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8 WASTEWATER SYSTEMS

OVERVIEW

Wastewater systems collect, transport, treat, and dispose of wastewater (sewage) from living quarters, homes, apartments, industries, commercial establishments, and in some cases, storms. Disposal is accomplished after treatment (usually) and discharge into a receiving body of water. Their primary purpose is to protect public health and the environment.

Wastewater systems have components that can be very unsafe, particularly due to presence of hazardous gases that can result in death if inhaled, or that can explode. Refer to the section on Post-Earthquake Investigation Procedures, Safety Issues for further discussion.

SYSTEMS

Typical systems gather wastewater in the collection system where it is transported to the treatment plant, and after treatment, the effluent is disposed. Figure 8.1 shows a schematic diagram of a typical wastewater system.

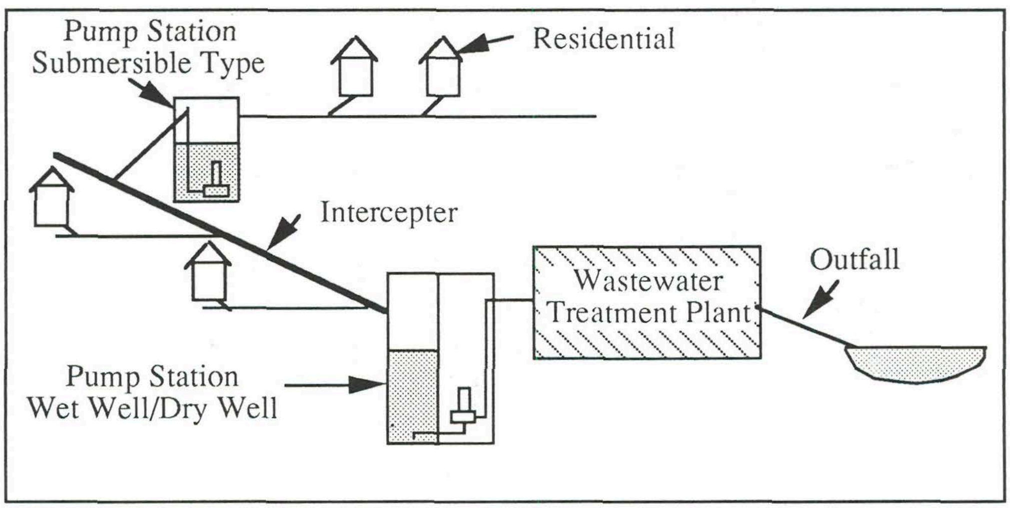

Figure 8.1 Schematic diagram of typical wastewater system.

GENERAL INFORMATION CHECK LIST

__ Service area
__ Service population
__ Flow and treatment capacities
__ System history/age of system

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SOURCES OF WASTEWATER

Sewage is discharged into the system from many sources. Domestic sewage comes from living quarters and commercial establishments. Industrial waste comes from industrial processes. Storm water run off may enter the system in the form of infiltration or inflow, or in the case of a combined sewer system, from catch basins or roof drains. All of this wastewater enters the system through pipe connections between the system and the facility where the sewage originates, commonly known as sewer laterals. In most areas, storm runoff is collected in a storm sewer system, separate from the sanitary sewer system, and is discharged into a receiving body of water.

An earthquake may cause hazardous materials to enter the wastewater system. These may include combustible or explosive materials such as gasoline or natural gas.

COLLECTION SYSTEM

This is the system of pipes that collects the sewage from the sources and conveys it to a central point for treatment and/or disposal. In contrast to the power and water distribution systems, the sewage collection system is not a network. Its configuration is in the form of a tree. The local portion of the system normally is designed to flow by gravity, i.e., the individual pipes are sloped downhill at a sufficient grade to carry the estimated flows and also to insure adequate scouring velocity. The pipe system generally follows the slope of the terrain.

Sewers are usually straight in both plan and elevation between manholes. The manholes, commonly spaced at about 300 feet along the sewer provide access to the sewer for maintenance and cleaning. Large sewers (5 feet diameter or more) can have manholes more widely spaced and horizontal curves and vertical grade changes are allowed. The local sewers flow into larger sewers sometimes called interceptors or trunks.

Sewage is often pumped, when the terrain dictates, through force mains routed around or over the obstacle. Inverted siphons are also often employed to pass under streams. Other variations from the conventional system include storage in or along the system, and overflow structures that allow discharge overland or to adjacent water courses when the collection system cannot handle the flow. Overflows are usually caused by storms which impose flows in excess of the capacity of the system.

TREATMENT PLANTS

Wastewater treatment plants can include physical/chemical and/or biological treatment processes. The following steps in the treatment process are those most

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commonly found in modern treatment facilities and are described in the usual order the process train follows.

Liquid Train

Figure 8.2 shows a schematic of a typical wastewater treatment plant liquid train.

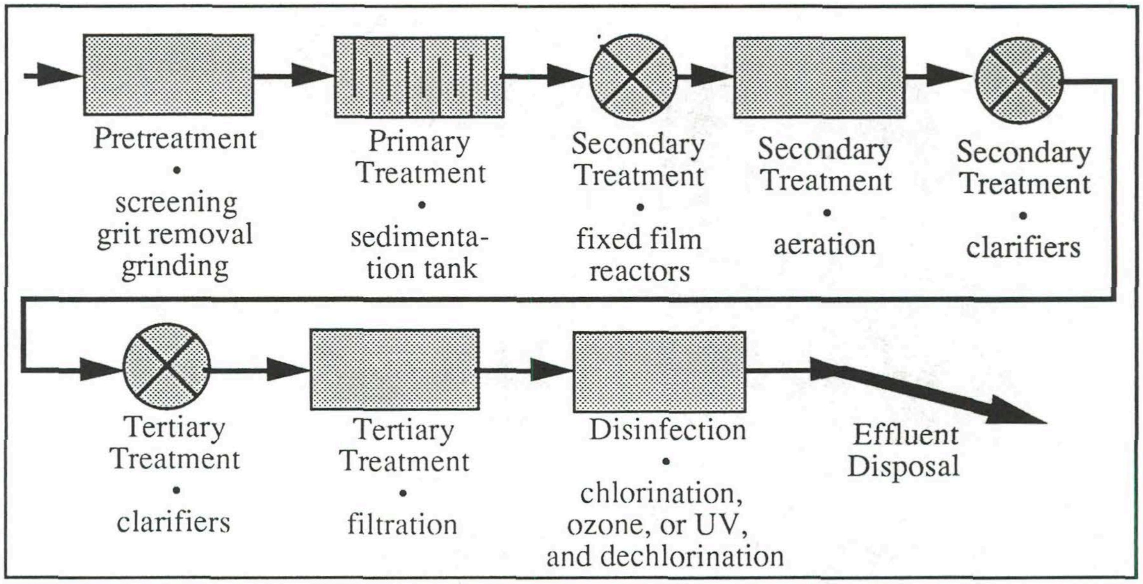

Figure 8.2 Schematic of a typical wastewater treatment plant liquid train. Chemicals are added to some processes.

Pretreatment

Pretreatment includes screening, grit removal, and grinding. Bar screens remove large, untreatable solid debris such as wood. Grit is removed to protect equipment later in the process from abrasion and wear and to keep the grit out of sedimentation tanks and digesters. It is accomplished by controlling the velocity of the sewage such that the grit, which has a higher specific gravity than other solids, settles out but the lighter solids do not. Solids are often ground up to reduce the size of solids to manageable dimensions.

Primary Treatment

Primary treatment is accomplished by sedimentation (clarification) or screening, this step separates the solids that are not in solution and makes it possible to treat them separately. The settling or clarification process for removing or separating solids involves the introduction of sewage into a basin, either circular or rectangular, where it is held for a period of time sufficient for the solids to settle, Figure 8.3.

Secondary Treatment

Secondary treatment is usually accomplished by biological treatment. This process utilizes the ability of organisms to break down the sewage into simpler

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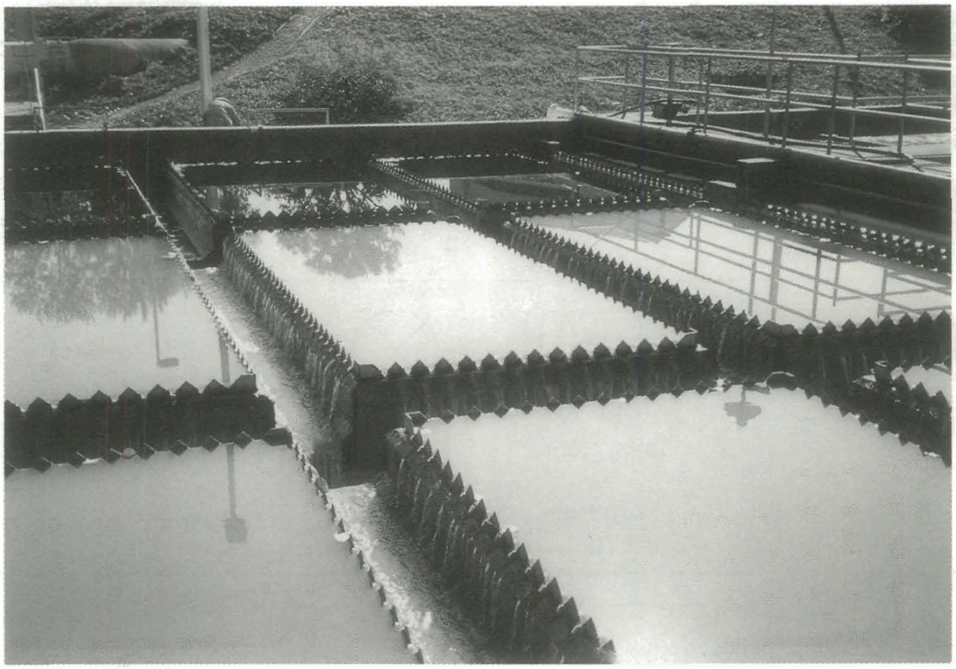

Figure 8.3 Primary sedimentation tank.

compounds and reduces the demand for oxygen (Biochemical Oxygen Demand, BOD). It is accomplished in two ways as follows: aerobically (with oxygen) byprocesses such as activated sludge (Figure 8.4), trickling filter, and aeration; and anaerobically (without oxygen) in closed digesters in which the solids previously separated are continuously mixed in the presence of bacteria which do not require oxygen and produce gasses, principally methane and hydrogen sulfide. These solids are then removed by secondary clarification (Figure 8.5).

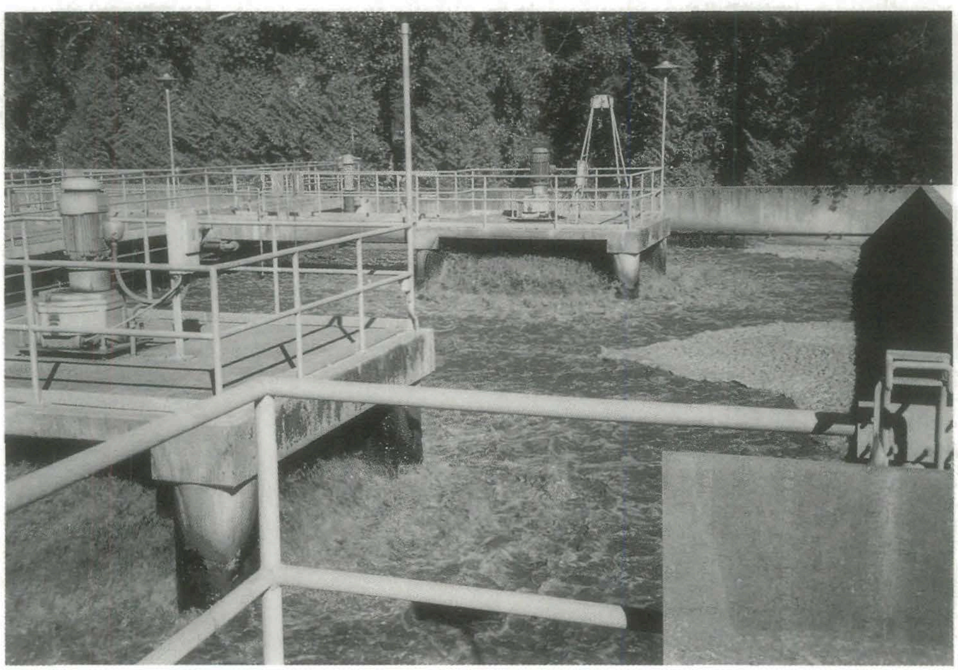

Figure 8.4 Aerobic secondary treatment.

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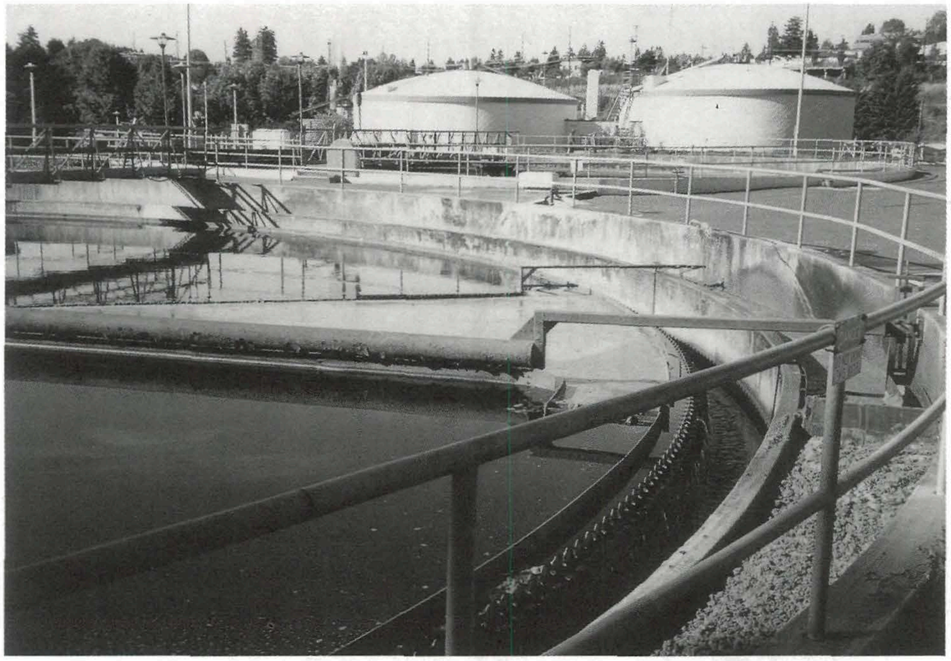

Figure 8.5 Secondary clarification.

Tertiary Treatment

Occasionally secondary effluent is treated to a higher quality using coagulation, filtration, demineralization, or tertiary processes. This results in a reclaimed water with a quality possibly equal to potable water for use in industry, agriculture, and landscaping.

Disinfection

This step is intended to kill any remaining harmful bacteria and is accomplished by the use of chlorine, ozone, ultraviolet light, or other processes. If chlorine is used for disinfection, the effluent is sometimes dechlorinated using sulfur dioxide gas or other reducing agents to protect fish in the receiving water.

Solids Train

Figure 3 shows a schematic diagram of a typical wastewater treatment plant solids train.

Digested solids (sludge) are dried on open beds or dewatered mechanically with centrifuges or filter belt presses, and deposited in land fills or sold as fertilizer or soil conditioner. The gas produced is either burned or utilized as fuel for heat or power.

Effluent Disposal

Liquids are normally discharged to a water course such as oceans, bays, rivers, or lakes, to a ground water basin or reclaimed water system (for tertiary effluent),

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or sometimes, if the treatment is incomplete, to a stabilization, evaporation, or infiltration pond.

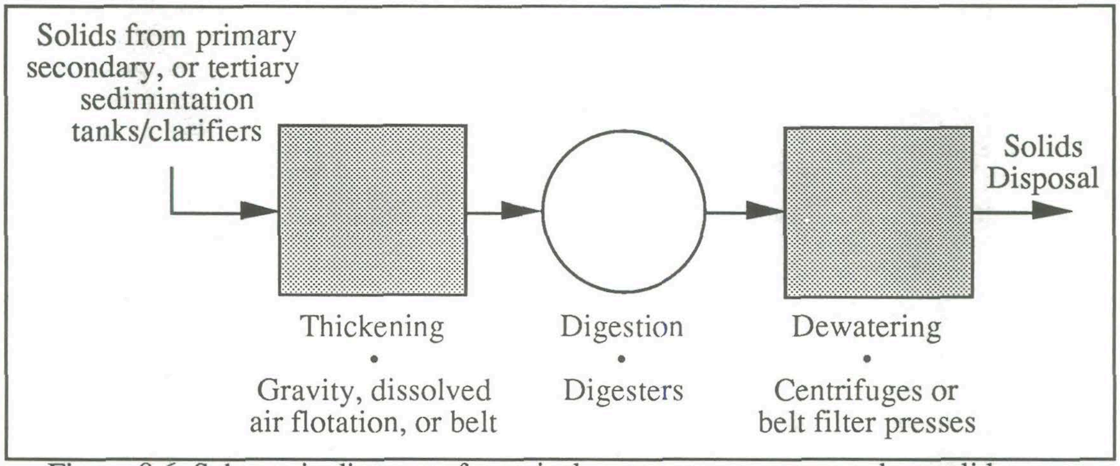

Figure 8.6 Schematic diagram of a typical wastewater treatment plant solids train.

SYSTEM COMPONENTS AND THEIR EARTHQUAKE VULNERABILITY

COLLECTION SYSTEM COMPONENTS

Buried Pipe

Collection system buried piping is typically constructed of concrete, vitrified clay pipe, VCP, asbestos cement, AC, or polyvinyl chloride, PVC. Nominal laying lengths are 3 to 6 feet for VCP and concrete, and 10 to 12 feet for AC and PVC. Bell and spigot joints caulked with cement mortar were common until about 30 years ago when the mechanical compression joint using an 0-ring or compression ring of polyvinyl chloride or polyurethane came into common use. This joint provides some flexibility and practically all sewer pipe is now installed with this type of joint. Large diameter interceptor or trunk sewers are typically reinforced concrete or cast-in-place concrete. Brick sewers are found in older cities. Some large sewers are pile supported.

Ground deformations caused by liquefaction-related lateral spreading or flotation, and movement at a fault crossing or slides generally are the cause of sewer damage in an earthquake, and can cause joint separation, joint compression/crushing, bending, or shear failures and/or change in grade. Ground shaking and wave propagation effects can also cause damage. where sewer pipe enters or joins a structure, earthquake damage can be expected, unless special precautions are taken in design and construction. Intense or prolonged ground shaking can cause pipe to crack or collapse and joints to open or compress resulting in leakage or blockage.

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Unless there is significant permanent ground deformation, damage to sewers may not be evident until sewage backups occur, or until sewers are internally inspected using television cameras pulled through the pipe.

The sewerage system in the Knollwood-Sylmar-San Fernando area was extensively damage in the 1971 San Fernando earthquake. Damage consisted of broken pipe and joints, pulled joints, and changes in grade. Pipe with flexible joints performed much better than rigid (cement mortar) jointed pipe. In the 1989 Loma Prieta earthquake, extensive sewer damage occurred in the Marina

District of San Francisco and in Santa Cruz, primarily in areas where there was differential settlement and/or liquefaction occurred. There was damage to the collection system in the 1994, Northridge Earthquake, even though there was limited liquefaction. Large permanent ground deformations in the 1995 Kobe Earthquake resulted in cross sectional failures of large diameter reinforced concrete pipe. The Japanese have reported flotation of sewers in other recent earthquakes.

PIPELINE SYSTEM CHECK LIST

__ Maps/Inventory: pipe size, type (concrete, reinforced concrete, VCP, AC, PVC), joint (mortared or gasketed), depth, age
__ Design standards (and historic design standards)

COLLECTION/TRANSPORT SYSTEM DAMAGE CHECK LIST

__ Overflows or backups with related consequences and mitigation
__ Manhole and pipe damage descriptions including damage mechanism (pulled joint, crushed joint, shear, bending, change in grade, lateral damage), and geologic cause (wave passage, permanent ground deformation, flotation, etc.)
__ Damage rates (as calculated from damages divided by inventory)

GEOLOGIC HAZARD DATA CHECK LIST

__ Surficial geology maps
__ Liquefaction hazard maps
__ Groundwater Depth
__ Permanent ground deformation with vectors and displacements
__ Earthquake intensity maps in terms of peak ground velocity
__ Peak ground acceleration for treatment plant sites

Manholes

Most manholes are precast concrete pipe sections installed vertically. Older installations may be brick. Manhole walls sometimes are cracked and rings and covers shifted out of alignment. Manholes with bases below the groundwater table in liquefiable soil areas will sometimes float (Figure 8.7). The junction between the

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sewer pipe and the manhole is particularly vulnerable, due to the different soil/pipe interaction characteristics.

Figure 8.7 Manhole floated to the surface when soil liquefied.

Pump Stations

Smaller pump stations are often pre-packaged units installed below grade in a large manhole or steel "can". An adjacent manhole often serves as the wet well, the volume used to store sewage and pump control. Larger pump stations are typically cast-in-place concrete or caisson type below grade structures, but sometimes include a superstructure to house electrical, odor control, or other types of equipment.

Pump stations that are below grade structures typically perform well. Superstructure performance is dependent on the design. Unreinforced masonry buildings may crack or collapse. Some older designs often had inadequate connections between the roof and walls, If soils are liquefiable, the entire pump station may float or move, and/or suction and discharge piping may fail, particularly if flexible couplings are not provided at the interface to the pump station structure. For example, in the 1995 Kobe several pump stations floated, damaging connecting piping. Unanchored equipment and/or inadequately braced or rigid piping can result in pipe damage inside the pump station, and can result in flooding of the dry well.

Pump stations are usually dependent on electrical power to drive the pumps. Loss of power will result in pump station failure if emergency power is not available. Refer to the following section for further information on building structures, equipment, and emergency power.

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Pump stations are usually tied to an operations center through telemetry often referred to as a Supervisory Control and Data Acquisition systems, SCADA. If this system becomes inoperable, the pump station is usually designed to continue operation using local control logic.

TREATMENT PLANT COMPONENTS

Treatment plants include the liquid train, solids train, and effluent disposal as previously described. These functional categories are comprised of groups of components including: buildings/superstructures, process tanks or basins, channels and yard (buried) piping, equipment, plant piping (exposed in galleries and equipment rooms), chemical storage and feed systems, power/emergency power supplies, control systems, and communications systems. Buildings can include administration, operations, maintenance, storage, laboratory, and control rooms, each with their own vulnerability peculiarities, and criticalities following an earthquake.

General Damage Mechanisms

Buildings/Super Structures

Above grade structures must have a load path to carry earthquake loads from their origin to the foundation, or the structure may be vulnerable to earthquake loading. Vulnerability of structures is related to their type. Structure types particularly vulnerable include unreinforced or inadequately reinforced masonry, non-ductile concrete frame, and older tilt-up structures. Adjoining structures may pound against one another if they do not respond as a single structure.

Process Tanks or Basins

If liquefaction occurs, tanks are subject to flotation or lateral movement. If tanks are pile supported, and not designed to resist lateral loading, the piles may fail as occurred at the Higashinada Treatment Plant in the Kobe Earthquake (Figure 8.8). Buried tank walls may be subject to unanticipated soil loading. Connections between structures may be subject to damage such as the point where a channel joins a basin due to differential movement due to settlement or dynamic response. Expansion joints in structures over approximately 100 feet long, may crack or spall due to differential displacement if the movement is greater than the designer anticipated. Treatment plant gallery and process tank walls expansion joints cracked in both the Northridge and Kobe earthquakes. Basin and vault covers perform similarly to building roofs during earthquakes, except that sloshing of the contained liquid can damage or lift covers off their supports. Floating digester covers at 4 different treatment plants were damaged in the Loma Prieta earthquake. Sloshing may damage baffles in clarifiers.

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