grinder pumps were 268 mg/L BOD and 64 mg/L TSS (11 samples each). For the purposes of this report, the data meet the MPCA recommended septic tank discharge concentrations of 65 mg/L TSS, but are slightly higher than the recommended discharge concentration for BOD.

Table 9. Tank Performance for Systems with Grinder Pumps.

	BOD Effluent Last Tank	**TSS** Effluent Last Tank
Median Value	268 mg/L	64 mg/L
Number of Samples	*11*	*11*

A summary table of all BOD and TSS data for gravity systems is located in Appendix A, Table A2. Two of the grinder pump systems (Grinder 3 and Grinder 4) had effluent BOD values that were consistently above 220 mg/L. However, neither system had a flow monitoring device installed, so there is no way to know whether they were operating at or near design flow. The Grinder 3 and Grinder 4 sites also had shallow tanks (4' and 5' liquid depth), which may be impacting the tank performance for these systems. This is contrary to general understanding of septic tank performance. Settleable solids removal via sedimentation is enhanced by shallow tanks because the overflow rates are lower and the shallow tanks allow quicker capture of the solids by the sludge blanket. The advantage of shallow tanks would be lost if the sludge blanket were allowed to get too high, but the data do not suggest that (R. Otis, personal communication, April 16, 2006). This issue needs further evaluation.

Figure 4 presents the median BOD values graphically from both types of systems. This limited data set indicates that five systems with less then 3 days of hydraulic retention time are not meeting the state standard of 220 mg/l. Of these five systems, three are gravity systems and two are grinder systems. At first glance, the table suggests that there is no differenced between grinder pump and gravity collection systems. However, due to the limited data set, no conclusion can be drawn.

Figure 4. Hydraulic Retention Time versus Median BOD Values

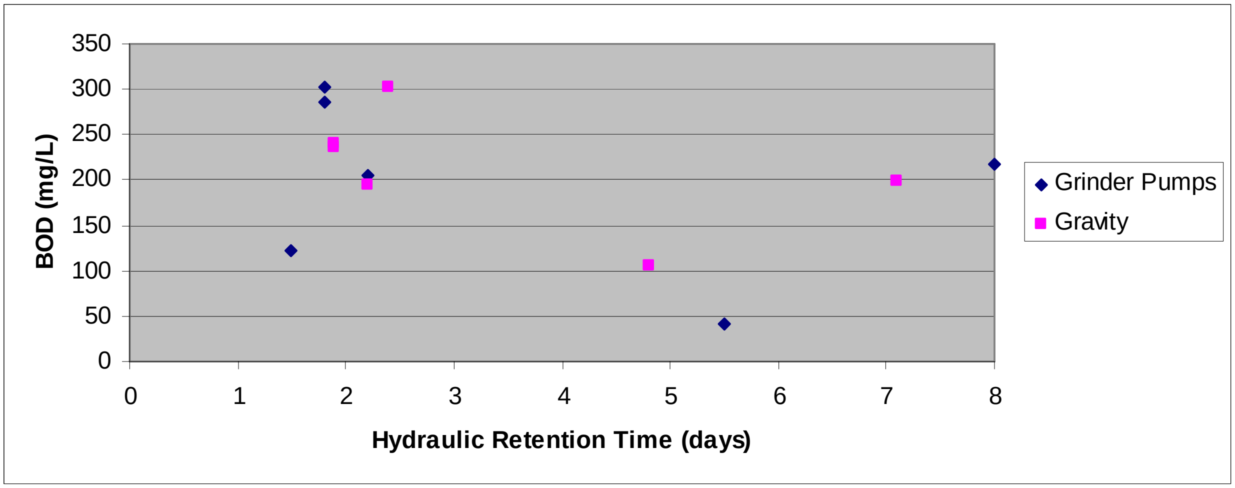


Table 10 presents the median effluent BOD and TSS data for the four STEP systems in this study. The usefulness of these data is limited, because the systems serve many seasonal homes that are not heavily occupied during autumn and winter. Thus, we suspect that the average flows for these systems during the time of this study were well below design flow, as evidenced by the very low BOD and TSS concentrations in the stilling tanks.

Table 10. Tank Performance for Systems with STEP Collection.

	BOD Stilling Tank	**TSS** Stilling Tank
Median Value	52 mg/L	32 mg/L
Number of Samples	*5*	*5*

Recommendations for Future Research

This report lends insight to the possible differences in septic tank performance for gravity and grinder pump systems that were designed and installed prior to the release of the LSTS Guidance Document and Draft Chapter 7081. Although the data are not conclusive, this study provides the groundwork for a reliable, more in-depth investigation of cluster system septic tank performance. Recommendations for future investigations include:

Identify whether there is a difference between grab and composite sampling.

Develop a standard instrument and protocol for measuring sludge. Currently, there is not a standard instrument or protocol for measuring sludge. The Sludge Judge (1″ OD) is too small for measuring thick sludge, and there were similar problems observed with the Sludge Judge II (1 ¼″ OD). There is another, larger, version of the Sludge Judge (1 ⅜″ OD; called the "Grease Trap Sampler"), which may be better suited for measuring sludge in large septic tanks.

It is also important for the sampling instrument to be affordable; the Dipstick Pro is roughly three times as costly as any of the Sludge Judge instruments. Once an instrument is identified, a protocol should be developed. In this study, we found sludge measurements to vary considerably within a sampling location and with the person sampling. As a result, we took measurements in triplicate. Practically speaking, it is important to develop a standard protocol for measuring sludge. Pumpers/maintainers and service providers need to be able to accurately assess the depth of sludge in a tank, since they are the ones who determine the frequency with which the tank needs to be pumped.

Be knowledgeable about site selection. Seven of the seventeen sites in this study did not have a flow measuring device installed even though it was required at the time of design/installation. Flow measurement and site accessibility needs to established during design and construction.

Perform a longer-term study. A longer-term study would provide a much more reliable BOD/TSS dataset, and possibly allow calculation of sludge/scum accumulation rates. The 3-month duration of this study was not long enough to calculate sludge/scum accumulation rates.

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References

Mayer, P.W., W.B. DeOreo, E.M. Opitz, J.C Kiefer, W.Y. Davis and B. Dziegielewski. 1999. *Residential End Uses of Water.* AWWA Research Foundation and the American Water Works Association. Denver, CO.

Minnesota Pollution Control Agency (2002) Minnesota Rules Chapter 7080.

Minnesota Pollution Control Agency (2005) Draft Revision of Minnesota Rules Chapter 7080 (version from 3/2/05).

Minnesota Pollution Control Agency (2004) *Design Guidelines for Large Subsurface Wastewater Treatment Systems (LSTS)*. http://www.pca.state.mn.us/water/wastewater-engineering.html.

Otis, Richard. April 16, 2006. Personnel Communication.

U.S. EPA (1991) *Design Manual*: *Alternative wastewater collection systems.* EPA/625/1-91/024, U.S. EPA Office of Research and Development: Washington D.C., United States.

Wallace S.D., Parkin G.F., Ballavance B., Brandt R.C. (2005) *Ecological Wastewater Management in Iowa.* Prepared for Iowa Policy Project, October 2005. Available online at www.iowapolicyproject.org.

U.S. Census Bureau: State and County QuickFacts. Data derived from Population Estimates, 2000 Census of Population and Housing. http://quickfacts.census.gov/qfd/states/27000.html

Appendix A:
Summary Tables

Table A1. Summary of Tank Attributes and Water Quality Data for Sites with Gravity Collection Systems

Site Code	Actual HRT (days)	Effluent Filter	Liquid Depth First Tank (ft)	Liquid Depth Last Tank (ft)	Sample Date	BOD (mg/L)			TSS (mg/L)		
						First Tank In	First Tank Out	Last Tank Out	First Tank In	First Tank Out	Last Tank Out
Gravity 1	2.4	No	6	6	9/13/05	n/s	274	303	n/s	55	70
					10/4/05	337	343	336	240	60	52
					11/8/05	194	192	210	58	52	40
Gravity 2	7.1	No	6	6	9/13/05	n/s	266	227	n/s	60	62
					10/11/05	162	190	198	68	78	64
					11/8/05	174	191	179	96	68	54
Gravity 3	1.9	No	6.5	6.5	9/13/05	n/s	288	305	n/s	137	110
					10/11/05	n/s	216	237	n/s	82	130
					11/8/05	n/s	229	184	n/s	66	66
Gravity 4		No	7	7	10/13/05	205	256	194	38	92	44
					11/10/05	189	233	237	60	92	58
					11/29/05	180	166	162	152	76	40
Gravity 5	4.8	No	7	4	10/20/05	110	98	81	n/s	n/s	n/s
					11/30/05	148	148	106	80	92	52
Gravity 6	1.9	Yes, in filter tank	7	6.5	10/20/05	198	240	10*	n/s	n/s	n/s
					11/30/05	261	291	12*	72	84	2*
					Average	*196*	*226*	*211*	*96*	*78*	*65*
					Median	***189***	***231***	***204***	***72***	***77***	***58***
					n	*11*	*16*	*14*	*9*	*14*	*13*

* Not included in average, median, or count (*n*) because samples were taken from filter or filter tank.

n/s = No Sample

Table A2. Summary of Tank Attributes and Water Quality Data for Sites with Grinder Pump Collection Systems

Site Code	Actual HRT (days)	Effluent Filter	Liquid Depth First Tank (ft)	Liquid Depth Last Tank (ft)	Sample Date	BOD (mg/L)			TSS (mg/L)		
						First Tank In	First Tank Out	Last Tank Out	First Tank In	First Tank Out	Last Tank Out
Grinder 1	2.2	No	6	6	9/13/05	n/s	278	n/s	n/s	86	45
					10/4/05	292	278	210	91	72	64
					11/8/05	314	246	205	132	64	58
Grinder 2	8	Yes, in filter tank	8	8	9/13/05	n/s	223	218	n/s	59	69
Grinder 3		No	5	5	9/13/05	n/s	299	268	n/s	104	62
					10/11/05	270	374	327	54	120	66
					11/8/05	225	230	286	136	66	50
Grinder 4		No	4	4	9/13/05	n/s	531	309	n/s	79	74
					10/11/05	447	354	303	74	90	72
					11/8/05	203	266	294	100	62	78
Grinder 5	30.6	Yes, in Tank 2	7	7	10/13/05	261	268	242*	52	144	76*
					11/10/05	195	n/s	250*	56	n/s	70*
					11/29/05	107	122	163*	108	108	76*
Grinder 6	5.5	Yes, in Tank 2	7	7	10/5/05	155	160	89*	68	72	64*
					11/21/05	192	248	16*	82	40	8*
					12/13/05	176	200	42*	26	32	10*
Grinder 7	1.5	Yes, in filter tank	6	7	10/20/05	164	154	88	n/s	n/s	n/s
					11/30/05	144	168	123	48	16	56
					Average	*225*	*259*	*239*	*79*	*76*	*63*
					Median	***199***	***248***	***268***	***74***	***72***	***64***
					n	*14*	*17*	*11*	*13*	*16*	*11*

* Not included in average, median, or count (*n*) because samples were taken from filter or filter tank.

n/s = No Sample

Appendix B:
Site Details and Field Data

System: Gravity #1

Collection Type	Gravity with lift station
Year of Startup	2000

Flow

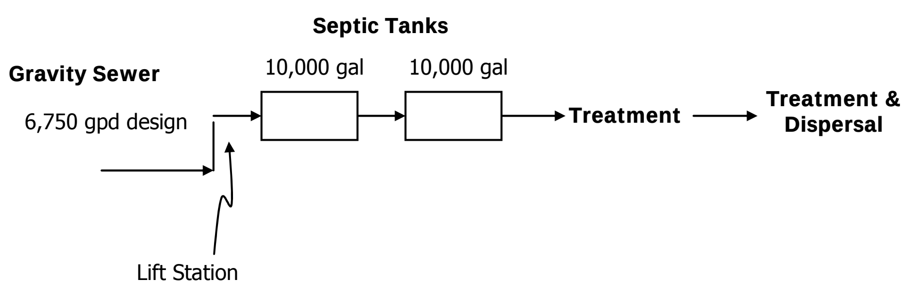
Design Flow	10,000 gpd
Average Flow	8,437 gpd (Aug – Nov 2005)
Number of Homes	39

Tanks

Number of Tanks	2
Total Tank Capacity	20,000 gallons

Other

Hydraulic Retention Time (Based on design flow)	2.0 days
Hydraulic Retention Time (Based on average flow)	2.4 days
Raw Sewage Manhole Prior to Tanks	No
Tanks last pumped	October 2004
Effluent Filter	No



BOD and TSS

	BOD			TSS		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
09/13/05	--[1]	274	303	--[1]	55	70
10/04/05	337	343	336	240	60	52
11/08/05	194	192	210	58	52	40

[1] not measured

Sludge and Scum

	Sludge (in inches)*			Scum (in inches)		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
10/04/05	6/6/4 brn, med thk	6/10/10 brn, med thk	6/6/4 blk, thn	0	0	0
11/08/05	12/14/12 lt brn, ch	12/12/10 lt brn, thinner	3/6/4 dk, thn	0.5	0	0

*triplicate measurements

Liquid Depth

Date	Tank 1	Tank 2
10/04/05	6′	6′
11/08/05	7′	6′

System: Gravity #2

Collection Type	Gravity with lift station
Year of Startup	1999

Flow

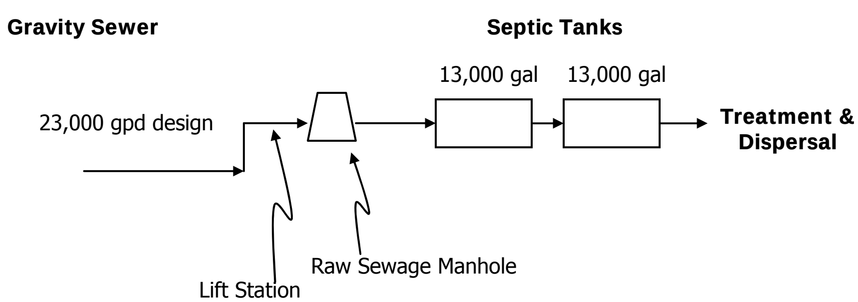
Design Flow	23,000 gpd
Average Flow	3,658 gpd (Aug – Nov 2005)
Number of Homes	40

Tanks

Number of Tanks	2
Total Tank Capacity	26,000

Other

Hydraulic Retention Time (Based on design flow)	1.1 days
Hydraulic Retention Time (Based on average flow)	7.1 days
Raw Sewage Manhole Prior to Tanks	Yes
Tanks last pumped	October 2004
Effluent Filter	No



BOD and TSS

	BOD			TSS		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
09/13/05	--[1]	266	227	--[1]	60	62
10/11/05	162	190	198	68	78	64
11/08/05	174	191	179	96	68	54

[1] not measured

Sludge and Scum

	Sludge (in inches)*			Scum (in inches)		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
10/11/05	10/15/12 brn, ch	18/24/18 brn, thk	4/6/3 blk, thn	0	0	0
11/08/05	12/18/14 brn, thk	8/6/10 lt brn, med thk	2/2/2 blk, thn	0	0	0

*triplicate measurements

Liquid Depth

Date	Tank 1	Tank 2
10/11/05	5.5′	5.5′
11/08/05	6′	6′

System: Gravity #3

Collection Type	Gravity with lift station
Year of Startup	2000

Flow

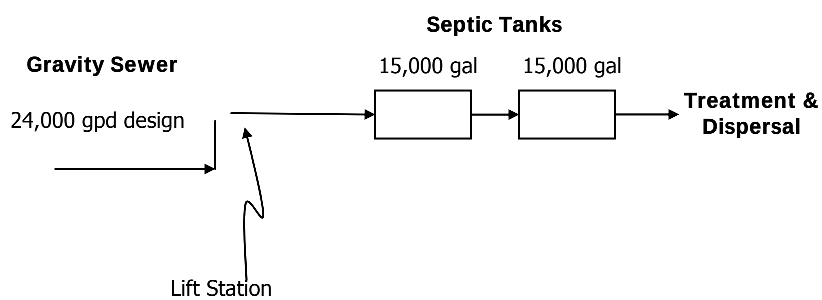
Design Flow	24,000 gpd
Average Flow	15,508 gpd (Aug – Nov 2005)
Number of Homes	62

Tanks

Number of Tanks	2
Total Tank Capacity	30,000

Other

Hydraulic Retention Time (Based on design flow)	1.3 days
Hydraulic Retention Time (Based on average flow)	1.9 days
Raw Sewage Manhole Prior to Tanks	No
Tanks last pumped	October 2004
Effluent Filter	No.



BOD and TSS

	BOD			TSS		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
09/13/05	--[1]	288	305	--[1]	137	110
10/11/05	--[1]	216	237	--[1]	82	130
11/08/05	--[1]	229	184	--[1]	66	66

[1] Could not open Tank 1 inlet manhole cover; could not collect data.

Sludge and Scum

	Sludge (in inches)*			Scum (in inches)		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
10/11/05	--[1]	12/18/12 brn, thk	4/12/8 lt brn, med thk	--[1]	3	0
11/08/05	--[1]	6/6/10 brn, thk	4/4/2 lt brn, med thk	--[1]	3	0

*triplicate measurements

[1] Could not open Tank 1 inlet manhole cover; could not collect data.

Liquid Depth

Date	Tank 1	Tank 2
10/11/05	6.5′	6.5′
11/08/05	6′	6′

System: Gravity #4

Collection Type	Gravity with lift station
Year of Startup	2004

Flow

Design Flow	28,000 gallons
2005 Average Flow	Not available
Number of Homes	82
Estimated Average Flow	20,500*

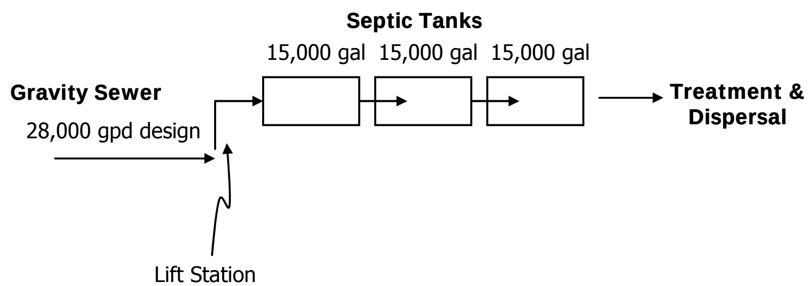
Tanks

Number of Tanks	3
Total Tank Capacity	45,000 gallons

Other

Hydraulic Retention Time (Based on design flow)	1.6 days
Hydraulic Retention Time (based on estimate)	2.2
Raw Sewage Manhole Prior to Tanks	No
Effluent Filter	No

* Estimate based on 2.5 people per home and 100 gpd/person.



BOD and TSS

	BOD			TSS		
Date	Tank 1 in	Tank 1 out	Tank 3 out	Tank 1 in	Tank 1 out	Tank 3 out
10/13/05	205	256	194	38	92	44
11/10/05	189	233	237	60	92	58
11/29/05	180	166	162	152	76	40

Sludge and Scum

	Sludge (in inches)*			Scum (in inches)		
Date	Tank 1 in	Tank 1 out	Tank 3 out	Tank 1 in	Tank 1 out	Tank 3 out
10/13/05	12/12/15 brn, ch	6/4/8 dk gr, thn	2/2/2 blk, thn	0	0	0
11/10/05	18/12/10 brn, thk	6/12/6 blk, thn	2/10/4 blk, thn	0	0	0
11/29/05	--[1]	--[1]	--[1]	--[1]	--[1]	--[1]

*triplicate measurements

[1]not measured

Liquid Depth

Date	Tank 1	Tank 3
10/13/05	7′	7′
11/29/05	6.5′	6.5′

System: Gravity #5

Collection Type	Gravity
Year of Startup	1999

Flow

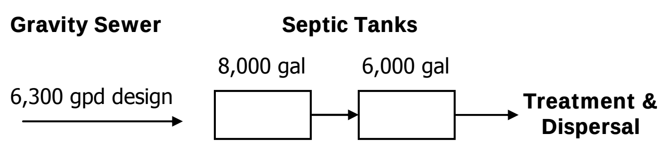
Design Flow	6,300 gpd
Average Flow	2,927 gpd (Oct – Nov 2005)
Number of Homes	25

Septic Tanks

Number of Septic Tanks	2
Total Tank Capacity	14,000 gallons

Other

Hydraulic Retention Time (Based on design flow)	2.2 days
Hydraulic Retention Time (Based on average flow)	4.8 days
Raw Sewage Manhole Prior to Tanks	No
Effluent Filter	No



BOD and TSS

	BOD			TSS		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank2 out
10/20/05	110	98	81	--[1]	--[1]	--[1]
11/30/05	148	148	106	80	92	52

[1] not measured

Sludge and Scum

	Sludge (in inches)*			Scum (in inches)		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
10/20/05	6/4/6 brn, med thk	10/8/10 brn, med thk	4/2/6 dk brn, thn	6	0	0
11/30/05	2/6/4 lt brn	10/10/6 lt brn, med thk	10/12/12 lt brn, thn	>12[1]	6	1

*triplicate measurements

[1]scum was too thick to shovel through

Liquid Depth

Date	Tank 1	Tank 2
10/20/05	7′	4′
11/30/05	6.5′	4.5′

System: Gravity #6

Collection Type	Gravity
Year of Startup	1999

Flow

Design Flow	44,875 gpd
Average Flow	21,227 gpd (Oct – Nov 2005)
Number of Homes	109 homes + 40,000 ft^2 commercial space

Septic Tanks

Number of Septic Tanks	4
Total Tank Capacity	40,000 gallons

Other

Hydraulic Retention Time (Based on design flow)	0.9 days
Hydraulic Retention Time (Based on average flow)	1.9 days
Raw Sewage Manhole Prior to Tanks	No
Effluent Filter	Yes

BOD and TSS

	BOD			TSS		
Date	Tank 1 in	Tank 1 out	Filter Tank	Tank 1 in	Tank 1 out	Filter Tank
10/20/05	198	240	12[2]	--[1]	--[1]	--[1,2]
11/30/05	261	291	10[2]	72	84	2[2]

[1] not measured

[2]sample taken from filter tank

Sludge and Scum

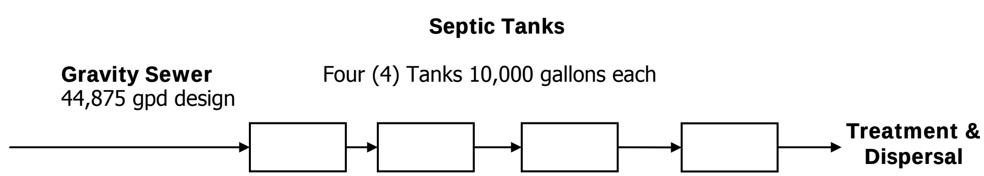
	Sludge (in inches)*			Scum (in inches)		
Date	Tank 1 in	Tank 1 out	Filter Tank	Tank 1 in	Tank 1 out	Filter Tank
10/20/05	--[1]	10/10/6 brn, med	6/4/4 dk brn	--[1]	1	0
11/30/05	--[1]	12/12/10	6/6/4	--[1]	1	2

*triplicate measurements

[1]scum was too thick to get reading

Liquid Depth

Date	Tank 1	Filter Tank
10/20/05	7′	6.5′
11/30/05	7′	6.5′



System: Grinder #1

Collection Type	Grinder pumps
Year of Startup	2002

Flow

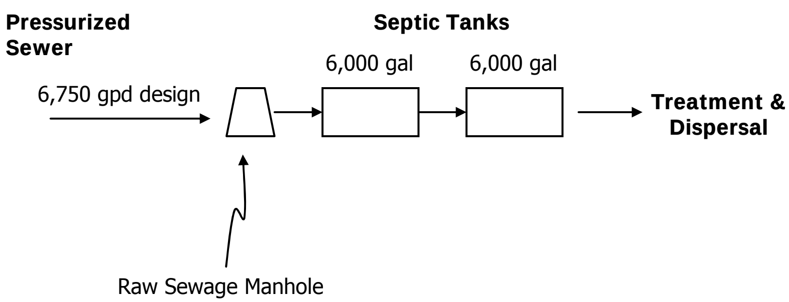
Design Flow	6,750 gpd
Average Flow	5,509 gpd (Aug – Nov 2005)
Number of Homes	20

Tanks

Number of Tanks	2
Total Tank Capacity	12,000 gallons

Other

Hydraulic Retention Time (Based on design flow)	1.8 days
Hydraulic Retention Time (Based on average flow)	2.2 days
Raw Sewage Manhole Prior to Tanks	Yes
Tanks last pumped	September 2004
Effluent Filter	Yes



BOD and TSS

	BOD			TSS		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
09/13/05	--[1]	278	--[1]	--[1]	86	45
10/04/05	292	278	210	91	72	64
11/08/05	314	346	205	132	64	58

[1] not measured

Sludge and Scum

	Sludge (in inches)*			Scum (in inches)		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
10/04/05	24/22/20 brn, thk	20/20/18 brn, thk	12/10/12 blk, thn	6	0	0
11/08/05	16/10/16 brn, thk ch	18/22/26 lt brn, thn	8/8/10 dk brn, thn	6	0	0

*triplicate measurements

Liquid Depth

Date	Tank 1	Tank 2
10/04/05	5.5′	5.5′
11/08/05	6′	6′

System: Grinder #2

Collection Type	Grinder pumps
Year of Startup	2003

Flow

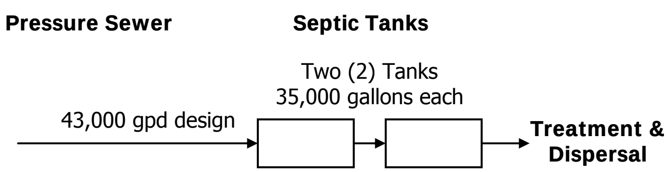
Design Flow	43,000 gpd
Average Flow	8,726 gpd (Aug - Sep 2005)
Number of Homes	113

Tanks

Number of Tanks	2
Total Tank Capacity	70,000

Other

Hydraulic Retention Time (Based on design flow)	1.6 days
Hydraulic Retention Time (Based on average flow)	8.0 days
Tanks last pumped	October 2004
Effluent Filter	Yes



BOD and TSS

	BOD			TSS		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
9/13/05	--[1]	223	218	--[1]	59	69

[1]not measured

Sludge and Scum: not measured

Liquid Depth

Date	Tank 1	Tank 2
9/13/05	7.5'	7.5'

System: Grinder #3

Collection Type	Grinder pumps
Year of Startup	2000

Flow

Design Flow	9,000
Average Flow	5,000 gpd*
Number of Homes	20

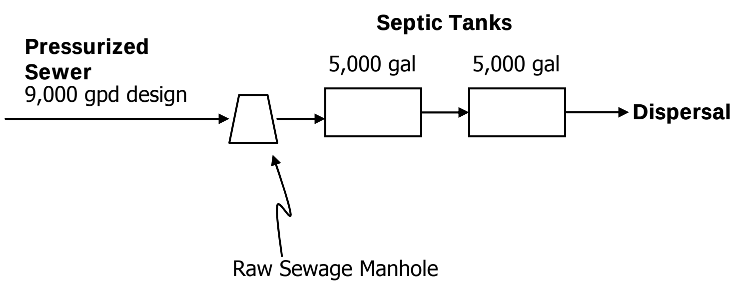
Tanks

Number of Tanks	2
Total Tank Capacity	10,000 gallons

Other

Hydraulic Retention Time (Based on design flow)	1.1 days
Hydraulic Retention Time (Based on estimated flow)	1.8 days
Raw Sewage Manhole Prior to Tanks	Yes
Tanks last pumped	Have not been pumped
Effluent Filter	No

* Estimate based on 2.5 people per home and 100 gpd/person.



BOD and TSS

	BOD			TSS		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
09/13/05	--[1]	299	268	--[1]	104	62
10/11/05	270	374	327	54	120	66
11/08/05	225	230	286	136	66	50

[1] not measured

Sludge and Scum

	Sludge (in inches)*			Scum (in inches)		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
10/11/05	21/24/21 brn, thk ch	10/6/8 brn, med thk	6/8/4 dk gr, thn	0	0	0
11/08/05	24/26/18 lt brn, thk	4/4/6 lt gr brn, thn	4/3/4 dk gr thn	0.5	0	0

*triplicate measurements

Liquid Depth

Date	Tank 1	Tank 2
10/11/05	5′	5′
11/08/05	5′	5′

System: Grinder #4

Collection Type	Grinder pumps
Year of Startup	2000

Flow

Design Flow	7,200 gpd
Average Flow	4,000 gpd*
Number of Homes	16

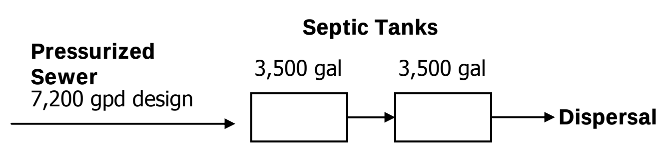
Tanks

Number of Tanks	2
Total Tank Capacity	7,000 gallons

Other

Hydraulic Retention Time (Based on design flow)	1.0 day
Hydraulic Retention Time (based on average flows)	1.8 days
Raw Sewage Manhole Prior to Tanks	No
Tanks last pumped	September 2004
Effluent Filter	No

* Estimate based on 2.5 people per home and 100 gpd/person.



BOD and TSS

	BOD			TSS		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
09/13/05	--[1]	531	309	--[1]	79	74
10/11/05	447	354	303	74	90	72
11/08/05	203	266	294	100	62	78

[1] not measured

Sludge and Scum

	Sludge (in inches)*			Scum (in inches)		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
10/11/05	18/14/18 brn, thk ch	14/14/14 brn, med thk	10/8/10 blk, thn	1	0.5	0.5
11/08/05	12/12/15 lt brn, ch	12/12/10 gr, med thn	6/6/6 blk, thn	0.5	0.5	0.5

*triplicate measurements

Liquid Depth

Date	Tank 1	Tank 2
10/11/05	3.5′	4′
11/08/05	4′	4′

System: Grinder #5

Collection Type	Grinder pumps
Year of Startup	2000

Flow

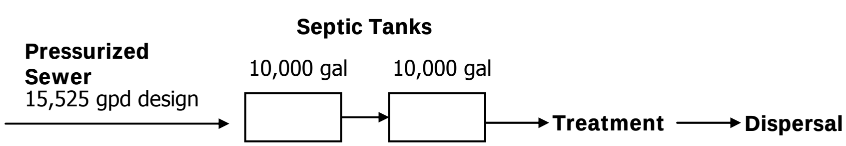
Design Flow	15,525 gpd
Average Flow	654 gpd (Oct – Nov 2005)
Number of Homes	46

Tanks

Number of Tanks	2
Total Tank Capacity	20,000 gal

Other

Hydraulic Retention Time (Based on design flow)	1.3 days
Hydraulic Retention Time (Based on average flow)	30.6 days
Raw Sewage Manhole Prior to Tanks	Yes
Effluent Filter	Yes



BOD and TSS

	BOD			TSS		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
10/13/05	261	268	242[2]	52	144	76[2]
11/10/05	195	--[1]	250[2]	56	--[1]	70[2]
11/29/05	107	122	163[2]	108	108	76[2]

[1] not measured

[2]sample taken from effluent filter

Sludge and Scum

	Sludge (in inches)*			Scum (in inches)		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
10/13/05	18/21/24 gr, ch	2/2/2 dk gr, thn	3/3/2 dk gr, thn	0	0	0
11/10/05	30/32/36 brn, med thk	--[1]	4/0/4 dk gr, thn	0	0	0
11/29/05	18/20/20 gr, thk	12/12/8 blk, thn	2/4/2 blk, thn	0	0	0

*triplicate measurements

[1] not measured

Liquid Depth

Date	Tank 1	Tank 2
10/13/05	6.5′	6.5′
11/10/05	7′	7′
11/29/05	7′	7′

System: Grinder #6

Collection Type	Grinder pumps
Year of Startup	2001

Flow

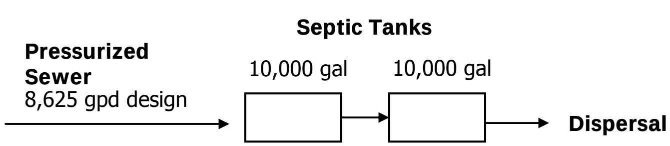
Design Flow	8,625 gpd
Average Flow	3,610 gpd (Oct – Dec 2005)
Number of Homes	23

Tanks

Number of Tanks	2
Total Tank Capacity	20,000 gallons

Other

Hydraulic Retention Time (Based on design flow)	2.3 days
Hydraulic Retention Time (Based on average flow)	5.5 days
Raw Sewage Manhole Prior to Tanks	No
Tanks last pumped	June 2004 (Tank 2) October 2005 (Tank 1)
Effluent Filter	Yes



BOD and TSS

	BOD			TSS		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
10/07/05	155	160	89[1]	68	72	64[1]
11/21/05	192	248	16[1]	82	40	8[1]
12/13/05	176	200	42[1]	26	32	10[1]

[1]sample taken from effluent filter

Sludge and Scum

	Sludge (in inches)*			Scum (in inches)		
Date	Tank 1 in	Tank 1 out	Tank 2 out	Tank 1 in	Tank 1 out	Tank 2 out
11/21/05	16/14/18 gr, ch	9/9/6	2/3/4 blk, thn	1	1	0
12/13/05	7/14/7 gr, ch	4/6/8	4/0/4 blk, thn	1	0.5	0.5

*triplicate measurements

Liquid Depth

Date	Tank 1	Tank 2
11/21/05	7′	7′
12/13/05	7′	7′

System: Grinder #7

Collection Type	Gravity sewer to grinder pump lift station
Year of Startup	2001

Flow

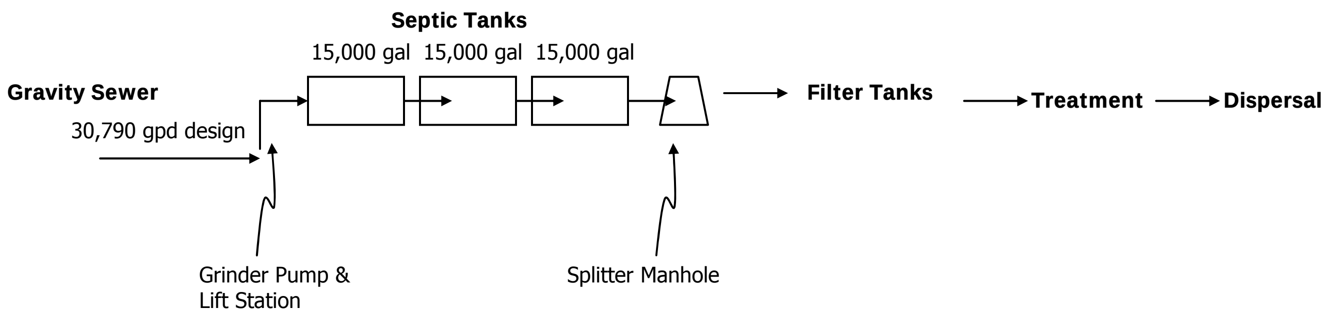
Design Flow	30,790 gpd
Average Flow	29,427 gpd (Oct – Nov 2005)
Number of Homes	74

Tanks

Number of Tanks	3
Total Tank Capacity	45,000 gallons

Other

Hydraulic Retention Time (Based on design flow)	1.5 days
Hydraulic Retention Time (Based on average flow)	1.5 days
Raw Sewage Manhole Prior to Tanks	No
Effluent Filter	Yes; in filter tanks



BOD and TSS

Date	BOD			TSS		
	Tank 1 in	Tank 1 out	Tank 3 out	Tank 1 in	Tank 1 out	Tank 3 out
10/20/05	164	154	88	--[1]	--[1]	--[1]
11/30/05	144	168	123	48	16	56

[1] not measured

Sludge and Scum

Date	Sludge (in inches)*			Scum (in inches)		
	Tank 1 in	Tank 1 out	Tank 3 out	Tank 1 in	Tank 1 out	Tank 3 out
10/20/05	--[1]	4/6/4 blk, thn	12/14/16 blk, thn	2	0	0.5
11/30/05	6/8/10 brn, thk	6/3/6 dk gr, med thk	12/10/12 blk, thn	2	0	0

[1]sludge consistency too thick to get an accurate reading

*triplicate measurements

Liquid Depth

Date	Tank 1	Tank 3
10/20/05	6′	7′
11/30/05	6′	7′

System: STEP #1

Collection Type	STEP
Year of Startup	1996

Flow

Design Flow	8,800
2005 Average Daily Flow	No flow device installed
Daily Flow Estimate	6,500*
Number of Homes	26, 30% seasonal use

Tanks

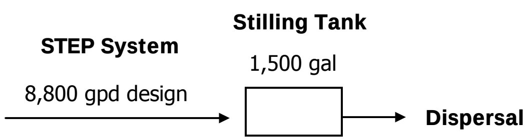
Number of Tanks	1 per home
Septic Tank Capacity at home	1000/500 gallon septic tank /pump tank
Total Septic Tank Capacity	26,000 gpd
Hydraulic Retention Time (based on flow estimates)	4.0 days**

Other

Raw Sewage Manhole Prior to Tanks	No
Effluent Filter	No

* Estimate based on 2.5 people per home and 100 gpd/person.

**Likely greater then value due to seasonal usage



BOD and TSS

	BOD	TSS
Date	Tank 1	Tank 1
11/15/05	58	28

Sludge and Scum

	Sludge (in inches)	Scum (in inches)
Date	Tank 1	Tank 1
11/15/05	10 blk, thn	0

Liquid Depth

Date	Tank 1
11/15/05	3'

System: STEP #2

Collection Type	STEP
Year of Startup	1998

Flow

Design Flow	8,100
2005 Average Daily Flow	No flow device installed
Daily Flow Estimate	8,250*
Number of Homes	33 homes, 60% seasonal

Tanks

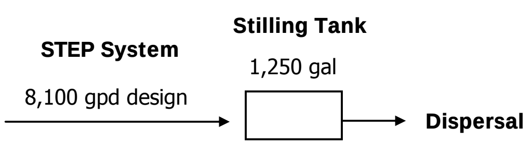
Number of Tanks	1 per home
Septic Tank Capacity at home	1000/500 gallon septic tank /pump tank
Total Septic Tank Capacity	33,000 gallons
Hydraulic Retention Time (based on flow estimates)	4.0 days**

Other

Raw Sewage Manhole Prior to Tanks	No
Effluent Filter	No

* Estimate based on 2.5 people per home and 100 gpd/person.

**Likely greater then value due to seasonal usage



BOD and TSS

	BOD	TSS
Date	Tank 1	Tank 1
11/15/05	52	22

Sludge and Scum

	Sludge (in inches)	Scum (in inches)
Date	Tank 1	Tank 1
11/15/05	10 blk, thn	0

Liquid Depth

Date	Tank 1
11/15/05	3'

System: STEP #3

Collection Type	STEP
Year of Startup	1995

Flow

Design Flow	8,700
2005 Average Daily Flow	No flow device installed
Daily Flow Estimate	6,750*
Number of Homes	27 homes, 40% seasonal

Tanks

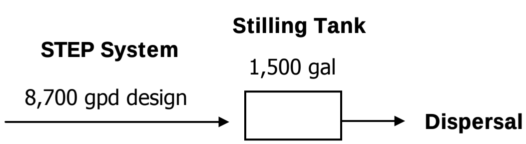
Number of Tanks	1
Septic Tank Capacity at home	1000/500 gallon septic tank /pump tank
Total Septic Tank Capacity	27,000 gallons
Hydraulic Retention Time (based on flow estimates)	4.0 days**

Other

Raw Sewage Manhole Prior to Tanks	No
Effluent Filter	No

* Estimate based on 2.6 people per home and 100 gpd/person.

**Likely greater then value due to seasonal usage



BOD and TSS

	BOD	TSS
Date	Tank 1	Tank 1
11/15/05	49	32
12/7/05	45	36

Sludge and Scum

	Sludge (in inches)	Scum (in inches)
Date	Tank 1	Tank 1
11/15/05	6 blk, thn	0

Liquid Depth

Date	Tank 1
11/15/05	3’

System: STEP #4

Collection Type	STEP
Year of Startup	1997

Flow

Design Flow	9,000
2005 Average Daily Flow	No flow device installed
Daily Flow Estimate	6,000
Number of Homes	24 homes, 30% seasonal

Tanks

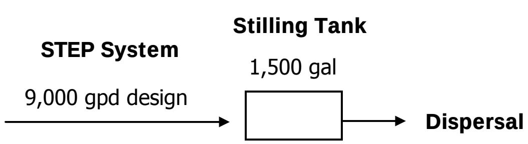
Number of Tanks	1
Septic Tank Capacity at home	1000/500 gallon septic tank /pump tank
Total Septic Tank Capacity	24,000 gallons
Hydraulic Retention Time (based on flow estimates)	4.0 days**

Other

Raw Sewage Manhole Prior to Tanks	No
Effluent Filter	No

* Estimate based on 2.5 people per home and 100 gpd/person.

**Likely greater then value due to seasonal usage



BOD and TSS

	BOD	TSS
Date	Tank 1	Tank 1
11/15/05	102	32

Sludge and Scum

	Sludge (in inches)	Scum (in inches)
Date	Tank 1	Tank 1
11/15/05	6 blk, thn	0

Liquid Depth

Date	Tank 1
11/15/05	3′