



Type of Sewer Systems

Solomon Seyoum



Learning objectives

- ▶ Upon completion of this lecture, the participants will be able to differentiate between types of sewer systems and discuss different aspects of each type of sewer systems such as
 - Design aspects
 - operation and maintenance aspects,
 - Cost aspects and
 - Applicability

Types of Sewer Systems

Types of sewer systems

► Principles of collection:

- Combined
- Separate
- Above ground/underground

► Principles of transport

- Gravity
- Pressure
- Vacuum

Types of sewer systems

• Asgrrnu

- ▶ Combined Sewers
- ▶ Separate Sewers
- ▶ Simplified Sewers
- ▶ Solid free sewers
- ▶ Pressurised sewers
- ▶ Vacuum sewers
- ▶ Open channel drains

Types of sewer systems

Combined Sewers

- ▶ are large networks of underground pipes that convey domestic sewage, industrial wastewater and stormwater runoff in the same pipe to a centralised treatment facility
- ▶ mostly found in urban areas
- ▶ do not require on-site pre-treatment or storage of the wastewater
- ▶ Transport all their wastewater to a WWTP where it is treated and discharged to a water body

Combined Sewers – design aspects

- ▶ Because the wastewater is not treated before it is transported, the sewer must be designed to maintain self-cleansing velocity (i.e. a flow that will not allow particles to accumulate), generally obtained with a minimal flow of 0.6 to 0.75m/s
- ▶ A constant downhill gradient must be guaranteed along the length of the sewer to maintain self-cleansing velocity

Combined Sewers – design aspects

- ▶ When the required slope cannot be maintained, a pumping station must be installed
- ▶ Primary sewers are laid beneath roads, at minimal depths of 1.5 to 3 m to avoid damages caused by traffic loads
- ▶ Access manholes are set at regular intervals along the sewer, at pipe intersections, at changes in pipeline direction and at drops

Combined Sewers – health aspects

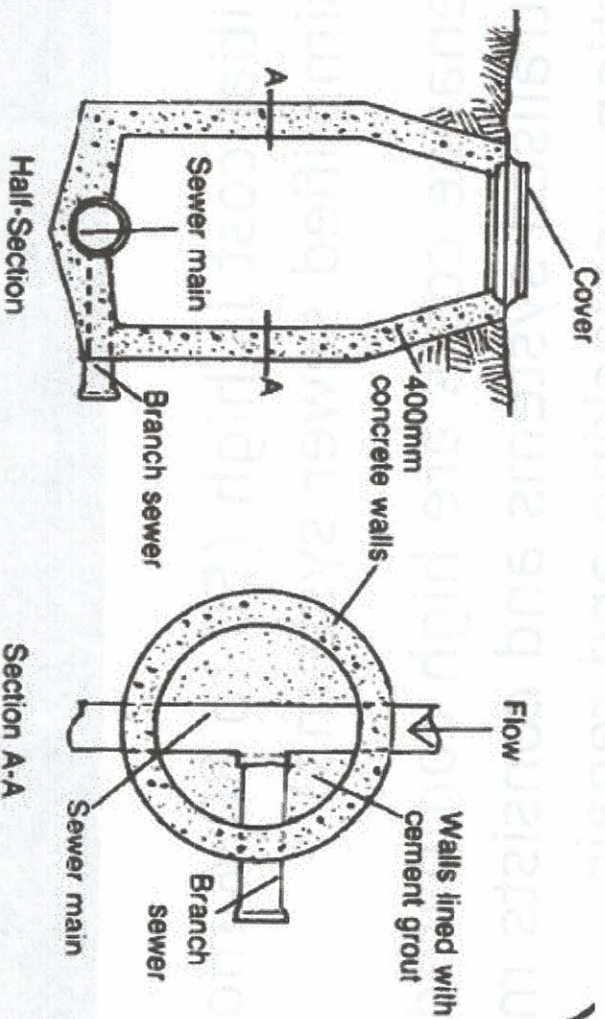
- ▶ provide a high level of hygiene and comfort for the user at the point of use
- ▶ the ultimate health and environmental impacts are determined by the treatment provided by the downstream wastewater treatment facility

Combined Sewers – cost consideration

- ▶ The initial cost is high (50 to 80% more than simplified sewer systems)
- ▶ Maintenance costs are high compared to decentralised systems and consists mainly inspection, unblocking and repair
- ▶ Extension of the system can be difficult and costly

Combined Sewers – Operation and Maintenance

- ▶ Manholes are installed wherever there is a change of gradient or alignment
- ▶ Maintenance require trained professionals



Combined Sewers – Applicability

- ▶ Suitable for urban areas with resources to implement, operate and maintain the system
- ▶ Appropriate when a centralised treatment facility is available
- ▶ Planning, construction, operation and maintenance require expert knowledge
- ▶ Infiltration may hamper the performance of combined sewers

Combined Sewers

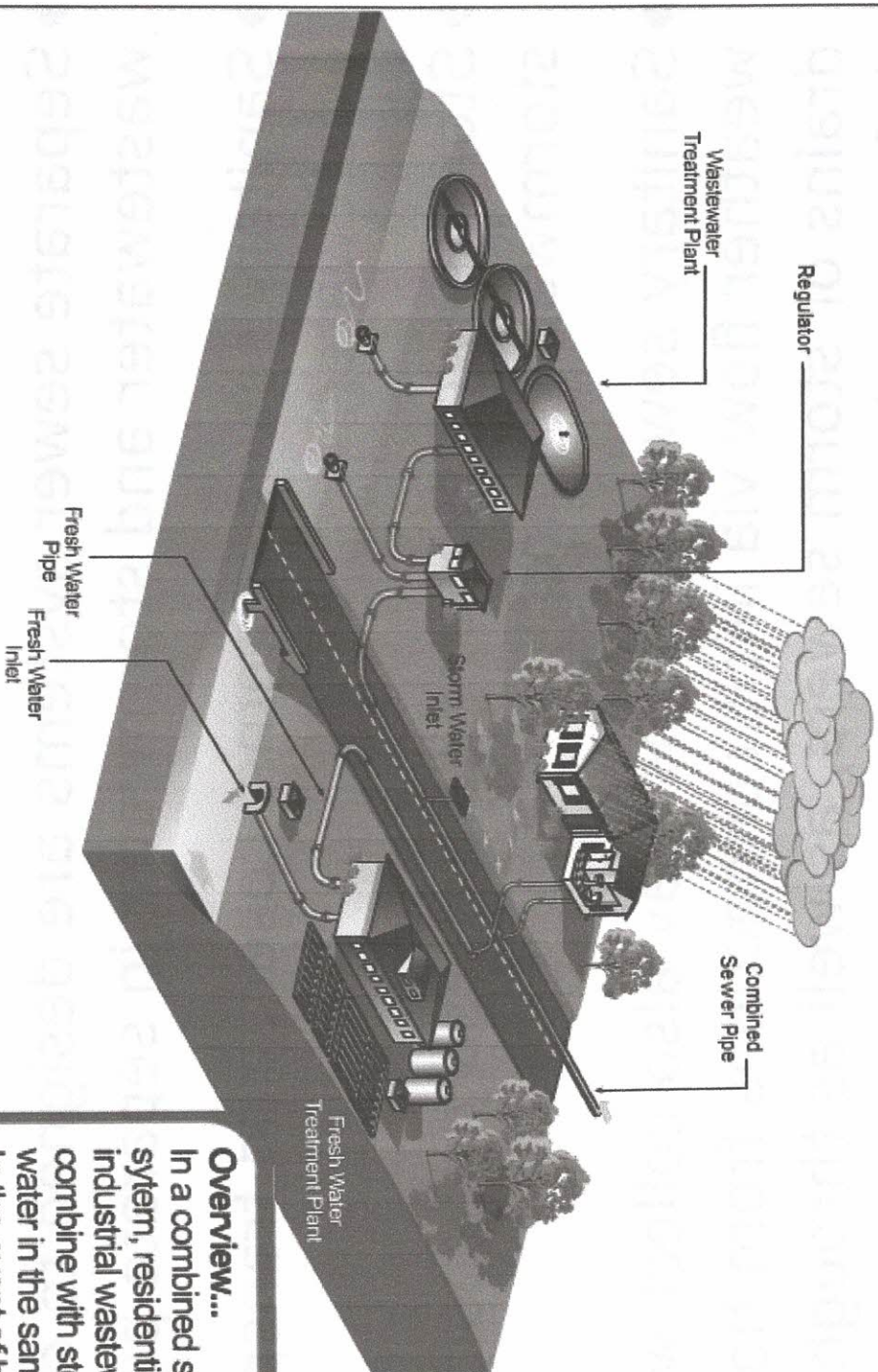
Advantages

Convenience (minimal intervention by users)	High capital costs
Low health risk	Need a reliable supply of piped water
No nuisance from smells, mosquitoes or flies	Difficult to construct in high-density areas, difficult and costly to maintain
Stormwater and wastewater can be managed at the same time	Recycling of nutrients and energy becomes difficult
No problems related to discharging industrial wastewater	Unsuitability for self-help, requires skilled engineers and operators
Moderate operation and maintenance costs	Problems associated with blockages and breakdown of pumping equipment
	Adequate treatment and/or disposal required

Combined Sewers

Combined Sewer System

Separate Sewer System



Overview...

In a combined sewer system, residential and industrial wastewater combine with storm water in the same pipe. In the event of heavy rains, the storm water can cause an overflow to the sewer system.

Overview

Residential Wastewater

Wastewater Facilities

Fresh Water Facilities

Separate Sewers

- ▶ Separate sewer systems are designed to convey wastewater and stormwater in separate pipes
- ▶ Sanitary sewer systems collect and transport wastewater
- ▶ Storm sewer systems collect and transport stormwater runoff
- ▶ Sanitary sewer systems may also collect wet weather flow via illicit connections from house drains or storm sewers, as well as through defects in the pipes and manholes

Separate Sewers – cost and health aspects

- ▶ The construction costs can be higher than for the combined sewer system because two separated networks are necessary
- ▶ they provides a high level of hygiene and comfort
- ▶ in a properly constructed separated system the sewage is transported in a closed system directly to the treatment plant and cannot overflow into the environment

Separate Sewers – Applicability

- ▶ The same applicability as combined sewer
- ▶ Suitable for urban areas with resources to implement, operate and maintain the system
- ▶ Appropriate when a centralised treatment facility is available
- ▶ Especially suitable in areas where irregular, heavy rainfall is expected to avoid frequent combined sewer overflows

Separate Sewers

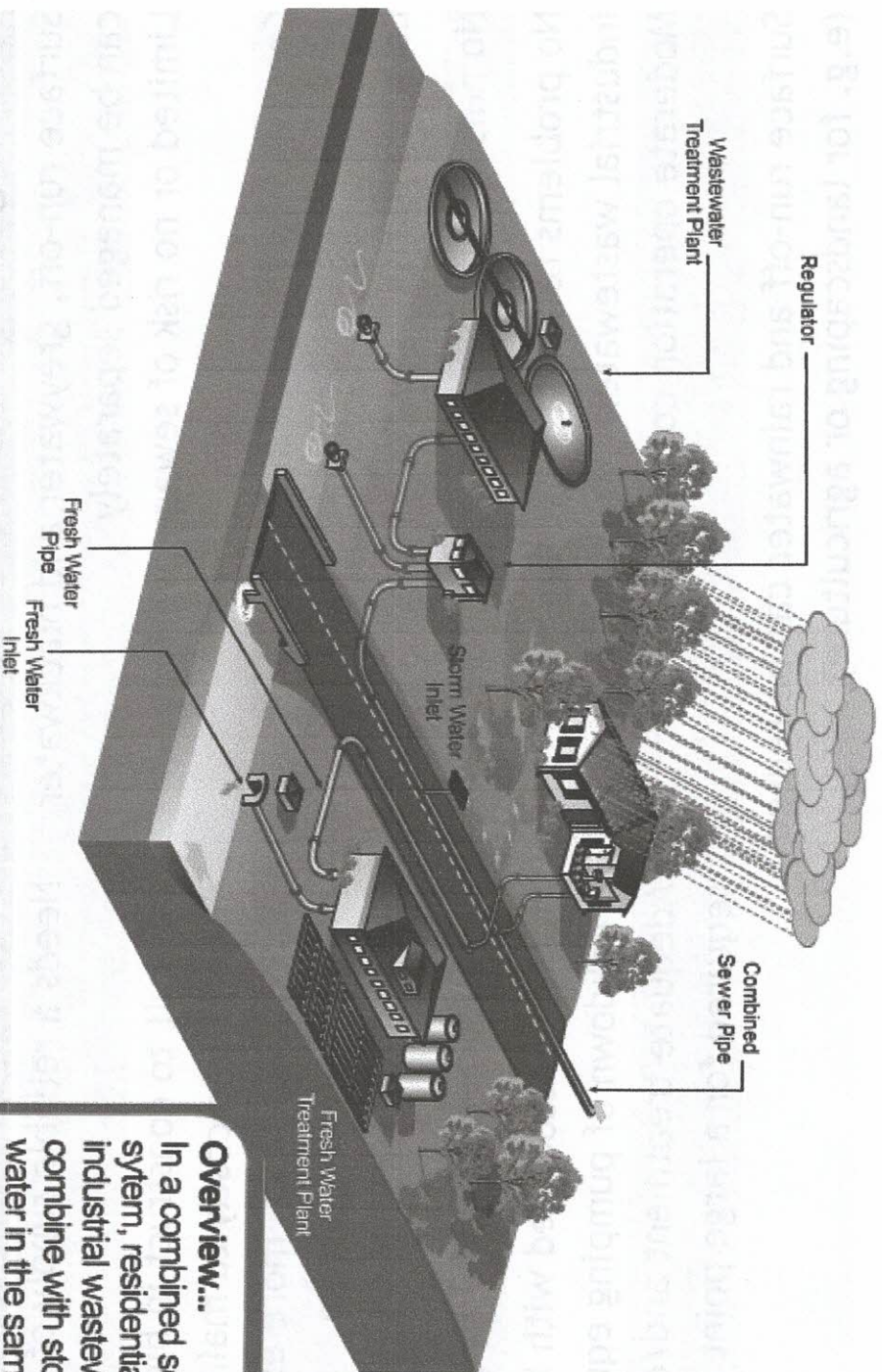
Advantages

Surface run-off, greywater and blackwater can be managed separately	Needs a reliable supply of piped water
Limited or no risk of sewage overflow	Difficult to construct in high-density areas, difficult and costly to maintain
Convenience (minimal intervention by users)	High capital costs, more expensive than combined sewer system
Low health risk	Requires skilled engineers and operators
No nuisance from smells, mosquitoes or flies	Need for pumping on flat ground
No problems related to discharging industrial wastewater	Problems associated with blockages and breakdown of pumping equipment
Moderate operation costs	Adequate treatment and/or disposal required for a large point source discharge
Surface run-off and rainwater can be reused (e.g. for landscaping or agriculture)	

Separate Sewers

Combined Sewer System

Separate Sewer System



Overview

Residential Wastewater

Wastewater Facilities

Fresh Water Facilities

Overview...
In a combined sewer system, residential and industrial wastewater combine with storm water in the same pipe. In the event of heavy rains, the storm water can cause an overflow to the sewer system.

Simplified and Condominal Sewers

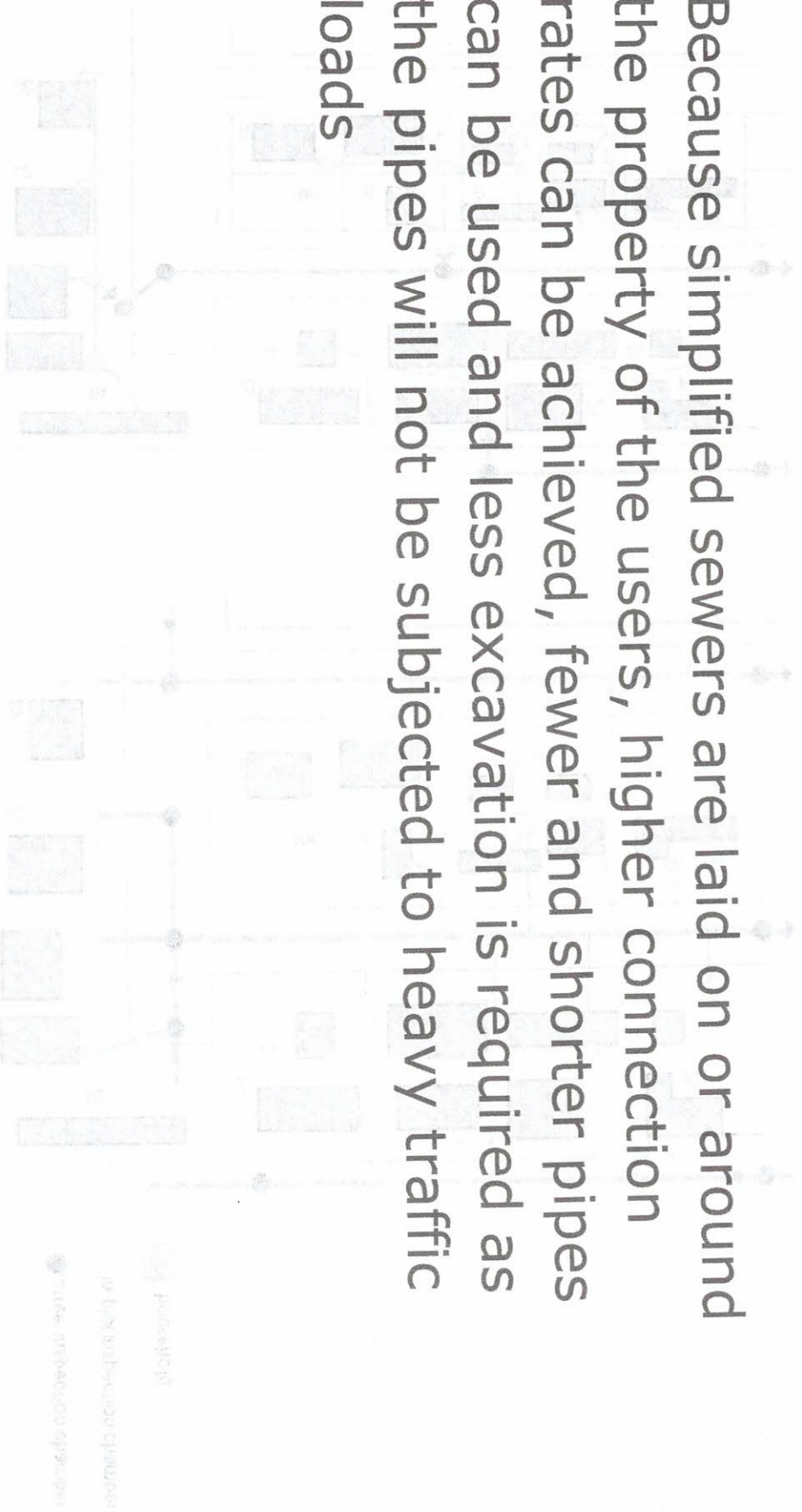
- ▶ describe a sewer system that is constructed using smaller diameter pipes laid at a shallower depth and at a flatter gradient than conventional sewers
- ▶ Allows for a more flexible design associated with lower costs and a higher number of connected households
- ▶ Because the sewers are more communal, they are often referred to as condominal sewers

Simplified sewer – basic design principles

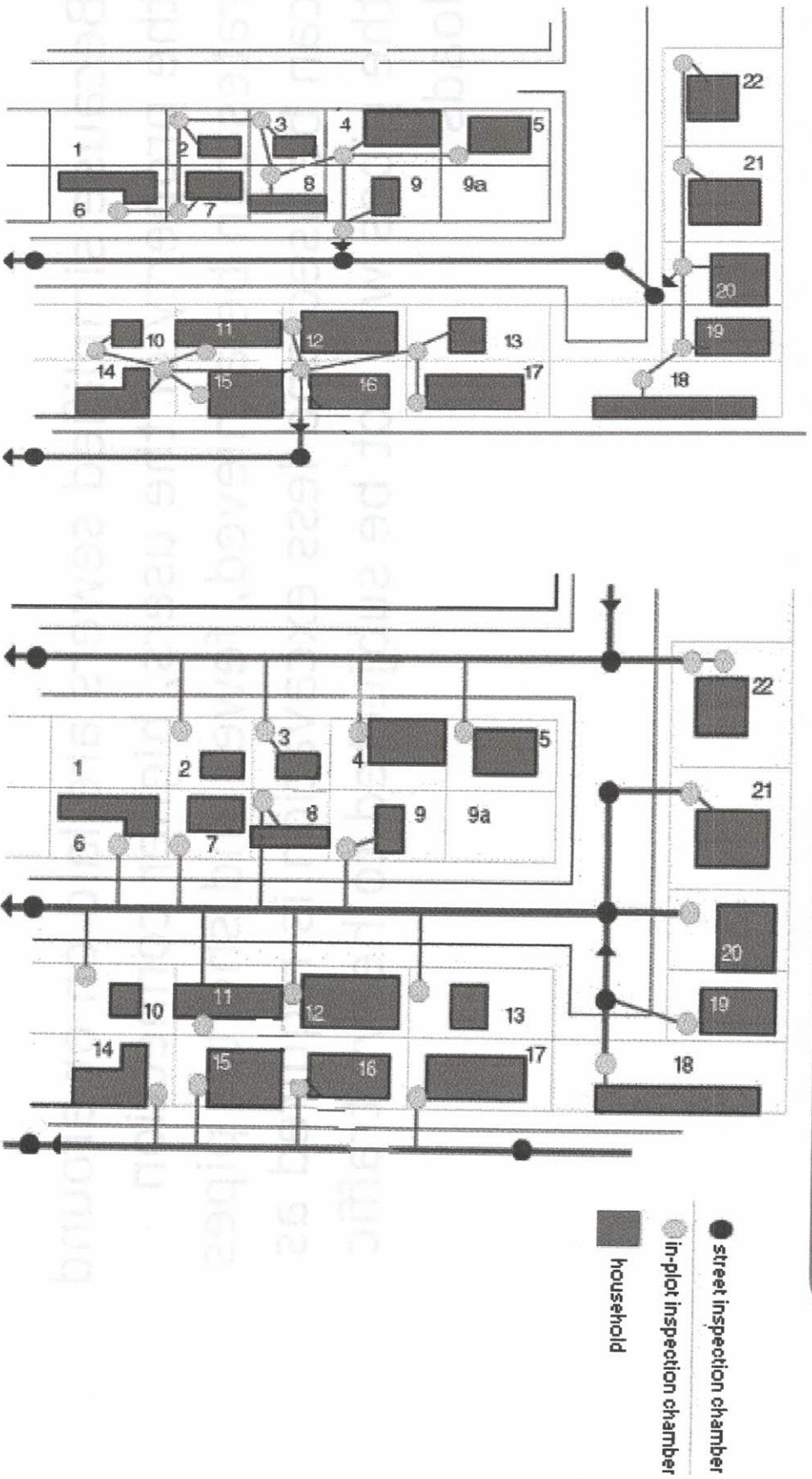
- ▶ They operate as conventional sewers but with a number of modifications:
 - the minimum diameter and the minimum cover are reduced
 - Expensive manholes are replaced with simple inspection chambers or flushing points
 - Sewers are laid within the property boundaries and side walks, rather than beneath the central road
 - the slope is determined by using the tractive force concept rather than the minimum velocity concept,
- Sewers should be designed to take into account the extra flow that may result from stormwater infiltration

Simplified sewer – basic design principles

- ▶ Because simplified sewers are laid on or around the property of the users, higher connection rates can be achieved, fewer and shorter pipes can be used and less excavation is required as the pipes will not be subjected to heavy traffic loads



Simplified and Condominial Sewers



Simplified vs conventional sewers pipe layout

Simplified sewer – cost consideration

- ▶ The costs of simplified sewerage systems are low (50 to 80 % less expensive than conventional gravity sewerage), sometimes even lower than those of onsite sanitation
- ▶ This is because simplified sewerage uses flatter gradient, shallow excavation depths, small diameter pipe and simple inspection units

Simplified sewer – Operation and Maintenance

- ▶ Blockages need to be removed and the system needs to be flushed periodically
- ▶ The pipeline system components, such as cleanouts or ventilation points should be regularly checked and maintained

35

- ▶ Even lower than those of onsite sanitation technologies (20 to 80 % less expensive than)
- ▶ The costs of simplified sewerage systems are

23

Simplified sewer – Applicability

- ▶ Where the ground is rocky or the groundwater table is high
- ▶ They can be installed in almost all types of settlements and are especially appropriate for dense urban settlements
- ▶ It is recommended that the scum from greywater, heavy solids and garbage be removed from the wastewater prior to entering the sewer to avoid frequent clogging

Simplified sewer

Advantages

Can be built and repaired with locally available materials

Capital costs are between 50 and 80 % less than conventional gravity sewers

Operating costs are low

Can be extended as a community changes and grows

Requires enough water for flushing

Requires expert design and construction supervision

Requires frequent repairs and removals of blockages

only suitable where there are interceptor tanks, septic tanks or other on-site pre-treatment systems

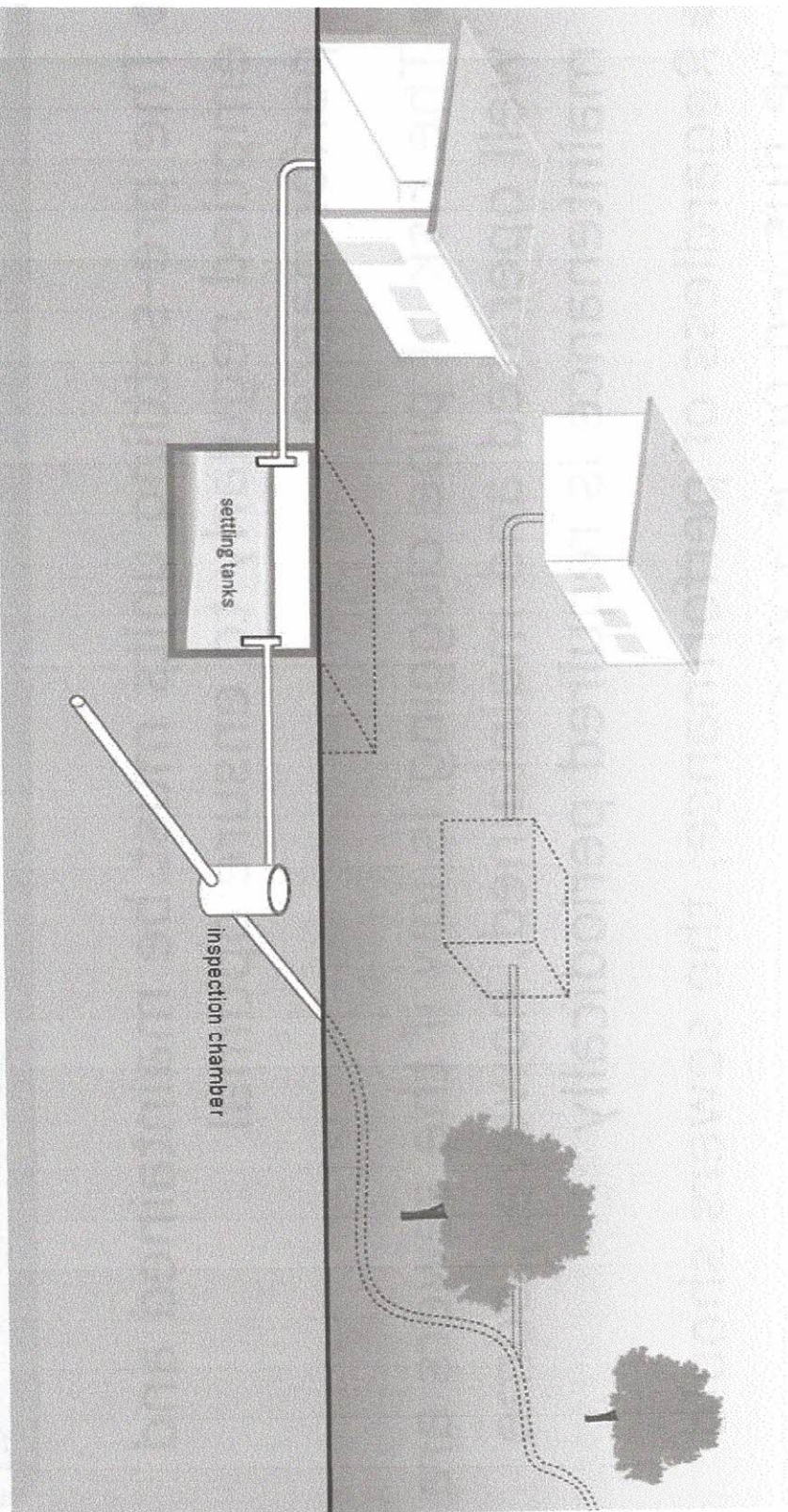
Solids-free Sewers

- ▶ These are similar to conventional sewer systems, except that the wastewater is pre-settled and solids removed before entering the system
- ▶ As solids are removed, sewer diameter can be much smaller and they can be constructed using less conservative design criteria (lower gradients, fewer pumps, less pipe depth, etc.) resulting in significantly lower investment costs
- ▶ Due to the simplified design, solids-free sewers can be built cheaper

Solids-free Sewers - design aspects

- ▶ A precondition is an efficient pre-treatment at the household level. The interceptors remove settleable particles that may clog the small pipes
- ▶ **If well used and maintained,**
 - there is little risk of clogging; hence, the sewers do not have to be self-cleansing and can be laid at shallow depths,
 - can have fewer inspection points (manholes),
 - can follow the topography more closely and can even have inflective gradients (i.e. negative slope)

Solids-free Sewers



Solids-free Sewers – Operation and Maintenance

- ▶ The pre-settling units must be maintained and emptied regularly to ensure optimal performance
- ▶ The risk of pipe clogging is low if the sewers are well operated and maintained, however, some maintenance is required periodically
- ▶ Regardless of performance, the sewers should be flushed once a year

38

Solids-free sewer – Applicability

- ▶ They are well suited for areas where soak pits are inappropriate due to sensitive groundwater or lack of space for on-site infiltration
- ▶ discharge of non-pre-settled wastewater into the sewers should be prevented
- ▶ require a constant supply of water, although less water is needed compared to conventional sewers

Solids-free sewer

30

Advantages

Can be built and repaired with locally available materials	Requires repairs and removals of blockages more frequently than a conventional sewer
Low operating costs if well maintained	Requires expert design and construction supervision
Can be extended as a community changes and grows	Requires education and acceptance to be used correctly
Appropriate for densely populated areas with sensitive groundwater or no space for a soak pit or leaching field	Effluent and sludge (from interceptors) requires secondary treatment and/or appropriate discharge

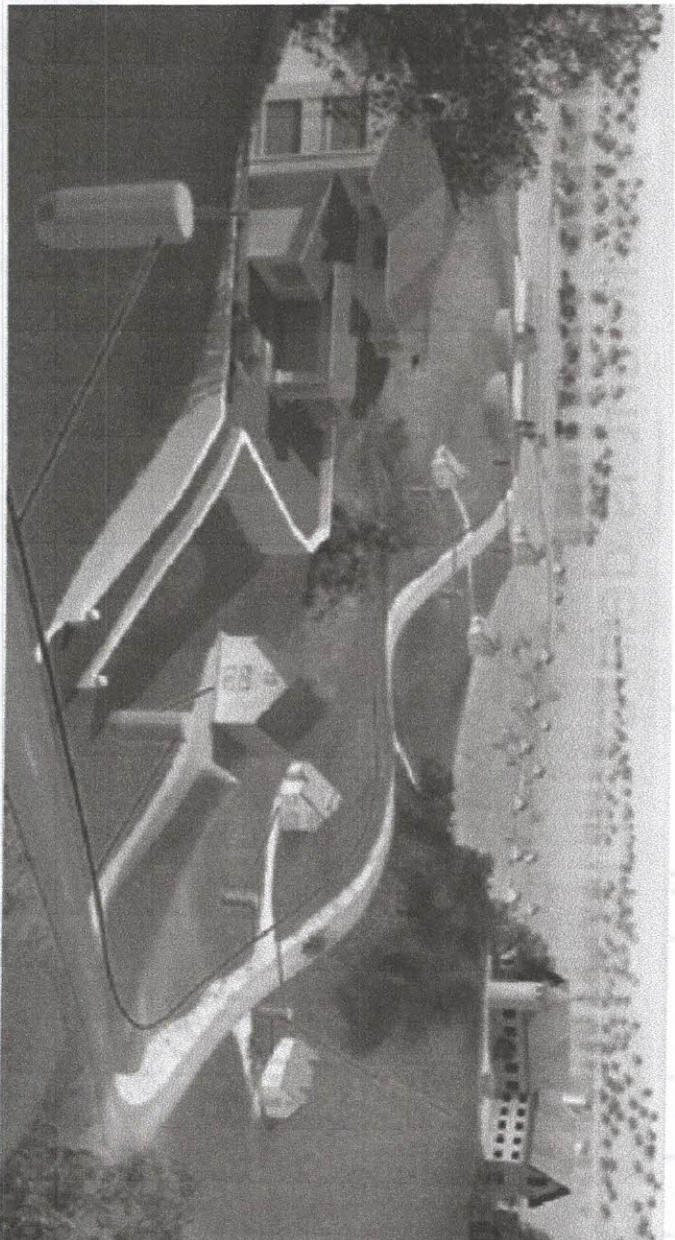
31

Pressurised Sewers

- ▶ Pressurised sewers differ from conventional gravity collection systems, because they use pumps instead of gravity to transport wastewater
- ▶ The primary effluent is delivered to the collection tank by gravity where it is grinded (pressed) before being transported into the pressurised system by pumps
- ▶ The system can be built with only shallow trenches and relatively small-diameter pipes

pressurised Sewers

- ▶ It is an effective solution where conventional systems are impractical such as in rocky, hilly or densely populated areas or areas with a high groundwater table



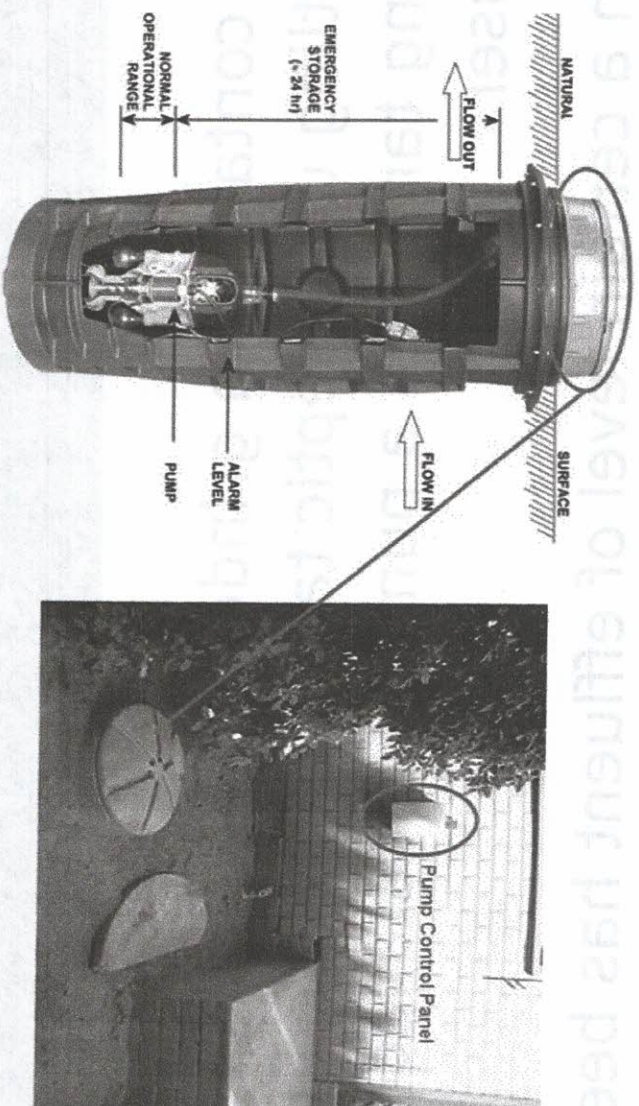
Pressurised Sewers - Working Principle

- ▶ A pit containing a grinder and pump or a settling unit (septic tank) connected to a holding tank with a pump are installed close to the user
- ▶ When a certain level of effluent has been collected, it is pumped into the sewer, generating the pressure for transportation

Pressurised Sewers – cost consideration

34

- ▶ High capital costs, but still lower than gravity sewer system
- ▶ The cost include the pump, basin, controls, electrical service, and installation



35

Pressurised Sewers – Operation and Maintenance

- ▶ All system components should be regularly serviced
- ▶ Electricity needs to be available all the time
- ▶ The pumps should be checked regularly and the pipe connections should be controlled for leakages
- ▶ Frequency of operation and maintenance depend on wastewater volume, relative risk to public health and the environment and the complexity of components used

pressurised Sewers – Applicability

- ▶ Flat topography: gravity systems demand installation at great depths to maintain adequate flow (and require pumping)
- ▶ Rock layers, running sand or a high groundwater table make deep excavation difficult
- ▶ Densely populated areas

Pressurised Sewers

Advantages

Effective wastewater transportation at minimum depth, minimising excavation for piping system	Needs expert design
Independent from land topography	Needs a permanent energy source for the grinder pumps
Less costs compared to a conventional gravity sewer	High capital costs
Requires little water only for transporting the excreta	Requires skilled engineers operators

Vacuum Sewers

- ▶ Vacuum sewer systems use a central vacuum source to convey sewage from individual households to a central collection station
- ▶ Vacuum sewers use differential air pressure (negative pressure) to move the sewage
- ▶ A central source of power to operate vacuum pumps is required to maintain vacuum (negative pressure) on the collection system

36

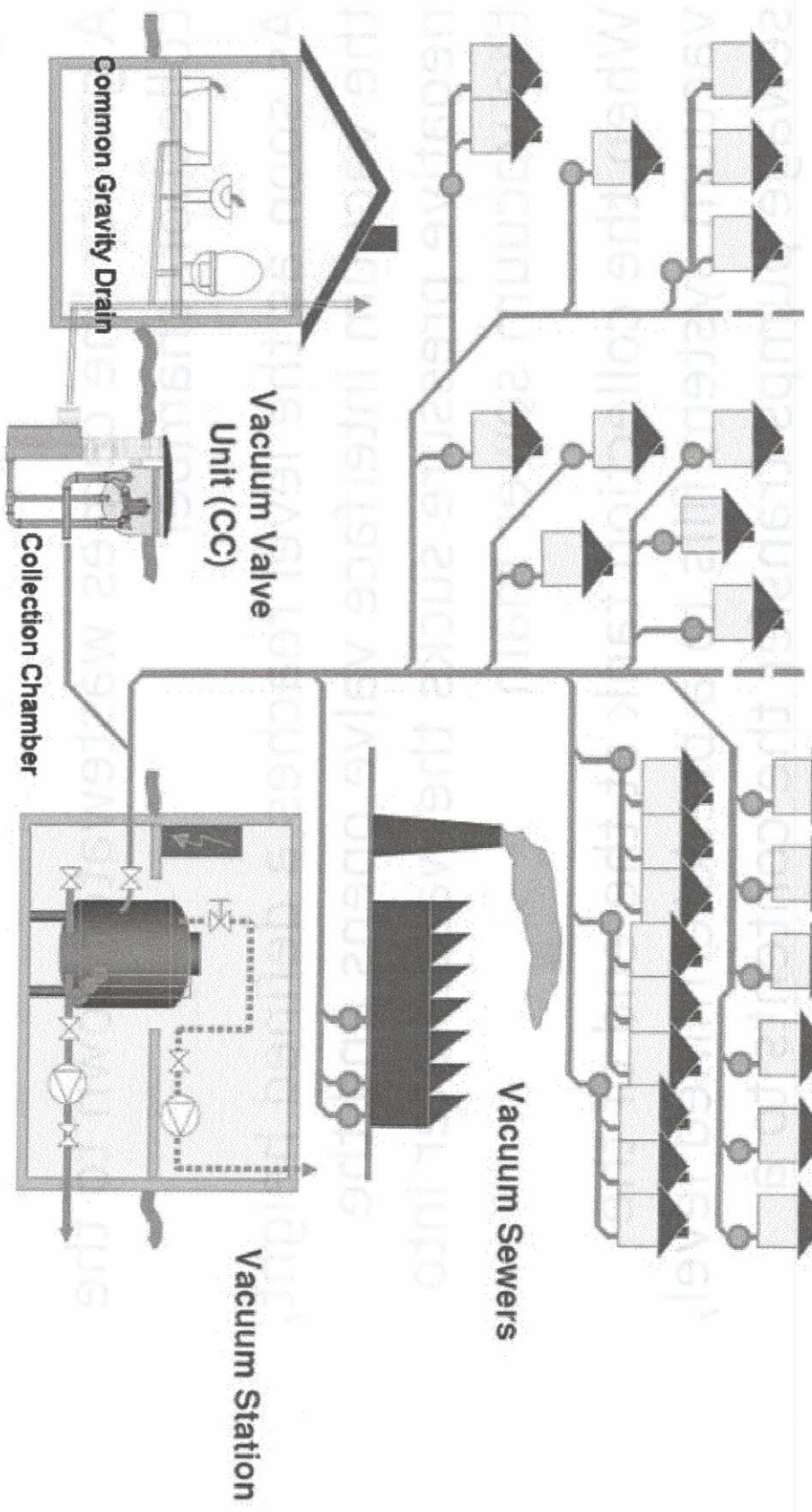
Vacuum Sewers

39

Vacuum Sewers – working principle

- ▶ A gravity line carries wastewater down to the collection chamber
- ▶ As soon as the level reaches a defined height, the vacuum interface valve opens and the negative pressure sucks the wastewater into the vacuum sewer main
- ▶ When the collection tank at the end of the vacuum system fills to a predetermined level, sewage pumps transfer the contents to a treatment plant via a conventional or separate sewer system

Vacuum Sewers



Vacuum Sewers - Working Principles

Vacuum Sewers - Costs Considerations

- ▶ As it is a high-tech system, it is costly, but cheaper than conventional sewer system
- ▶ Piping costs are lower (smaller dimensions) and pipe installation can be cheaper because piping is independent from the topography
- ▶ No heavy machinery is necessary to excavate deep trenches,
- ▶ Big amounts of flushing water can be saved
- ▶ The constant energy requirement for the permanent vacuum generation, however, can increase the costs

Vacuum Sewers - Operation and Maintenance

- ▶ The system needs instructed workers for maintenance and operation works
- ▶ Pressure in the vacuum sewer system should be tested from time to time
- ▶ The risk of clogging is low and there is almost no cleaning/emptying work to do

45

Vacuum Sewers - Costs

43

Vacuum Sewers - Applicability

► Suitable in

- areas where a collection is needed but other options are too costly or not feasible
- Flat topography: gravity systems demand installation at great depths to maintain adequate flow
- areas where rock layers or a high groundwater table make deep excavation difficult
- areas short of water supply necessary for operation of gravity systems
- areas with obstacles to a gravity sewer route

Vacuum Sewers

Advantages

Requires less water to transport the excreta	Needs expert design
Considerable savings in construction costs, and much shorter construction period	Needs energy to create the permanent vacuum
Pipelines laid in shallow and narrow trenches, Small diameter pipelines, flexible pipeline construction	High capital costs
Sewers and water mains can be laid in a common trench	Recycling of nutrients and energy becomes difficult
Closed systems with no leakage or smell	Unsuitability for self-help, requires <u>skilled engineers operators</u>
No manholes along the vacuum sewers	

Open Channels and Drains

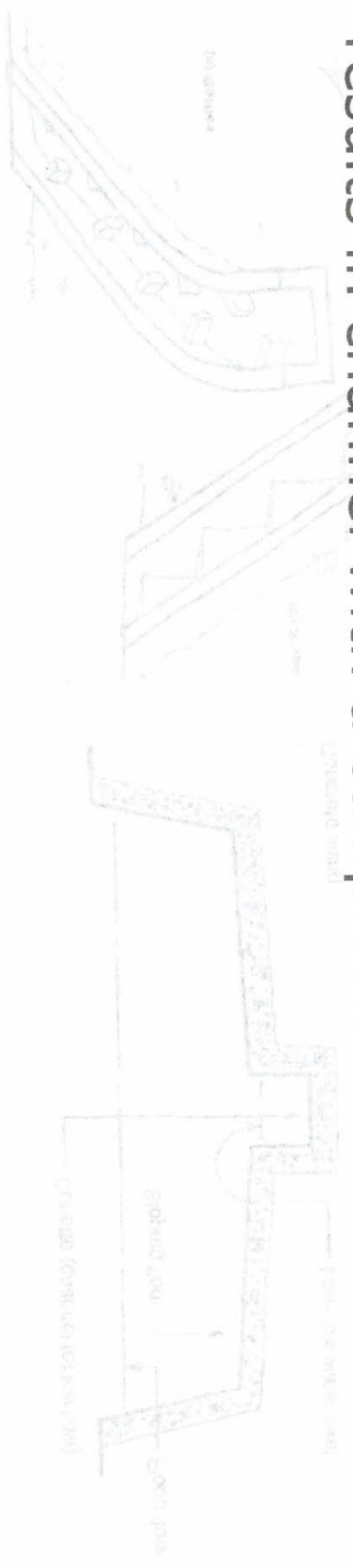
- ▶ An open channel is a conveyance in which water flows with a free surface
- ▶ Although closed conduits such as culverts and storm drains are open channels when flowing partially full, the term is generally applied to natural and improved watercourses, gutters, ditches, and channels

Open Channels and Drains – design principle

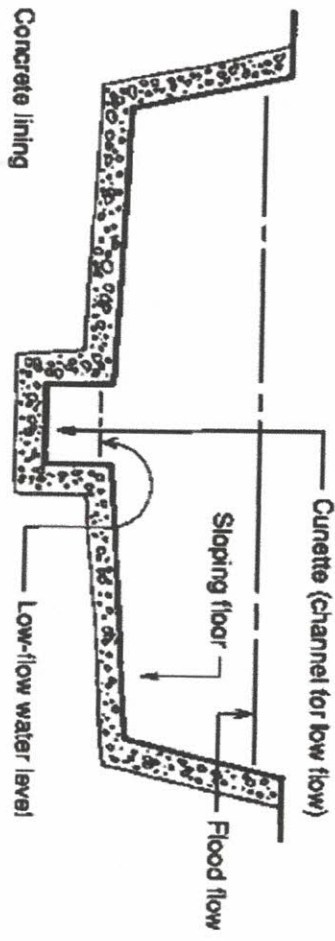
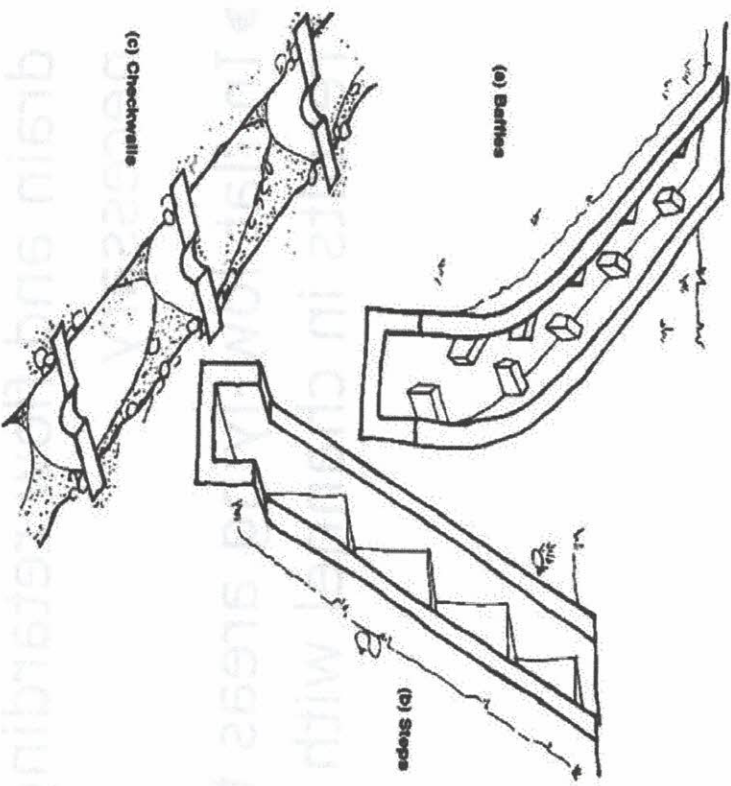
- ▶ An open channel or drain system generally consists of a secondary drainage system, with a network of small drains attached
- ▶ These small drains bring the water to a primary drainage system, composed of main drains (also called interceptor drains), which serve large areas
- ▶ The main drains are generally connected with natural drainage channels such as rivers or streams

Open Channels and Drains – design principle

- On steep terrain, erosion could damage the drain and flow retarding structures may be necessary
- In flat low-lying areas the limited slope may results in channel with a composite



Open Channels and Drains



channel with a composite section in flat low-lying areas

affiles, steps and check walls to atard flow in steep terrains

Open Channels and Drains - Cost Considerations

- ▶ Less expensive compared to underground sewer systems
- ▶ The cost depends on local conditions
 - in very steep terrain - extra construction to slow down the flow velocity and
 - in very flat areas or high groundwater table – wide excavation could raise the cost

Open Channels and Drains - Applicability

30

- Can be constructed in almost all types of settlements (urban or rural), but enough land area is required to build a reasonable construction
- Even though they offer simple solutions for stormwater drainage, they bear many risks for public health and the environment due to the risk of illegal discharge of wastewater and solid waste

51

Open Channels and Drains

Advantages	
Less expensive	High health risk due to illegal discharge of wastewaters and solid waste
Simple to construct	Breeding ground for insects and pests
Construction materials are often locally available	Regular cleaning service required to remove solids and blockages which usually causes spill-over and flooding

References

- ▶ Walski, T. M., and T. E. Barnard (2004), *Wastewater collection system modeling and design*, Haestad Press.
- ▶ <http://www.sswm.info>
- ▶ <http://www.cleanwateratlanta.org>