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Municipal Sewer Systems: *Case Studies*

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Introduction

There are two kinds of municipal sewer systems: sanitary sewer systems and storm sewer systems. Sometimes the two systems are combined. This course will deal with both systems and then present two small town case studies: one involving sanitary sewer systems and the other involving storm sewer systems.

Sewer Systems

The Industrial Revolution took place from the late 1700s to the early 1800s. It involved the transition from using hand tools to the deployment and use of machine tools. Machine tools led to improvements in manufacturing and raising the standard of living first starting in England and eventually spreading to the United States.

In the 1800s, the rise in the standard of living led to the growth of cities which brought about crowded living conditions and concerns over public health. In the late 1800s and early 1900s, cities constructed extensive networks of sanitary sewer systems to help control the outbreak of diseases such as typhoid and cholera. Initially the pipelines discharged human waste to rivers and streams without treatment. As these bodies of water became polluted, treatment plants were added leading to the development of the sewerage treatment systems as we know them today.

The purpose of the sanitary sewer plant is to treat raw sewerage and release an effluent (discharge fluid) that does not pollute or cause harm to the surrounding environment.

The sanitary sewer systems of today are a network of underground pipes running from buildings to larger underground lines to convey human waste and water mixture (wastewater) to treatment plants. Pipes running from buildings to the street are called “laterals”. Laterals run underground to the street where they connect to the larger “mains”. The mains of a group of streets run to the still larger “trunk” lines which deliver the wastewater to the sewerage treatment plants. In some systems, a “pumping station” is located in a pipe line to lift or assist the flow of sewerage to the treatment plant.

Wastewater usually contains a small per cent of solid matter. It may come from sinks, garbage disposals, toilets, and industrial sites. The mixture is then piped to the wastewater treatment plant where it is treated (purified) and the resulting liquid (effluent) recycled back to the sea. Untreated sewerage has an odor and can kill fish and other aquatic life and plants and be dangerous to human health.

The Clean Water Act of 1972 provided federal money and set new minimum levels of treatment. It mandated that all sewerage plants provide at least a secondary level of treatment.

Waste water treatment plants employ up to three degrees of purification: primary, secondary, and tertiary (advanced). Sometimes there is a preliminary step and the primary and secondary degrees of purification are combined.

- **Primary:** The first stage in waste water treatment involves screening out most of the solids and removing them or simply grinding them in place and leaving the residual matter dispersed in the influent to be removed in a settling tank. Wastewater will still contain small suspended solids and dissolved organic (from living) matter. The suspended solids consist of minute particles of matter which are removed by skimming, gravity settling, filtration, or chemical coagulation. If these particles are not all removed, they can cause wear to pumps and other mechanical equipment further down the stream in the treatment system.
- **Secondary:** After primary treatment, the wastewater enters into the secondary phase of treatment. The secondary phase removes about 90 percent of the organic matter using biological (living organism) treatment methods. Air and useful bacteria (single-celled organisms) are circulated throughout the wastewater converting organic matter into larger masses of material which are removed in a settling tank. The settling or sludge from the tanks is treated with bacteria which produces a material that can be used as a fertilizer or as a fuel and the useful gas methane.
- **Tertiary (Advanced):** Sometimes in pristine or other controlled environments, sewerage treatment plants effluent must be purer than what is produced by secondary treatment. Examples are when treatment plant effluent is discharged in close proximity to domestic water intakes, bathing beaches, fishing grounds, or aquatic plant areas.

- Ammonia, present in secondary treatment plant effluent removes oxygen which is required by fish and aquatic life in lakes, streams, and rivers. Using a process called nitrification, ammonia can be removed; however, excess nitrates can also contribute to the growth of algae. Denitrification is then used to convert nitrates to nitrogen which is released as a harmless gas (nitrogen gas comprises 80 percent of the earth's atmosphere).
- Phosphorus, present in secondary treatment plant effluent, can also stimulate the growth of algae. A process called coagulation-sedimentation is used to remove phosphorus.
- Alum, lime, or iron salts are added to secondary treatment waste water coagulating smaller particles into larger masses which settle to the bottom enabling removal by sedimentation.
- Carbon Adsorption can remove trace organic matter from secondary treatment effluent that resisted removal by biological methods. This matter can cause taste and odor problems in water and kill fish. The effluent is passed through a bed of activated carbon which removes 98 percent of all trace organic substances.
- The use or disposal of wastewater residual material is closely controlled by federal law. Federal law requires environmentally sound residual management techniques and to beneficially use bio solid waste material whenever possible. More than half of this waste material is used as fertilizer or as a soil conditioner. The remaining solids are incinerated or deposited in landfills. Ocean dumping of these solids is prohibited.

Figure 1 has a fluid flow schematic for a state-of-the-art small town sewerage treatment plant designed to treat 2.0 million gallons of influent per day:

- Wastewater is delivered to the plant through a 16 inch diameter pipe to a receiving tank shown on the upper left of the sketch. Notice there is an optional storage tank connected to the receiving tank to assist the

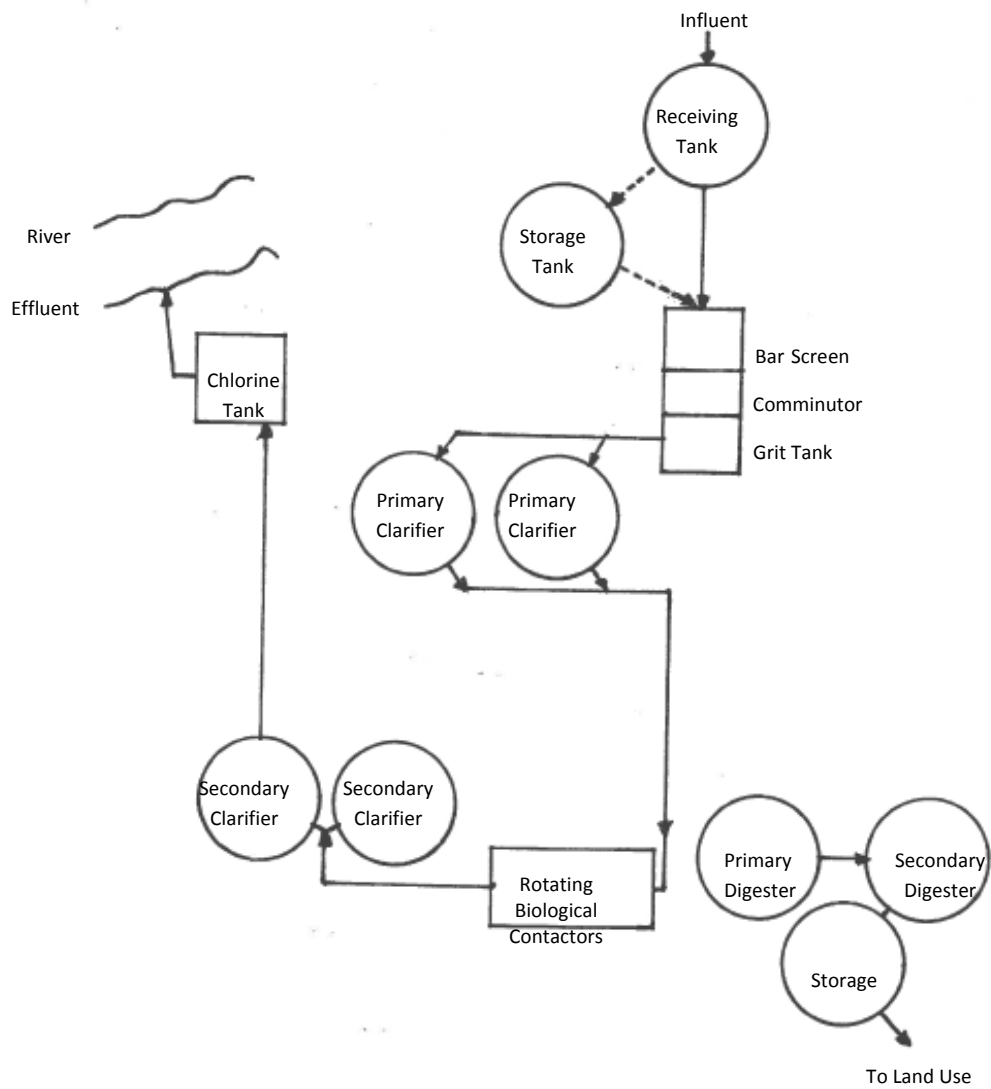
receiving tank in containing inflow during plant maintenance and/or heavy rains. Optional storage tanks prevent the plant from being overfilled and having to dump raw sewerage into the environment.

- The incoming wastewater is passed through a manually cleaned bar screen. This screen has 2½ feet wide parallel bars that remove large objects from the incoming sewerage.
- The wastewater then flows through a comminutor. The comminutor catches and shreds solid matter which is discharged into a grit tank.
- The aerated grit tank permits the settling of coarse heavy inorganic solids such as sand, while allowing the lighter organic solids to pass through.
- Grit-free wastewater from the grit tank then flows to two primary clarifier sedimentation tanks through a 24 inch pipe.
- The two primary clarifier sedimentation tanks remove a major part of the influent suspended solids and a smaller fraction of the biochemical energy demand from the waste water. Many pollutants place a demand on the natural supply of dissolved oxygen in waste water. Dissolved oxygen is needed in water to support fish and aquatic plant life. (Biochemical oxygen demand or BOD is used to determine how efficiently a sewerage treatment plant is operating.) The solids separated in these tanks are collected as sludge and skimming material. The primary sludge is pumped to the primary digester. The settling tank overflow (primary effluent) is discharged to ten rotating biological contactors.
- Rotating Biological Contactors use large closely-spaced plastic discs that rotate around a horizontal shaft. The discs move alternately through the wastewater and out developing a biological growth on their surfaces that removes oxygen-demanding materials in the wastewater as food and take on oxygen from the air for respiration. As the process

continues, some oxygen-bearing bacteria dislodge from the contactors into the purified wastewater.

- This mixture of bacterial solids and wastewater flows from the biological contactors through 24 inch diameter pipes to two secondary clarifiers where solids are separated and accumulate as sludge at the bottom of the tanks.
- This secondary sludge is then pumped, along with the primary sludge, to the primary digester. The sludge is processed in the primary and secondary anaerobic (without air) digesters where it is stabilized and reduced in volume. Stabilized sludge from the digesters is disposed by land application (fertilizer or soil conditioning).
- Treated effluent from the secondary clarifier tanks is delivered to the chlorine contact tank where it is diffused with chlorine solution and detained for an adequate disinfection period before discharge to the environment. Excess chlorine is removed by adding sodium bisulfite. The plant also has provisions for introducing alum and polymer to the wastewater in both the primary or secondary sedimentation tanks for phosphorus removal and improved clarification.

Figure 1
Treatment Plant Flow
(Schematic)



Case Study I: A Small Town Sanitary Sewer Court Case

A sanitary sewer system, as mentioned above, is a network of pipelines that conveys human and industrial waste to a treatment plant. The treatment plant then separates the waste material and discharges the remaining fluid to a stream or river for dispersal to a nearby larger body of water.

Initially, sanitary sewer piping systems were combined with storm sewer systems. Storm sewer systems are similar to sanitary sewer systems except that they collect and convey rain water to a stream or larger body of water for disposal without having to treat it.

The advantage of a combined sanitary sewer system and storm sewer system is that rain water helps dilute and pass raw sewerage through pipelines more easily. It also helps purify wastewater and aides in preventing sewer line plugging. The disadvantage of a combined sanitary and storm sewer system is that during a heavy rain downpour treatment plants sometimes become filled to overcapacity resulting in having to pump raw sewerage into open waterways. This presents a health hazard, not only to human beings, but to aquatic life as well. Separation of the two systems has thus become common.

The court case involves a city that lies in a northern state of the U.S. on the shores of one of the Great Lakes. It is a small community with a population just under 10,000. The town is experiencing slow but steady growth because of its school system, beautiful beaches, and Midwestern values. Some call it a “bedroom community”.

A river flows through the city and empties into one of the Great Lakes. A new, ultra-modern, wastewater treatment plant was built on the river mandated by the government.

As mentioned above, there are three levels of waste water treatment; primary, secondary, and tertiary (advanced). Primary treatment separates the solid material from the liquid using fine screens or other separating devices. Secondary treatment breaks down organic material by using biological treatment. Advanced treatment involves a variety of methods to further purify the treatment plant

effluent. Federal law requires that treatment plants process sewerage through at least the secondary cleanliness level.

The plant that was built in this town was a secondary level plant with some advanced treatment features. One such advanced treatment is having secondary sewerage effluent chlorinated before being discharged. This was done as a safety precaution as the treatment plant output is in the same general vicinity as the city drinking water intake and popular bathing beaches and fishing grounds. The plant also has facilities for introducing alum and polymers for further purification of the discharge.

The government also required that the plant be constructed with enough capacity to adequately serve the entire river basin. The main branch of the river runs about 30 miles as the crow flies and drains an area of 416 square miles including large portions of two counties and small portions of three other counties along its route. Therefore, it can easily be seen that the plant mandated would be much larger than what would otherwise be required for such a small town.

There are several small towns on the river that have their own wastewater treatment plants. This raises the question of why the mandate called for the treatment plant in question to be of sufficient capacity to serve the entire river basin, especially since, over the years, there has been very little settlement in this area; a region which is comprised chiefly of farm land.

Because of the high cost of building such an ultra-modern, high capacity wastewater treatment plant sufficient enough to serve such a large area, the project was turned over by the city to the county. The county provided the funds, constructed the plant, and now maintains full control of the plant. The county also took responsibility for operation and maintenance of the sanitary sewer lines in the surrounding local community.

It has been reported that, after a short period of time, the county began to use some of the excess capacity of the plant to serve part of the needs of a much larger city nearby; a city that happens to be the county seat and, furthermore, falls outside the river basin in question. One might question the legality of such a

move or at least whether or not good judgment was used in making the decision to treat raw sewerage that is pumped over ten miles from a much larger and presumably more prosperous city to a much smaller community of considerably less means.

One area along the lake of this small community has been experiencing a housing boom. To keep pace with this demand, the existing wastewater pumping station, which is located approximately midway between the new developments and the new treatment plant, was updated to provide increase system flow. This newly upgraded pumping station was an immediate success in relieving sewerage backup problems that were occurring in some of the adjacent neighborhoods, both upstream and downstream of the station; however, in one of the new outlying upstream developments, the main line has malfunctioned three times in the last few years resulting in raw sewerage flowing into residents' basements. In the first two of the three incidents, the main line overflowed because of heavy rain downpours. The third incident occurred when there was no rainfall.

The sanitary and storm systems in this small town are supposed to be independent and not interconnected. Prior to this time, when the city owned and operated the sanitary sewer system, excessive rain water did occasionally enter the sanitary sewer system during very heavy rain storms. In order to detect the entry point of rainwater entering the sanitary sewer system, smoke bombs were set off inside sanitary sewer lines to determine where rain water was entering the system leading to the problems being fixed.

During this third occurrence of raw sewerage entering basements, one of the residents affected decided to take action. The local sanitation company was called and determined that the line from his house to the main line along the street was not plugged. The sanitation company workers then opened up a manhole cover near the home and saw that the fluid level in the manhole serving the main county line had risen above normal levels indicating a blockage somewhere in the system causing the problem. The county was called and immediately went to work in discovering that the main line had plugged on the first street downstream

from the one in question causing upstream backup and raw sewerage to flow into this elderly resident's basement.

It took three days for a restoration company to clean, disinfect and ventilate this basement at a cost of over two thousand dollars, not including the pain and suffering incurred by this elderly resident as a result of the incident.

The resident, without counsel, filed suit in the local community small claims court for costs incurred including a small amount for pain and suffering. At the trial, the county, evidently trying to avoid an uprising by its constituents, sent two high level employees: the Department of Human Services Engineer and a Prosecutor's Office Attorney.

The Plaintiff argued that he was of modest means and through no fault of his own, and because of the failure of the county sanitary sewer system, great harm was done to his home and to himself. Also, the county, because of some questionable decisions in some prior non-sewer ventures, had found itself deeply in debt and had failed to maintain the sanitary sewer system in a manner consistent with practices necessary to provide satisfactory services to all its customers.

It was also pointed out that, because the problem was a recurring one, a simple device such as a fluid level gage or a small camera could have been installed with remote readouts in a county monitoring station giving sufficient warning of impending danger within the system. (The County Engineer, who was present at the hearing, commented that it was something he would investigate.) If that was not feasible, it was argued, employees, taking only seconds of time at each manhole, could monitor the fluid level of the entire system on a daily basis at a minimum cost.

The judge, evidently having a problem with how to decide the case, took over a month to render a decision. The decision came in the form of a lengthy letter with the following excerpts:

- The County testified that the location of the blockage was in an area where the sewer line was repaired in the last few years with a new liner fitted inside the existing pipe.
- The County also testified that blockages occur as a result of a buildup of grease, roots and other objects residents allow passing through their pipes. (The Plaintiff countered with the explanation that anything that passes through a small residential sewer pipeline should easily pass through a much larger county main pipeline.)
- The County explained that, before the incident, the plaintiff was advised to have a backflow inhibitor installed while the elderly plaintiff countered that such a device costs many thousands of dollars and was beyond his financial means.
- The County explained that the liquid level monitoring system proposed by the plaintiff warns of a backup in the system but does not prevent one (an obvious observation but one that does not completely negate the usefulness of such a system).
- The judge explained that the County was not without liability based on the results of previous litigation occurring in the state, but that negligence against the County would have to be proven.
- The Judge ruled that there was no evidence presented that that the County was negligent in this case.
- The judge ruled in favor of the Defendant but warned the County that, if the blockage had occurred in an area of the pipeline that was not updated with a new liner, the ruling would have gone in favor of the Plaintiff.

The resident is considering appealing to a higher court because he believes the judge, in this case, based his decision on faulty reasoning. The Plaintiff believes, the fact that the blockage occurred in an area of the pipeline that was relined, indicates that the County, heavily in debt, is not maintaining the system as it should be. It has been noticed that, since the County assumed responsibility for

the system, cleaning of the main lines has seldom been undertaken, nor has smoke bomb testing been attempted. Ironically, after the case was settled, County personnel and equipment have been seen busily cleaning the main lines in a nearby neighborhood.

Case Study II: The People vs. City Hall Storm Sewer Case

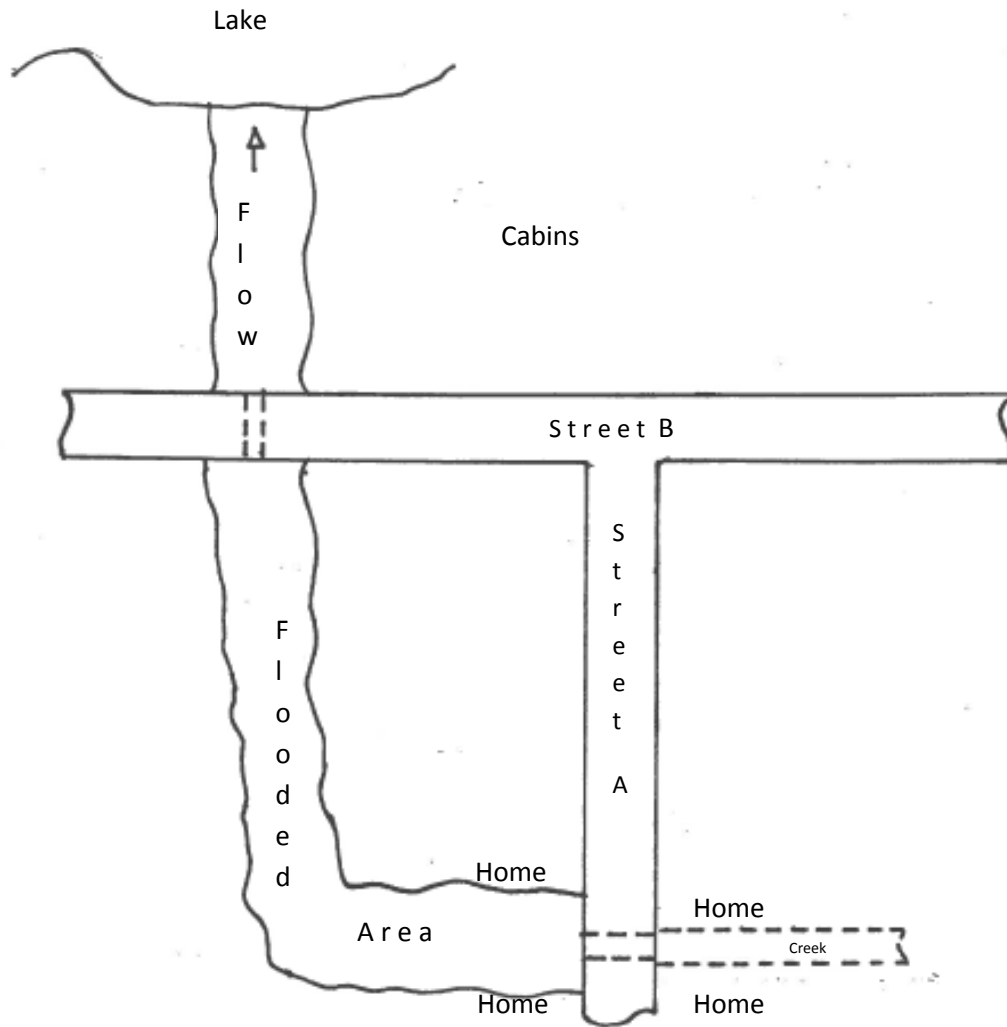
This case takes place in the same small town as above. As previously mentioned, this small town is in an expanding state which means that more concrete is being laid and more rain water is running off rather than being absorbed by the ground. More rain water run-off means more work for the storm sewer system in providing a means to channel the flow of water to the nearby Great Lake.

In one of the older established sections of the town, the storm sewer system is archaic and very often poorly maintained. Most of the system is piped; however, in some locations, the sewer system lies as an open channel of water or creek. It is in one of these open areas where problems occur.

Figure 2 depicts the downstream-most section of the storm sewer system in question. It is an unpiped open creek that flows through a weedy and wooded area and happens to be the most troublesome part. This open area receives drainage from a 36 inch duct lying under “Street A”; and, after winding around a 90 degree bend, flows to “Street B” where there is a 24 inch duct under the road.

Figure 2

Storm Sewer Segment



In addition to water being restricted because of having to flow from a large diameter duct to a small diameter duct, the drop in elevation between the two ducts is just two 2 feet. The drop in elevation from Street B to the lake is even less, 1 foot, primarily because the outlet of this drainage channel must be above the high water level of the lake; otherwise, back flow will occur. This section of the storm sewer system from Street B to the lake passes water through a channel with sandy soil banks that erode and collapse partially filling the bottom which also impedes flow. The result is that the complete section of this open area of the storm sewer system from Street A to the lake floods for long periods of time after a season of rain that can last for many weeks. This results in a condition that provides a swamp-like haven for the growth of dense high weeds, trees, brush, algae, and infestation of mosquitoes, rats, snakes and other varmints at the distress of people living in nearby homes. There have been reports of people contacting West Nile Virus, a sometimes deadly disease, from mosquito bites.

After repeated attempts by local homeowners urging city officials to fix the failed system, a petition was drawn up and presented to the city council. City officials argued that since a portion of the flooded open section of the storm sewer system in question passes over private property (two adjacent lots shown on Figure 2), the city could not take action. It was argued by residents that the owners of the two lots could not be held responsible for operation of a city storm sewer system that served hundreds of people living upstream of their location, and that the principles of Eminent Domain who maintain the city, not the two lot owners, are responsible for the operation of the entire system. The city then stated that they would take action to alleviate the problem but that all the property owners affected would have to pay for the work. The property owners then pointed out they cannot be charged to pay for a basic city function which had major design flaws and which was not properly maintained for years. The city then consented to fixing the storm sewer without affected property owners having to pay.

After a few weeks, a representative of the property owners then met with the City Engineer to be briefed on the plan to be taken by the city to correct the flooding problem. The city plan was to install a pipeline from Street B to the lake.

The reasoning was that sandy soil in that open area of the storm sewer system was impeding the flow of water and that installing the pipe would correct all upstream flooding. The property owner representative at the meeting suggested that the pipeline be extended to run from “Street A” all the way to the lake. The City Engineer pointed out that such an undertaking would entail running the pipeline through a large corporation’s land. The property owner representative reminded the city that, in the past, the large corporation was most generous in parting with its land; however, the plan, proposed by the city, was conditionally accepted.