# Sewer systems

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## Schedule

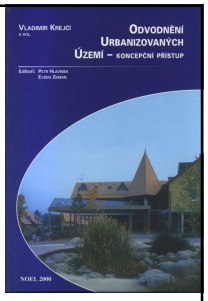
| Lecture | |
|---|---|
| Introduction, urban water management, urban drainage, drained waters, types of sewer systems, materials, structures | David |
| Wastewater + rainwater (flow + composition), design (rational method) + video Jochen Miller keynote ICUD2017 | Ivana |
| Rainfall monitoring | David |
| Discharge monitoring | David |
| Impacts - urban streams + Protective measures (tanks, SuDS, RTC…) | Ivana |
| **Field trip - Biomonitoring** | David |
| **Field trip – Sewer system** | David |
| Sustainable drainage systems (SuDS in detail) | David |
| Urbanization and phosphorus cycle | David |
| **Urban flooding** | invited |
| Innovative systems | Ivana |
| test | |

## Classification

- No special requirements regarding lessons attendance
- Correct answers 9 points
- We will add points from field trips and invited lecture to points from the test (1 point for each), i.e. maximum score is 12 points
- 11-12 points – classification A; 9-10 p. – classification B; 8 p. – classification C; 7 p. – classification D; 6 p. – classification E; less than 6 p. – test must be repeated

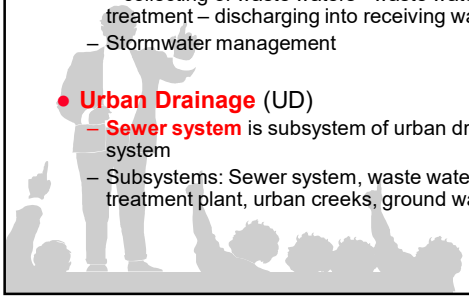
## Literature

- Vladimír Krejčí a kol. – Odvodnění urbanizovaných území – CTU library
- Willi Gujer – Siedlungswasserwirtschaft
- Willi Hager – Wastewater hydraulics
- David Butler a John Davies – Urban Drainage




## Terminology

- **Urban water management** (UWM)
  - Water resources – water treatment – water supply – collecting of waste waters - waste water treatment – discharging into receiving waters
  - Stormwater management
- **Urban Drainage** (UD)
  - **Sewer system** is subsystem of urban drainage system
  - Subsystems: Sewer system, waste water treatment plant, urban creeks, ground water



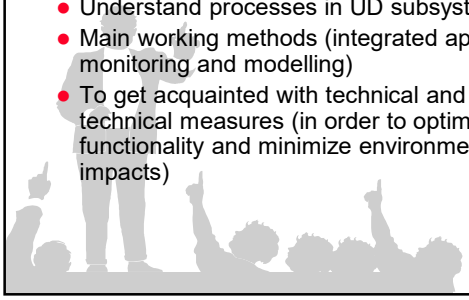
## Urban drainage

- Complex field of tasks
  - Hydrology
  - Hydraulics
  - Chemistry
  - Microbiology
  - Technology
  - Hydrogeology
  - Civil engineering
  - Economy and management
  - System engineering
  - etc.

## Urban drainage

**Goals of lessons:**

- To learn concept and context
- Understand processes in UD subsystems
- Main working methods (integrated approach, monitoring and modelling)
- To get acquainted with technical and non-technical measures (in order to optimize UD functionality and minimize environmental impacts)



## Introduction

- Urban drainage as part of Urban Water Management (UWM)
- Urban drainage: past – present - future
- Types of drained waters
- Types of sewer systems

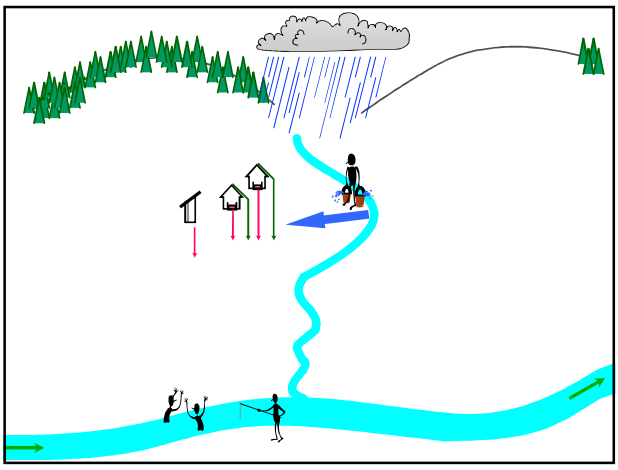
## Urban water management

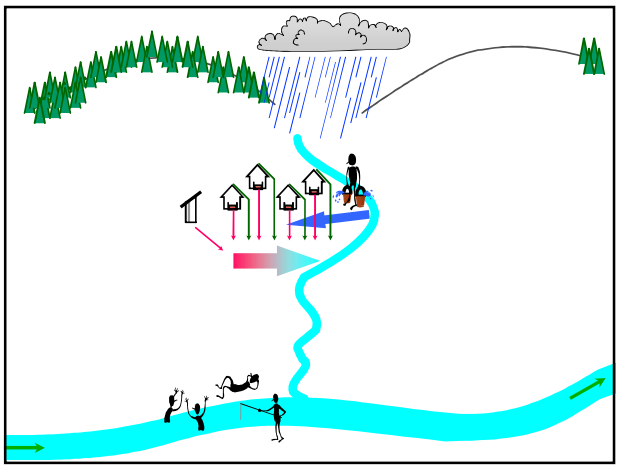
- Economical sector – ensures **services:**
  - Drinking water, hygiene
  - Process water for industry
  - Drainage, treatment of wastewaters
  - Flood protection and fire water
  - Recreation and landscaping in urbanized catchment
  - Climate change adaptation
- Uses **raw materials and sources:**
  - Water and substances in water
  - Construction materials
  - Chemical substances and energy
  - Environment as a donor and recipient
  - Capital, human resources

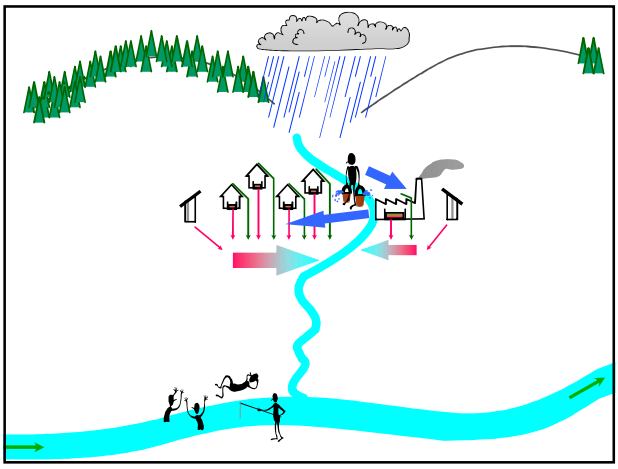
## Urban water management

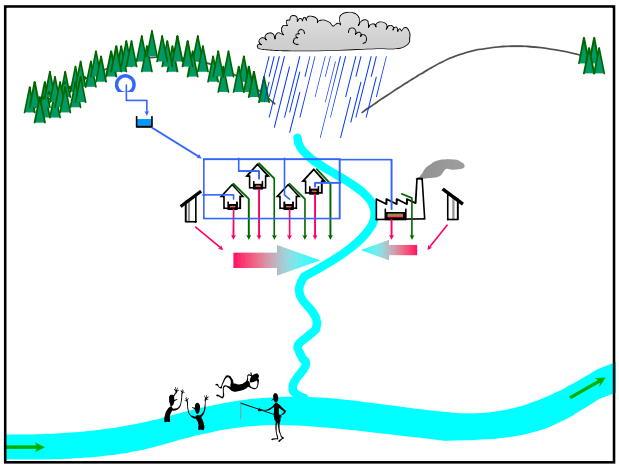
**Evolution:**

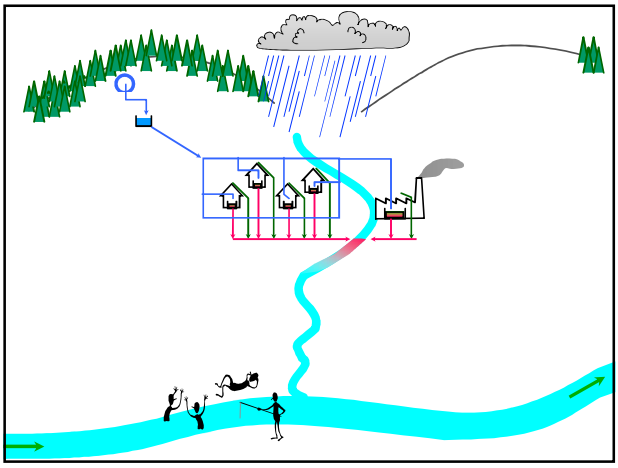
- Closely connected with urbanization

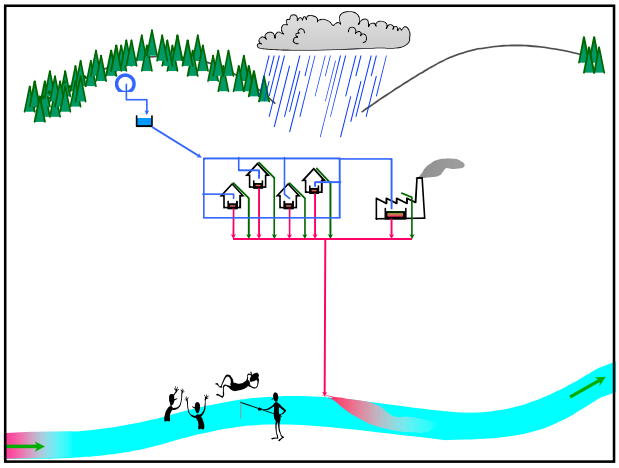


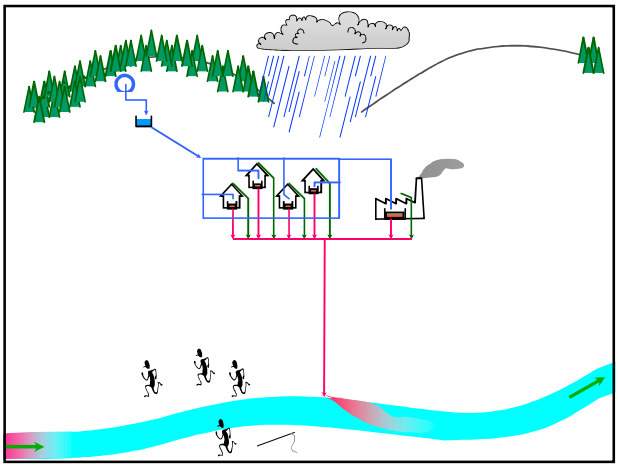


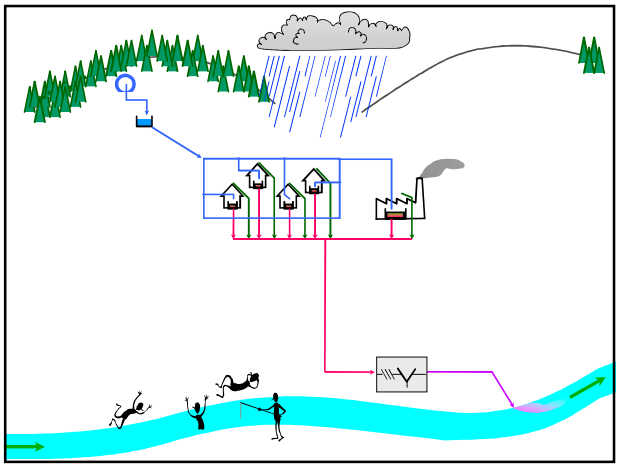


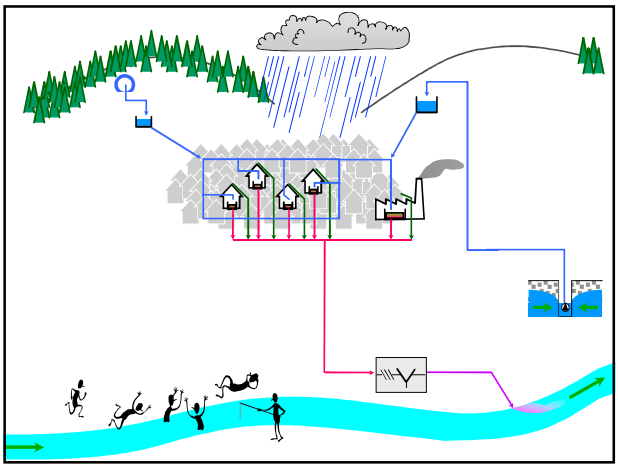


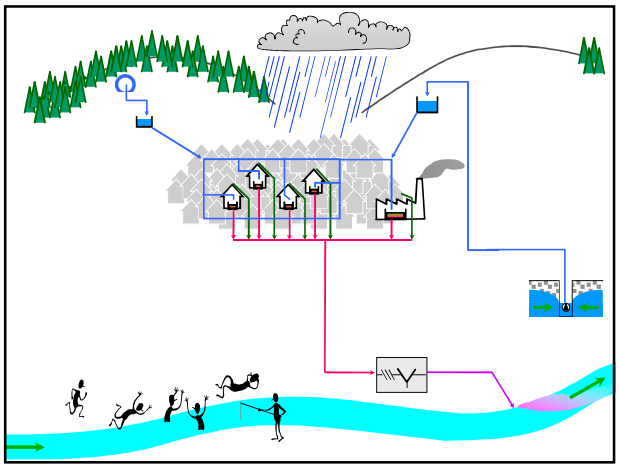


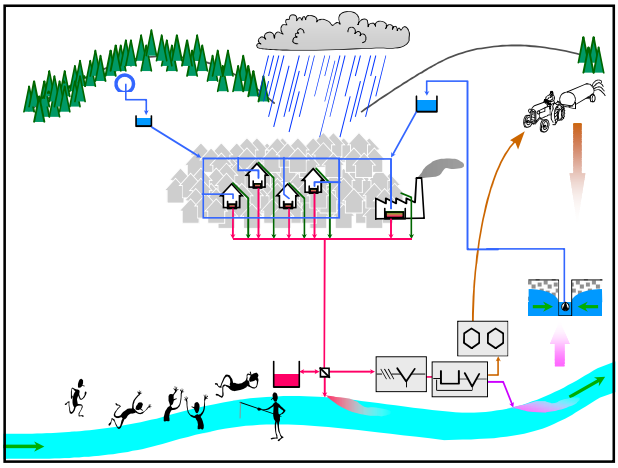


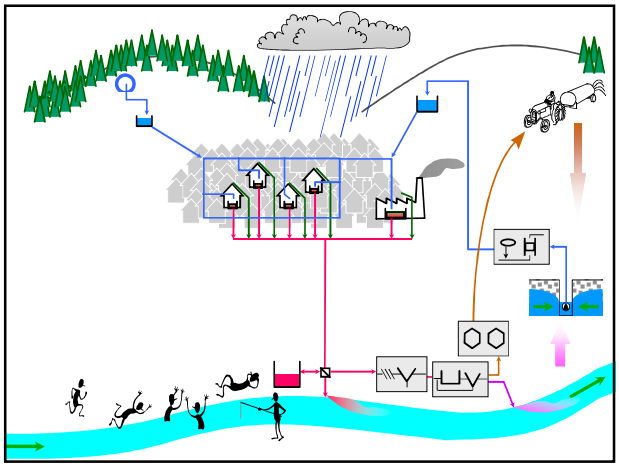


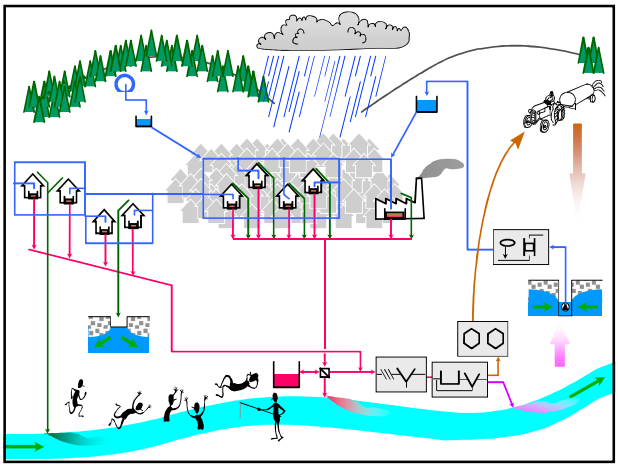


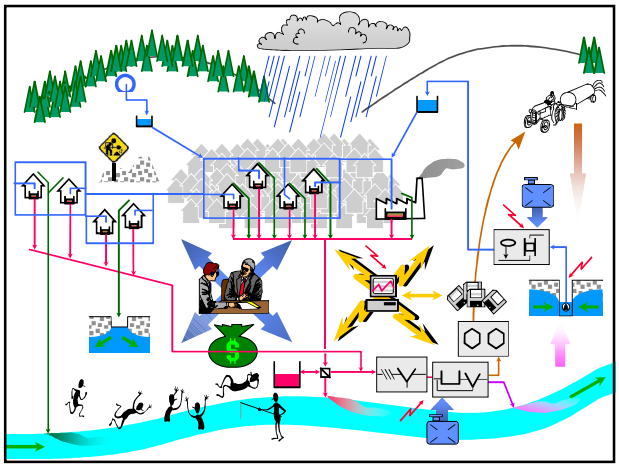












## Urban drainage

**Subject area definition:**

- Part of UWM
- origin, transport and treatment of wastewaters
- Wastewaters effect on surface waters and water sources
- Main elements: sewer system, WWTP, surface waters, ground waters, SuDS devices

## Urban drainage

**Purpose:**

- Inhabitants and area hygiene
- Protection of property against floods
- Surface waters– recreation and landscaping in urbanized catchment
- Protection of environment
- Climate change adaptation
- Living comfort

## Urban drainage

**Ensures the purpose by:**

- Technologies (high-tech)
- Natural based solutions (low-tech)

**Supported by:**

- Administrative tools (legislative, normative, procedural)
- Economical tools

## Urban drainage:

Compromise between conflicting interests

**Protection of people against nature !**

Hygiene, flood and drought protection

**Protection of nature angainst people!**

Surface waters and groundwaters protection, Protection of habitats and water related organisms

## New (emerging) UD concept

- **Opposite** of present definition of UD
- Drainage mimicking/maintaining **natural water regime** as it was before urbanization
- Decreased surface runoff volume, decreased speed of runoff
- **Higher protection** of surface and ground waters
- **Integrated approach to urban drainage**

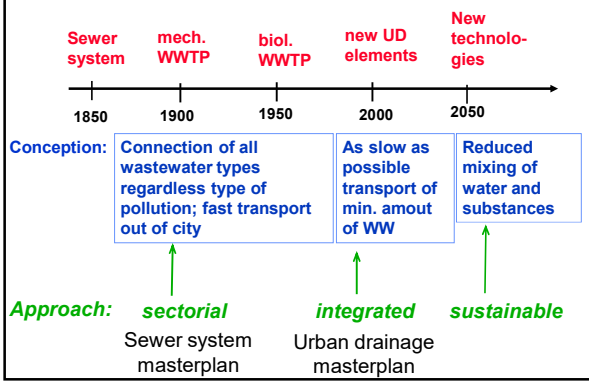
## Sectorial approach

- **Isolated assessment** of problems and processes in sewer system, WWTP, surface and ground waters
- **Emission strategy** (no concern of local conditions)
- Technical (esp. structural) measures to protect surface watres

## Integrated approach

- All technical and natural elements of UD assesed as a **one complex**
- **Imission strategy**, identification of problems in surface waters
- Structural and non-structural measures to protect surface waters

## UD concepts evolution




- Value of infrastructure (2,500 inhab. community)

| Infrastructure type | Value in Mio EUR | % of entire infrastructure value |
|---|---|---|
| Public (town hall, fire department,…) | 6 | 7 |
| Schools, incl. gym | 10 | 12 |
| Culture, sport (concert hall, football field,…) | 5 | 6 |
| Retirement house | 4 | 5 |
| Public streets | 10 | 12 |
| Water supply | 21 | 25 |
| Urban drainage | 28 | 33 |

## Drained waters

a. Sewage
b. Storm waters
c. Industrial waste waters
d. Infectious waters
e. Wet sweeping waters
f. Infiltration/Inflow

## Drained waters

### a. SEWAGE

BROWN WATER
YELLOW WATER
GREY WATER

- From kitchens, bathrooms, laundries, toilets
- From public buildings and amenities, social and cultural amenities, eateries etc.

- Coarse, fine, colloid and dissolved substances
- Organic character
- hourly, diurnal and seasonal dynamics
  *(not so large compared to storm waters)*

## Drained waters

### a. SEWAGE

- From kitchens, bathrooms, laundries, toilets
- From public buildings and amenities, social and cultural amenities, eateri

- Coarse, fine, coll
- Organic characte
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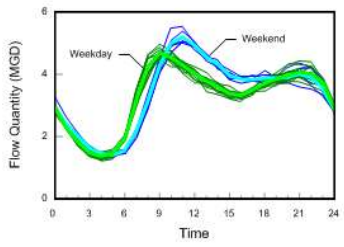
  *(however not so*




## Drained waters

### b. STORM WATERS

- From atmospheric precipitation, that creates surface runoff

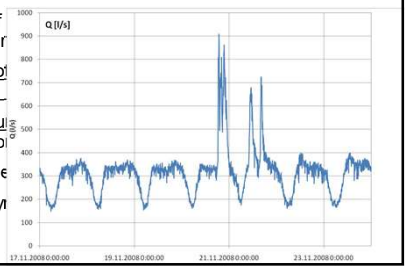
- Wash-off of organic and inorganic pollution from urbanized surfaces
- Polluted runoff from: heavy traffic areas, industrial areas, truck parking lots etc.
- Unpolluted runoff from: non-metal roofs, low traffic areas, pedestrian zones, green areas, terraces etc.
- Significant dynamics

## Drained waters

### b. STORM WATERS

- From atmospheric precipitation, that creates surface runoff

- Wash-off of urbanized sur
- Polluted runot truck parking
- Unpolluted ru pedestrian zo
- First flush phe
- Significant dy




## Drained waters

### c. INDUSTRIAL

- From production process (incl. small producers)
- From agricultural production

- Pollution cannot exceed limits defined by authority
- Otherwise must be pre-treated prior to discharge to public sewer system

## Drained waters

### d. INFECTIOUS

- from hospitals, TBC sanatoria, microbiological labs, vaccination industry etc.

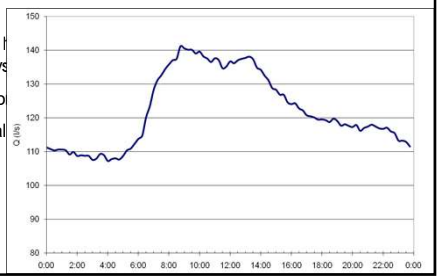
- Must be hygienically safe before discharge to public sewer system
- Special pre-treatment technologies in hospitals
- Individual dynamics

## Drained waters

### d. INFECIOUS

- from hospitals, TBC sanatoria, microbiological labs, vaccination industry etc.

- Must be h sewer sys
- Special p
- Individual




## Drained waters

### e. WET SWEEPING

- Water used for sweeping of streets, walkaways, parking lots etc.

- Pollution similar to storm waters
- Dynamics similar to runoff from low-intensity rainfalls

## Drained waters

### f. INFILTRATION/INFLOW

- Unpolluted waters (cooling w., ground w., springs; clean storm water)

Why is I/I important?

↓ Sewer system hydraulic capacity
↑ Combined sewer overflows
↑ Pumping costs
↑ WWTP hydraulic load
↓ Temperature
↓ Pollution concentration and treatment efficiency

## Drained waters

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- Unpolluted waters (cooling w., ground w., springs; clean storm water)

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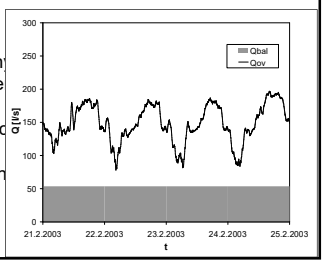



## Drained waters

### WHAT SHOULN´T BE DISCHARGED

1. Dangerous substances, e.g. mercury, cyanides, metaloids …
2. Radioactive substances
3. Infectious, carcinogenic, mutagenic etc. Substances
4. Poisons, explosives, caustics
5. Pesticides, biocides and their derivates
6. Narcotics
7. Flamable substances
8. Biologically stable tenzides
9. Organic solvents
10. Persistent mineral oils and motor, hydraulic etc. oils
11. Anorganické P compounds
12. Solid waste from kitchens (shredders), oils
13. Used covers/bottles of dangerous substances
14. Etc.

## Sewer system types

Two basic types of sewer systems

a. Combined sewer system
b. Separate sewer system
   - Separate sanitary (foul) sewer system
   - Separate storm water sewer system

## Sewer system types

### a. COMBINED SEWER SYSTEM

- All types of drained waters together
- Pipes must be underground
- Prevailing type – technical benefits
- Disadvantages - hygienic and environmental unfriendly
  - **Combined sewer overflows (CSO) – waste water discharged into environment without treatment**

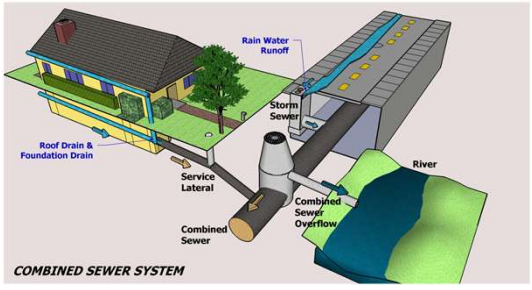
## Sewer system types

### a. COMBINED SEWER SYSTEM

- Annual volume of sewage (24/7) >> annual volume of storm waters (5-8% of year)
- Peak discharge of sewage << peak discharge of storm waters
- Designed to storm water flow
- Dry weather flow taken into account only when it is more than 10% of wet weather design flow

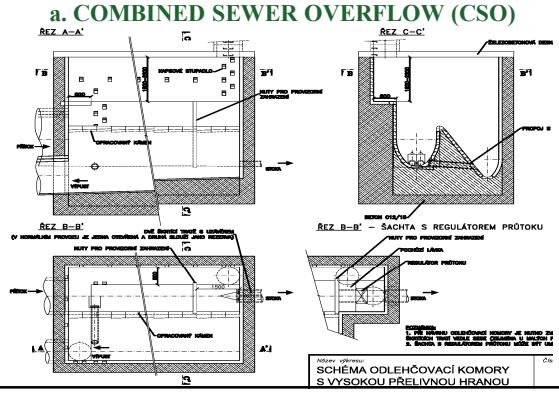
## Sewer system types

### a. COMBINED SEWER SYSTEM



## Sewer system types

### a. COMBINED SEWER OVERFLOW (CSO)




## Sewer system types

### a. COMBINED SEWER OVERFLOW (CSO)

## Sewer system types

### a. COMBINED SEWER SYSTEM

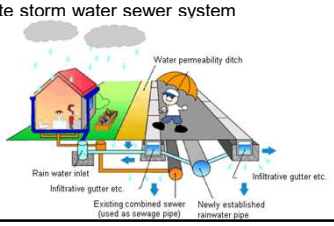
- Increased flow during storm runoff = overflow of water to receiving waters
- Even there is often high dilution of sewage by storm water, faecal pollution is discharged
- CSO – source of toxic and hydraulic stress
  → affects water communities of organisms
- turbidity, organic substances, temperature
  → impacts on natural self-treating processes in rivers

## Sewer system types

### b. SEPARATE SEWER SYSTEM

- Storm water separated from the rest
- Usually two independent sewer systems

- Separate sanitary (foul) sewer system
- Separate storm water sewer system




## Sewer system types

### b. SEPARATE SYSTEM - SANITARY

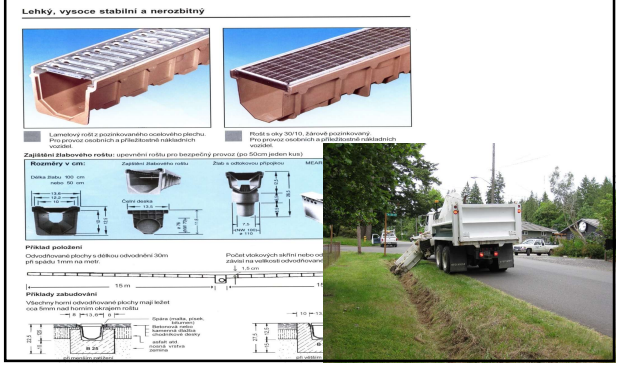
- Sewers must be underground
- Small diameter pipes
- Flow dynamics is not so violent = no CSO needed

### b. SEPARATE SYSTEM – STORM WATER

- Underground sewer or surface ditches
- Larger diameters than sanitary sewers
- Discharged to receiving water, usually no treatment is needed, retention to mitigate peak flows can be applied

## Sewer system types

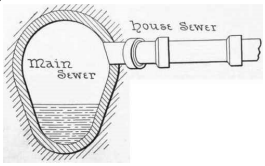
### b. SEPARATE SYSTEM – STORM WATER



## Waste water trasport

Transported by:

a. Gravity systems
b. Pressure systems
c. Vacuum systems
d. Pneumatic systems




## Waste water trasport

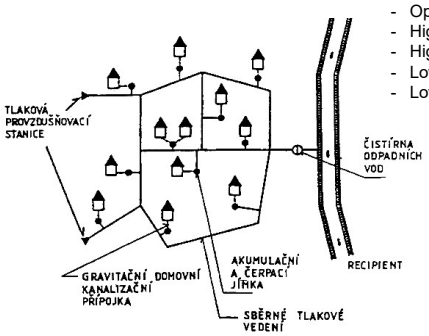
### a. GRAVITY SYSTEMS

- Most common way of transport
- Free surface flow
- Slope of sewers critical
- advantages: technically easy,
  low energy demands
  low failure rate
- disadvantages: when combined sewers – environmental risks
  less suitable in flat terrain

## Waste water trasport

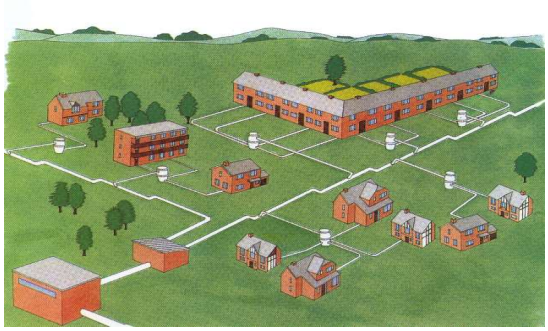
### b. PRESSURE SYSTEMS

- Optimal in flat terrain
- Higher failure rate
- Higher operational costs
- Lower investments
- Low I/I rate



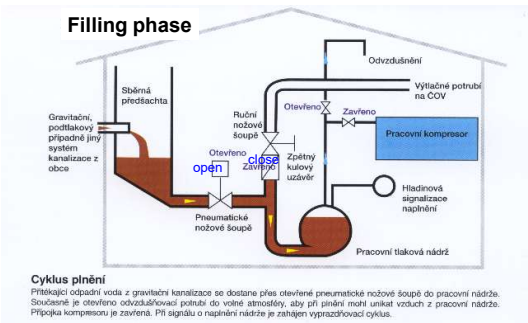

## Waste water trasport

### c. VACUUM SYSTEMS



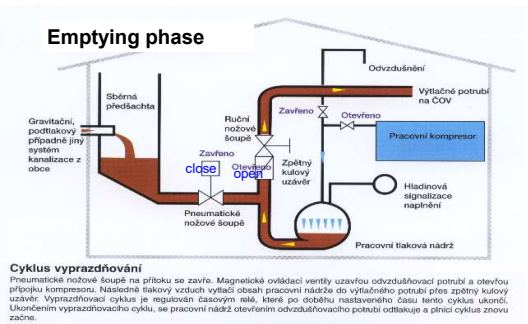
## Waste water trasport

### d. PNEUMATIC SYSTEMS




## Waste water trasport

### d. PNEUMATIC SYSTEMS

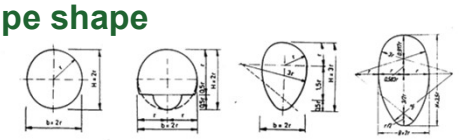


## Waste water trasport

a. Pressure systems
b. Vacuum systems
c. Pneumatic systems

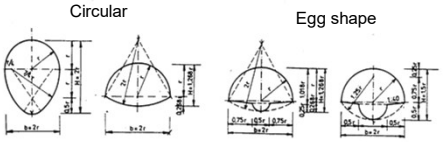
| Advantages | Disadvantages |
|---|---|
| Effective wastewater transportation at minimum depth, minimising excavation for piping system | Needs expert design |
| Independent from land topography | Needs a permanent energy source for the grinder pumps |
| Less costs compared to a conventional gravity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

## Pipe shape



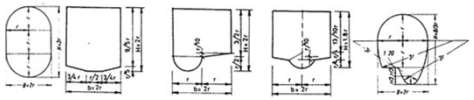
Circular

Egg shape



Parabolic

Other



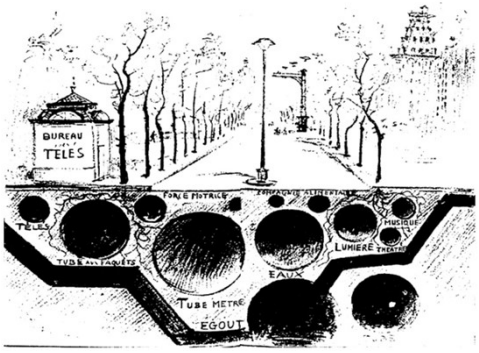
## Sewer pipe materials

- concrete or reinforced concrete,
- PE, PVC
- stoneware
- brickwork
- basalt
- cast iron
- glass-fiber

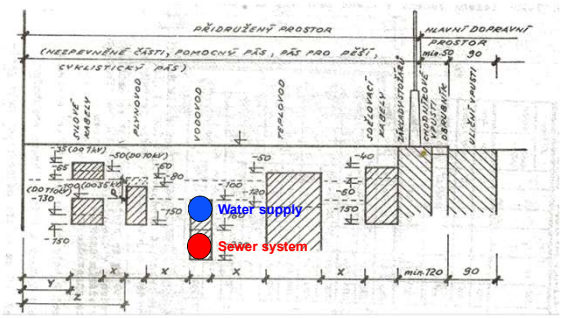
## Sewer pipe slopes

- **Maximal water velocities**
  - risk of pipe damage
  - $v_{max}$ up to 5 m/sec generally
  - $v_{max}$ up to 10 m/sec for resilient materials
  - $v_{max}$ up to 3 m/sec – concrete and reinforces concrete
- **Minimal water velocities**
  - risk of sedimentation
  - Shear stress ( $\tau > 4$ Pa)
  - Minimal transport velocities ( $v_t = 0,75$ m/sec)
- **Minimal slopes**
  - At least 0.1-0.2% for D > 1.5 m
  - At least 1.5-2.0% for DN < 0.3 m

## Disposition

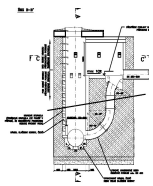


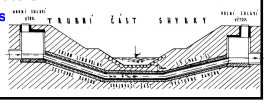

## Disposition



## Sewer system structures

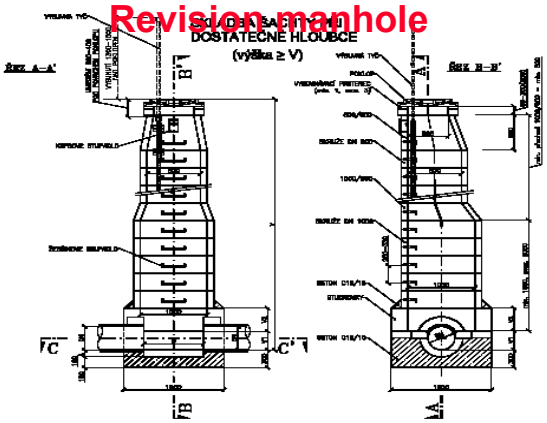
- Revision manholes
- Confluence chambers
- Diversion chambers
- Vertical drop chambers
- Spillways
- Street gutters
- Sedimentation basins
- Household connections
- Inverted syphon
- Wash-out structures
- Outlets anf backwater flaps
- Pumping stations
- Combined sewer overflows
- Vortex separators
- Stormwater tanks
- Snow inlets
- Mountain inlets
- Decentralized devices



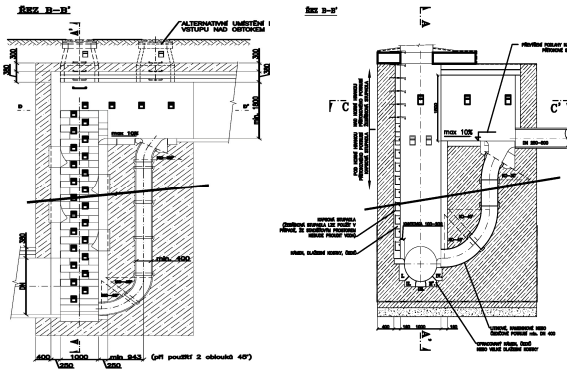



## Revision manhole

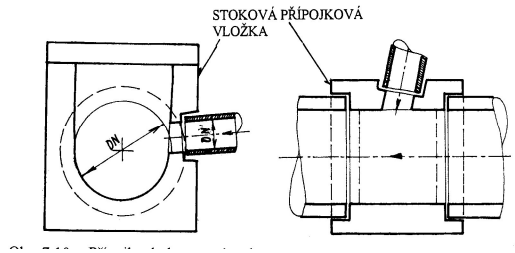
## Revision manhole




## Vertical drop



## Household connection




## Inverted syphon