Chapter 6 - Rochester's Wastewater Treatment System

Water is not limitless. Water consumption is required for everyday life and we have an obligation to be good stewards of the water we use. This means we have a responsibility for returning clean water to the local environment as part of the larger goal of maintaining a healthy global water cycle.

In the hydrological cycle, water is cleaned by nature through multiple chemical, physical, and biological processes. Examples of natural, water-cleaning processes are filtering water through soil, bacteria and algae feeding on suspended nutrients, or solids settling to the bottom of a lake. The key component to the natural water cycle is balance. Ideally, the supply of chemicals used by microbes and plants will match their population size. However, as the amount of chemicals in the water increases, the populations of plants and microorganisms can explode. When they die, their decomposition uses the oxygen that other aquatic organisms need to survive, upsetting the natural cycle. Adding a large population of humans to a local water cycle can also upset the balance. Rochester's Water Reclamation Plant (WRP) was built to treat the large amount of wastewater produced here, to help maintain the natural water balance. As the City's population has grown, the municipal WRP has expanded operations, as well.

Municipal is the term used to refer to a city owned system, such as Rochester's Water Reclamation Plant and sewer system.

Wastewater is used water that is generated from residences, commercial buildings and industrial plants. It is also sometimes called sanitary sewage. According to the U.S. Environmental Protection Agency (EPA), the average American produces 100 gallons of wastewater each day. In this case, the term "waste" does not mean that the water is thrown away. The goal of the City of Rochester is to return wastewater to the water cycle at the Zumbro River, with as little environmental impact as possible.

An Aerial View of the WRP

Source: Rochester Public Works

After water goes down the drain or the toilet is flushed, where does the water go? Wastewater is carried from homes, and commercial and industrial businesses, through a network of buried pipes, called a sanitary sewer collection system, to the WRP located in NW Rochester at the intersection of 37th Street and the Zumbro River. Once there, the water undergoes an advanced and complex process that reduces contaminants to levels required by WRP's operating permit before being returned to the environment via the Zumbro River. The WRP engineered processes mimic natural processes to treat most pollutants, but complete them at a much faster rate and in a controlled environment.

Rochester's WRP serves Rochester's 108,000 residents, its visitors, and its businesses. Initially, the WRP was located far outside the City limits, but as Rochester's population grew, the City encircled the treatment campus. More people also meant more wastewater and the WRP has expanded many times over the years to meet the new demands. Plans have been made to ensure that WRP can be expanded at its current site to serve a future population of over 300,000 people. The existing treatment capacity of this High Purity Oxygen (HPO) facility is 19.1 million gallons per day (mgd). The parallel treatment facility, called the Aeration Basin Complex (ABC), is rated at 4.75 mgd capacity. Currently, about 14 mgd of wastewater is treated at WRP. Each gallon of wastewater takes about 24 hours to treat from the time it enters the plant as influent to the time it is released from the system as effluent. Separately, the solids that result from the 24-hour treatment process undergo further treatment that takes over 30 days.

The WRP is not supported by taxes. Instead, it is part an "enterprise fund utility" that operates on a fee-for-service basis. Each month, customers receive a bill that covers the cost of all these WRP operations, along with the cost to build and maintain the sanitary sewer network.

Influent - wastewater entering the WRP

Effluent - treated water leaving the WRP

Sanitary Sewers

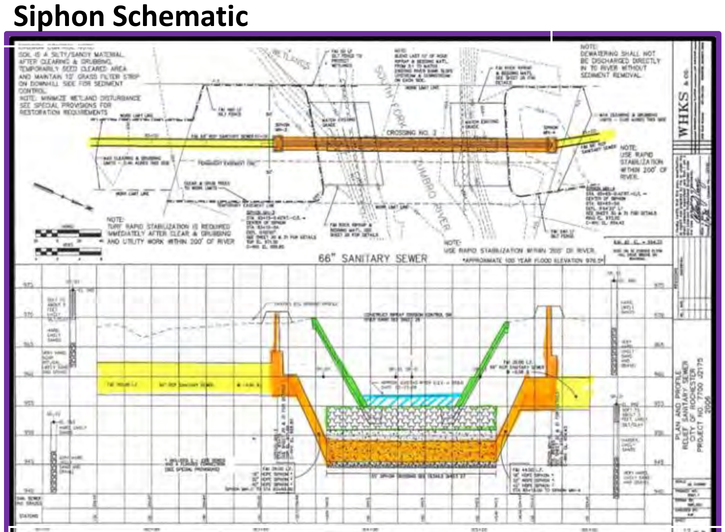
Sanitary Sewer Installation

Source: Rochester Public Works

The sanitary sewer system in Rochester carries both domestic (i.e., residential) and industrial wastewater. The wastewater is carried from each building in Rochester through 2,670,520 feet (505.8 miles) of pipe to the WRP. New sanitary sewer is added as City grows. The diameters of the pipes in the network vary, generally from 8 to 84 inches, although some older 4 and 6 inch pipes are still in service. The smallest pipes are service connections between buildings and the main, or “trunk” sewers that are 12 inches or larger. The largest pipe is 84 inches and it is the final pipe entering the WRP. Rochester has over 488,320 feet (92.5 miles) of trunk sewers as of 2013. It takes wastewater about two hours to be conveyed from downtown Rochester to the WRP.

Most of the wastewater moves through the pipes in gravity or siphon mains, although there are a few areas in Rochester where “lift stations” are needed. Since water flows downhill, pumps are needed to lift wastewater through areas with an uphill grade. Rochester has four public lift stations that are owned and operated by the City. Developers and/or home owner associations own and operate an additional 9 private lift stations. This unusually small number of lift stations, for such a large City, is due to the fact that the City is located in a river valley.

Siphon Schematic



Source: Rochester Public Works

The Zumbro River and its tributaries are obstacles for installing buried pipe. To solve the problem of getting under rivers while maintaining the needed slope, engineers design a specialized set of pipes called inverted siphons or depression sewers. To work, the pipes must dip below the river and then rise to the needed pipe elevation on the other side. This prevents the wastewater from moving simply by gravity, as it does in other areas. The siphon system uses basic hydraulic principles to keep the sewage moving at 3 ft/sec, the speed needed to keep materials in suspension and to prevent pipes from clogging. Because of the pipe bends in an inverted siphon (highlighted in orange), the liquid flowing in one end of the pipe forces the liquid up and out the other end. To create the necessary velocity, pipe size and the discharge or volume of wastewater must be balanced. Typically, a series of three pipes with different diameters are used. If flow is low, the smaller pipe captures the flows to keep the desired pressure. Inverted siphons are also used to avoid other underground objects in Rochester, such as major utilities or Mayo Clinic's pedestrian tunnels.

Wastewater Reclamation Plant (WRP)

At the WRP's pump station entrance, wastewater is screend with 3 inch opening trash racks. These trash racks prevent large debris from entering the WRP lift station. The WRP influent lift station is composed of five pumps that lift wastewater up 72 feet.. Water travels via gravity through the rest of WRP until it flows into the Zumbro River.

Raw Wastewater Pump Entrance Station

Raw Wastewater Pump Discharge Pipes

Source: Deb Las (all photos)

Preliminary Treatment – Screening

Once the wastewater reaches WRP, it must undergo a series of treatments before it can be released into the Zumbro River. The initial process removes large solids by passing the wastewater through ¼" stainless steel screens. The only items that should go down the toilet are water, human excrement, and toilet paper. Other products, such as cleaning wipes, paper towels, and pet waste, for example, should be disposed in the garbage so they don't lead to costly equipment repairs. After screening, the collected solid materials are transported via conveyer belts to a shoot where they fall into plastic bags and are readied for incineration at the Olmsted Waste-to-Energy Facility.

Influent Screen

Solids Conveyor

Solids Disposal Preparation

Next, the wastewater passes through the grit chamber where the wastewater is slowed enough for sand, grit, and gravel to fall to the bottom of the tank. The grit is then washed to prepare it for disposal at the Olmsted County Kalmar Landfill.

Grit Washing Process

Washed Grit Ready for Disposal

Primary Treatment – Settling Tank

Primary Clarifier

After preliminary treatment, wastewater moves to the primary treatment stage. The water is conveyed into large settling tanks called clarifiers. This stage removes about 30% of the pollutants. Most of the solids that can either float to the top of the tank or sink to the bottom are collected. Mechanical scrapers loosen solids that have settled out of suspension so they can be pumped out of the bottom of the tank. The heavier, sludge-like material is known as "primary solids" and the light materials that float, such as oil and grease, are skimmed off the top of the water. Both waste materials are pumped to the anaerobic digesters for further treatment.

Primary Solids Pumps and Pipes Deliver Sludge to the Anaerobic Digester

Secondary Treatment – Aeration & Biological Treatment

Secondary treatment is a two stage process that involves aeration with biological treatment and settling. In this process, dissolved solids are consumed by microorganisms and converted into "settleable solids".

Aeration Basins

Secondary treatment is an important step because organic matter is removed at this time, thereby lowering Biological Oxygen Demand (BOD) so aquatic life in the Zumbro River does not have to compete for oxygen.

While some of the solids are removed in primary treatment, the wastewater still contains contaminants that are dissolved in the water. In nature, many of these contaminants would be food for living microscopic animals and plants, such as protozoa and algae, or bacteria. The engineered wastewater treatment process uses an artificial environment that mimics the ideal conditions of nature where these microorganisms also consume such pollutants. The engineered process controls oxygen levels and detention time so microorganisms can work quickly and efficiently to consume dissolved solids, converting them into settleable solids within the man-made habitat. To achieve this, wastewater that has completed the preliminary and primary treatment steps is combined with microorganisms in a large aeration basin. Oxygen is added and mixing occurs for several hours to produce carbon dioxide (CO_2), cleaner water (H_20), and more microorganisms. This first stage is known as the activated sludge process and it takes several hours.

In the HPO plant the secondary treatment is divided into first and second stages. The first stage is for the removal of BOD during a detention time of about 2 hours. Some of the microorganisms are returned to the first stage aeration process and the solids are removed for processing. During the second stage, ammonia is oxidized to nitrate after a detention time of about 4 hours.

Intermediate Clarifiers

The term BOD is most commonly expressed in milligrams of oxygen consumed per liter of sample during 5 days of incubation at 20 °C.

In *The Field of Dreams* movie, the main character hears: “If you build it, he will come.” That is the case with the bacteria in sludge. As long as the proper environment is provided, the bacteria will multiply and keep eating the dissolved pollutants. The particular strain of bacteria in this process is not important as long as it is a type that clumps together as it multiples. By clumping, enough mass is produced to force the bacteria to fall to the bottom of the tank. Bacterial samples are monitored weekly to prevent the production of filamentous bacteria that do not settle out as well. Filamentous bacteria can be caused by over aeration of the wastewater.

After the microorganisms have been allowed to interact with the wastewater, the mixture is sent to settling tanks called final clarifiers. The wastewater is evenly distributed to each of the four final clarifier basins via a splitter structure. The wastewater enters the platform from the center and the flow is divided by going over one of the four sides. The final clarifier further separates the suspended solids from the treated water, leaving the heavier solids on the clarifier floor. By the end of the secondary treatment process, about 95-98% of the waste has been removed from the flow of water.

The settled sludge is then sent to the anaerobic digesters or recirculated. The sludge is recirculated to the aeration basin to provide the necessary life forms to continue the secondary treatment process (this material is called return activated sludge). The remainder of the sludge is sent to anaerobic digesters and is converted to biosolids. (See the Section titled "Byproducts of Wastewater Treatment for more information.)

Final Clarifier Splitter Structure

Final Clarifier

Final Clarifier Effluent Water

Vocab Focus:

Aerobic - with oxygen

Anaerobic - without oxygen

Tertiary Treatment – Chemical Additions & Biological Oxidation

In the tertiary, or advanced stage, phosphorus is removed. Phosphorus is a plant nutrient that can cause excess algae growth in surface water. Excessive algae growth can block sunlight from reaching beneficial aquatic plants that provide food, shelter, and oxygen to the aquatic environment. Excessive algae can also decrease the dissolved oxygen in water when the algal cells die and decompose. Because the WRP discharges to the Zumbro River, which eventually flows into Lake Zumbro, it is important to remove phosphorus for both river and lake health. Phosphorus is removed three different ways in Rochester: the settling of solids, biological uptake by microorganisms, and chemical addition of ferric chloride and alum. Ferric chloride is added to the influent in the primary clarifier. Alum and an anionic polymer are added to the final clarifiers to further remove phosphorous. Both chemical additions help precipitate the phosphorus so it comes out of solution.

Disinfection – Chlorine

The last step in the treatment process is the addition of chlorine to disinfect the water by killing bacteria and viruses. The chlorine gas is injected into the flow coming from the final clarifiers into the chlorine disinfection basins, where it remains for several hours. Sodium bisulfite is then added to neutralize the chlorine as the water leaves the WRP via a single pipe. The effluent water now meets the permit requirements and can be returned to the Zumbro River to rejoin the natural hydrological cycle.

Chlorine Disinfection

Effluent Discharge to the River

Byproducts of Wastewater Treatment

Biosolids are one of the key byproducts of wastewater treatment because they can be reused as fertilizer. In fact, the White House lawn is fertilized by biosolids. About half of the solids that settle during the clarification steps are reused in the secondary process. All the rest of the solids are transported to an anaerobic digester where they are processed in much the same way as a human stomach would breakdown food. The activated sludge is thickened on gravity belt thickeners, blended with primary sludge and then digested in an oxygen-depleted environment for about 20 days to create the biosolids. The biosolids are rich in nitrogen and phosphorus, the primary nutrients used in commercial fertilizers. The WRP stores its biosolids all year and then applies it to local farm fields as fertilizer in the spring and fall.

Gravity Belt Sludge Thickener

There are regulations for application of biosolids. Fields must meet specific conditions, such as slope and soil type, to receive a land application permit from the state. While WRP has about 8,000 acres available under its permit, biosolids are applied to only about 2,000 acres annually. Extra land is needed because applications are rotated to different fields each year. Approximately 12,000,000 gallons of biosolids (at 6% solids content; this is equivalent to 3,000 dry tons) are generated and used as fertilizer each year. The value to the farmer is estimated at $300 per acre.

The WRP coordinates the transfer of biosolids from two large storage tanks in the loading garage to tanker trucks that are driven to the farm fields. At the fields, application tractors distribute the biosolids and inject them into the soil. Both the City and the farmers benefit from the biosolids application process.

Biosolids Load-Out Facility

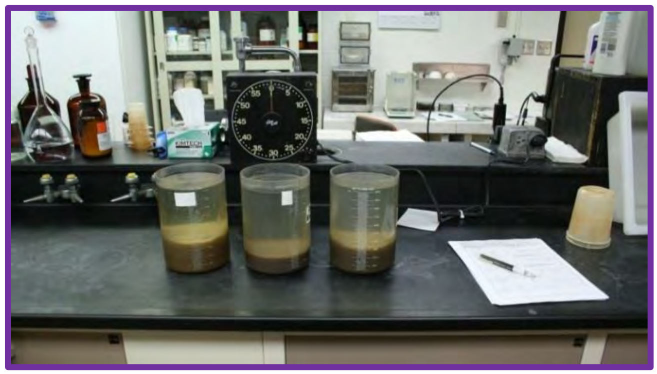
Biosolids Applicator Tractors

Tanker Trucks

High Pressure Gas Storage Sphere

Another byproduct of treating Rochester's wastewater is biogas. Digesting solids gives off biogas, a mixture of about 61% methane (CH_4), plus carbon dioxide (CO_2) and hydrogen sulfide (H_2S). Biogas produced is used immediately or stored in a separate containment facility, the high pressure gas storage sphere. Since it is similar to natural gas, it can be burned. The WRP produces about 40% of its own energy by using this gas. That is equivalent to about $600,000 worth of energy per year. The gas is burned in two engines to generate electricity and the jacket water and exhaust boiler heat exchangers provide heating for the buildings.

Engine Generators

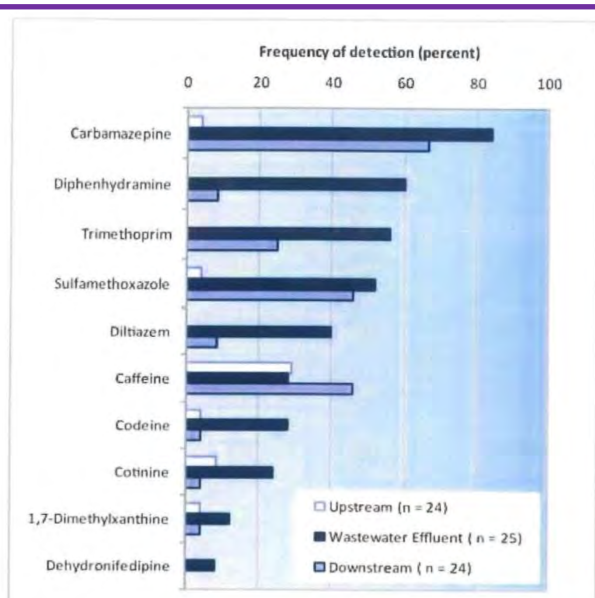


Each step of the wastewater treatment process is chemically monitored. Water samples are collected automatically from around the plant and transported to a centralized location about every six minutes. This creates an averaged water sample that is held in collection containers until analyzed by the lab technicians, using the specialized equipment shown.

Contaminants of Emerging Concern

An area of emerging concern for wastewater treatment is the issue of chemicals contained in pharmaceuticals (i.e., prescription and over-the-counter medications) and personal care products. Personal care products can enter wastewater by washing our bodies. Drugs may not be entirely absorbed into the body and can enter into wastewater in urine and excrement. The treatment processes do not remove all of these chemicals from wastewater. Recent research has shown very low concentrations of these chemicals in water that are now being detected because of advances in analytical technology. The EPA and the University of Minnesota are continuing their research into the possible effects these chemicals may have on aquatic and human health. Do not dump unused pharmaceuticals down the drain. Either put these medicines in the trash mixed with coffee grounds or cat litter or bring them to a drop off location established by local organizations.

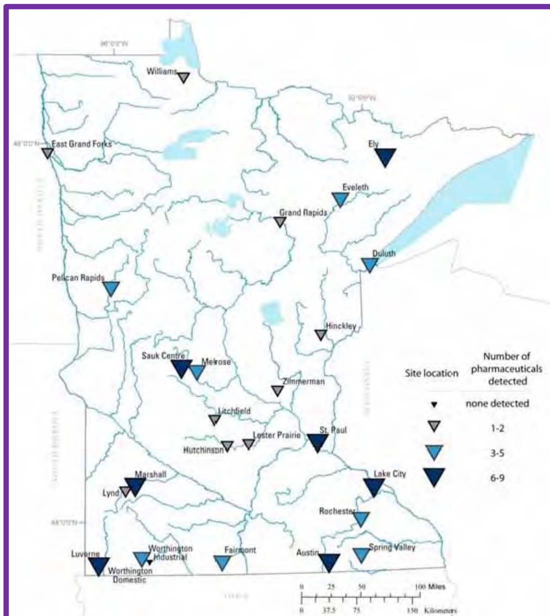
Pharmaceutical Chemicals Detected in Wastewater and Surface Water



Graph showing the frequency of detection of pharmaceutical compounds measured in water samples collected from wastewater effluent and from stream sites located upstream and downstream of effluent discharge during 2009.

Source: U.S. Geological Survey

Wastewater Treatment Plant Sampling Locations



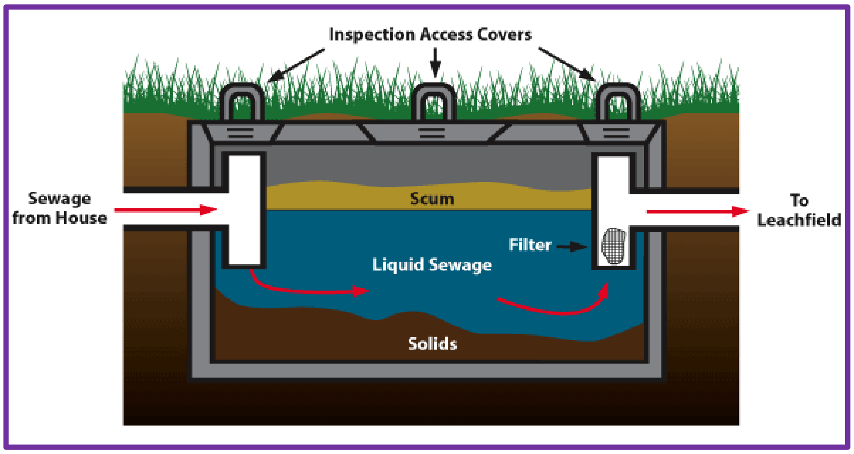
Source: Minnesota Pollution Control Agency

Septic Systems

Before centralized wastewater treatment became available, people either discharged their wastewater to a sewer that emptied directly into the river or used an individual sewage treatment system made up of a septic tank and a drain field. In the 1990's, many homes in older subdivisions surrounding Rochester were dealing with failing septic systems and did not have large enough yards to support a new drain field. Because failing septic systems can cause groundwater pollution, the City began working with the older neighborhoods to extend sanitary sewer and water lines to them, annexing those neighborhoods into the City. This Water Quality Protection Program was assigned $22.5 million of sales tax revenue to fund this effort. Since the first project was constructed in 1999, the City has helped connect about 1,350 homes to the WRP and the City's water supply.

There are still a few homes in Rochester that are not connected to the City's sanitary sewer system. Some houses may be too far away to hook up to the system. Other houses may have been built before the sewer lines extended to their area. These homes still rely on individual septic systems buried in their yards to treat their wastewater.

Septic Tank Diagram



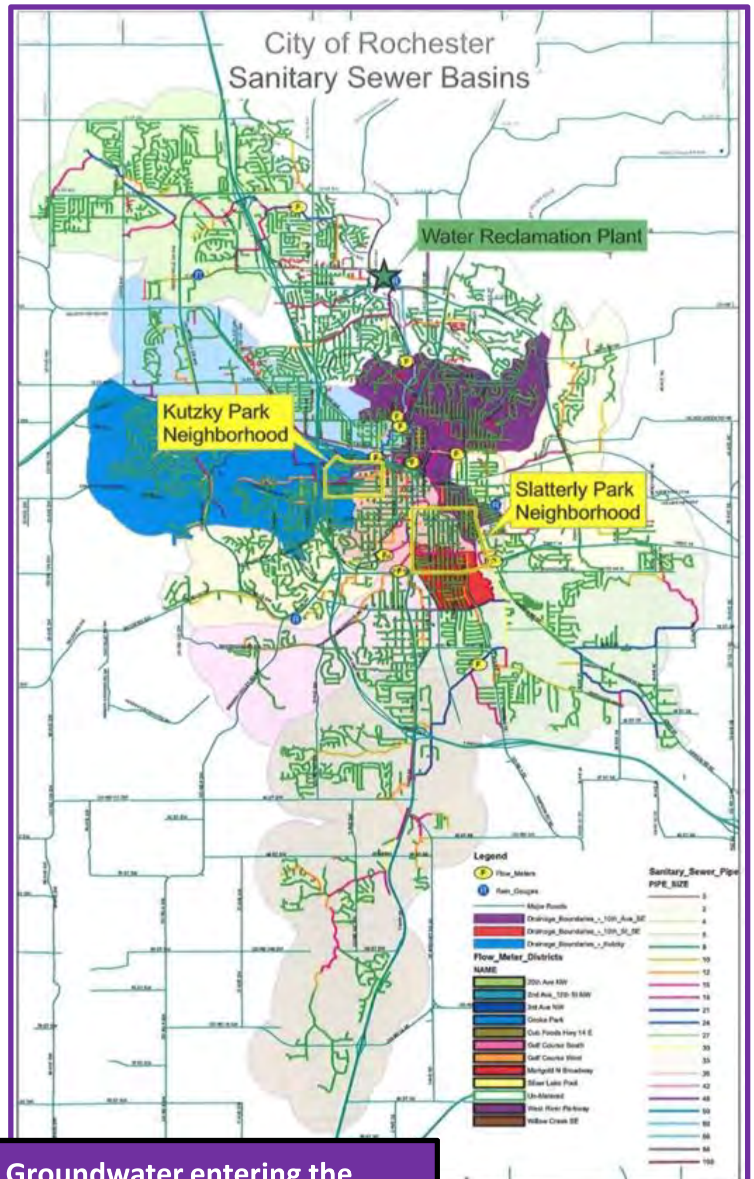
Source: Septic System Installation by J. Hockman, Inc.

A septic tank is a large (usually 1,000 gallon) concrete or plastic tank that is buried underground. Wastewater enters one side of the tank and flows out the other side into the underground area known as the drain field or leachfield. The tank acts a bit like a simple wastewater treatment plant. Heavier solids sink to the bottom. Lighter materials float to form the scum layer. Water with dissolved pollutants is found between the layers. The drain field is a series of pipes with small holes that are laid in a gravel bed to drain the effluent. The overlying plants and the underlying soils provide an environment where bacteria and plants can consume the dissolved pollutants.

Case Study: Slatterly Park and Kutzky Park Neighborhoods 2007-2008 Sewer Backup

Rochester's sanitary sewer system is an engineered network of pipes that, with the exception of four municipal lift stations, uses gravity to move wastewater throughout the entire City. As the City expands and older pipes degrade, there is a need for constant additions and upgrades. Insufficient capacity in older pipes or leaking pipes can cause conveyance problems and, occasionally, problems for homeowners.

A record rainfall event that started on August 18, 2007 caused several sanitary sewer backups in homes located in the older Slattery Park and Kutzky Park neighborhoods. When backups occur, sewage flows from the pipe into the home, instead of the other way around. The City has conducted an infiltration and inflow (I & I) study to identify causes for the backups. Recommendations from this study and others are being implemented throughout the City to minimize these types of situations.



***Infiltration*- Groundwater entering the sewer due to defective pipe joints or broken pipes**

***Inflow* - Surface water entering the sewer due to inappropriate connections between the surface and the pipes (e.g., sump drainage or leaking manholes)**

Review the PowerPoint presentation that was given to neighborhood residents about the I & I study and then read the summary of the Slatterly Neighborhood Sewer Rehabilitation and Capacity Assurance Program Report found at the hyperlinks listed below:

https://www.rochestermn.gov/departments/publicworks/hottopics/SanitaryIIStudy/Slatterly/Slatterly%20Park%20Meeting%20Powerpoint%20January%2022,%202008.pdf

www.rochestermn.gov/departments/publicworks/hottopics/SanitaryIIStudy/Slatterly/Slatterly%20Park%20Meeting%20January%2022,%202008.pdf

Answer These Questions:

1) What is the problem that needs to be solved?
2) What are the factors related to this problem?
3) What actions by individuals might be contributing to the problem?
4) What sanitary sewer system conditions might be contributing to the problem?
5) What might be a possible solution?

Important Dates in Rochester's Wastewater Treatment History

- 1895 Rochester's sewer control ordinance adopted
- 1926 Typhoid epidemic in SE MN linked to sewage contamination of the water supply
- 1926 Rochester open its first wastewater treatment plant south of Elton Hills Drive using a suspended growth process only six years after the process is patented
- 1950 Rochester opens its second wastewater treatment plant out of town at the current 37th Street location, naming it the Wastewater Reclamation Plant
- 1957 A County study of water quality in subdivisions without sanitary sewers found high nitrate levels, leading to the adoption of the Olmsted County Sewage and Wastewater Treatment Ordinance
- 1964 Rochester adopted a policy requiring annexation into the City before sewers could be extended to unsewered areas
- 1966 Several local committees and boards recommended extension of sewer services into older subdivision areas outside of Rochester
- 1971 Olmsted County adopted a requirement that residences utilizing septic systems must have lots at least two acres in size to provide space for future replacement drain fields
- 1980s WRP added the two-stage high purity oxygen activated sludge process. The project was partially funded through a Federal grant.
- 1990 WRP added solids treatment processes.
- 2004 WRP expanded to add treatment capacity