PUBLIC WORKS

LECTURE NOTES AND PRACTICAL MANUAL

Knolmár Marcell – Fülöp Roland – Darabos Péter

Department of Sanitary and Environmental Engineering

Budapest University of Technology and Economics

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LECTURE NOTES

1. DEFINITION OF PUBLIC WORKS

Infrastructure:

In economic point of view it is a generic noun for economic conditions (road network, transportation, public works, public education etc.) which are not participating directly in the economic production process, but they have indirect influence on the quality and the potential of the production development. The level of infrastructure means the general conditions of the economic (mainly industrial) growth in a region or a country:

- Transportation
- Public works

Public Works:

All the facilities and the organizations performing supplier activities in order to satisfy the continuous or temporary demands of the communal and other consumers.

1.1. Main Features of Public Works

- They are working based on their own facilities (e.g. production plants, networks) or connecting to network systems.
- Consumption is following a temporal curve (trend), therefore these systems should be designed and built to a much more capacity than the average consumption.
- It should be operated continuously, even if in a certain moment or for a longer time there would be no consumption. This is called continuous accessibility.
- At the establishment of public works the technical possibility of the satisfaction of future demands should be created.
- Extra resources should be built into the system because of the accidental failures, breakdowns.
- A consumers are mainly connected directly only with the network or the part of the network.
- The distribution networks are usually located on public areas.
- Some public services are monopolistic within a settlement or within a part of the settlement.

1.2. Grouping of Public Works

Based on sector type

- Water resources
  - water supply
  - sewerage
- Energy
  - gas
  - electricity supply
  - district-heating
- Telecommunication

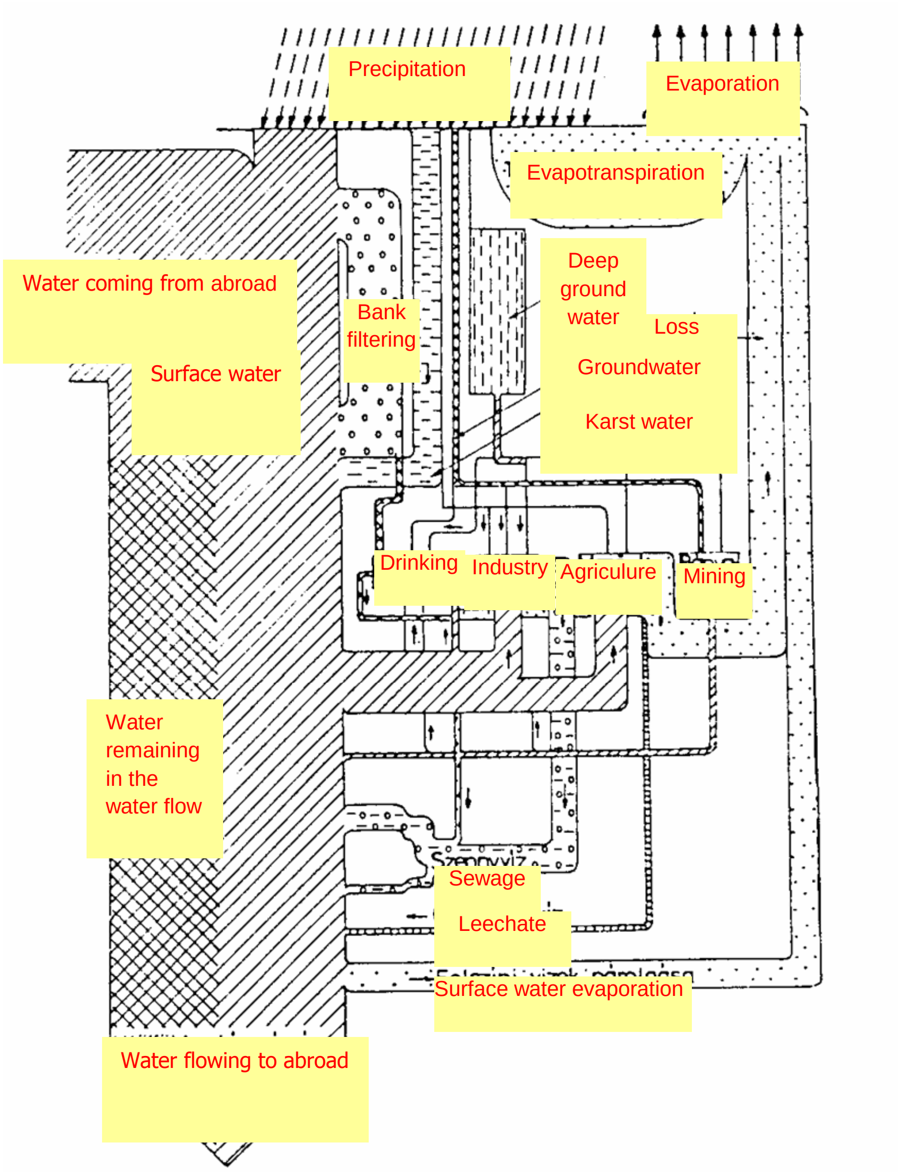
    - telephone
    - cable TV systems
- Other public work-like systems
    - product conduits (thermal water)
    - traffic light cables of public roads
    - cables for public road transportation
    - cables for train transportation

Based on their location

- Settlement size small networks
    - District heating, public transportation, traffic light cables of public roads, cable TV
- Regional
    - Water supply, sewer system
- Country-wide
    - gas, electricity supply
- Continental
    - gas, electricity supply
- Global
    - Telecommunication

2. WATER AND WASTEWATER ENGINEERING

- Water networks and sewer networks provide the controlled recycle between the settlements and their environment. Water and wastewater engineering is dealing with this recycle, ie. the transportation of the water and the transported particles (contaminations).
- Water and wastewater engineering means therefore not only the technical establishments for the water recycle of the settlements, but all the technical, scientific, economic and administrative activities focusing the compromise between the natural water balance and the demands of the settlements (i.e. us, the population) and the requirements regarding the environmental protection.



Recycle between the settlements and the nature

(the width of arrows proportional to the quantity)

2.1. Water Recycle in Settlements

Processes of the water recycle:

- Closed cycle process:
  - Water supply system
  - Wastewater canalization and treatment system
- Open system:
  - Storm water canalization

A part of the precipitation is evaporating and the vegetation is consuming, the rest flows with the runoff or with the groundwater flow into the receiving water or into deeper strata.

The two parts of the water recycle are connected closely to each other (e.g. storm water flowing into wastewater canal, wastewater desiccation).

2.2. Basic Technical Parameters of Water Public Works

- Water supply system
  - quantity,
  - quality,
  - energy content (pressure).

- Sewer system
  - quantity,
  - quality
    - in the canal,
    - In the receiving water,
  - Energy content (mainly thermal and chemical energy bound in organic matters).

3. WATER RESOURCE

3.1. Definition

- In the literal sense the water acquisition establishments of the water supply network
- In the full sense a natural formation including the demand satisfying water resource and the environment around the water resource.

3.2. Parts of the water resource

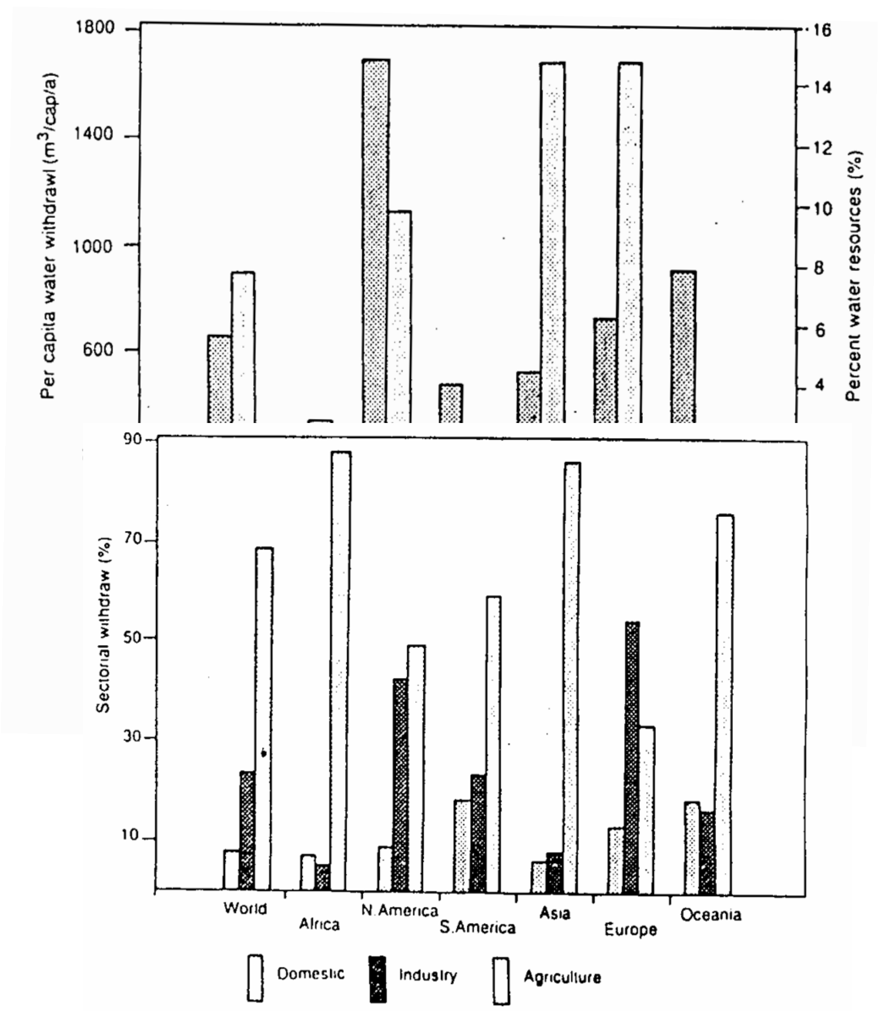
- **Static resource:** quantity, which is continuously (for decades or for centuries) present on the given area at the surface or below the surface, but not (or hardly) participating in the water cycle.
- **Dynamic resource:** those part of the full water resource, which is participating in the hydrological cycle, i.e. in a manageable time (regarding the water resource management) is renewing, can be substituted.

Only the dynamic resource can be used for continuous purpose (as a resource for consumption) for a long time!

4. WATER CONSUMPTION

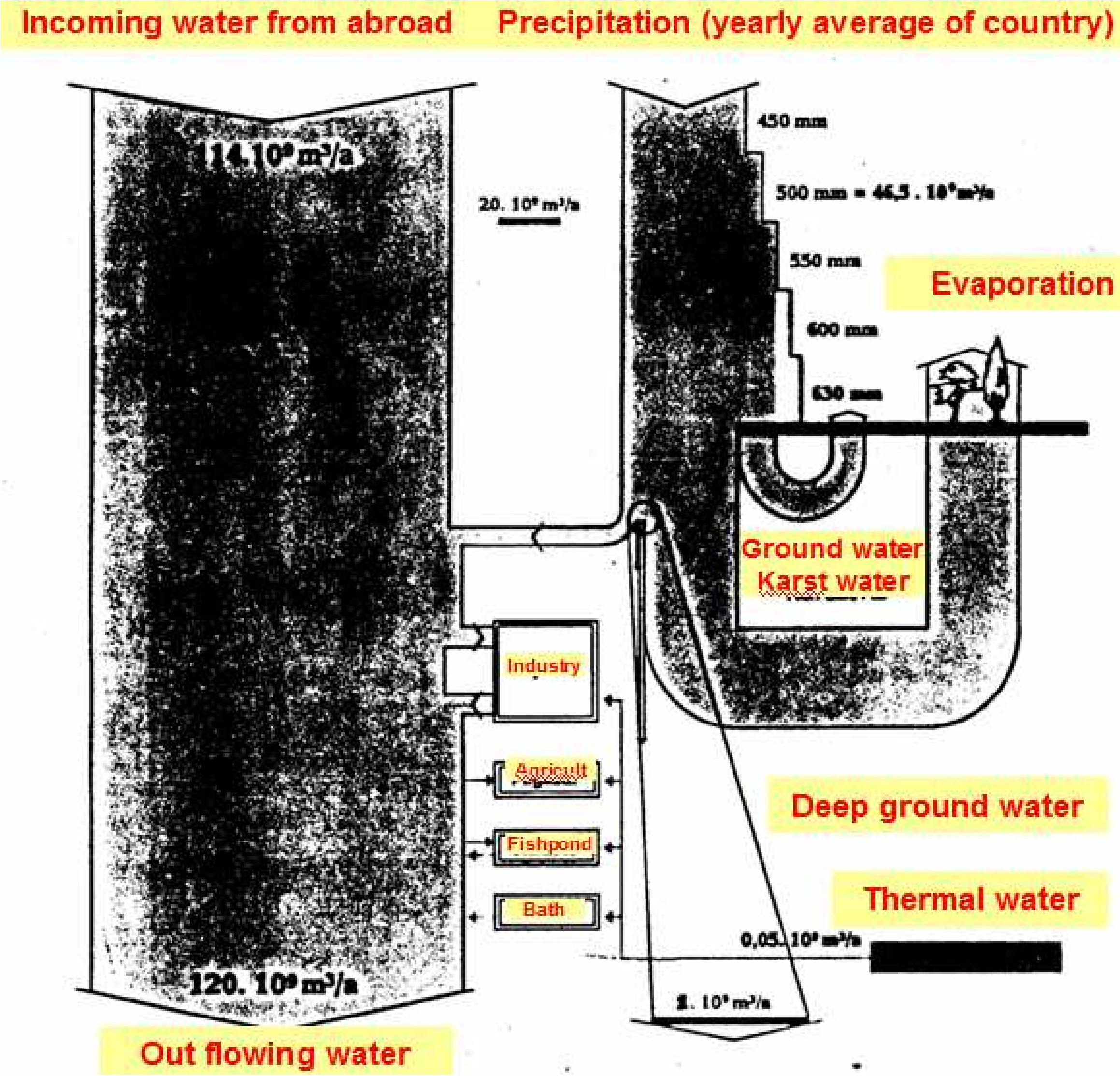
Main types of water consumption:

- Communal (domestic usage and basic public institutions)
- Agricultural (irrigation, fishponds, etc.)
- Industrial

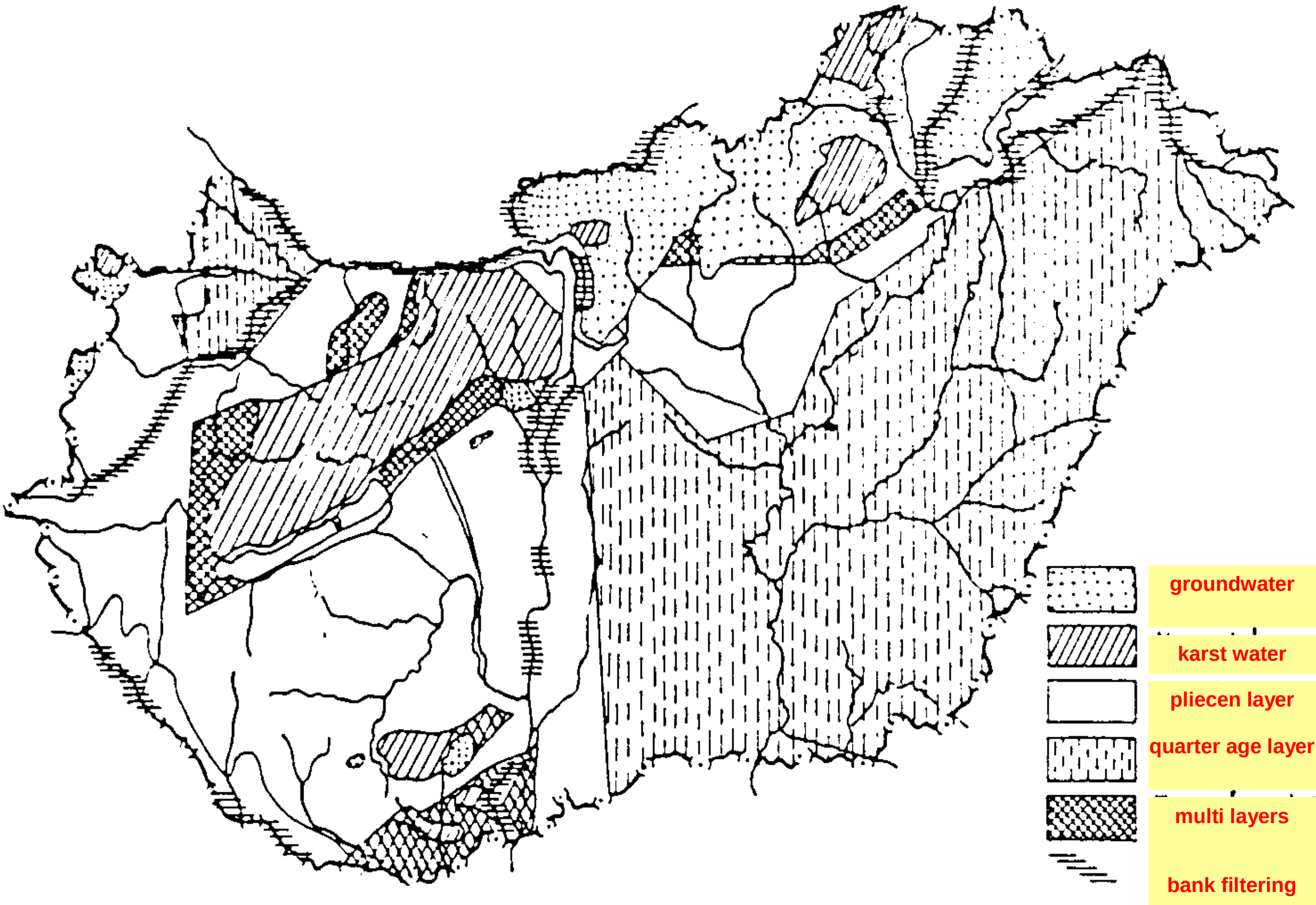


'e 2 *Sectoral use of water resources: domestic, industry and agriculture as a percentage of total withdrawal*

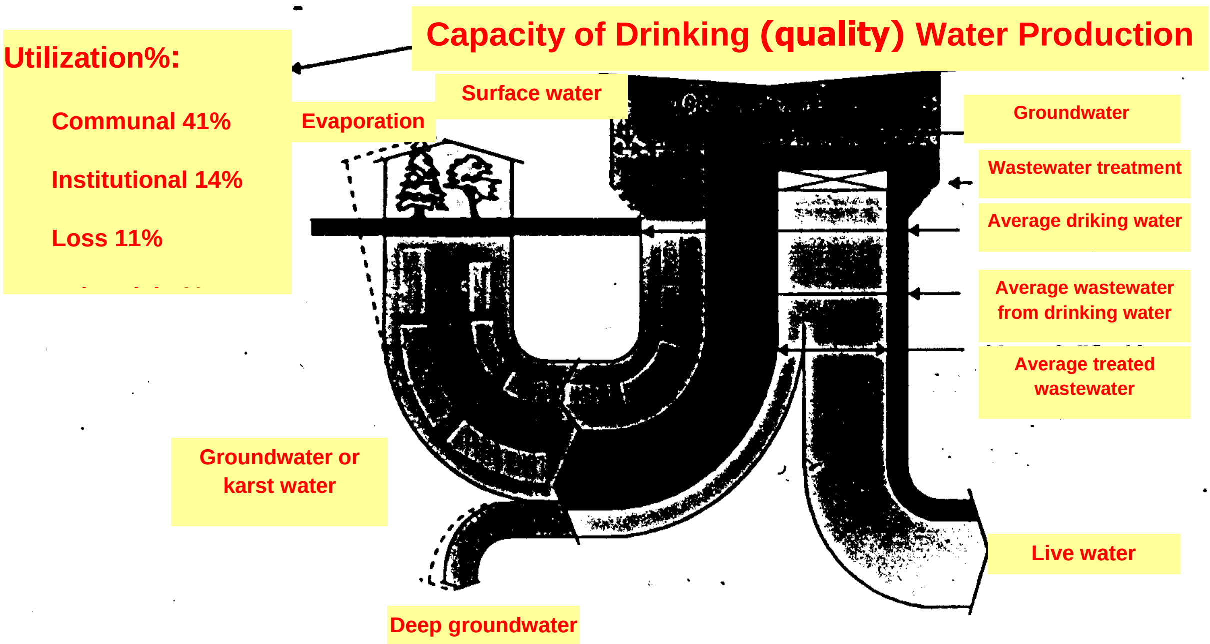
4.1. Water Consumption of a Country (Hungary)



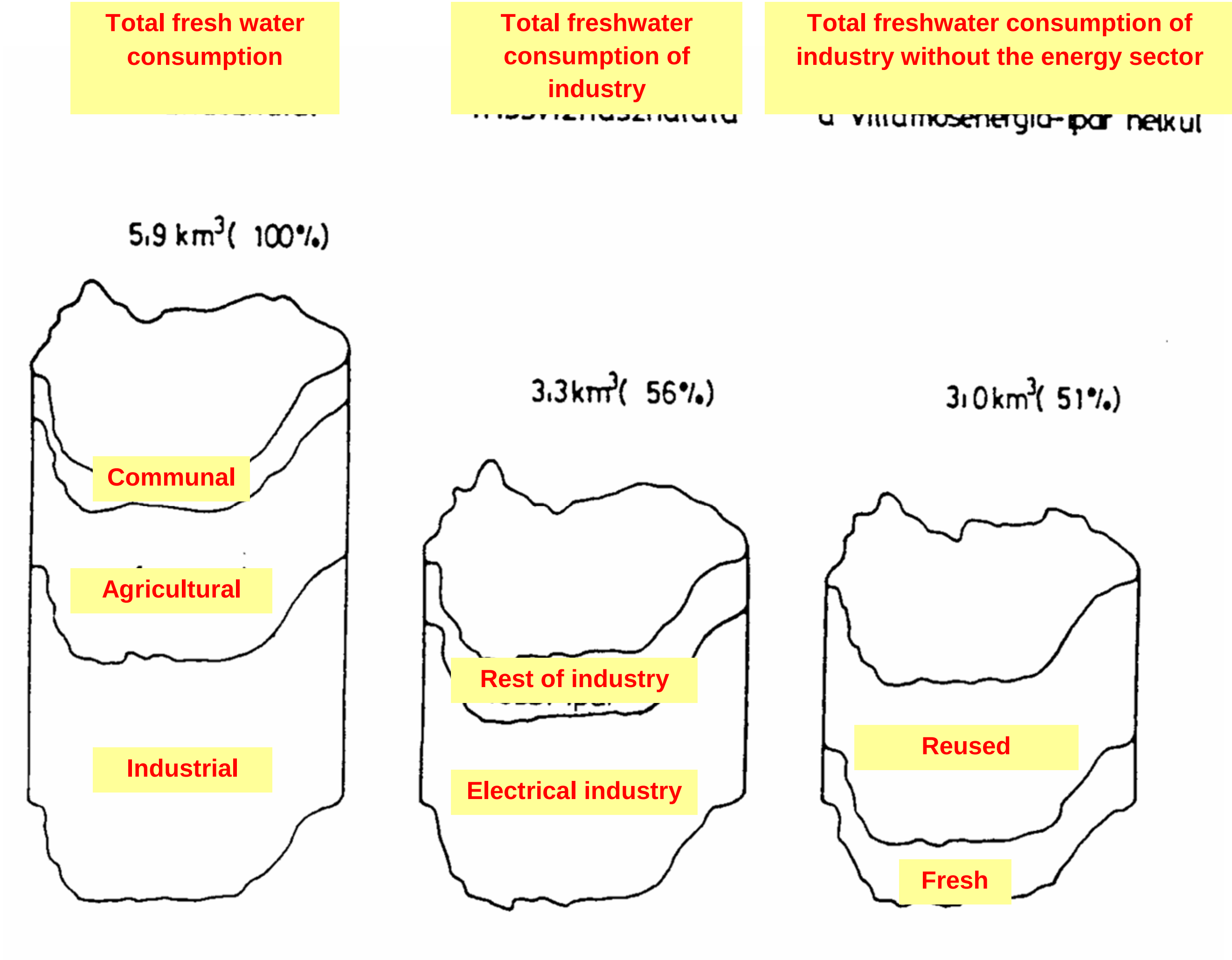
4.2. Main Water Resource Types in Hungary



4.3. Underground Water Resources in Hungary



4.4. Utilization of Water Resources in Hungary



4.5. Protection of Water Resources

- Protection systems should be established in order to protect the water quality of the water acquisition areas for water supply.
- The protection system includes protection areas having triple structure:
  - Internal protection area,
  - External protection area,
  - Hydrological protection area.
- Indicating the borders not only on the surface, but also below the surface, it is called protective form.
- In these areas the human activities resulting in contamination are limited, the extent depends on the type of protection areas.

■

4.6. Consumers in Settlements

- Domestic consumers
- Large consumers (public institutions eg. hotel, restaurant, hospital).
- Industrial factories
  - social water demand required for the workers for theirs work,
  - and the technological water demand required for the production.

4.7. Supply Level (Comfort Zones)

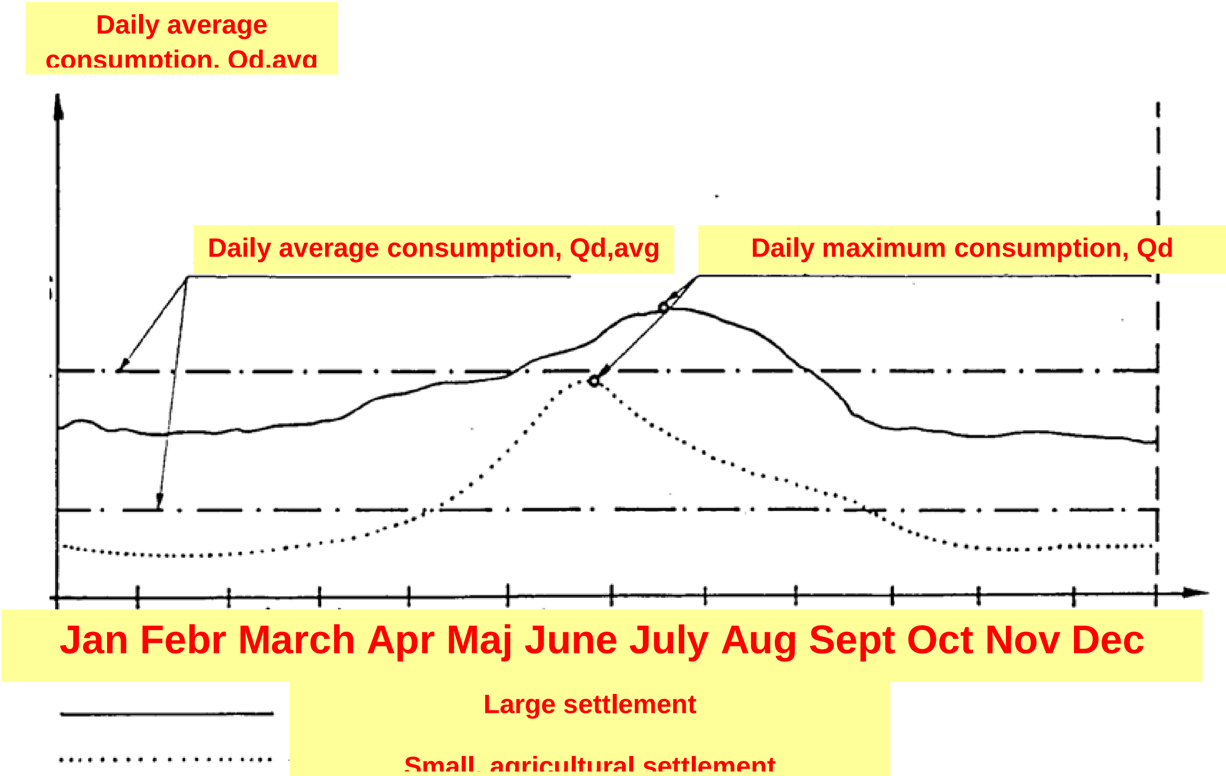
- street fountain
- half comfort
  (one tap in one flat)

- comfort
  (more tap in one flat)

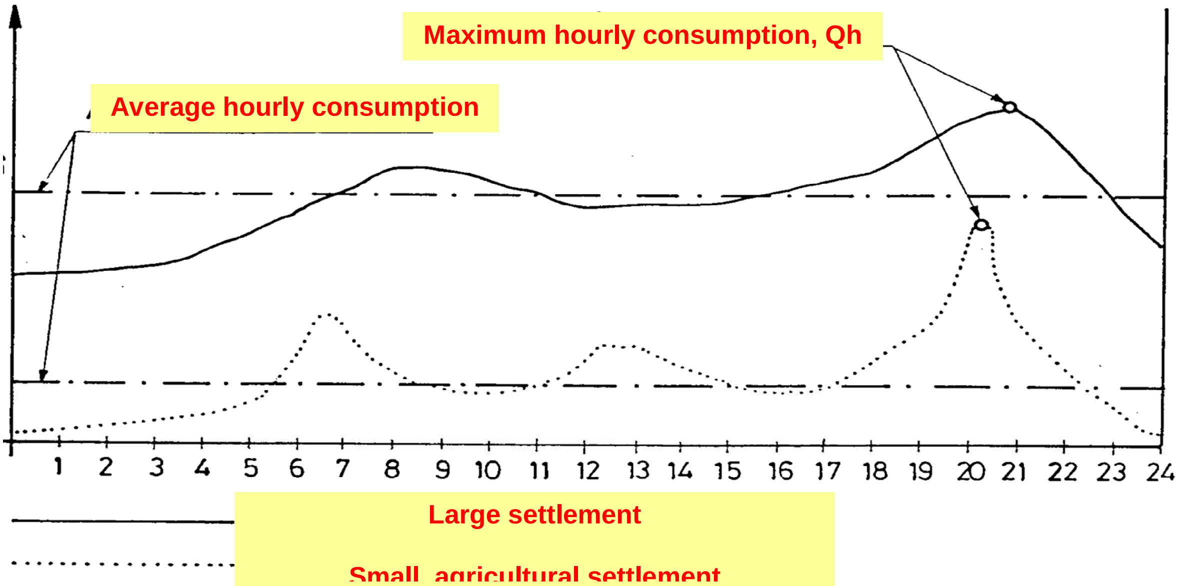
- full comfort
  (central hot water supply)

- The domestic water consumption and demand is usually given in one day per capita (specific) water quantity (l/cap/day).

4.8. Temporal (yearly) Change of Water Consumption



4.9. Temporal (diurnal) Change of Water Consumption



5. WATER SUPPLY AND SEWERAGE LEVEL IN SOME EUROPEAN COUNTRIES (1990)

Country	Supplied with drinking water %	Connected to sewer network %	Difference* %
Denmark	98.7	74	27.7
Denmark (2004)	100	89	11
France	95.5	86	9.5
France (2003-2004)	99.5	82	17.5
Germany	99.2	96	3.2
Germany (2006)	100	93	7
Norway	98.0	76	22.0
Switzerland	96.1	67	29.1
Sweden	97.3	76	21.3
Portugal (2008)	93	76	
European average	70.0	50	20.0
Hungary	76.0	42	34.0
Hungary (1995)	89.0	43.5	45.5

* flats supplied with drinking water but not connected to the sewer network

6. WATER QUALITY, WATER CLASSIFICATION

- Water quality means all the properties of the water
- The required water quality is determined by the type of water utilization.
  - Drinking water supply
  - Recreational utilization of the surface water
  - Irrigation
  - Industrial utilization ...
- Parameter groups of the water classification
  - physical (which means also radiological)
  - chemical
  - biological
  - bacteriological
  - toxicological

6.1. Physical Parameters

- Density
- Viscosity
- Surface stress
- Temperature
- Electrical conductivity
- Dissolved solids
- Suspended solids
- Volatile matters and ignition deposit
- Floating and settleable solids
- Colour
- Transparency
- Turbidity
- Radioactivity
  - Total β-activity
  - Total α-activity
  - Strontium-90
  - Césium-137
  - Polonium-210
  - Lead-210
  - Radium-226
  - Uranium
  - Tritium

6.2. Chemical Parameters (general)

- pH value
- Carbonate hardness
- Calcium és magnesium
- Sodium(Na) and potassium(K)
- Iron, manganese és aluminium
- Chloride

- Sulphate
- Carbon dioxide, bicarbonate, carbonate
- Silicates
- Ammonia és ammonium ion
- Nitrite, nitrate
- Organic- and total nitrogen
- Orthophosphate, phosphate és total phosphorus (TP)
- Dissolved oxygen (DO)
- Biochemical oxygendemand (BOD)
- Chemical oxigendemand (COD) permanganic and dichromatic
- Organic carbon
- Ultraviolet absorption of light
- Extractable matters

6.3. Chemical Parameters (inorganic pollutants)

- Heavy metals
  - cadmium
  - chrom
  - nickel
  - led
  - arsenic
  - copper
  - mercury
  - selenium
  - vanadium
  - antimony
  - barium
  - beryllium, etc.
- Cyanides, cyanates, thiocyanates
- Hydrogen-sulphide, sulphides, sulphites
- Fluorides, iodide, bromides
- Residual chlorine and chlorine-dioxide

6.4. Chemical Parameters (organic pollutants)

- Phenols (steam-volatile)
- Anionic active tensides
- Cationic active tensides
- Non-ionic tensides
- Petroleums (mineral oils) and petroleum fractions
- Polycyclic aromatic carbonic hydrogens
- Aldehydes and ketones
- Organic solvents
- Benzene and toluol
- Caprolactam
- Mercaptan, organic sulphides
- Methyl-ethyl-ketone, dimethyl-amine, dimethyl-formamide
- Organic chlorinated compounds

- Multiple-chlorinated definiles
- Organic acids
- Humic acids
- Pesticides
- Nitriles
- Silicones
- Pyridinbases
- Polyacrylamine
- Sugars and starches

6.5. Biological and Microbiological Parameters

- Chlorophyl-A
- Total count of algae
- Degree of saprobity, indices of saprobity
- Composition of benthos
- Toxicity for fishes, for oxygen uptake
- Biological tests for phyto- and zooplancton organisms
- Coliform bacteria
- Psychrophyl organisms
- Mezophyl organisms
- Termophyl oranisms
- Virologic coefficients
- Bakteriophages, etc.

6.6. *Water Quality in the Public Work Service*

- Quality demands of water utilizations

(e.g. drinking water treatment plants)

- Providing accordance between the quality of the produced waste and the load limit values given for the capacity of receiving waters

(e.g. waste water treatment, sludge treatment)

Drinking Water Quality Requirements
201/2001. (X.25.) edict
about the quality requirements of drinking water and the method of control

Annex No.1 to the Edict 201/2001.(X.25.):

Microbiological water quality parameters

Water quality parameter	Limit value (count/100ml)
Escherichia coli (E.coli)	0
Enterococcusok	0

Chemical water quality parameters

Water quality parameter	Limit value	Unit
Akrilamid	0.1	µg/l
Antimony	5.0	µg/l
Arsenic	10	µg/l
Benzene	1.0	µg/l
Benz(a)piren	0.010	µg/l
Boron	1.0	µg/l
Bromic	10	µg/l
Cadmium	5.0	µg/l

Water quality parameter	**Limit value**	**Unit**
Chromium	50	µg/l
Copper	2.0	mg/l
Cyanide	50	µg/l
1,2-dichlorine-ethan	3.0	µg/l
Epichlorinehydrine	0.10	µg/l
Fluorid	1.5	µg/l
Lead	10	µg/l
Mercury	1.0	µg/l
Nickel	20	µg/l
Nitrate	50	mg/l
Nitrite	0.50	mg/l
Pesticides	0.10	µg/l
Total pesticides	0.50	µg/l
Polyciclic aromatic hydrocarbons	0.10	µg/l
Selenium	10	µg/l
Tetrachlorine-ethylene and trichlorine-ethilene	10	µg/l
Total trihalomethane	50	µg/l
Vinil-chloride	0.50	µg/l
Cis-1.2-dichlorine-ethylene	50	µg/l
Chlorite	0.20	mg/l
Bond active chlorine	3.0	mg/l

Indicator water quality parameters

Water quality parameter	Limit value	Unit
Aluminium	0.1	µg/l
Ammonium	5.0	µg/l
Chloride	10	µg/l
Chlostridium perfringens (with spores)	1.0	Count/100ml
Colour	Acceptable for consumers and no abnormal change	
Conductivity	2500	µS cm^{-1} at 20°C
pH	>=6.5 and <=9.5	
Iron	200	µg/l
Manganese	50	µg/l
Odour	Acceptable for consumers and no abnormal change	
Permanganate indices (CODps)	50	mg/l O_2
Sulphate	250	mg/l
Sodium	200	mg/l
Taste	Acceptable for consumers and no abnormal change	
Plant nr. on 22°C and 27°C	no abnormal change	Count/ml
Coliform bacteria	0	Count/100 ml
Pseudomonas aeruginosa	0	Count/100 ml

Total organic carbon (TOC)	no abnormal change	
Turbidity	Acceptable for consumers and no abnormal change	
Hardness	Min.50, max.350	mg/l CaO
Phenic indices	20	µg/l
Oil-products	50	µg/l
Radioactivity		
Triterium	100	Bq/l
Total indicative dose	0.10	mSv/év

6.7. Quality of Receiving Waters (Natural Waters)

- The water quality of the natural waters as the receiving waters of the treated or the untreated wastewaters results from metabolism between the organic life and the inorganic environment.
- Water pollution

All the effects changing the water quality into the direction, that its suitability for the inner natural life processes and for the human utilization is decreasing or in extreme cases even finishing.

- Organic pollution + oxygen + heterotrophic organisms, toxic metabolic products
- Inorganic vegetable nutrient-> eutrophycation

trophy – inorganic nutrient -> organic matter (primary product)

6.8. Biological Water Classification

Trophity: the extent of the primary organic matter production of the water ecosystem. Depends on the conditions of light, temperature and inorganic nutrients and on the green vegetable containing chlorophyl. The increase of trophity increases the energy receptivity of the ecosystem and results to eutrophication.

Saprobity: the decomposing capacity of the water ecosystem, contradictory process to the trophity, resulting in energy loss. Depends on the presence of the organic matters which can be rotted and the presence of the heterotrophic organisms which can decompose these matters.

Halobity: all the biologically important inorganic chemical parameters of the water. Generally depends on the geochemical parameters of the watershed, but can be influenced by the human activities.

Toxicity: toxic capacity of the water, which can be caused by the poisons coming from outside of the water or can be built inside the water.

6.9. Spatial Location of the Pollution

- **Point-type pollution sources** are reaching the water course or lake at a discrete, determinable location.
- **Regional** or **non-point pollution sources** can not be located unambigously, the pollutants are reaching the receiving waters from the air by sedimentation and with the precipitation by surface runoff (inwash) or through the ground water, by under surface runoff.
  Most important sources of regional pollution:
  - agricultural activity,
  - transportation (salting, pollutants accumulating on the road surface),
  - settlements (urban storm water runoff, desiccated wastewater),
  - waste deposits,
  - industrial factories (air pollution).

6.10. Water Quality Control

Depends on Limit Values

- Limit values of parameters specified for the receiving water, required for sustaining the water life
- Specified for the effluent wastewater, regarding to the concentration of the discharged pollutant or the volume of the acceptable effluent load.

The specified limit values for the effluent wastewater are different regarding the protection of the receiving waters.

7. WATER SUPPLY

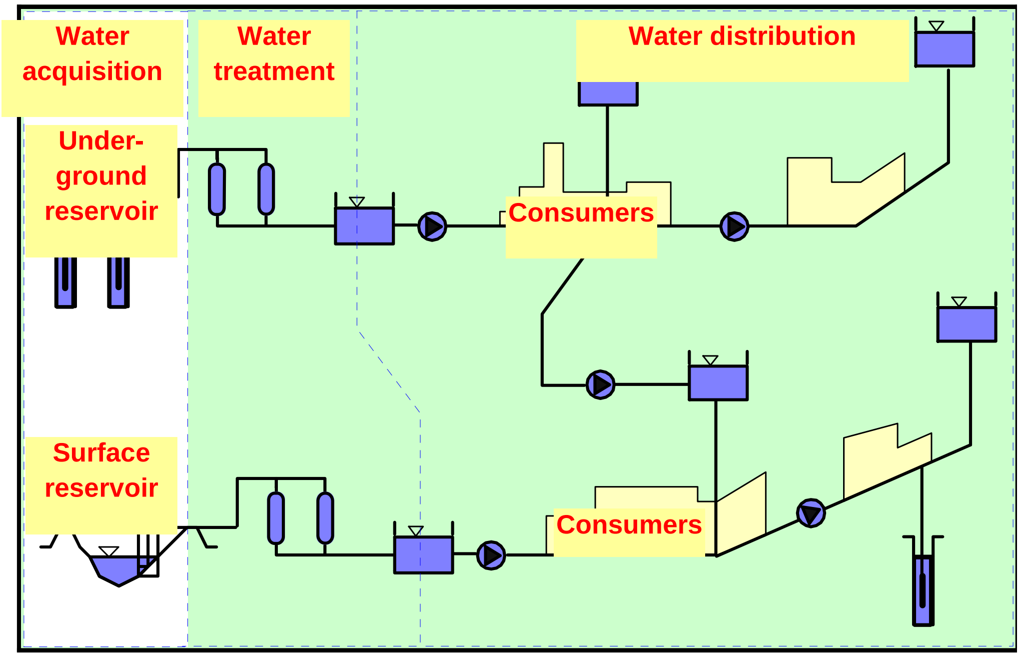
- Supplying the population with drinking water.
- Supplying industrial factories and other productive units with industrial water of necessary quantity, quality and pressure for manufacturing products.
- Supplying agricultural factories, farms with irrigation water.

- Providing hygienic water for human consumption
- Minimizing public health insecurity

7.1. Water Supply System

- Continuous operation because of having changing quantity in time, but always having demands.
- Dangerous operation !
  The conduits are under pressure !

- Permanent failure. Somewhere something is wrong always !



7.2. Type of Water Resources

Underground storage:

From granular medium: Close to the surface Groundwater
Bank filtering

Deep from the surface Deep groundwater

From cracked medium: Karst water

In Hungary there are plenty of underground water of good or sufficient quality. Most of the Hungarian municipal waterworks based on that type of water resource.

The bank filtering mean transition between the underground and the surface water resources, because that means natural filtering of surface water.

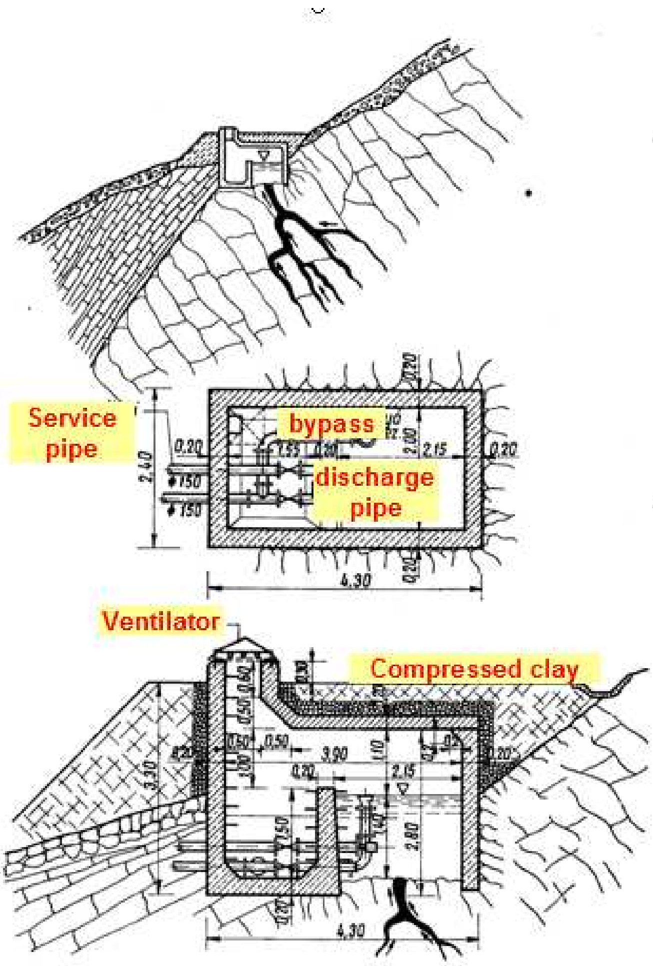
Surface flow:

From natural waters - from live watercourses, lakes

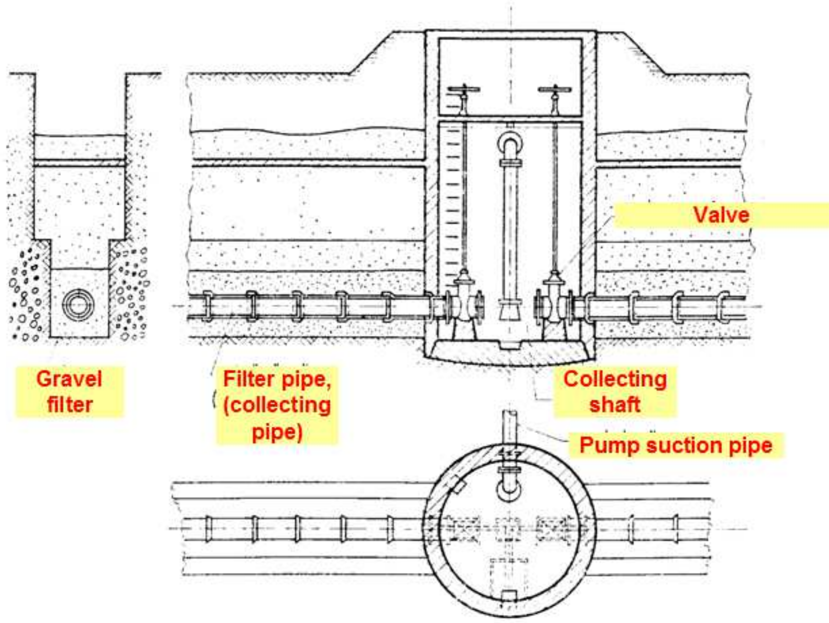
From artificial reservoirs

7.3. Important Establishments of Underground Storage Water Acquisition

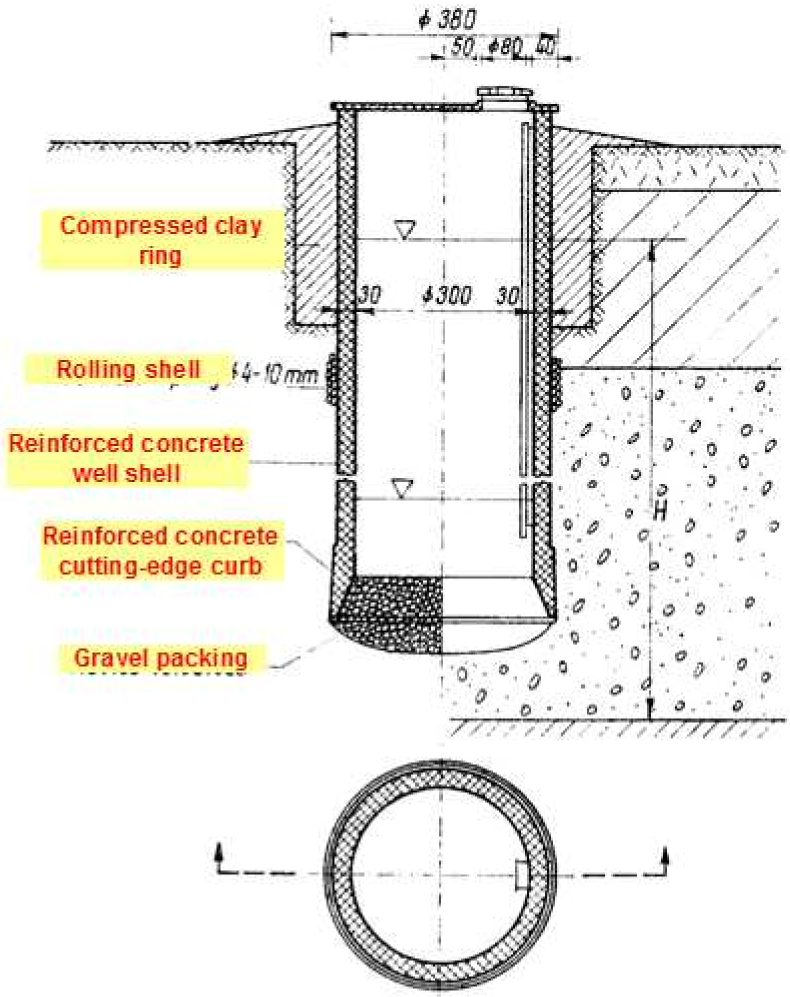
BEHEADING OF SPRING


Service
pipe
bypass
discharge
pipe
Ventilator
Compressed clay

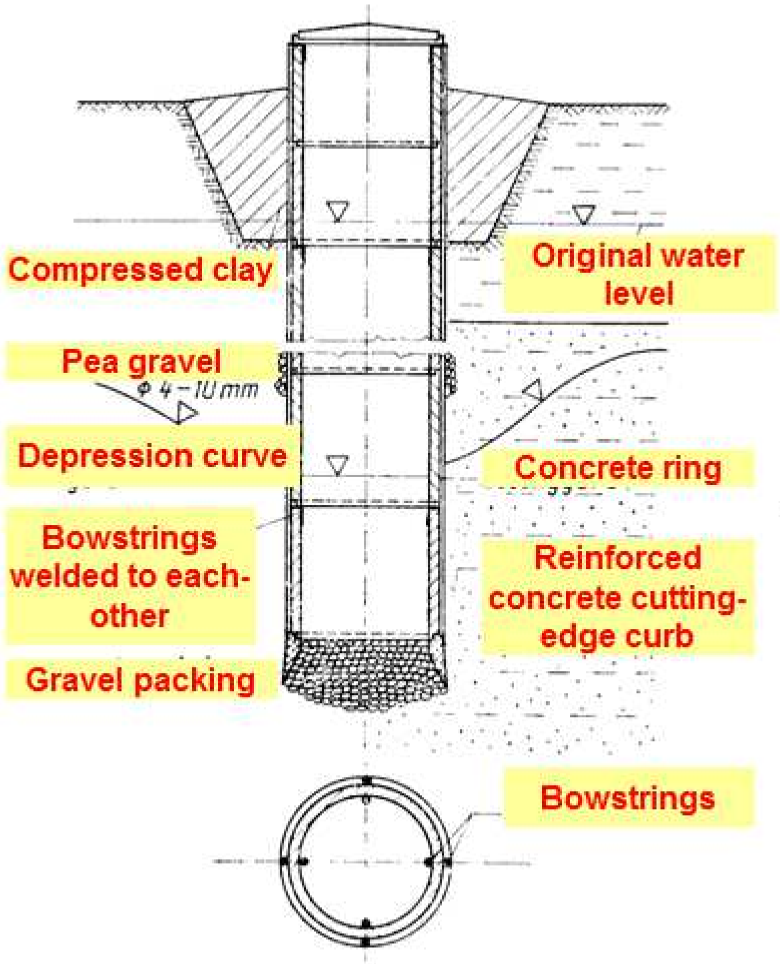
Gallery


Valve
Gravel
filter
Filter pipe,
(collecting
pipe)
Collecting
shaft
Pump suction pipe

Dug Well


ϕ 380
50
ϕ80
40
Compressed clay ring
30
ϕ300
30
Rolling shell
4-10 mm
Reinforced concrete well shell
Reinforced concrete cutting-edge curb
Gravel packing
H

Drop-Shaft Well



7.4. Water Distribution System

Consumers

Consumption = Effective take-in

Water demand = What the consumer wanted !

(But only strange noises came from the tap instead of water !)

Quantitative demand

It is changing in time regarding the customs of consumptions.

Quality demand ...

Pressure demand

That is actually energy demand!

Network

- The water producing, water treatment plants are usually far away from the consumers, therefore maintenance of water delivery should be necessary. The pipe network is delivering water.
- Friction loss, energy loss.
- The pipe network is not continuous and not closed!
- Most of the failures occurs in the network, which should be eliminate continuously.
- For the repair in the network certain pipe sections should be put taken out of operation.
- Fire-fighting.
- The network includes several fittings, structures, shafts etc. besides the conduits.

Engine-houses

- In order to satisfy the pressure demands of the consumers and to substitute the friction energy loss due to the delivery, energy should be transformed into the network.

Delivery by pumping, pressure-zones, pressure borders

- The maximum allowed operation pressure in the network at the consumer's junction point 60 [m water height], protecting the fittings and equipments inside the buildings.

Storage

- The difference between the constant, continuous water production and the changing consumption can be balanced with storage.

7.5. Water Supply Tasks for the Future

- Effective protection of water resources
- Reconstruction (rehabilitation) of existing, but used establishments
- Improvement of the drinking water quality, including emphasized the reasons and the elimination of the secondary contamination occurs in water networks implied by the decreased consumption worldwide.

In Hungary to eliminate the lags:

- To decrease the service loss:
  - correct water quantity measurements
  - systematic discovery and repair of the network failures
  - reconstruction (rehabilitation) of network conduits and fittings
- Applying up-to-date process control, operation systems, establish the optimization conditions of the operation
- Building-up of inventory system of public works, modern solutions for the tasks of informatics regarding the operation problems, information systems (GIS).

8. SEWERAGE

- Sewerage is important part of water management and specially means one field of the water management of settlements.
- The job of sewer works: collection, conduct, treatment and disposal of wastewater and storm water produced in a settlements and on its belonging watershed satisfying the specified technical, economic and hygienic requirements, discharge and treatment.
- Parts of the sewer works:
  - Sewer network system for collection and conduct of storm water and sewage,
  - and treatment system for storm water and wastewater

8.1. Classification of Sewer Systems

Based on the type of collection and conduct:

- combined system
- separated system
- mixed system

Based on the operation of the sewer:

- gravity type
- pressure type
- vacuum type

8.2. Combined System

The sewage and the storm water are conducted in the same gravity type system.

Advantages

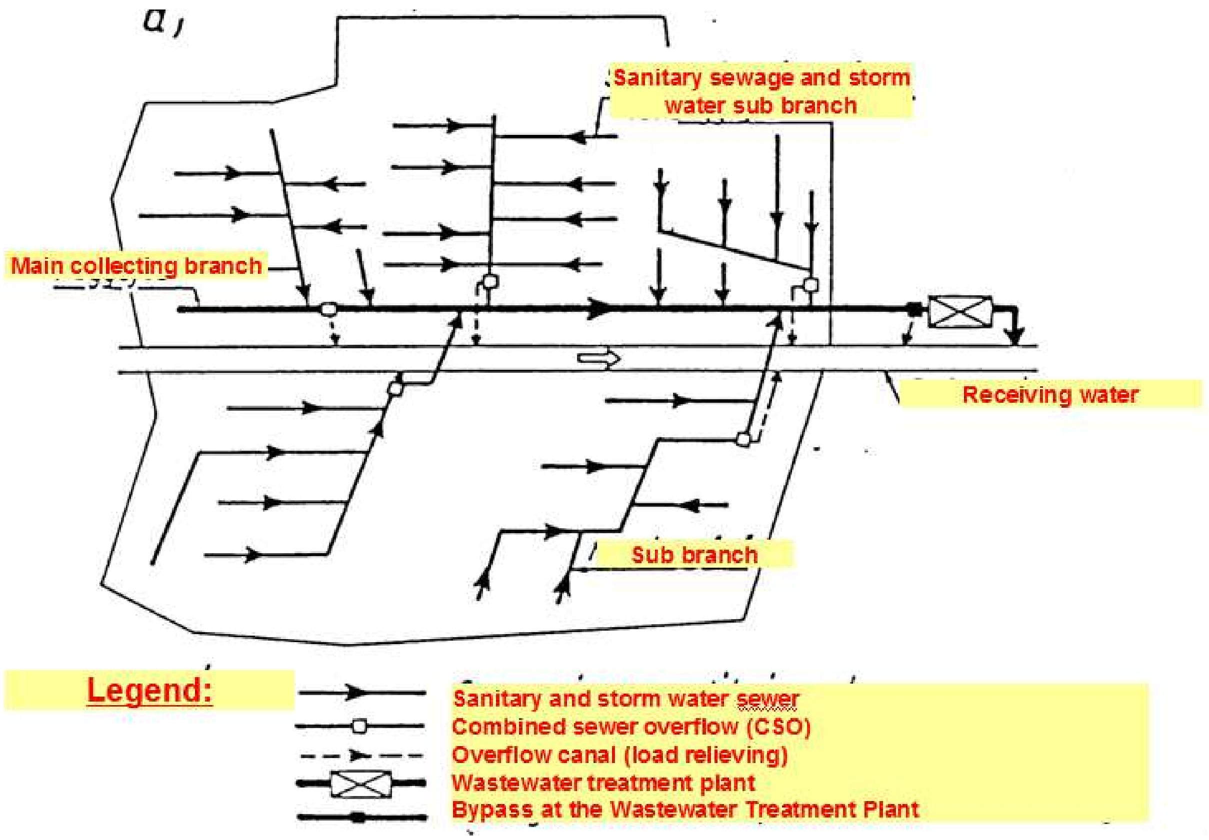
- the operation of the system is more simple because of the hydraulic runoff conditions in the pipes,
- the space demand of the only one conduits is less, the connection to the buildings is more favourable,
- inventory, operation, maintenace of one conduit is more simple,
- the investment cost in general less

Disadvantages

- not satisfying the present specifications of the environmental protection of the receiving waters because of the discharge load of the mixed sewage,

- the load of the wastewater treatment plant is not even, periodically is overloaded because of the storm water,
- the backwater effect can be occurred frequently in the system because of the large volumes of the water to be conducted (plane surface, not sufficient slope),
- in case of unfavourable hydraulic conditions the increase of runoff time results in the „rot" of the sewage (emerging anaerobic conditions), the danger of formation of deposit is increasing.
- the system is less appropriate for connecting new watersheds and for accepting the change of surface coverage because of the limited hydraulic capacity (pipe section)
- the gravity pipe sewers having relatively large diameters generally can not be built in a duct for services.

TYPICAL LAYOUT



8.3. Separated System

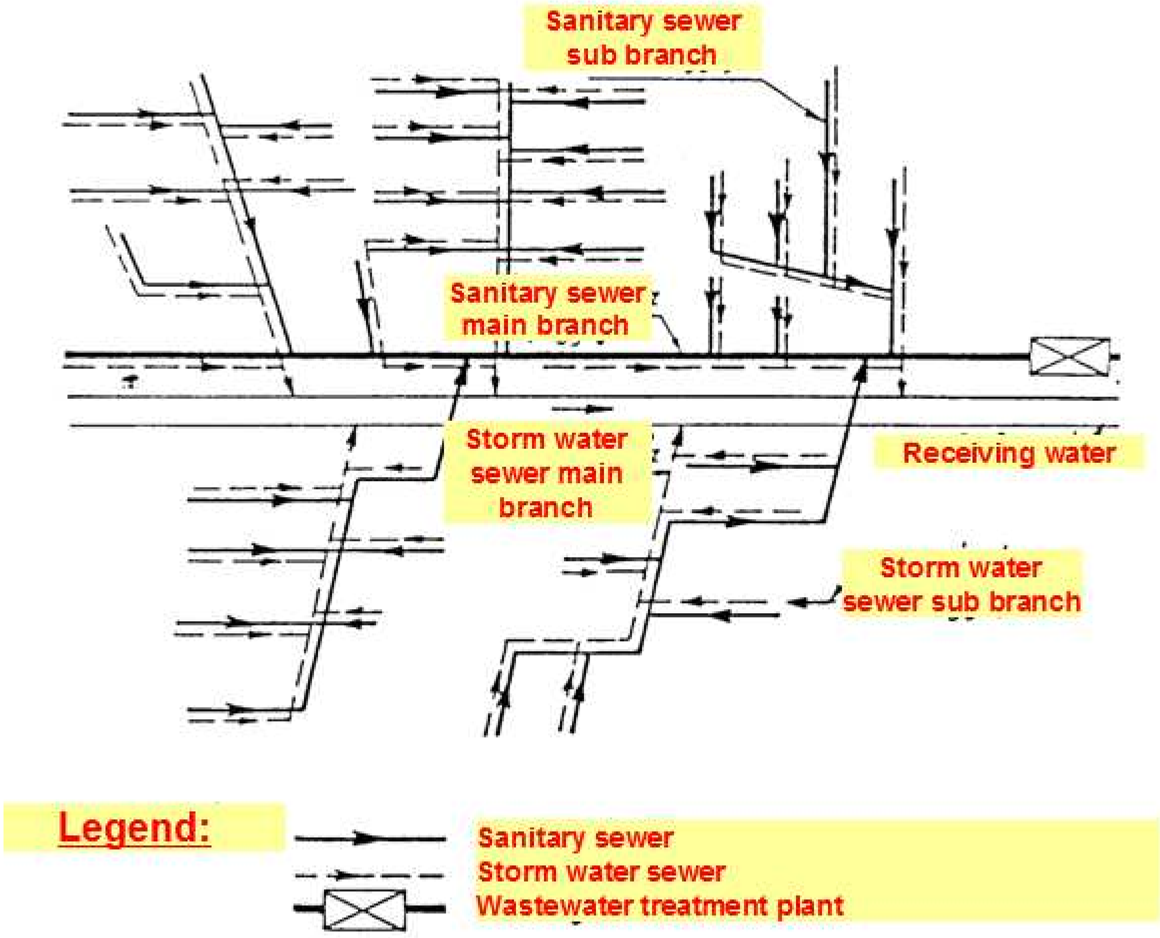
Sewage is conducted by the sanitary sewers,

precipitation is conducted by the storm water sewers.

Based on their operation they can be of:

- gravity type
- pressure type
- vacuum type

Typical layout



Advantages

- the hydraulic and wastewater load of the wastewater treatment plant is more even (because there is no storm water load),
- more economic pipe section sizes can be applied,
- the geometry of the sanitary sewer network is more favourable hydraulically (the sewers will not be oversized because of the storm water, the danger of formation of deposits is less),
- the sanitary sewers can be built in a duct for services,
- the sanitary and storm water conduits generally can be laid horizontally closer to the junction points of the buildings,
- it is more flexible to the local conditions (more extendable).

Disadvantages

- the sanitary sewer conduits should be built with higher slope to maintain their flushing capacity,
- there is a higher demand for designing pump stations and conduits driven by pressure,
- the precipitation flows into the receiving water without treatment (the pollution of the receiving water can be reduced building storm water reservoirs),
- the location of two different sewers is more difficult in a narrow street, their inventory, operation, maintenance are more expensive and need more man-power,
- the investment cost of the total capacity is generally higher.

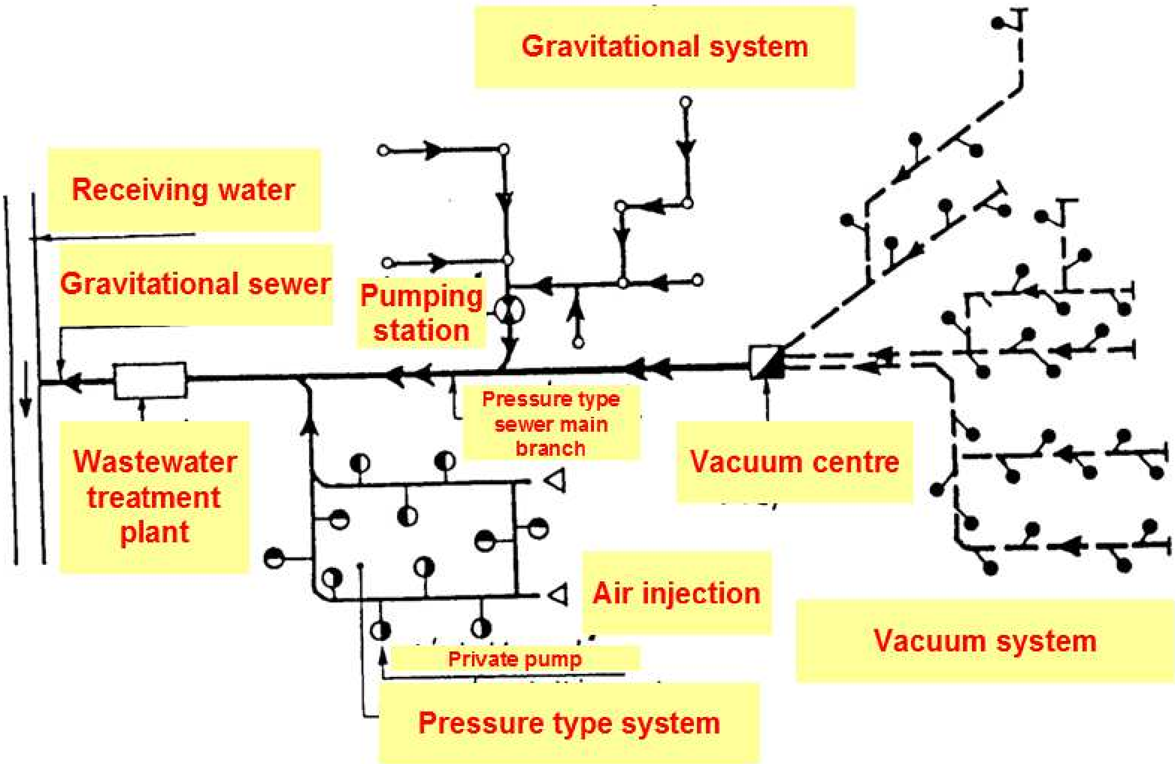
8.4. *Mixed System*

The mixed systems are containing the combined and separated systems as subwatersheds, as the part of the system.

Based on their operation (like the separated systems) they are of:

- gravity type
- pressure type
- vacuum type

Typical Layout



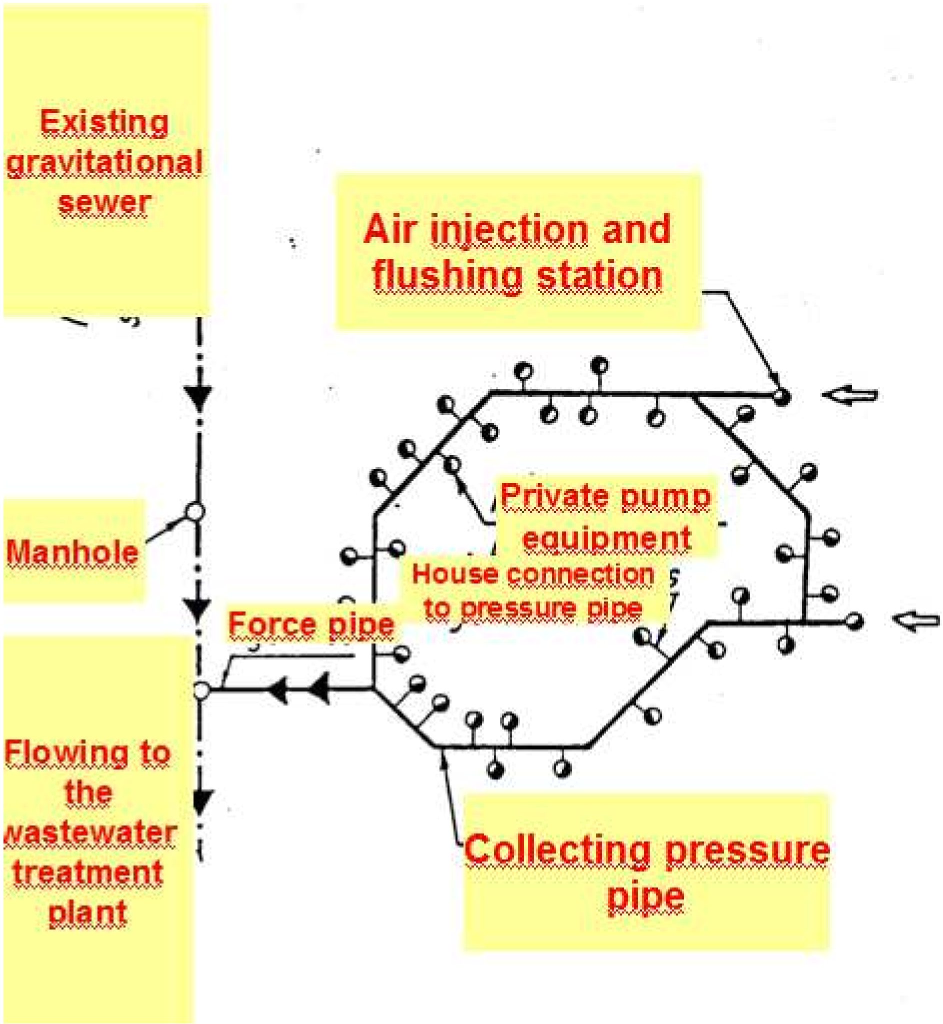
8.5. Pressure type sanitary sewer system

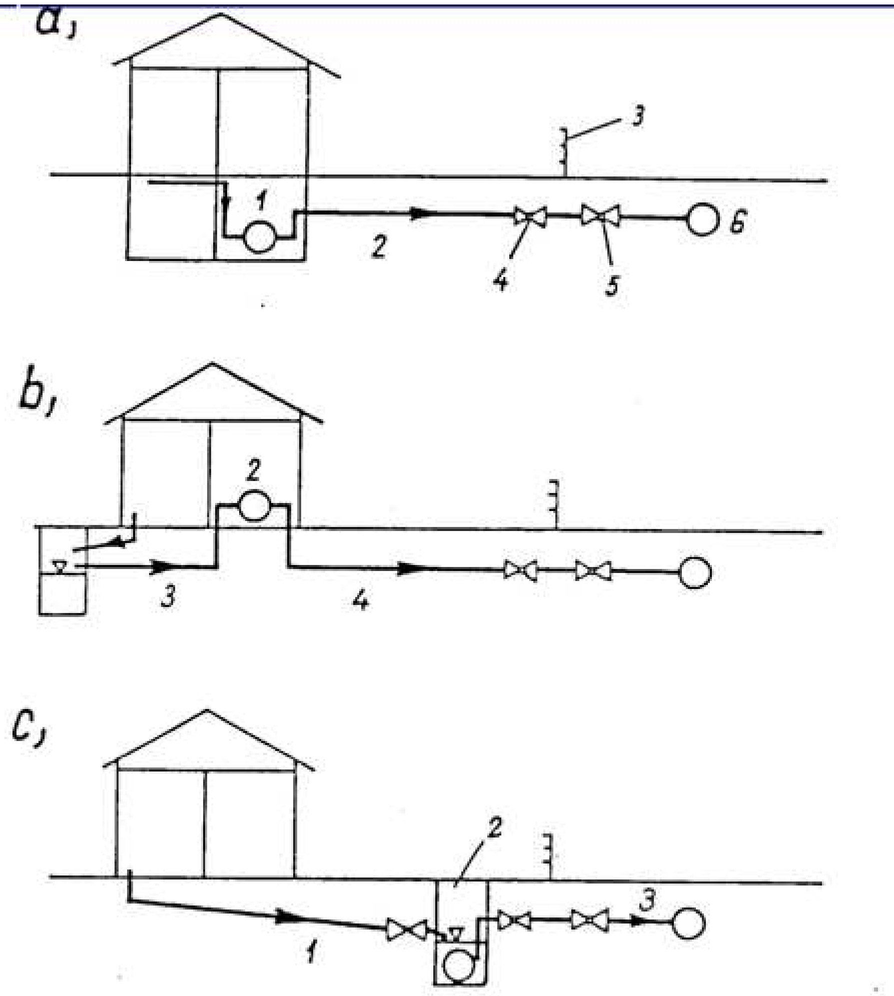
Features

- External energy source is necessary for its operation.
- There are no limitations in their vertical location.
- The residence time of the sewage is decreasing.
- The sewage can be collected by gravity in the parcel and then can be pumped into the pressure type public sewer system by anti-choking, crushing sewer pump at each house or block of house.
- The backflow of the sewage into the gravitational collection sewer before the pump is prevented by one-way valve.

Horizontal location

- Branched network
- Looped network





a) Air-driven pump

b) Air-driven force-and-suction pump

c) Deep-well turbine pump

8.6. *Vacuum Type Sewer System*

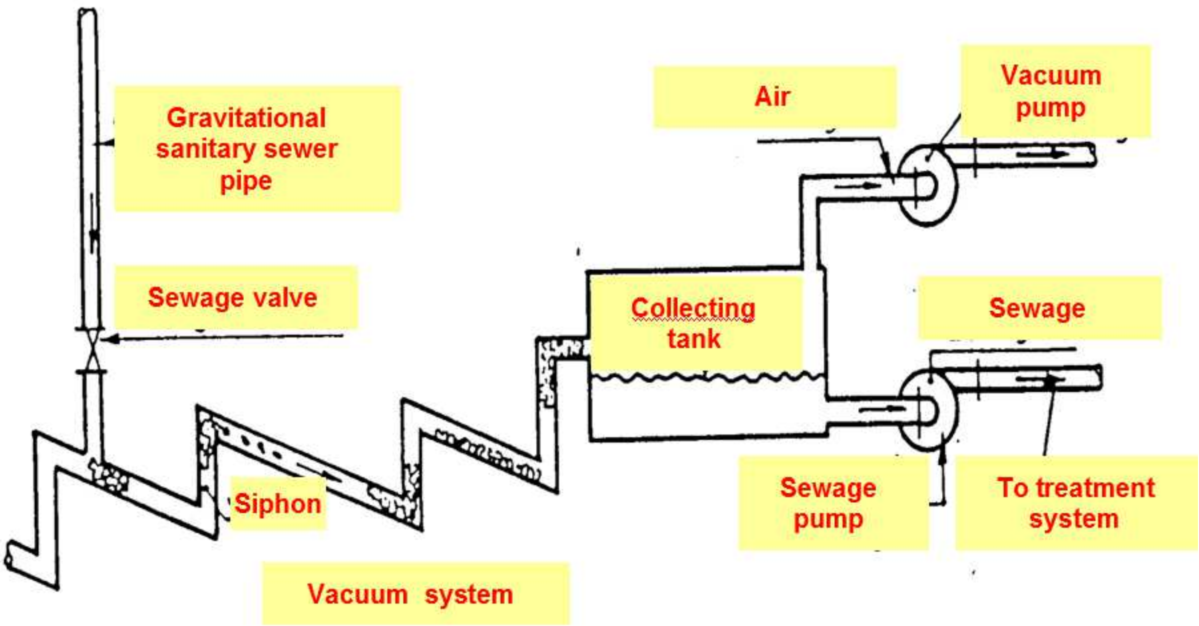
Features

- External energy source necessary for its operation
- On densely populated areas, where the installation of gravitational system is not possible because of the topographic or soil conditions

Elements

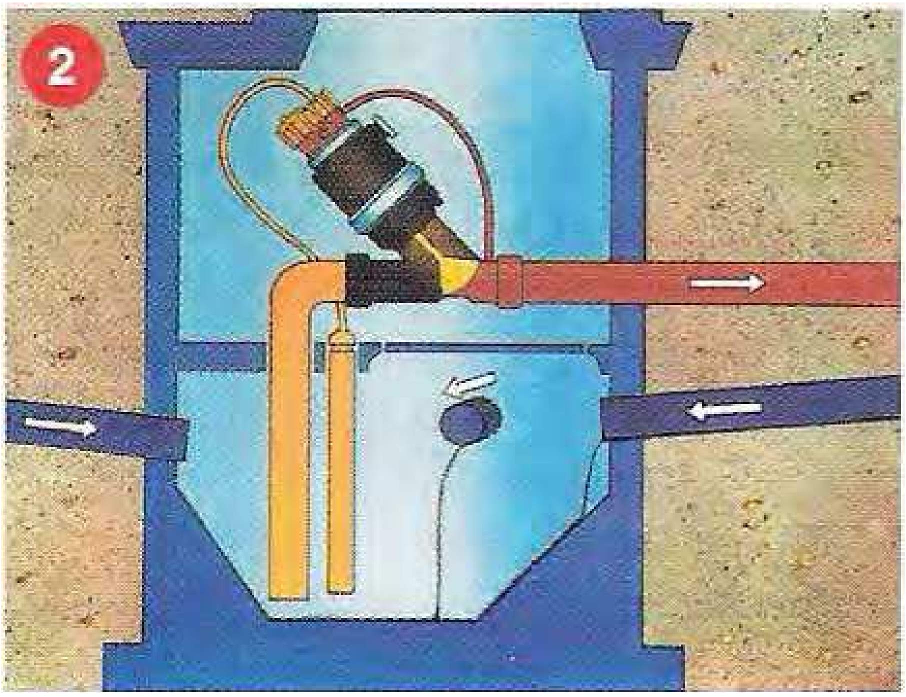
- Vacuum in the centre
- Gravitational pipe
- Vacuum sewer valve
- Vacuum sewer network

The sewage is moving in the vacuumed pipes not continuously but as sewer plugs.



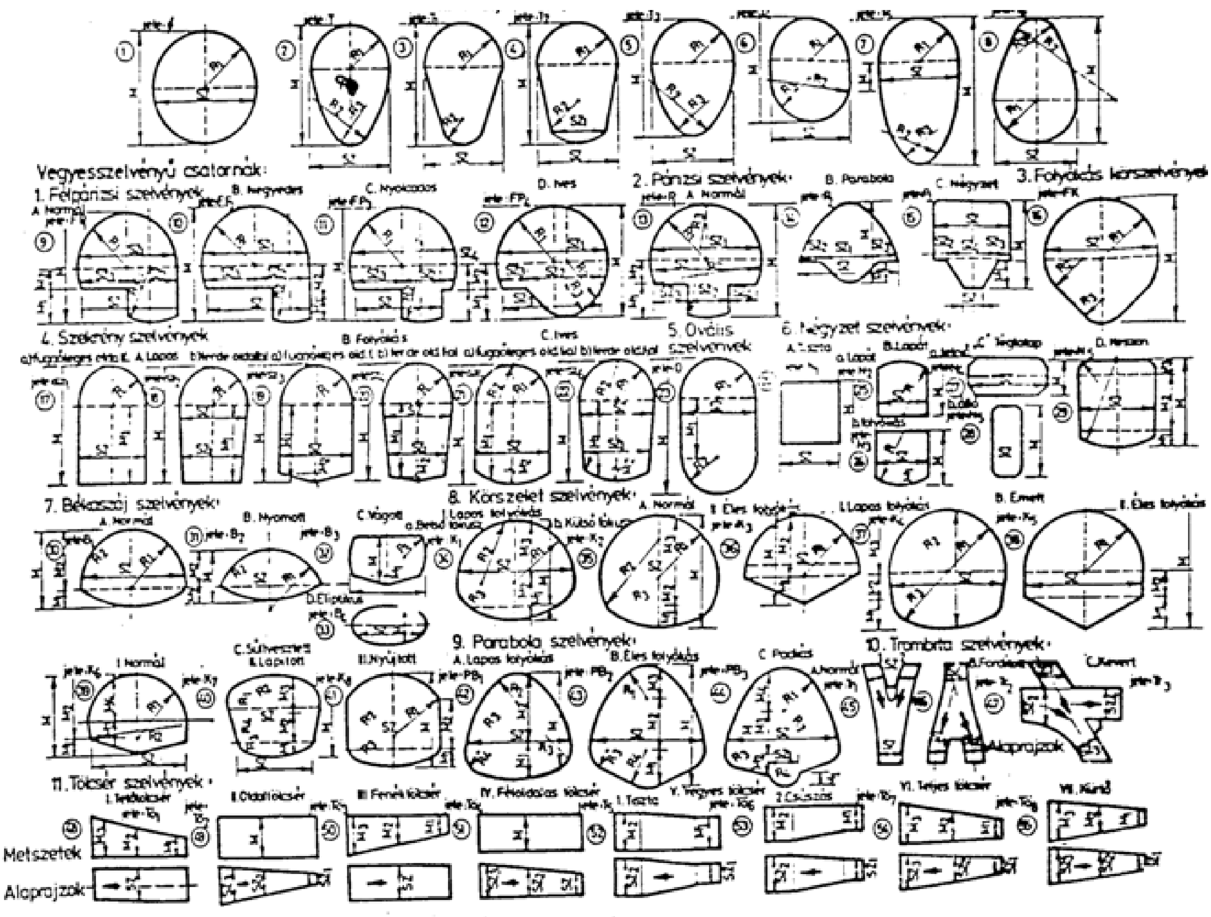
- The sewage is flowing by gravity from the buildings to the vacuum sewer valve, which provides the connection between the two systems.
- The valve opens automatically, if in the gravitational pipe section before the valve or in the manhole a given volume of sewage has already been accumulated.
- The sewage is flowing in the vacuum type sewers only while the valve is open. Therefore should be given air (having normal pressure) into the network after the sewage was flowing through the valve. This air expands regarding the extent of the vacuum being in the network after the valve closes. Then the sewage delivery stops. Therefore the sewage is moving in the vacuumed pipes not continuously but as sewer plugs.
- The fundamental principle of the operation is, that the vacuum valve closes delayed, therefore also air is going into the conduit, which is expanding due to the vacuum and the air is moving the sewer plugs.

Vacuum Valve



8.7. Cross Sections of Gravity Type Sewers

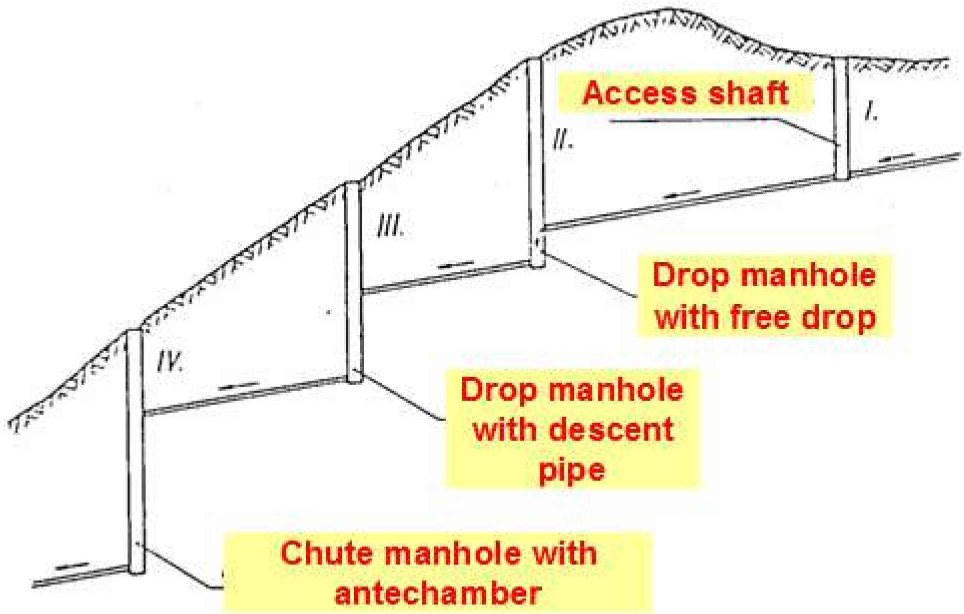
Sample Cross Sections of the Sewers in Budapest

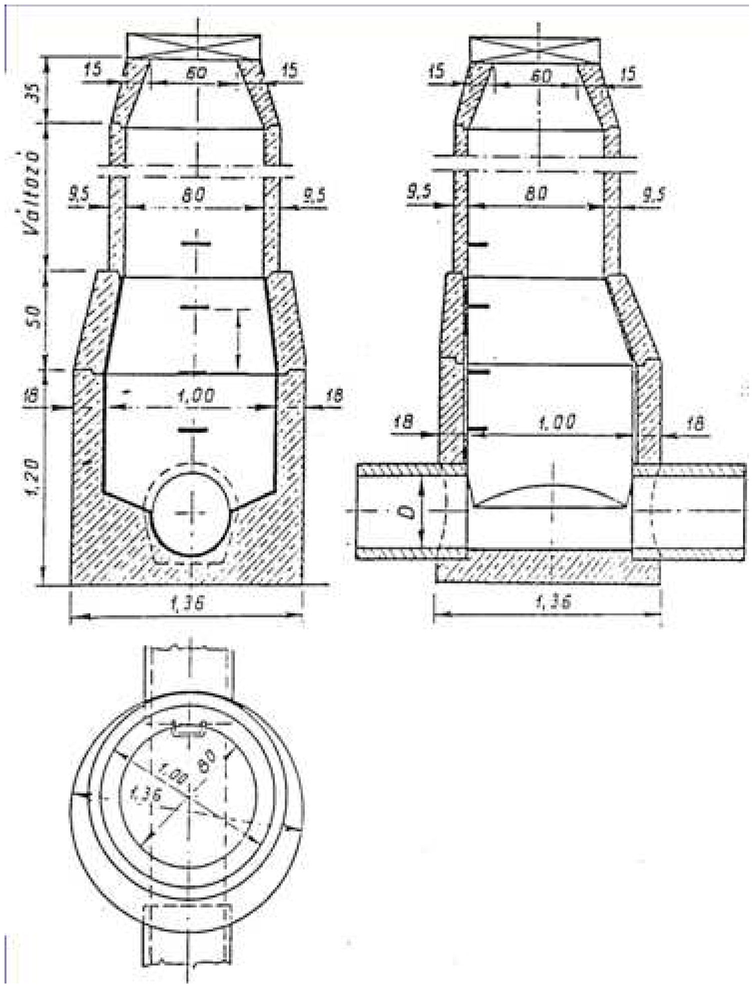


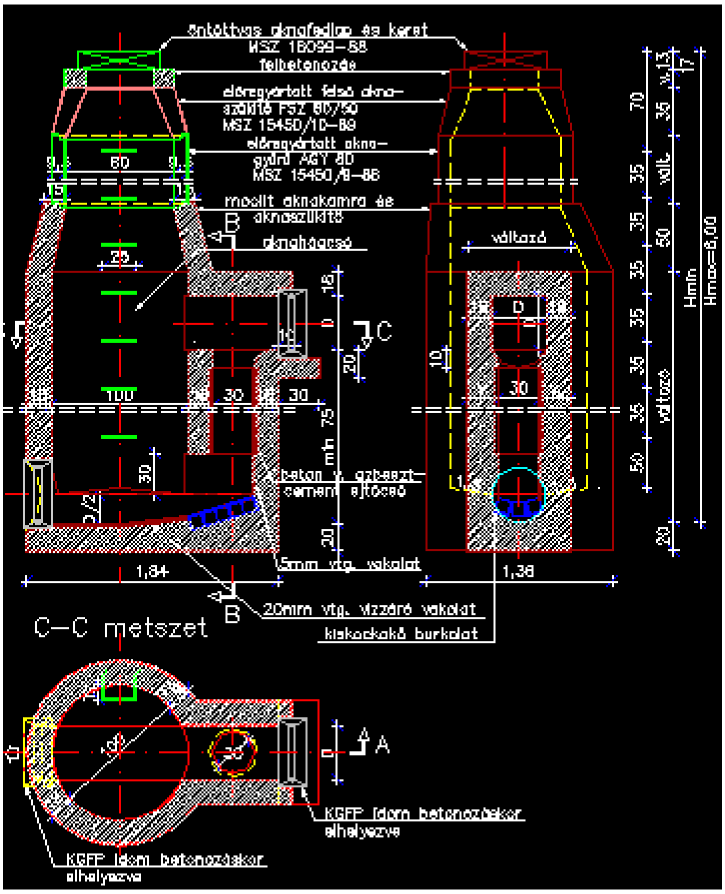
8.8. Structures of the Sewer System

- the structures of the house sewer network, binding-in sewer,
- local wastewater treatment structures (grease-trap, petrol-trap, oil-trap),
- structures in the road cross section,
- manholes (drain-trap, drop manhole, chute manhole, flush manhole, snowdrop manhole, ventilating shaft),
- junctions,
- load relieving structures (e.g. CSO),
- fittings, canal lock, gate valve,
- flow meter,
- pumping station in the sewer network,
- reservoirs in the sewer network.

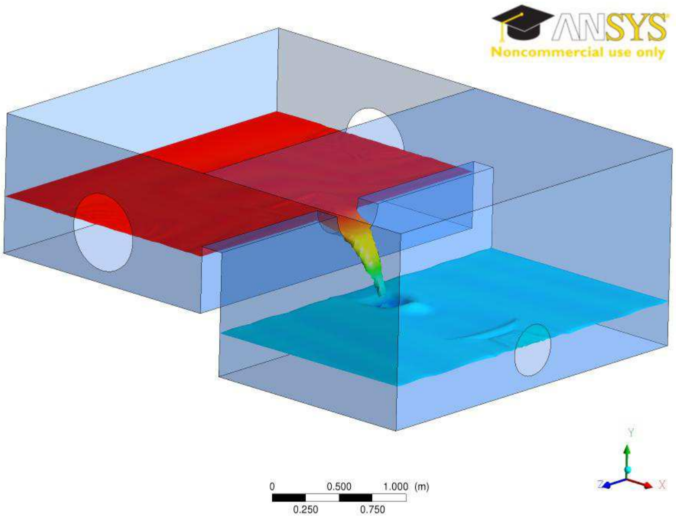
Sewer Manholes

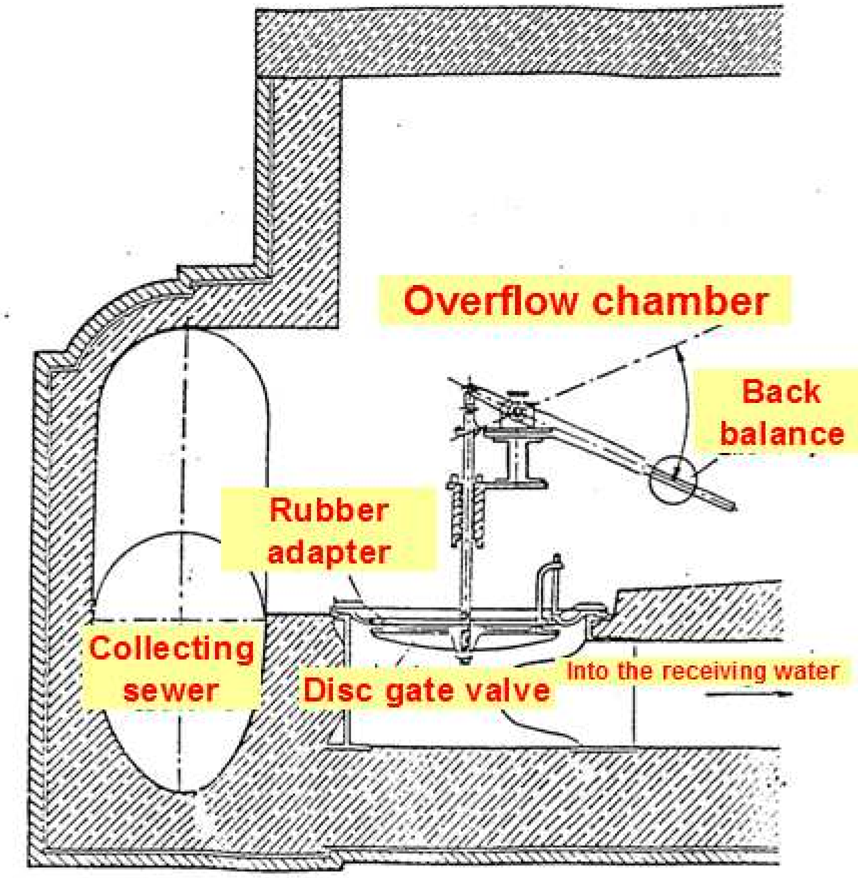




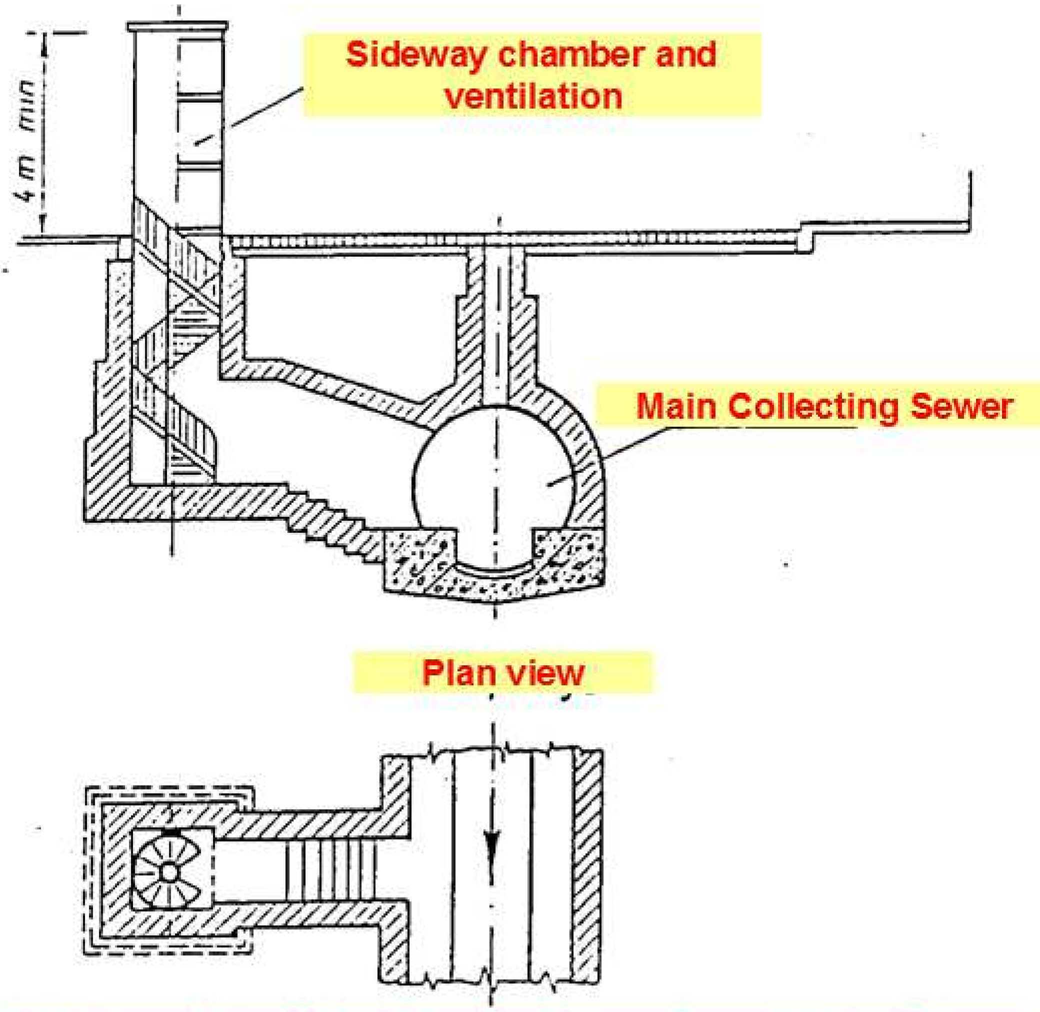

öntöttvas aknafedlap és keret
MSZ 16099-88
felbetonozás
előregyártott felső akna-
szűkítő FSZ 80/50
MSZ 15450/10-89
előregyártott akna-
gyűrű AGY 80
MSZ 15450/9-88
monolit aknakamra és
aknaszűkítő
aknahágcsó
változó
beton v. azbeszt-
cement elfolyó
5mm vtg. vakolat
20mm vtg. vízzáró vakolat
kiskockakő burkolat
C–C metszet
KGFP idom betonozáskor
elhelyezve
KGFP idom betonozáskor
elhelyezve
Hmin
Hmax=6,00
1,84
1,36

Sewer Constructions



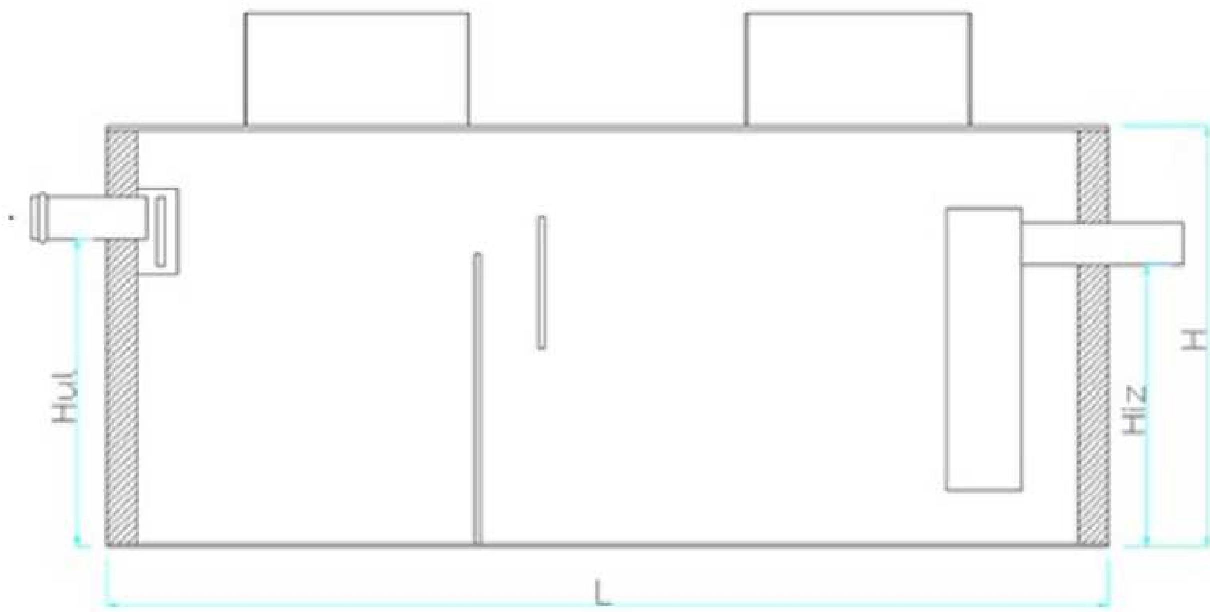


Overflow With Disc Gate Valve



Ventilation of the Main Collecting Sewer Through the Sideway

Grease and Oil Trap



Pumping Station (MOBA type)

1 Control automation (outside of the manhole)

2 Floating switch (alarm)

3 Inflow pipe

4 FLYGT type pump

5 Ventilation pipe

6 Force pipe

7 Gate lock

8 One way valve

9 Concrete ring

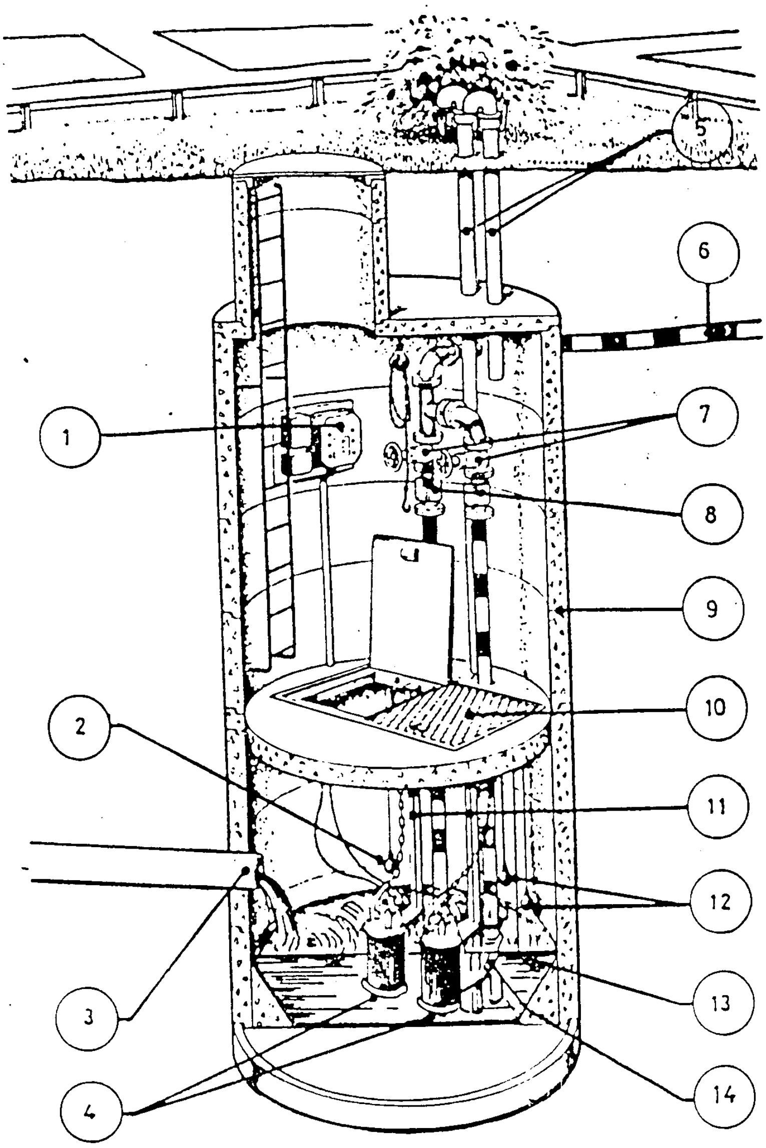
10 Operating floor covering

11 Guide pipe

12 Floating switch (start)

13 Floating switch (stop)

14 Elbow with base


1
2
3
4
5
6
7
8
9
10
11
12
13
14

8.9. Exfiltration

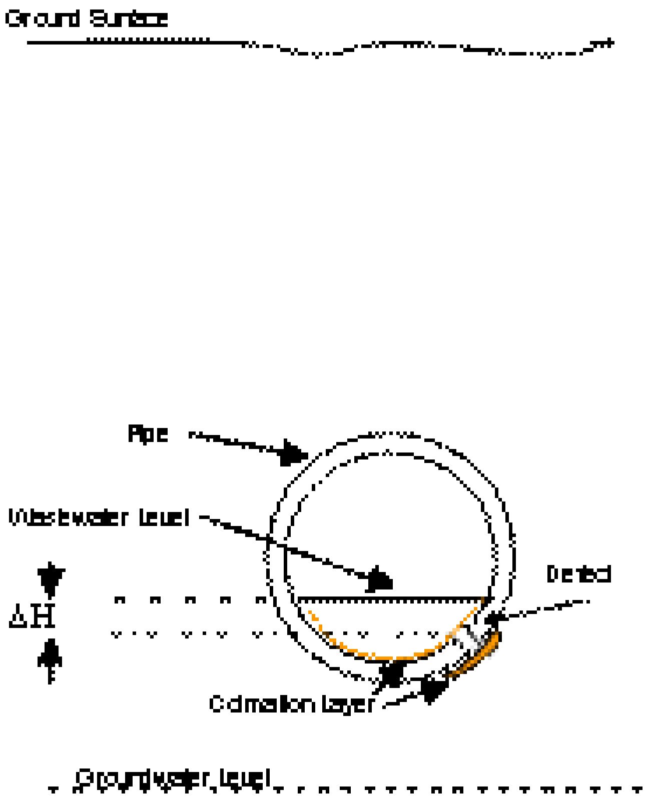
Q(Exfiltration) = Aleak. ΔH . (*k*c /ΔL) (m3/s)

Aleak = Defect area (m2) (from the generic defects file)

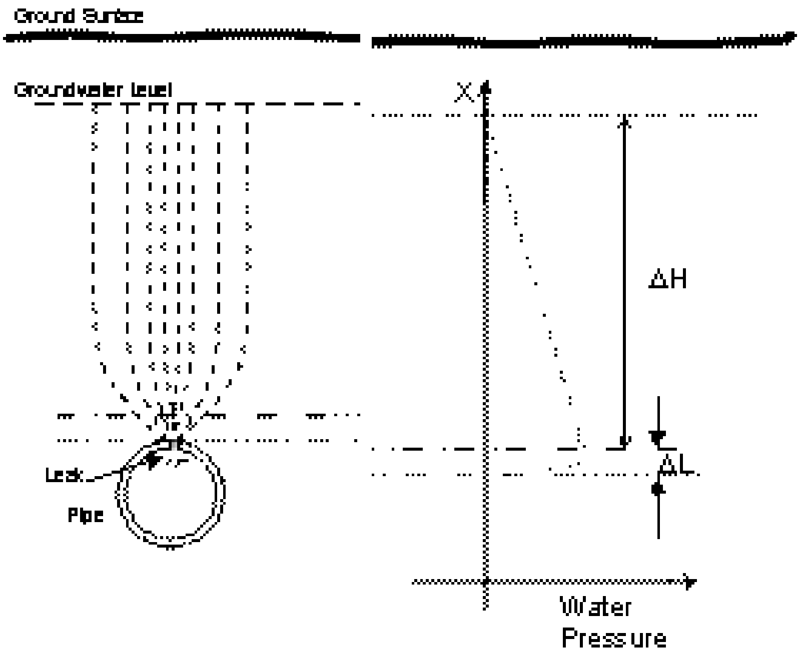
ΔH = Height of water within pipe from defect (m)

*k*c = Conductivity of colmation layer (m/s)

ΔL = Thickness of colmation layer (m)



8.10. Infiltration



Q(infiltration) = Aleak. ΔHGW . (*kf* / ΔL) = 10 * Aleak.. ΔH . *kf*

Aleak. = Defect area (m2) (from the generic defects file)

ΔH = Depth of pipe below groundwater level (m)

ΔL = Thickness of limiting soil layer (assumed to be 0.1 m)

kf = Conductivity of soil (m/s) (from literature)

9. DIMENSIONING OF PRESSURE TYPE DISTRIBUTION SYSTEMS

- The calculation methods of the complicated distribution systems are based on mathematical models.
- The models applied for the networks have usually three parts:
  - TOPOLOGICAL model describing the geometry of the network
  - PHYSICAL-HYDRAULICAL model describing the performance of the network
  - CONSUMPTION (or LOAD) model describing the consumptions (loads)
- The up-to-date models are interpreting the distribution systems as graph network, where physical properties are connected to the edges of the graphs by different relations and algorithms.

9.1. Topological model

- The topology of the network means the geometry of the networks, not dealing with the physical qualities of the network.
- GRAPH THEORY
- The topological model in the hydraulic calculations of the pressure flow pipe networks always can be described as a connected, oriented graph.
- The SWITCHING MATRIX is used for the description of the connections of the oriented graph.
- The switching matrix is describing the connections between the branches and nodes of the graph, where the nodes are regarding to the rows of the matrix and the branches are regarding to the columns of the matrix. The elements of the switching matrix can have the values of 0, +1 or -1 as follows:

+1 if the node i is the start node of the branch j

-1 if the node i is the end node of the branch j

0 if the node i is not on the branch j

KIRCHOFF I. (continuity) law: $A * q = q_f$

The „loop matrix” is deriving from the switching matrix, where the loops (rings) are equivalent to the rows of the matrix and the columns are equivalent to the branches.

The B(i,j) element of the loop matrix is equal to:

+1 if the loop i contains the branch j and the orientation of the branch and the loop are equal,

-1 if the loop i contains the branch j and the orientation of the branch and the loop are different,

0 if the loop i does not contain the branch j.

9.2. Composing of the Loop Matrix

$\mathbf{A}_a = \lfloor \mathbf{A}_f \, \mathbf{A}_h \rfloor$

$\mathbf{B} = \lfloor \mathbf{B}_f \, \mathbf{B}_h \rfloor$

$\mathbf{B}_h = \mathbf{I}$

$\mathbf{B}_f^* = -\mathbf{A}_f^{-1} * \mathbf{A}_h$

KIRCHOFF II. law, where **h** is the pressure loss vector of the branches:

$\mathbf{B} * \mathbf{h} = 0$

9.3. Physical-Hydraulical model of the water supply network

Conduit

$$h_v = \lambda \frac{l}{d} \frac{v^2}{2g} = C\, Q\, |Q|$$

$$C = \frac{8\, l\, \lambda}{d^5 \pi^2 g}$$

Colebrook-White equation: $$\frac{1}{\sqrt{\lambda}} = -2\,\lg\left(\frac{k}{3.7d} + \frac{2.51}{\mathrm{Re}\sqrt{\lambda}}\right)$$

Derivative: $h_v' = 2\, C\, |Q|$

Reservoirs, fixed pressure points

- dummy branch, along the branch the pressure loss is not depending on the delivered flow,
- dummy node, the special point of the network, which is located on the base level.

Modelling of reservoirs introduced a dummy branch and a dummy node.

- The reservoir is modelled with a dummy branch which has a dummy start node. The pressure loss along this branch is exactly equal to the water level above the base level independently from the flow.
- Disabling the dummy node from the network the dummy branches are connecting the reservoirs and the pressure loss along these branches equal to the actual water level difference of the reservoirs independently from the flow.

Pump (centrifugal pump):

$$H_{sz} = a_0 + a_1 Q_{sz} + a_2 Q_{sz}^2$$

$$H_{sz} = H_0 - a\, Q_{sz} |Q_{sz}|$$

$$H'_{sz} = -2\, a\, |Q_{sz}|$$

Well

$$H_k = H_0 - k\, Q_k$$

Filter

$$h_{vs} = C\, Q_s\, |Q_s| + k_s\, Q_s$$

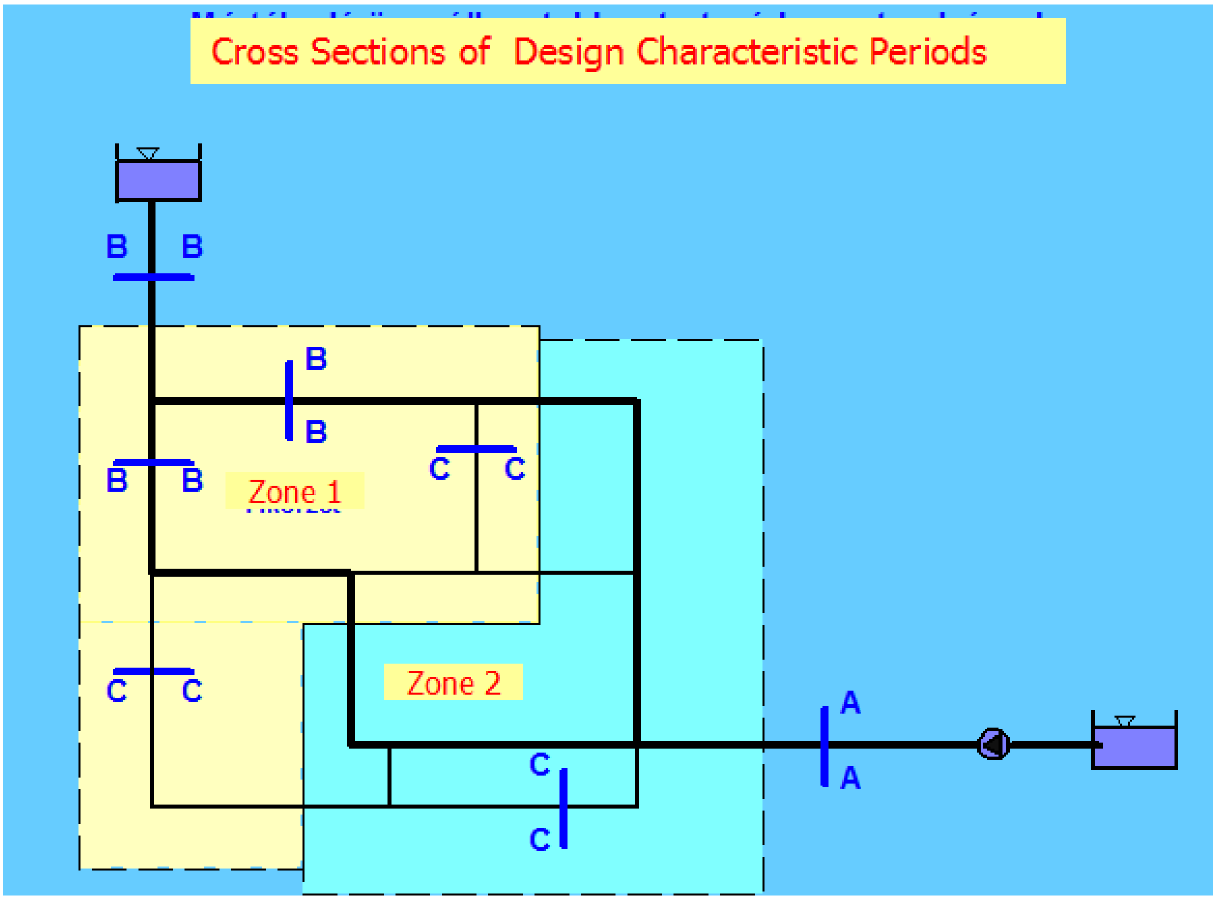
Modeling of the consumption …

9.4. Dimensioning and Checking of the Water Supply Network

The behavior of the water supply system is described by the KIRCHOFF equations having a quadratic expression for the pressure loss, therefore there is no explicit solution of the equation system based on our present knowledge. Therefore the dimensioning should follow the following steps:

- Assessment of the design flow for the certain pipe sections based on the consumption model.
- Calculation of the necessary pipe diameters based on the design flow.
- Iteration of hydraulic calculations, based on the above detailed mathematical model and checking of the velocities and pressures in the network in the characteristic design periods.
- Modifications of the previously assumed diameters, if the velocities in the network would be unfavourable high or low. Back to the checking.
  - The optimal velocity range in a water supply system: 0.4 - 1.2 m/s.
  - The pressure value in any nodes of the network can not be lower than the pre specified value based on the floor levels of the buildings in any characteristic design periods. In case of distribution conduits the maximum pressure is 60 m water column.
  - The optimal specific pressure loss along a conduit is: ~ 10 ‰

9.5. „Characteristic Periods” of the Water Supply System



Cross Section	**Water Consumption**	**Remarks**
A-A	Qpmax	The design state for the conduit from the input points.

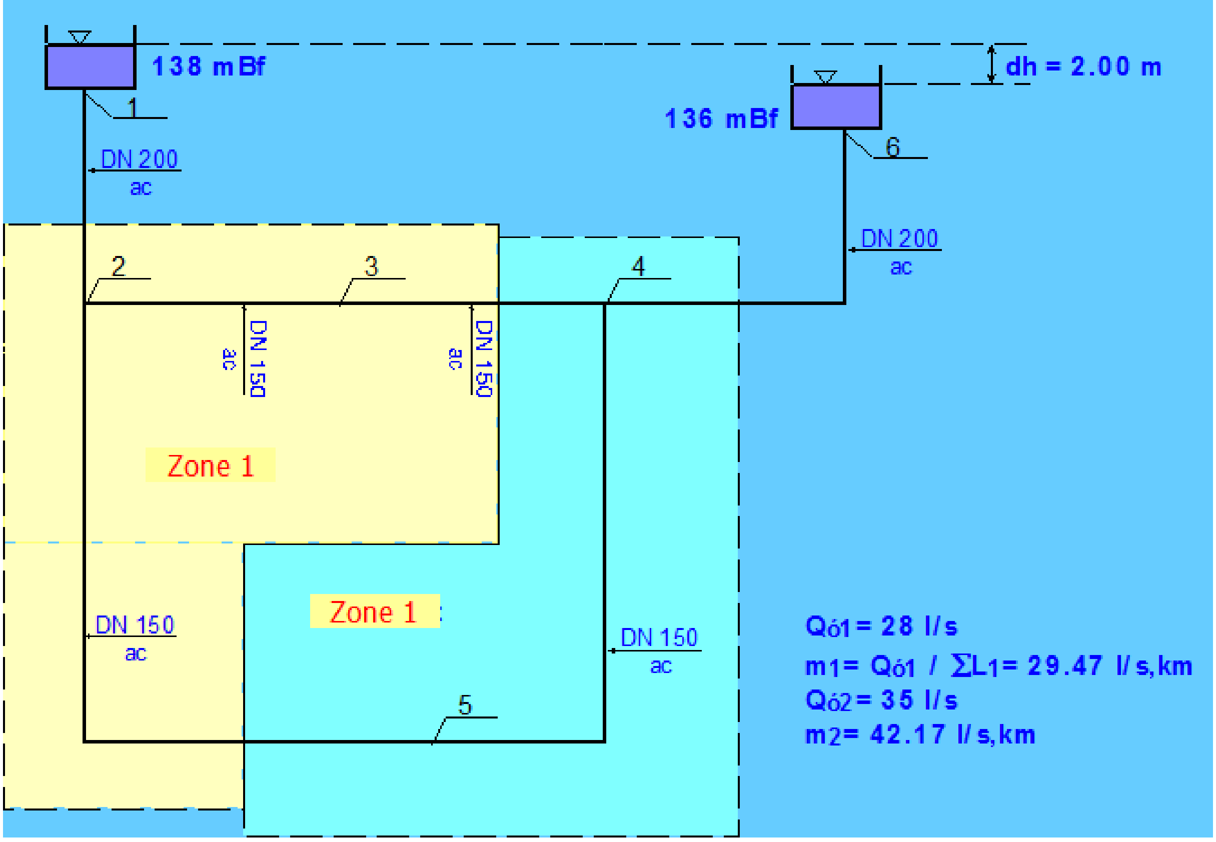
B-B	Max|Qp-Qcmax|	The design state for the conduits connecting the input point(s) and the reservoir(s) is the highest positive or negative value of the difference between the pumping and the consumption. In other words its is the condition of the highest filling or emptying of the reservoirs.
C-C	Qh	The first order distribution conduits should be designed for the maximum hourly value of their consumption area.

9.6. *Example*

CALCULATION OF LOADS

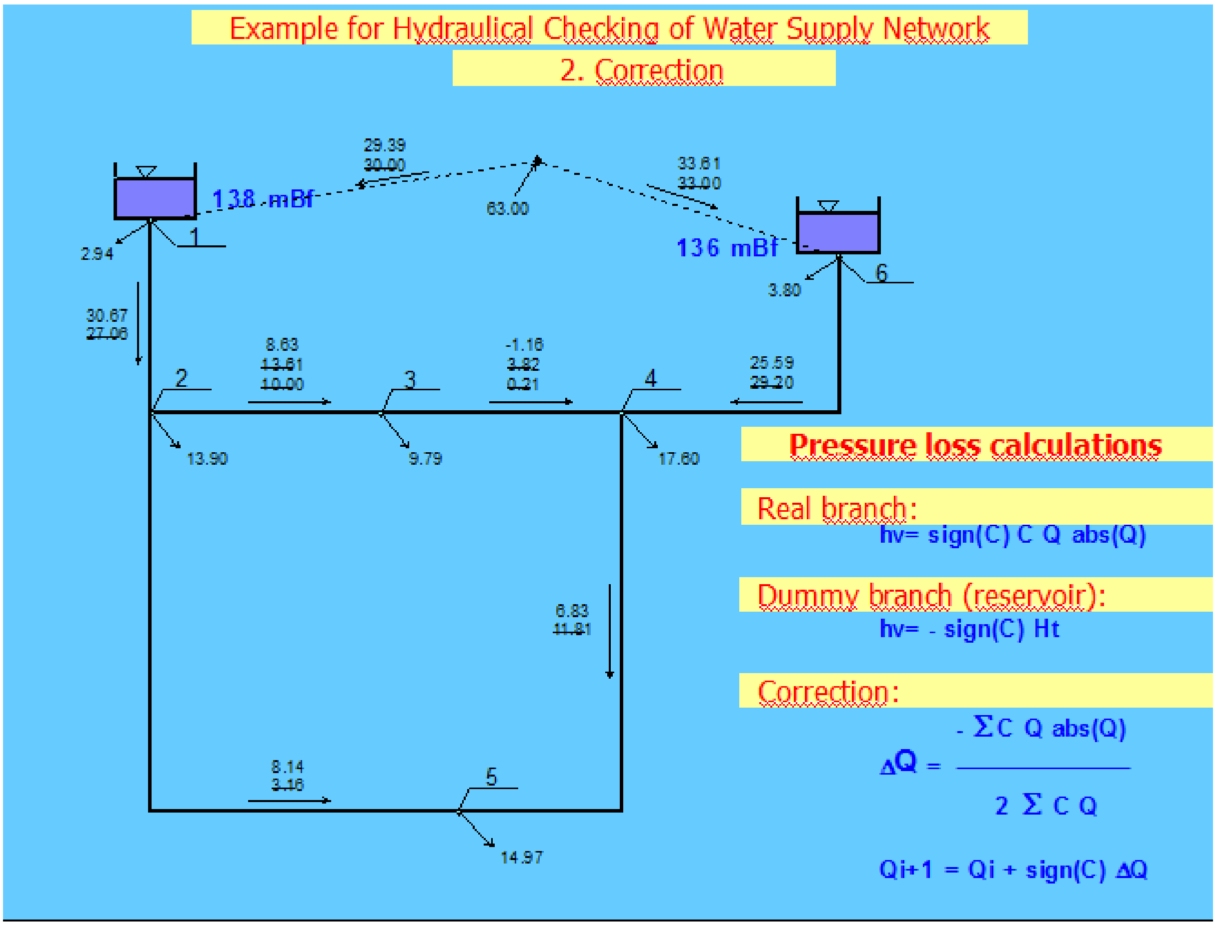
Example for Hydraulical Checking of Water Supply Network

1. Calculation of Loads



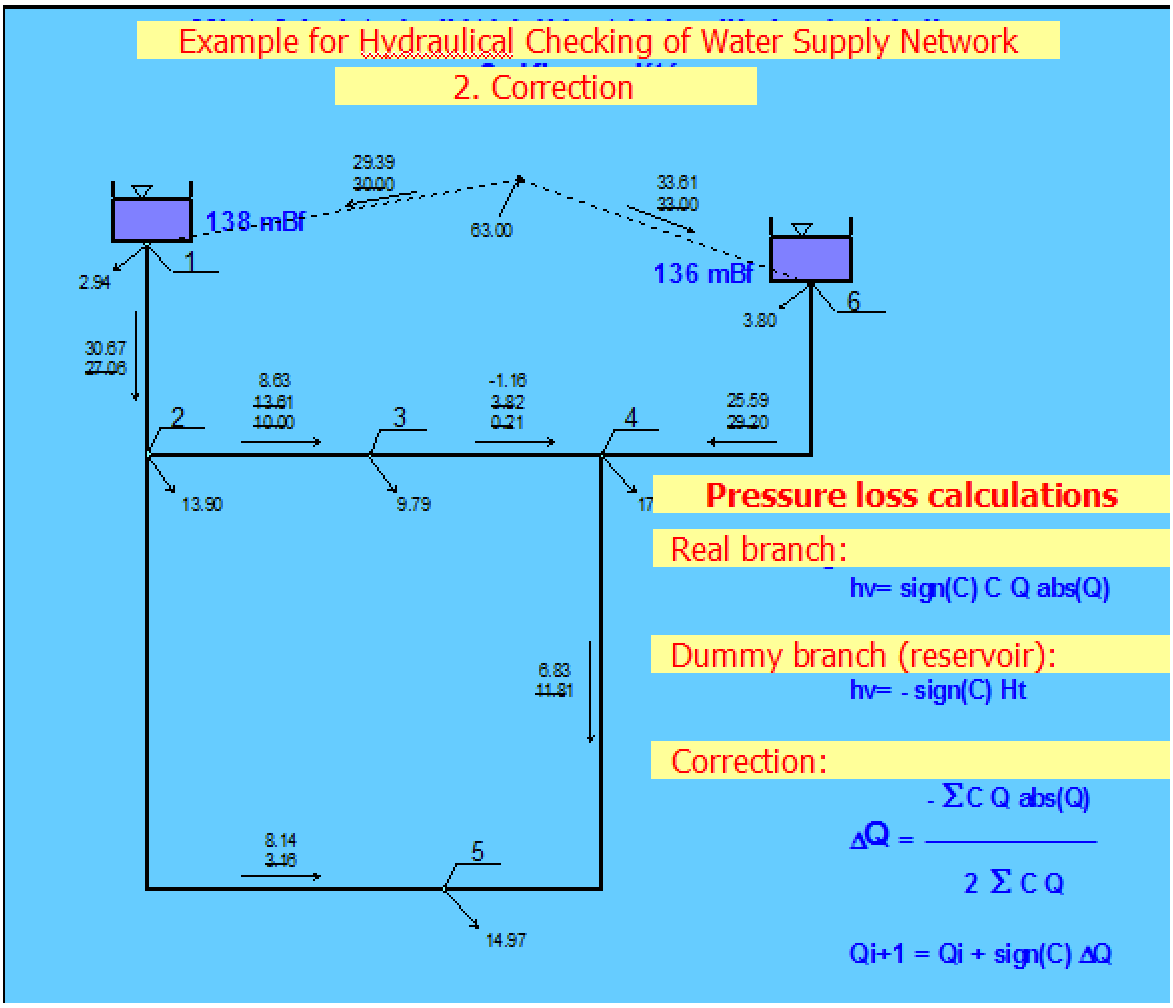
Branch name (j)	Length [km] L_j	Count of Zones (i)	Length in the Zone [km] L_i			Loads= $m_i L_i$			C=c1
			0	1	2	1	+ 2	= Σ	
1-2	0.5	2	0.3	0.2	-	5.89		5.89	3.18
2-3	0.3	1	-	0.3	-	8.84		8.84	8.64
2-5	0.4	2	-	0.3	0.1	8.84	4.22	13.06	11.52
3-4	0.3	2	-	0.15	0.15	4.43	6.32	10.75	8.64
4-5	0.4	1	-	-	0.4		16.87	16.87	11.52
4-6	0.6	2	0.42	-	0.18		7.59	7.59	3.82
ΣL_i			0.72	0.95	0.83	28.00	35.00	63.00	<- Control

1st Correction



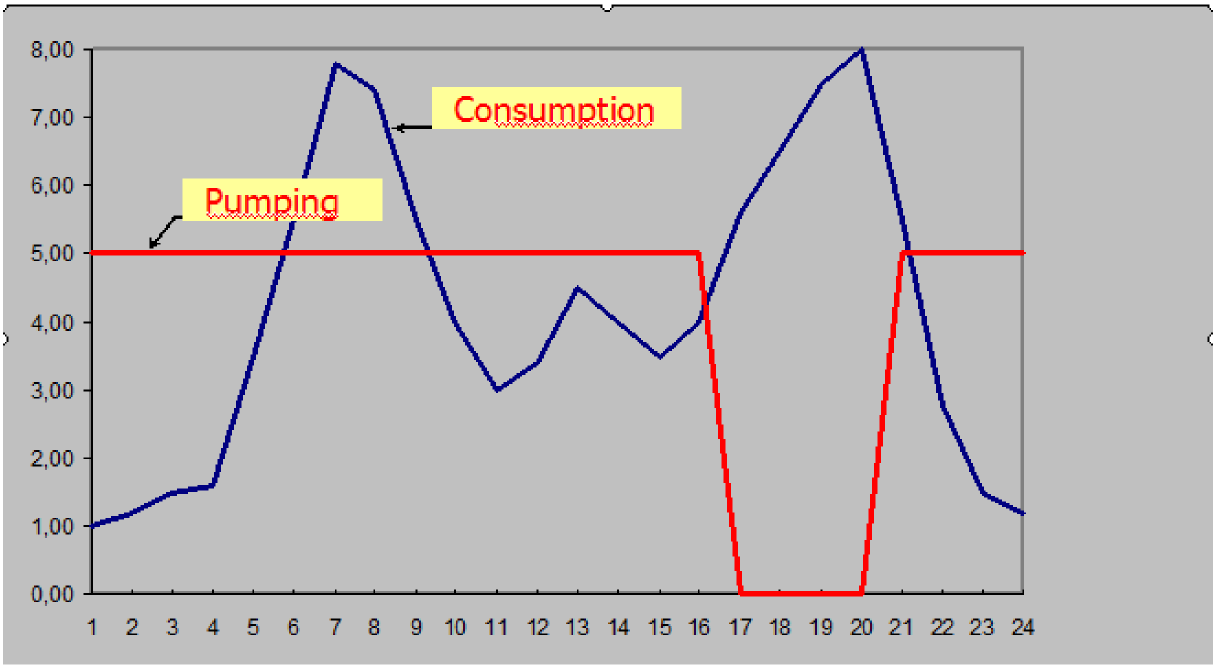
Branch (j) Node (k)	1-2	2-3	2-5	3-4	4-5	4-6	Σ
1	2.94						2.94
2	2.95	4.42	6.53				13.90
3		4.42		5.37			9.79
4				5.37	8.44	3.78	17.59
5			6.53		8.44		14.97
6						3.78	3.78
This is about 63 l/s which is equal to the controlof the previous table						Σ	62.97

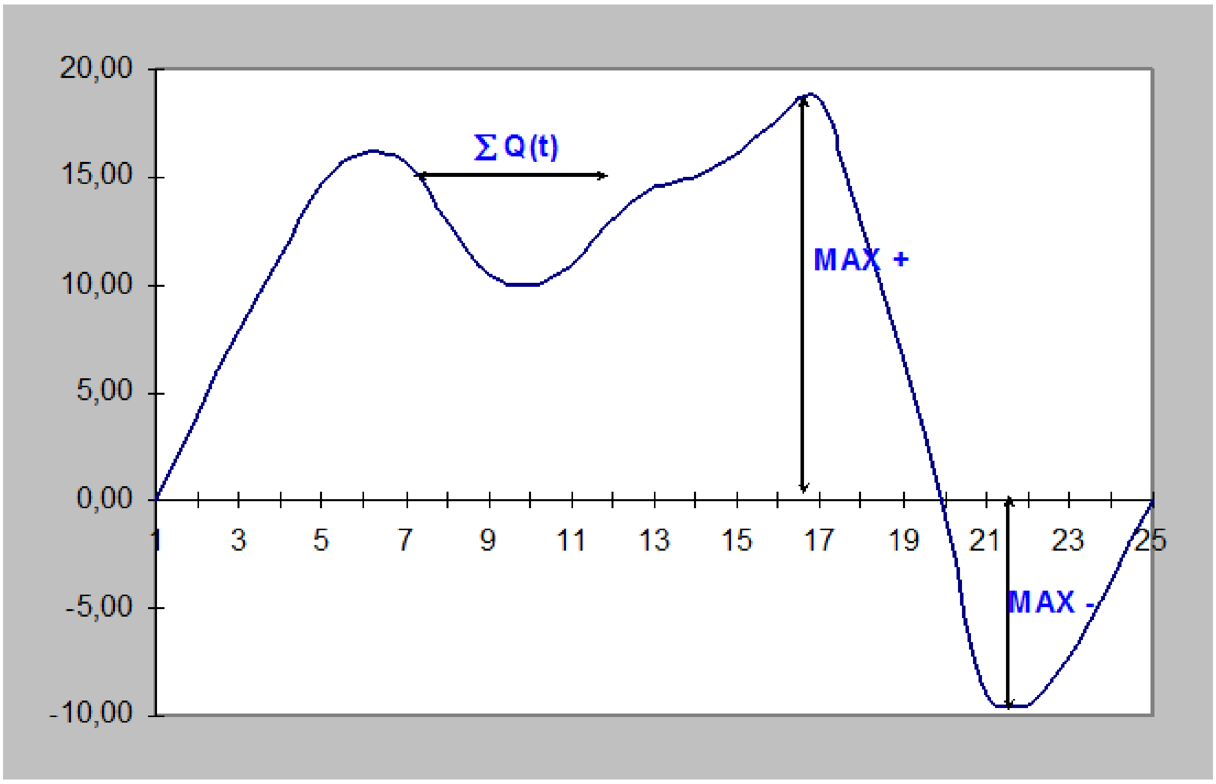
2nd Correction



branch	C	Q	CQ	CQ^2	Q+ΔQ
1-0	-0	+30.00	0	138000	+33.61
0-6	+0	+33.00	0	-136000	+29.39
6-4	-3.82	-29.20	111.54	+3257.08	-25.59
4-3	-8.64	+0.21	1.81	-0.38	+3.82
3-2	-8.64	+10.00	86.40	-864.00	+13.61
2-1	-3.18	+27.06	86.05	-2328.53	+30.67
		Σ	285.80	2064.17	**ΔQ = -3.61**
2-3	+8.64	13.61	117.59	+1600.66	8.63
3-4	+8.64	3.82	33.00	+126.15	-1.16
4-5	+11.52	11.81	136.05	+1606.76	6.83
5-2	-11.52	3.16	36.40	-115.03	8.14
		Σ	323.04	+3218.54	**ΔQ = -4.98**

Design of Reservoir Volume





$$\int_0^T Q(t)dt = 0$$

$$Q(t) = Q_{sz}(t) - Q_f(t)$$

Where:

T - length of the equalization

Q(t) – flow at the reservoir (filling or emptying) at time **t**

Tabular solution

Time period [h]	Consumption Q(t) [%]	Pumping Q(t) [%]	Flow at thereservoir Q(t) [%]	Σ Q(t) [%]
1	1,00	5,00	4,00	0,00
2	1,20	5,00	3,80	4,00
3	1,50	5,00	3,50	7,80
4	1,60	5,00	3,40	11,30
5	3,50	5,00	1,50	14,70
6	5,50	5,00	-0,50	16,20
7	7,80	5,00	-2,80	15,70
8	7,40	5,00	-2,40	12,90
9	5,50	5,00	-0,50	10,50
10	4,00	5,00	1,00	10,00
11	3,00	5,00	2,00	11,00
12	3,40	5,00	1,60	13,00
13	4,50	5,00	0,50	14,60
14	4,00	5,00	1,00	15,10
15	3,50	5,00	1,50	16,10
16	4,00	5,00	1,00	**17,60**
17	5,60	0,00	-5,60	18,60
18	6,50	0,00	-6,50	13,00
19	7,50	0,00	-7,50	6,50
20	8,00	0,00	-8,00	-1,00
21	5,50	5,00	-0,50	-9,00
22	2,80	5,00	2,20	**-9,50**
23	1,50	5,00	3,50	-7,30
24	1,20	5,00	3,80	-3,80
Sum	100,00	100,00	0,00	0,00

10. MODELLING OF SEWER SYSTEMS

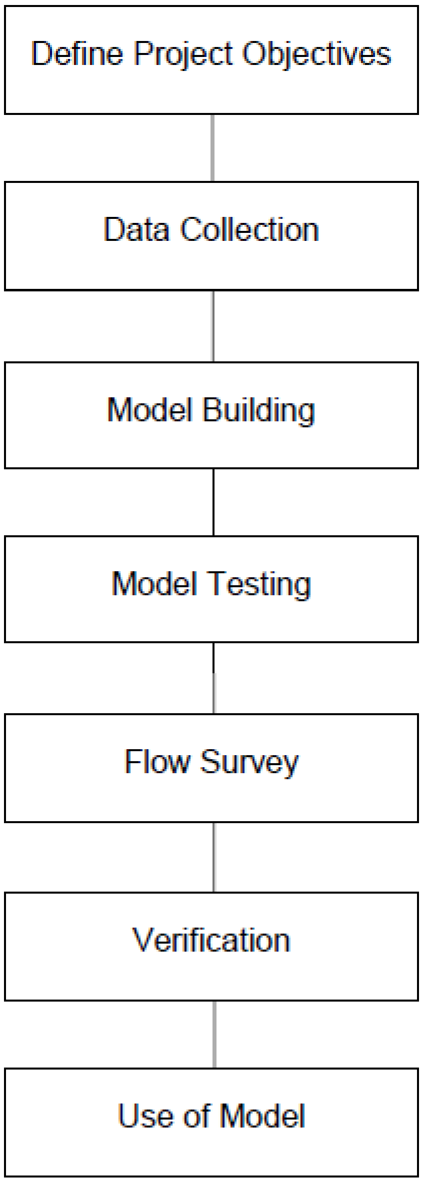
10.1. WaPUG

In 1984 the National Water Council Sewers and Water Mains Committee (UK) authorised the creation of the Wallingford Procedure Users Group, now the Wastewater Planning Users Group (WaPUG).

Sewer hydraulic modelling has now become an indispensable tool in the planning and design of sewer systems. It is therefore important that all network models constructed for use in hydraulic modelling should be built to an agreed standard and adequately documented.

In response, WaPUG promoted the production of this Code of Practice which has incorporated the views of recognised “expert” users from within the water industry. The Code is divided into 10 sections covering all aspects of model building for hydraulic analysis and testing, flow surveys and verification, and documentation, all of which can be incorporated into a quality system.

Flow diagram of hydraulic modelling work



Model Objectives

Model objectives could include:

To predict the volumes and frequencies of discharge from all the combined sewage overflows in the catchment and to provide the basis for designing upgrading solutions to improve the river water quality. Depending on the findings of the investigation the model may later be used as the basis for a sewer quality model.

To identify the locations and causes of all flooding in the catchment as well as the volumes and frequencies of discharge from combined sewer overflows to develop a drainage study incorporating schemes to resolve the hydraulic, receiving water quality and structural problems in the catchment.

To identify the causes of the sewer flooding problems at [a specific location] and to provide the basis for designing flood alleviation scheme options.

To predict the volume and frequency of discharges at the outfall from the catchment and to provide the basis for designing a new tank and pumping station to improve the bathing water quality.

Rain Gauge Densities

Type of terrain	Typical number of raingauges
Flat	1 + 1 per 4 km^2
Average	1 + 1 per 2 km^2
Mountainous	1 + 1 per 1 km^2

Notes:
1. A minimum of 3 raingauges is required.
2. It may not be possible to achieve these levels in large type I models. In these cases the modeller will have to use judgement to determine the number used.

Location of Flow Survey Monitors

a) At the system outfall, to give a check on the overall accuracy of simulation and to enablethe significance of inaccuracies at individual monitoring sites to be assessed.

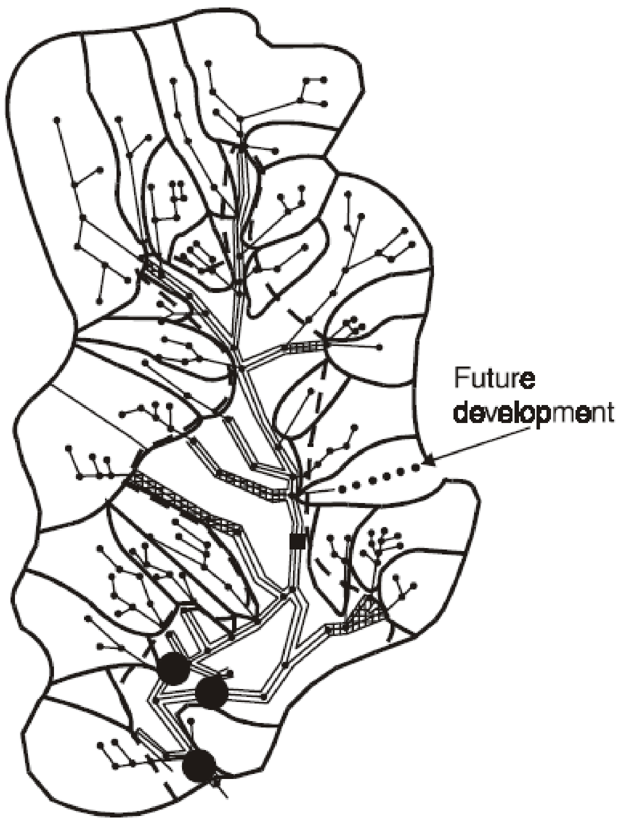
b) In large subcatchments free from known major problems, a single monitor should be placed on each main branch sewer near the junction with the trunk sewer. The recorded data will confirm whether the modelled response from the subcatchment is accurate.

c) In subcatchments experiencing known performance problems, where accuracy in modelling is particularly important, monitors should be placed at critical points to enable

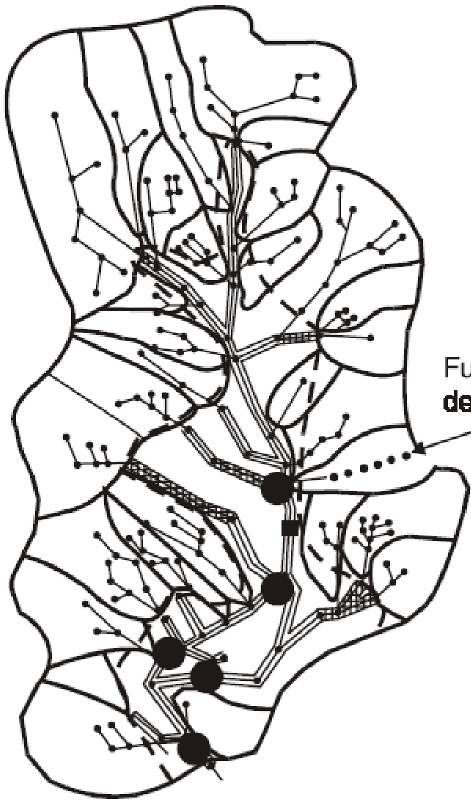
verification of these areas.

d) Monitors should also be placed at points along the main trunk sewer at or near major junctions where the effects of major subcatchment flows can be assessed. They may also indicate any major connections or features, such as overflows, that have been omitted.

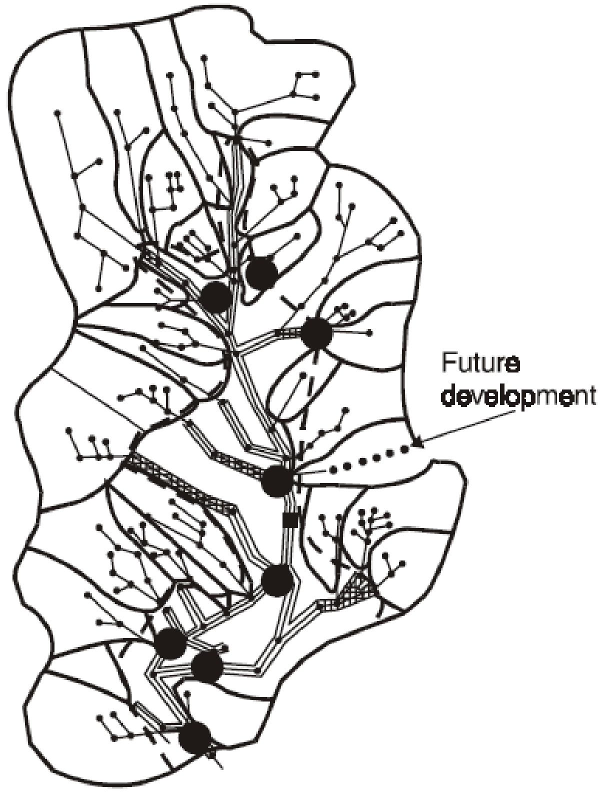
e) Upstream and downstream of major combined sewer overflows, bifurcations, loops or specific problem points, so that their behaviour can be defined, provided that there is adequate rainfall during the survey. When there are large numbers of combined sewer overflows it will not generally be possible to monitor all of them. In these cases groups of combined sewer overflows should be monitored upstream and downstream.



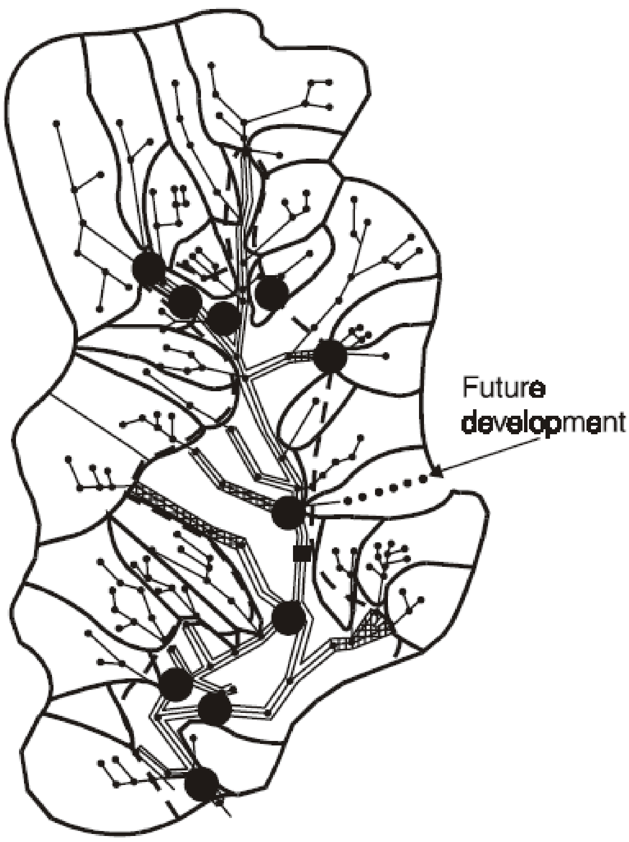
Case 1 Monitoring at outfall



Case 2 Monitoring at keys sites

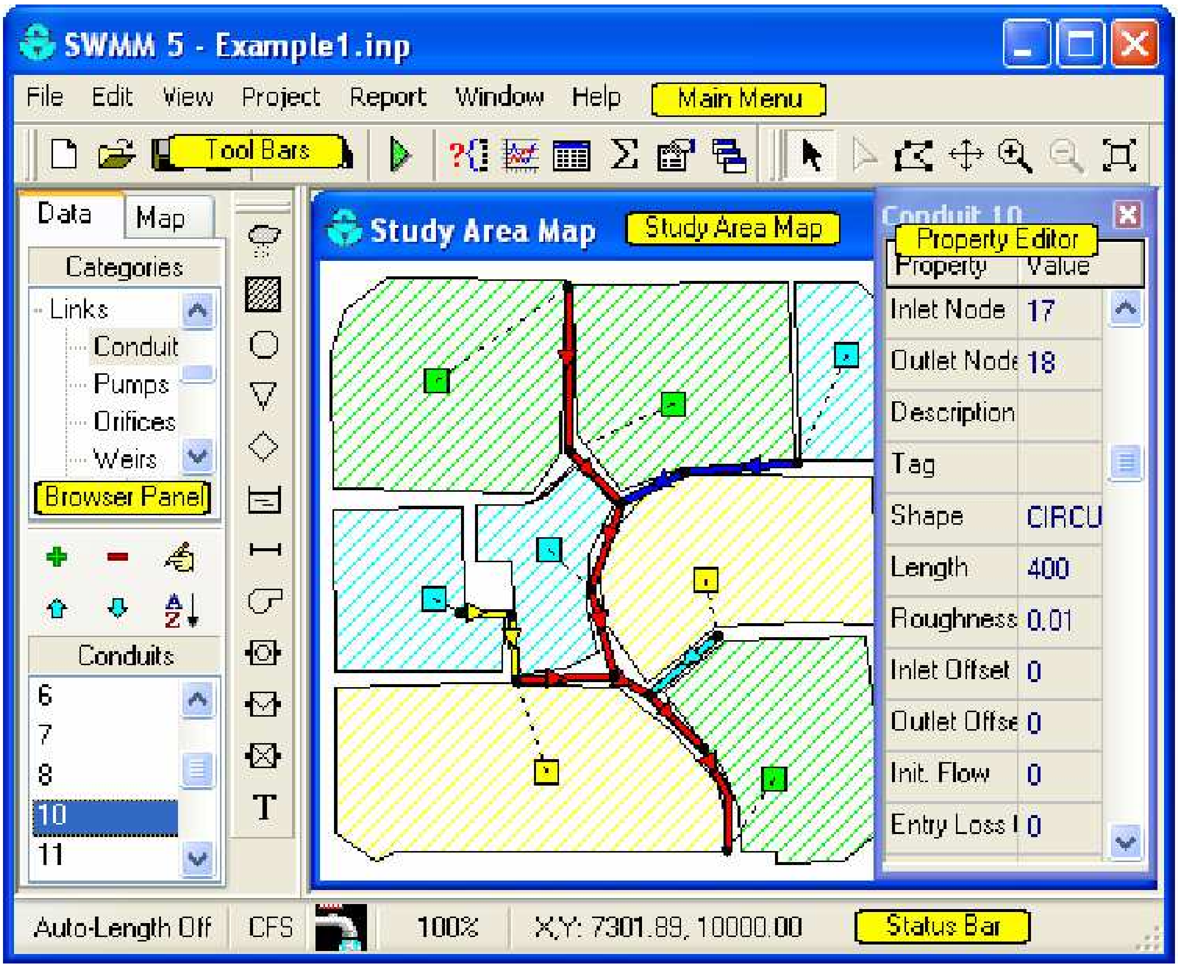


Case 1 Monitoring throughout catchment



Case 4 More detailed monitoring throughout catchment

10.2. SWWM: Storm Water Management Model



Main Features

Dynamic model for quantitative and qualitative simulation of runoff from mainly urban areas in short or long time period.

The surface runoff model generates runoff and pollution flood wave from the rainfall reaching the subcatchments.

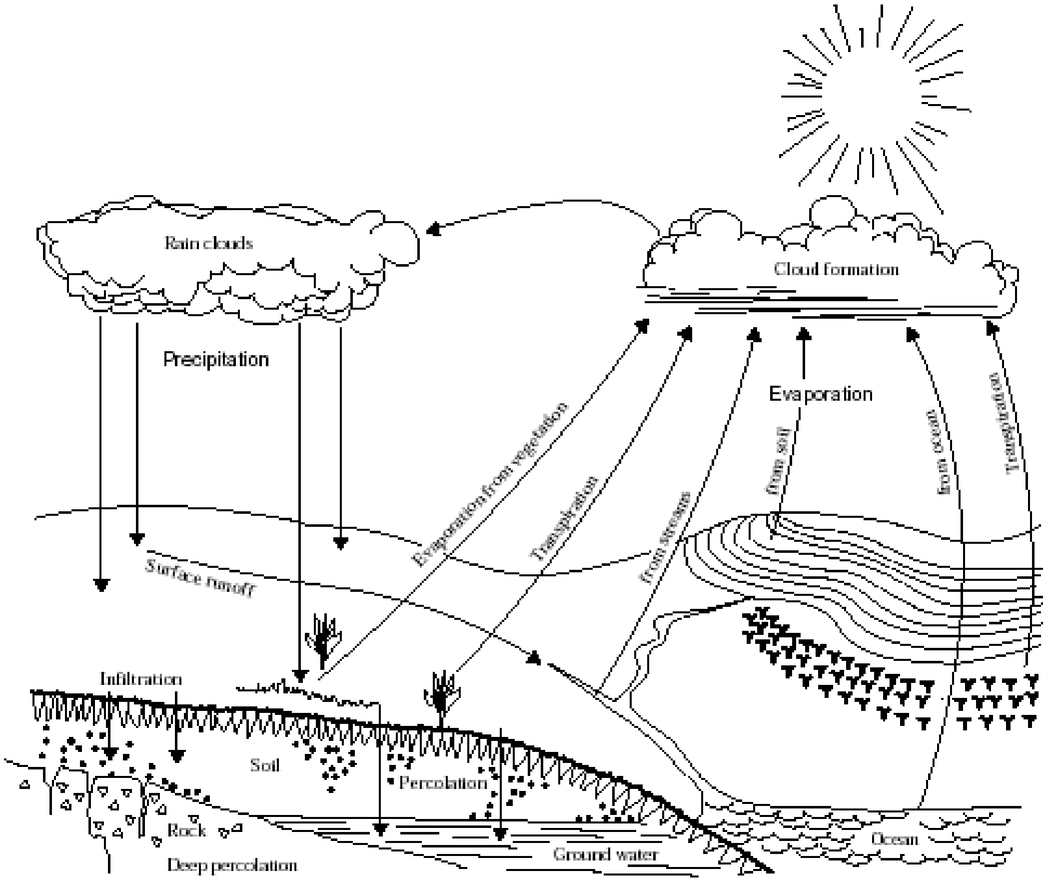
From this load calculates the routing model the runoff in the pipes, open channels, reservoirs, treatment units, pumps and controls.

The SWMM traces the quantity and quality of runoff from the subcatchments and in the pipes and channels, calculates the flows, water levels and water quality in different time-steps.

Modifications in the Versions

- 1969-1971: EPA (Metcalf and Eddy) the first complex urban runoff model
- 1975 version 2
- 1981 version 3
- 1988 version 4: dynamic wave
- 2004 November: version 5
  - graphical user interface
  - object oriented C program language (instead of Fortran 77)
  - more general models e.g.:
    - routing between subcatcments
    - general management of the tags of the momentum equation and local losses
    - user defined control rules for the operation of pumps and overflows
  - eliminating the limits e.g.:
    - number of elements (nodes and other hydraulic elements)
    - number of water quality parameters
  - building of missing connections between models e.g.:
    - rainfall series and infiltration into the conduits
    - water quality modeling simultaneously with flow
  - numerically more stable methods
  - input files can be imported from SWMM4 to SWMM5

Features of the Hydrological Model



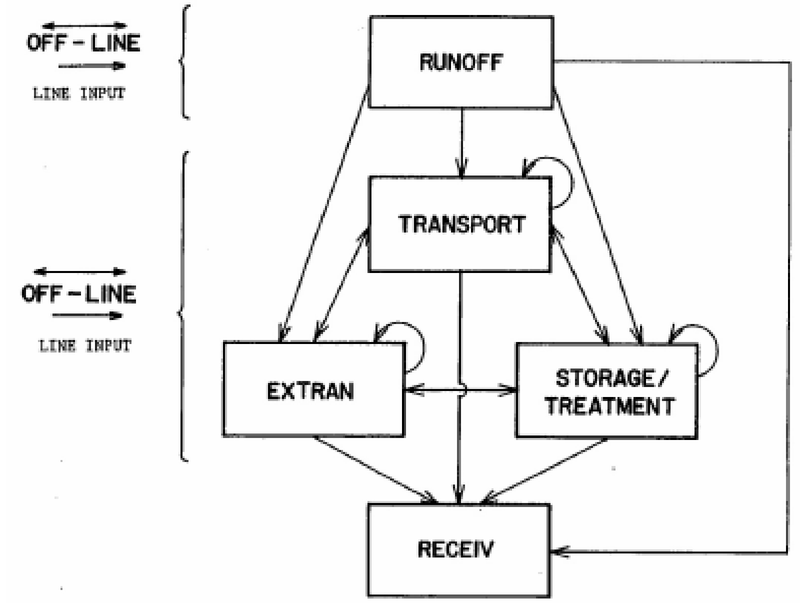
- non permanent **precipitation**
- **evaporation** from the surface of lakes
- Concentration and melting of **snow**
- **concentration** of precipitation on deeper areas
- **infiltration** of precipitation into the non-saturated soil layers
- **percolation** of infiltrated rainfall into the groundwater layers
- **flow** between the groundwater and the sewers
- **surface runoff** is modeled as non-linear reservoir

The spatial distribution of the above processes modeled by dividing into subcatchments (divided into pervious and impervious subareas). The surface runoff can be routed between subcatchments, subareas and sewer inlet points.

Features of the Hydraulical model

- the network size is **not limited**

- **pre-defined** and **user-defined** closed and open **cross sections**



•

special elements: reservoir, treatment unit, divider, pump, weir, orifice, outlet

- external **inflows** and **pollution** loads from surface runoff, ground water, infilltration/inflow from precipitation, dry weather flow and other user defined flow

- selection between **kinematic** and **dynamic** flood wave

- modeling different flow: **backflow**, **pressure flow**, surface depression storage from runoff

- user defined **dynamic controls** for the operation of the pumps, weirs, outlets

The Main Computational Blocks of SWMM Model

Off-line input-output:

via files

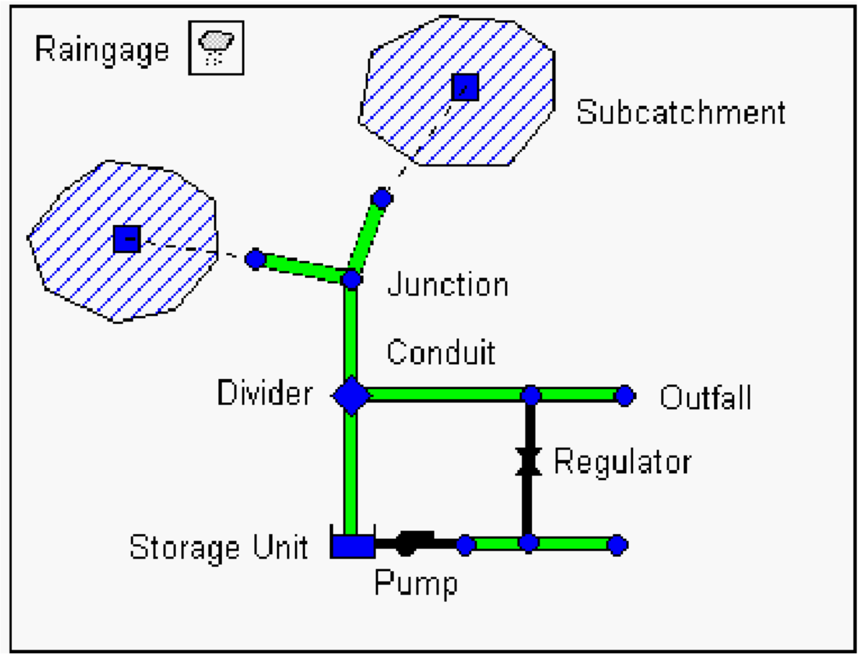
Easy connections to external programs

E.g.. Arcview, Mike-SWMM (Mouse)

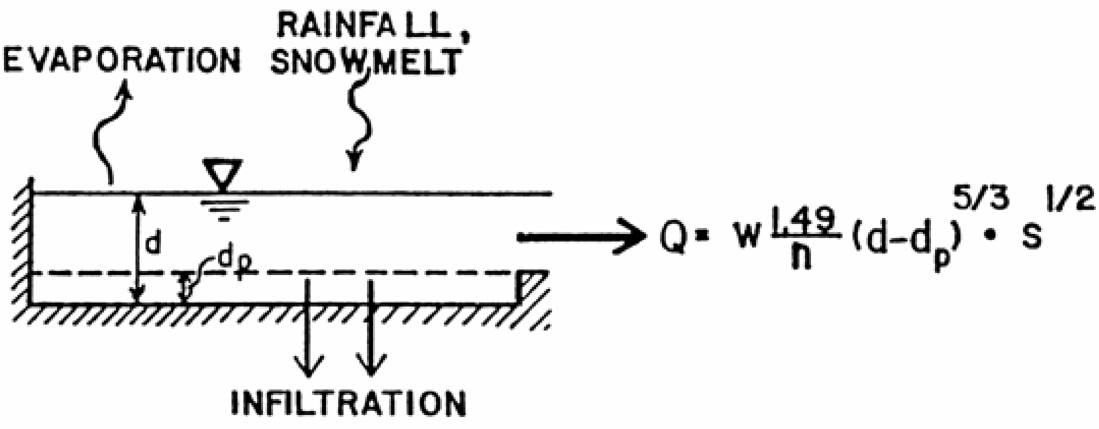
Objects in the Model

1. Outfall – Only for dynamic wave, in case of kinematic wave only simple junction
2. Divider – Only for kinematic wave, in case of dynamic wave only simple junction

3. Regulator – as reservoir outlet always, otherwise only for dynamic wave, otherwise only simple junction

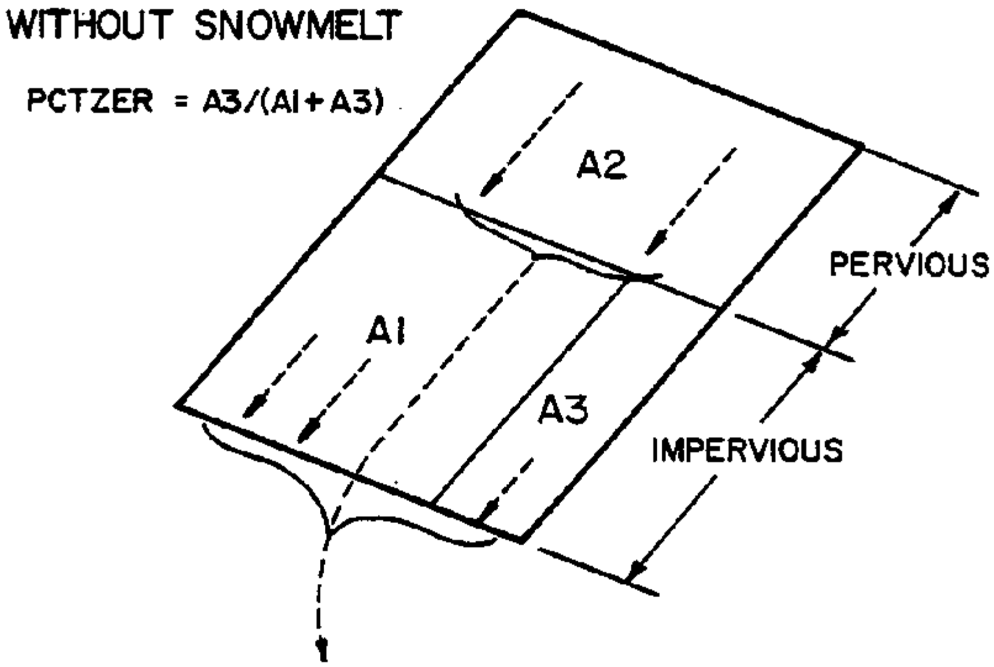


Modeling of Subcatchments as Non-Linear Reservoirs



Dividing of Subcatchments

A1=impervious area with depression storage

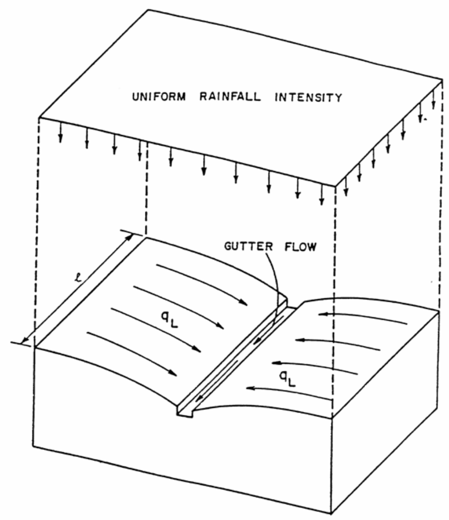


A2=pervious with depression storage

A3=impervious area without depression storage

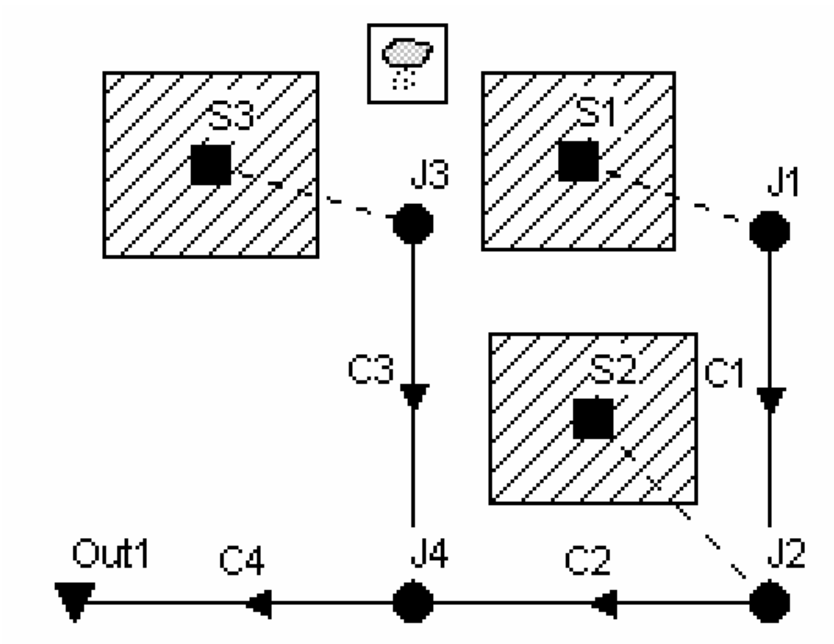
Water can flow from each subarea directly to inlet or through another subarea.

Interpretation of Subcatchment Area Width (W)



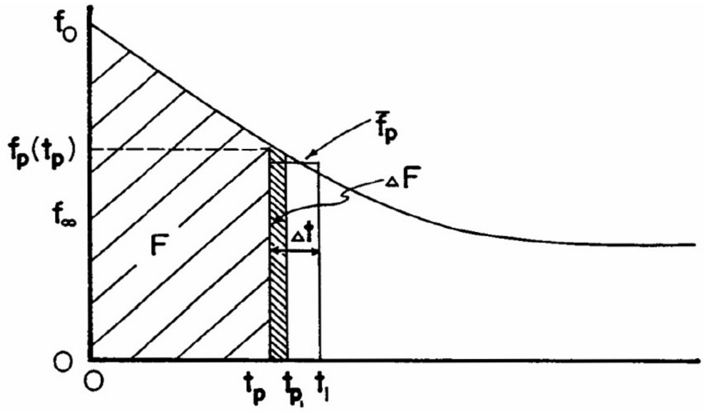
q_L = RATE OF OVERLAND FLOW/UNIT WIDTH.
W = 2ℓ = TOTAL WIDTH OF OVERLAND FLOW

Connecting Subcatchment and Junctions



Possible Infiltration Models

Horton model



$$f_p = f_\infty + (f_0 - f_\infty) \cdot e^{-\alpha \cdot t}$$

$$f(t) = \min[f_p(t), i(t)]$$

f = actual infiltration

I = rainfall intensity

fp = infiltration capacity

f∞ = end (minimum) infiltration capacity

f0 = initial (maximum) infiltration capacity

t = time from the beginning of the rainfall

α = rate of decrease

Green-Ampt model

$$f_p = K_S \cdot \left(1 + \frac{S \cdot IMD}{F}\right)$$

f = fp , means that actual infiltration=infiltration capacity

Ks = hydraulic conductivity of saturated soil

S = average capillaric pressure at the bottom of the capillaric zone

IMD = initial moisture deficit

F = summed infiltration flow

SCS curves

Parameters to give:

- curve number
- soil conductivity
- drying time

Flow Calculation in the Surface Runoff Model

Continuity equation:

Change of stored volume in unit time	Surplus precipitation (inflow to the subcatchmant)	Runoff (outflow from the subcatchment)

$$\frac{dV}{dt} = \frac{d(A \cdot d)}{dt} = \left(A \cdot I_e\right) - Q$$

where:V = A*d = water volume on the subcatchment

A = area of the subcatchment

d = water depth on the subcatchment

t = time

Ie = surplus precipitation=

rainfall intensity – evaporation - infiltration

Q = outflow from the subcatchment

Manning equation:

$$Q = A_k \cdot \left(\frac{\beta}{n}\right) \cdot R^{2/3} \cdot S_0^{1/2} = W \cdot \left(\frac{\beta}{n}\right) \cdot \left(d - d_p\right)^{5/3} \cdot S_0^{1/2}$$

Ak = cross sectional area of the flow from the subcatchment=w*(d-dp)

n = Manning coefficient

R = hydraulic radius of the flow from the subcatchment=[w*(d-dp)]/w=d-dp

S0= slope of the subcatchment (which is assumed to be equal to the slope of the energy line)

β = 1.49 (in case of US units),

1 in metric system

w = width of flow from subcatchment

dp = maximum storage depth on the subcatcment

combining the 2 equations:

Nonlinear equation can be solved to dn

assuming d=(dn+dn+1)/2

From this Q can be calculated based on the

Manning equation.

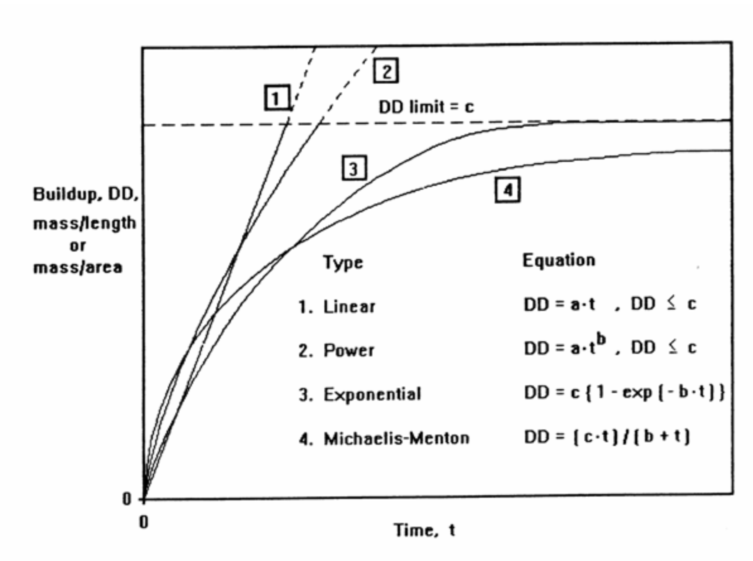
The method is numerically relatively stable, only in case of small subcatchment area (a few m2) and big time-step (>10 minutes) can be unstable.

Parameters of the Water Quality Variables

- concentration in the precipitation
- concentration in the ground-water
- concentration in the inflow/infiltration
- K – decay coefficient
- only in snow or always present
- co-pollutant (washing out together)
- co-pollutant rate

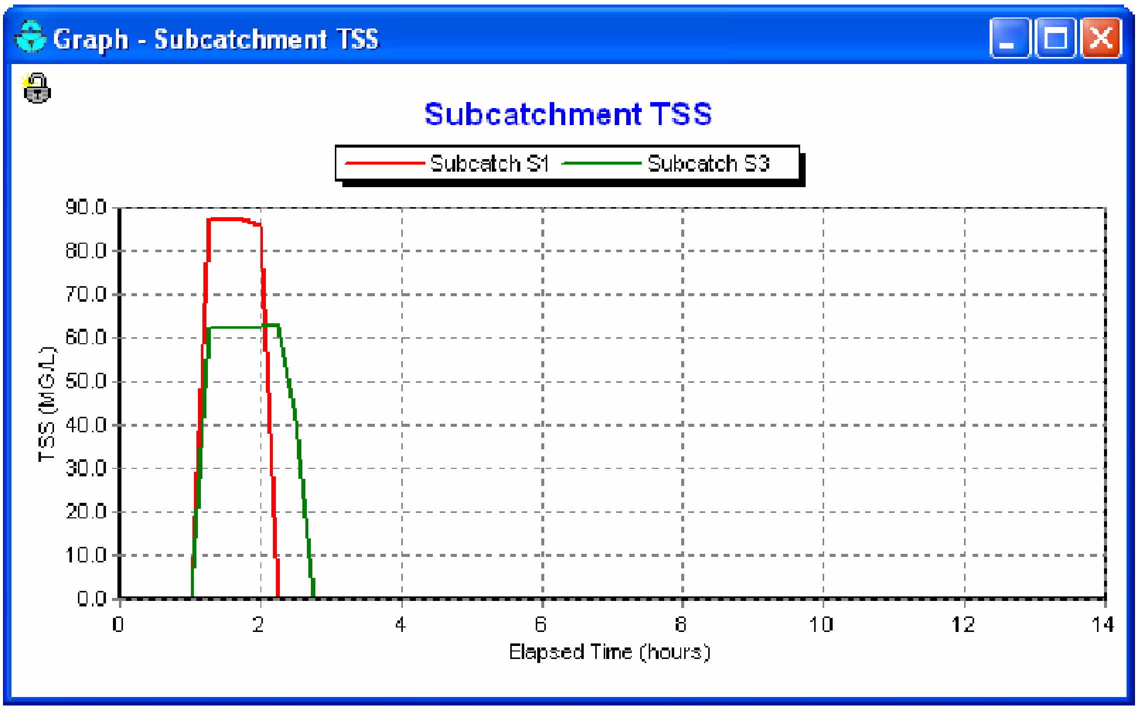
The precise calibration of the water quality model is important (otherwise the results are comperable only within a project).

Pollution Build-up in the Surface Runoff Model

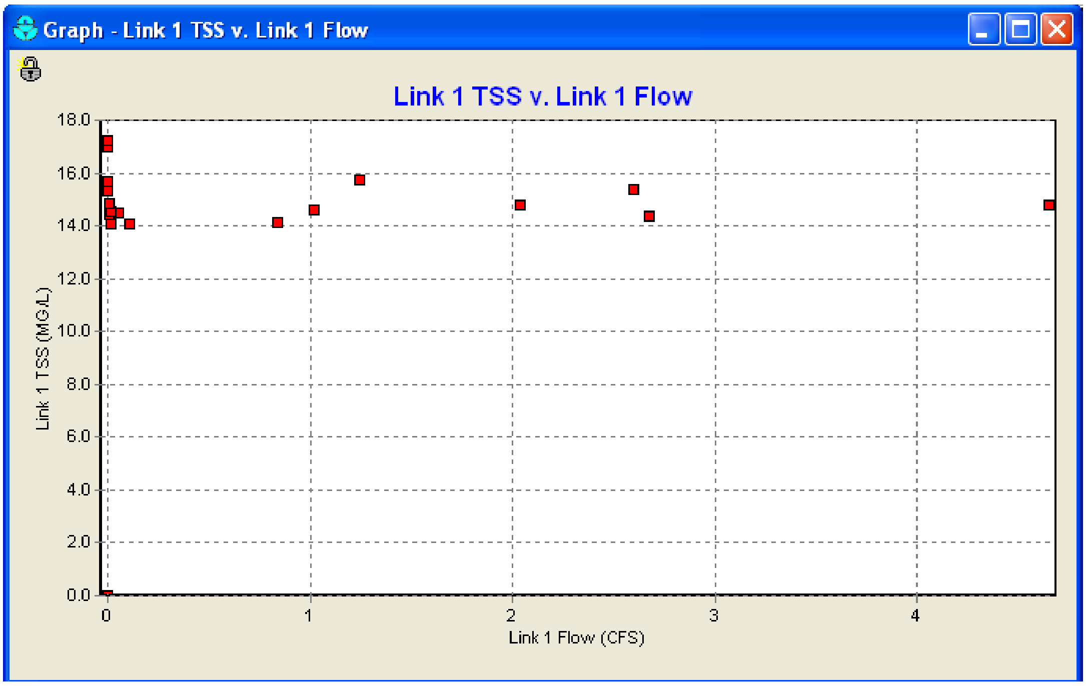


The parameters of the functions can be given for land uses categories for each pollutant.

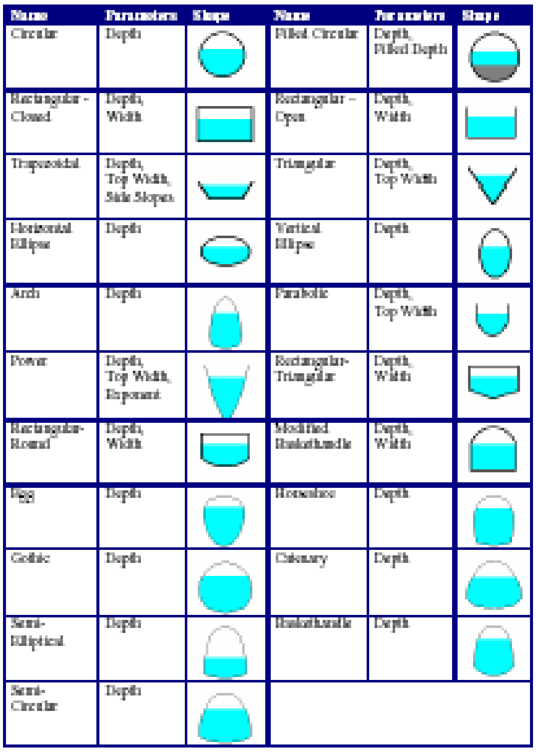
Time Series of Water Quality Parameters in Subcatchments



Time Series of a Water Quality Parameter vs. the Flow in a Pipe

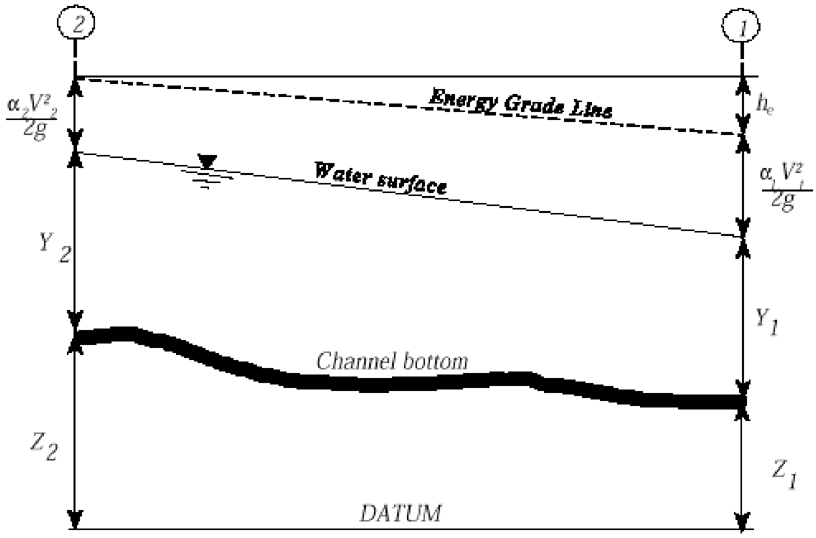


Cross section Profiles of Sewers



Name	Parameters	Shape	Name	Parameters	Shape
Circular	Depth		Filled Circular	Depth, Filled Depth	
Rectangular - Closed	Depth, Width		Rectangular - Open	Depth, Width	
Trapezoidal	Depth, Top Width, Side Slopes		Triangular	Depth, Top Width	
Horizontal Ellipse	Depth		Vertical Ellipse	Depth	
Arch	Depth		Parabolic	Depth, Top Width	
Power	Depth, Top Width, Exponent		Rectangular-Triangular	Depth, Width	
Rectangular-Round	Depth, Width		Modified Baskethandle	Depth, Width	
Egg	Depth		Horseshoe	Depth	
Gothic	Depth		Catenary	Depth	
Semi-Elliptical	Depth		Baskethandle	Depth	
Semi-Circular	Depth				

Energy Grade Line



Saint-Venant Equation

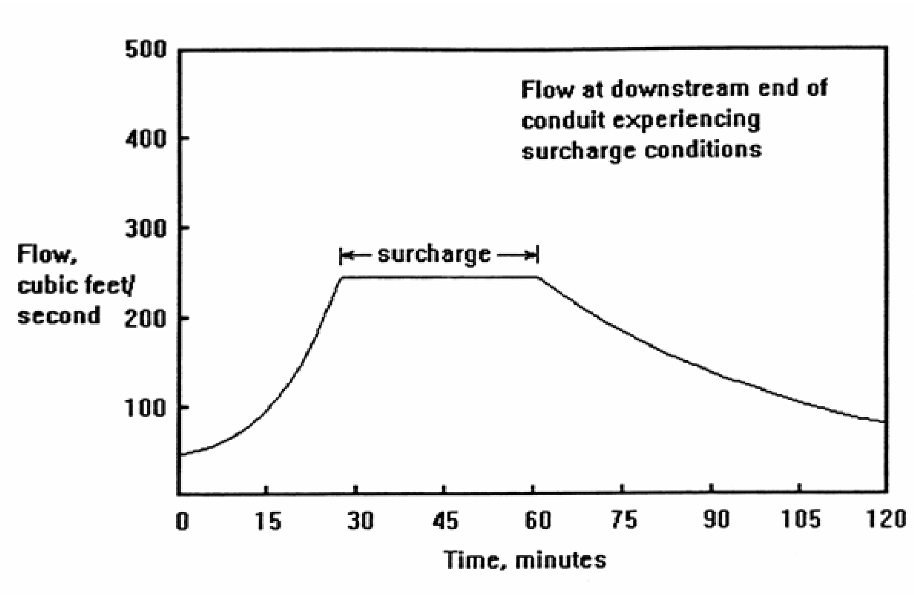
$$S_f = S_0 - \frac{\partial y}{\partial x} - \frac{V}{g}\frac{\partial V}{\partial x} - \frac{1}{g}\frac{\partial V}{\partial t}$$

Relative Magnitudes of Momentum Energy Terms

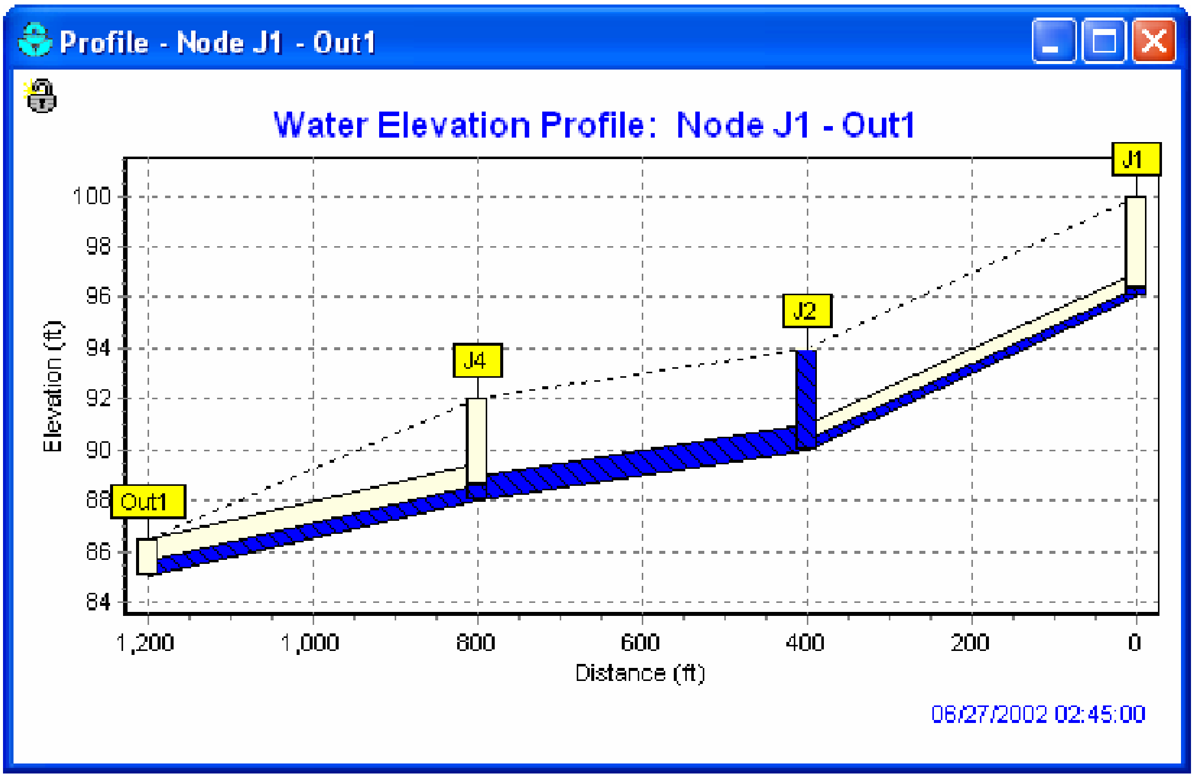
Table 8-1. Relative magnitude of momentum equation terms for steep channel, rapidly-rising hydrograph (from Henderson, 1966)

Term (1)	Magnitude (2)
S_o (bottom slope)	26
$\frac{\partial y}{\partial x}$ (pressure gradient)	0.5
$\frac{V}{g}\frac{\partial V}{\partial X}$ (convective acceleration)	0.12-0.25
$\frac{1}{g}\frac{\partial V}{\partial t}$ (local acceleration)	0.05

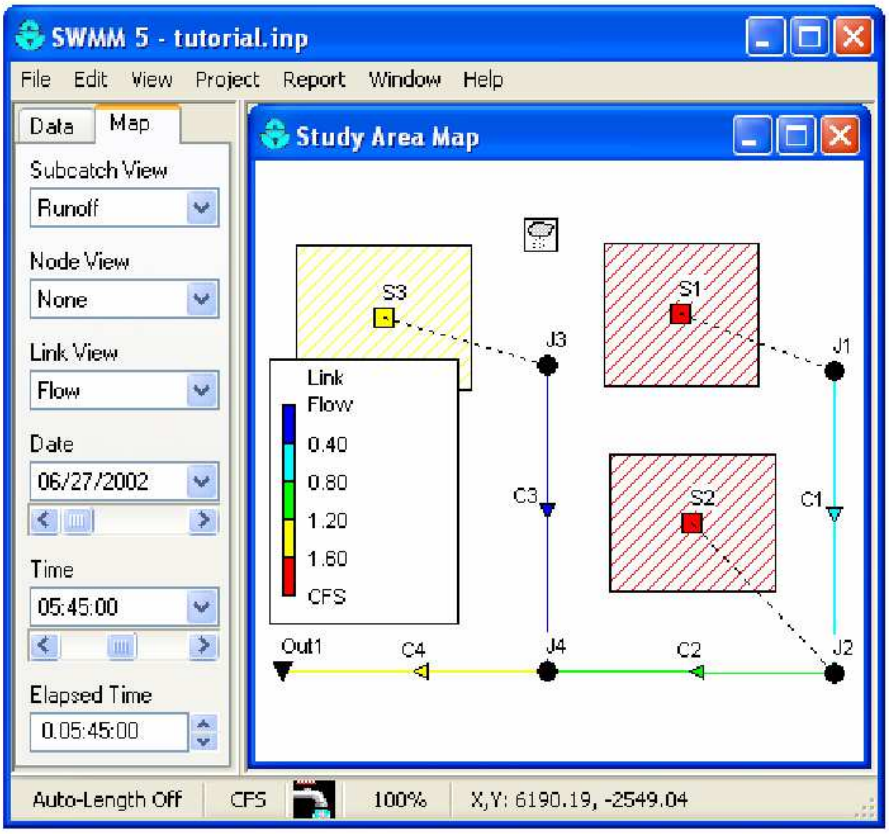
Effect of the Kinematic Wave Method on the Flood Wave



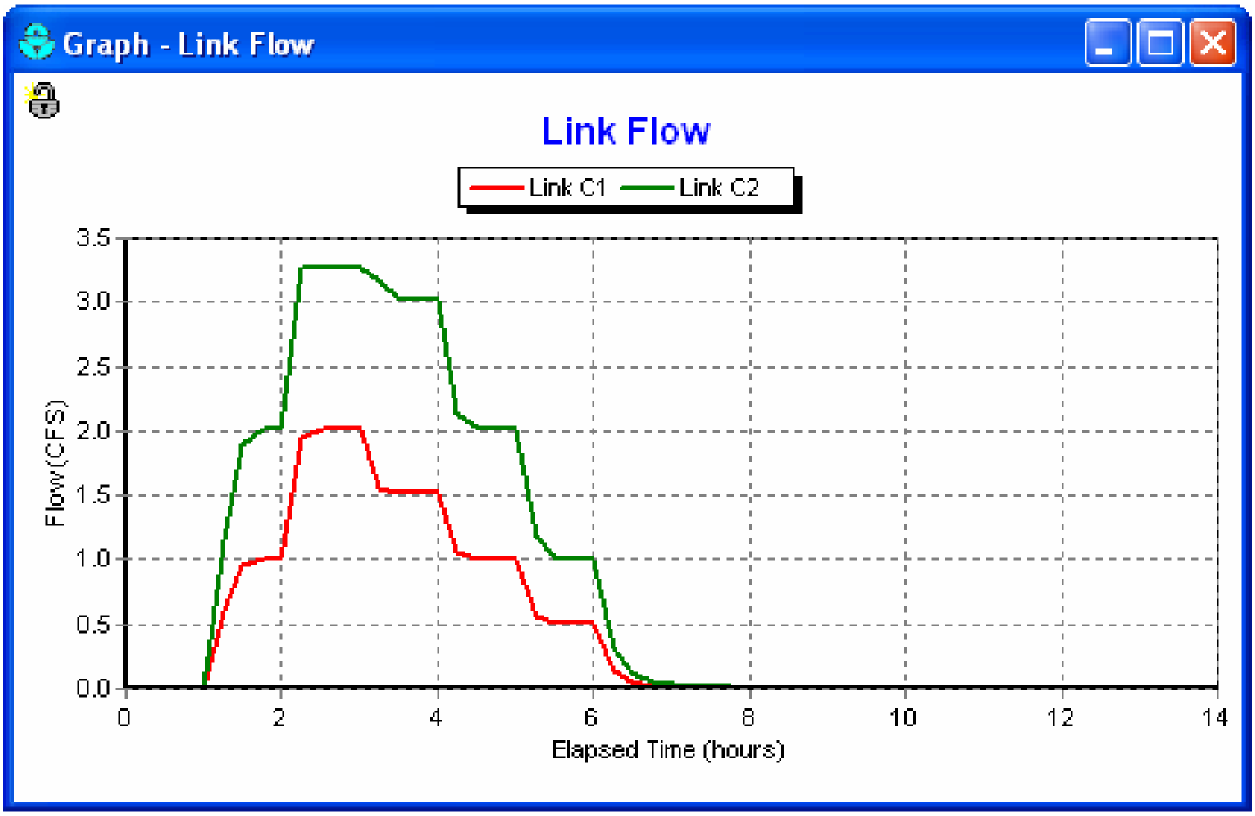
Results on Longitudinal Profile



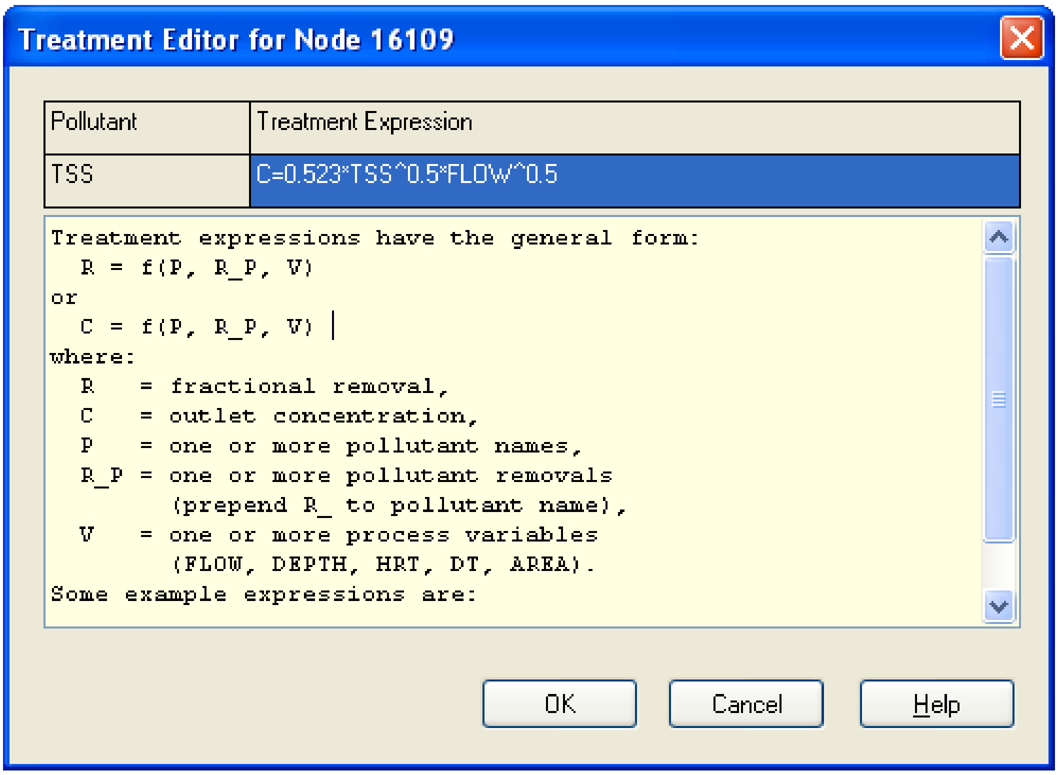
Results on Layout



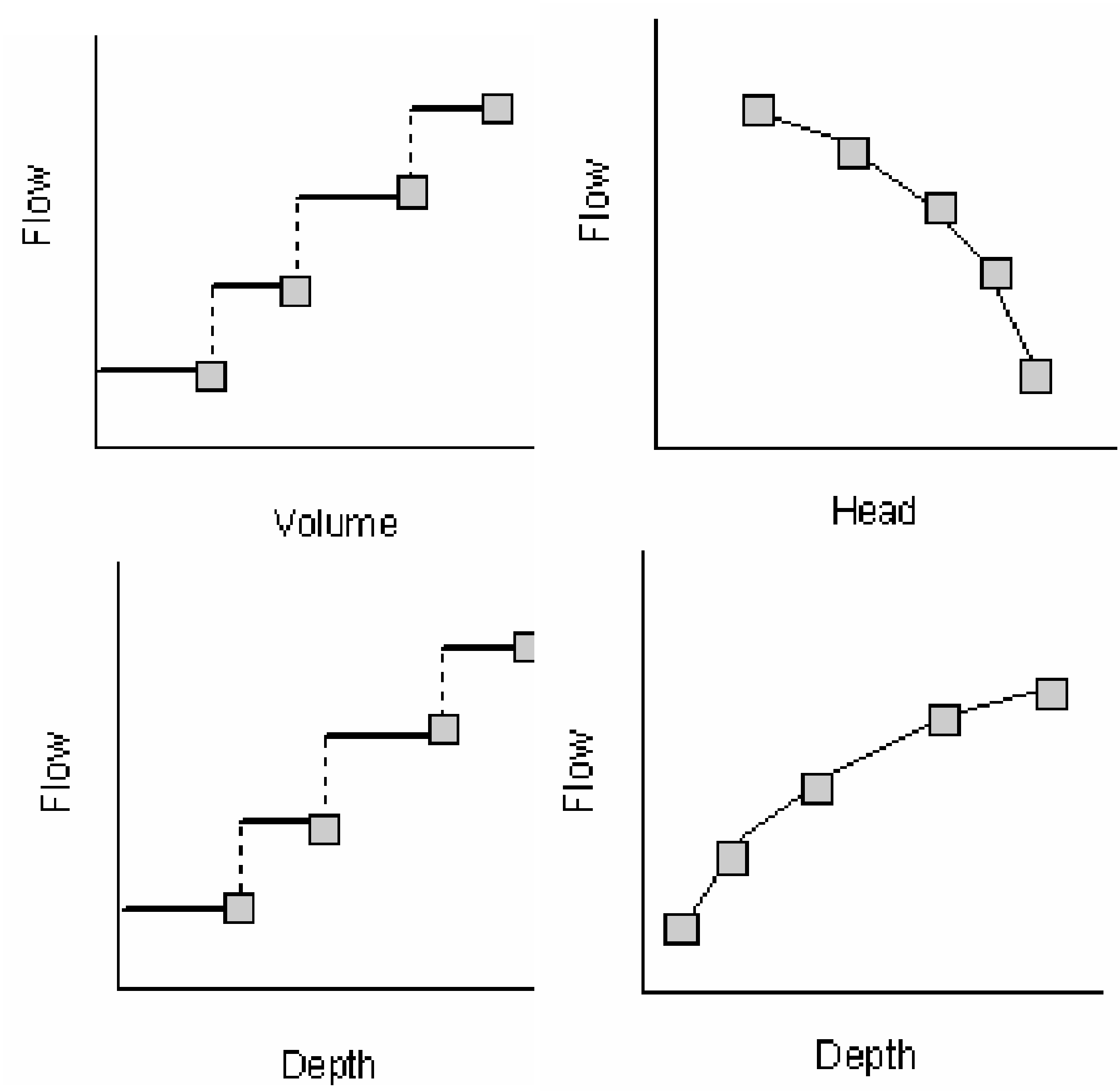
Results in Time Series



Treatment in Nodes

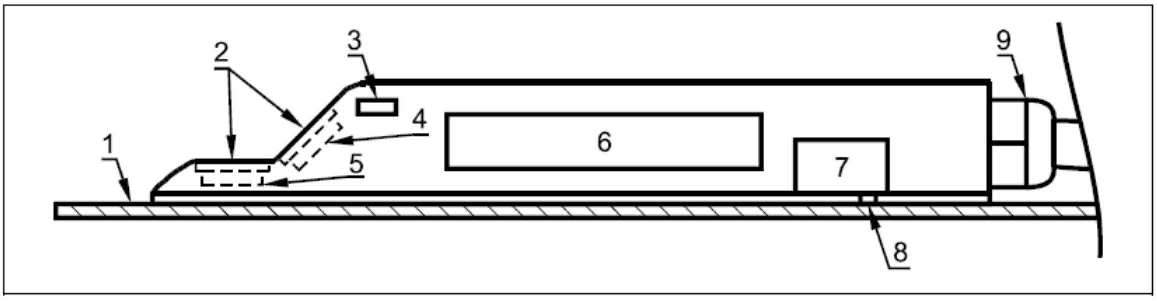


Q-h Curvesof Pumps



11. MEASUREMENTS

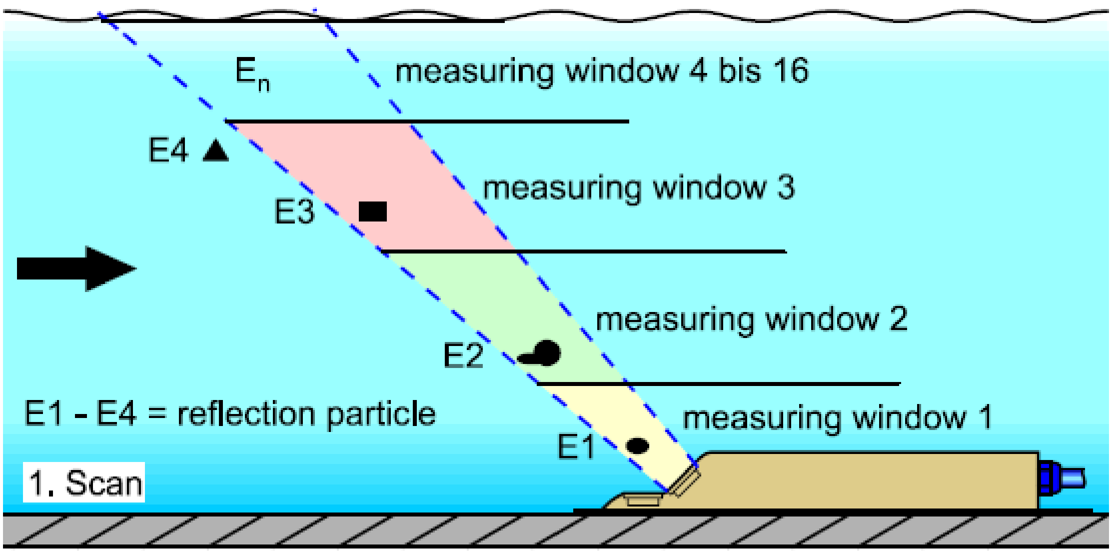
11.1. Ultrasonic flow meter device



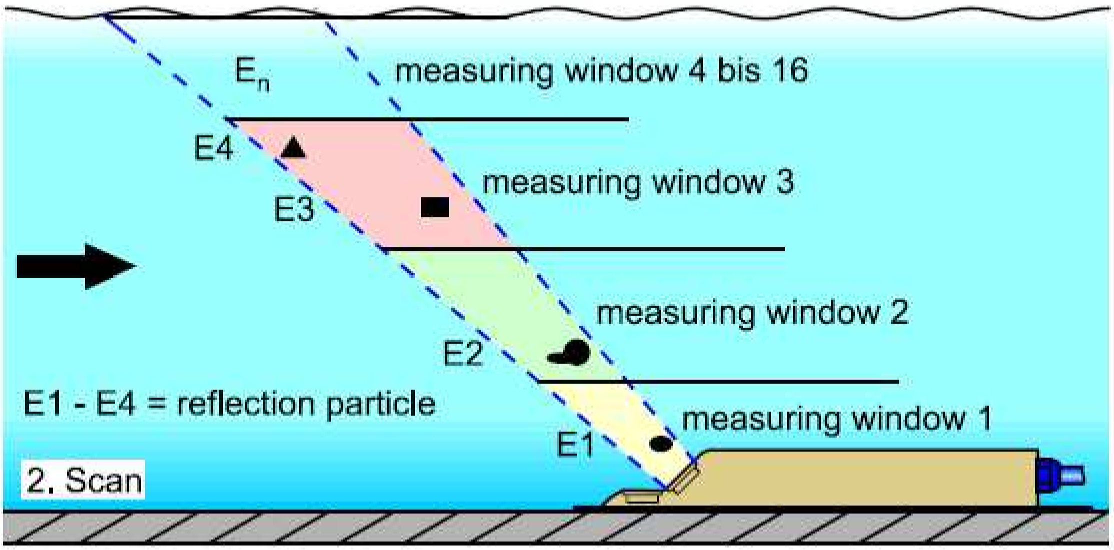
1 Ground Plate
2 Acoustic coupling layer
3 Temperature Sensor
4 Flow Velocity Sensor
5 Level Sensor
6 Electronics
7 Pressure Sensor
8 Duct to Pressure Measurement
9 Cable Gland

11.2. Ultrasonic velocity measurements

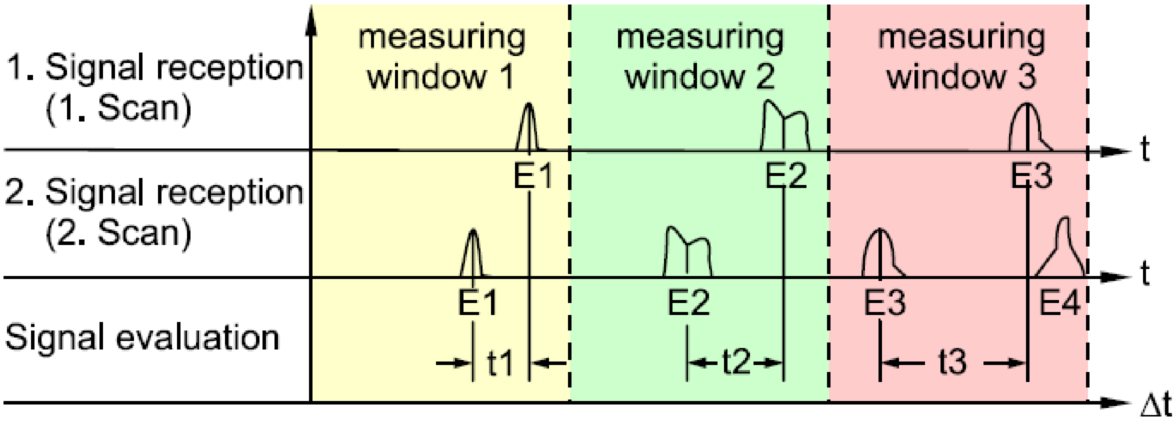
Situation on first signal detection



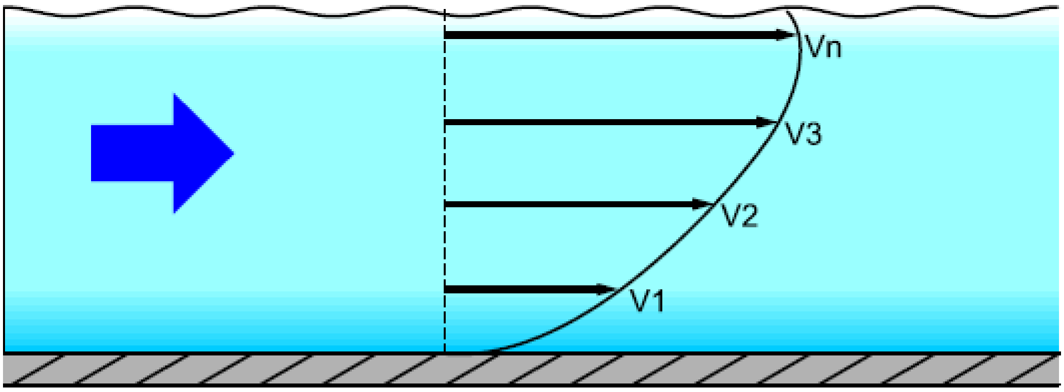
Situation on second signal detection



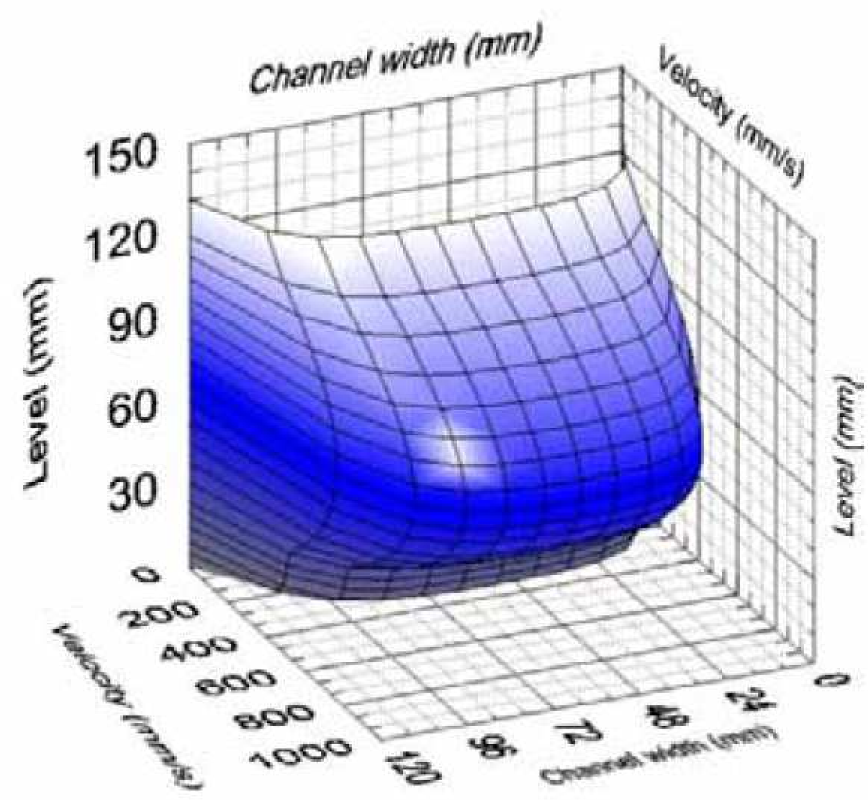
Echo signal images and evaluation



Evaluated flow profile



Calculated 3-dimensional flow profile



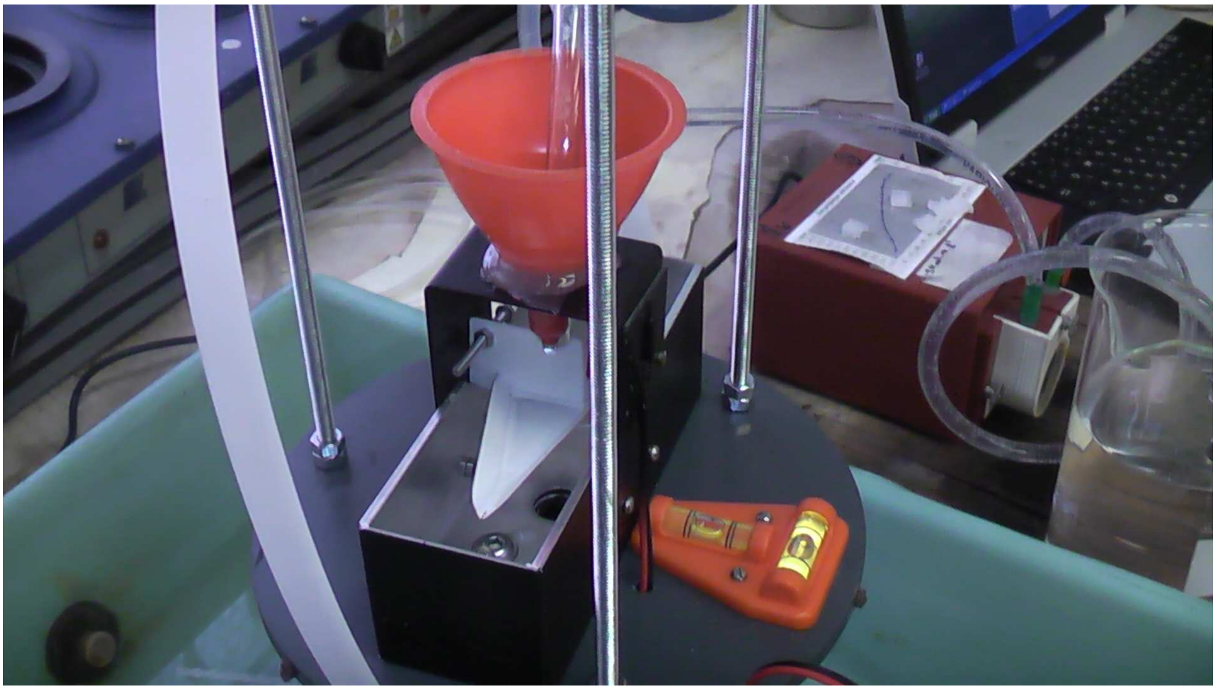
Pipe mounting system with support plate for air-ultrasonic sensor mounting

11.3. Rain measurements

Tipping bucket devices


GYŐR 001
SOPRON 001

The Interior of the Tipping Bucket Rain Gauge

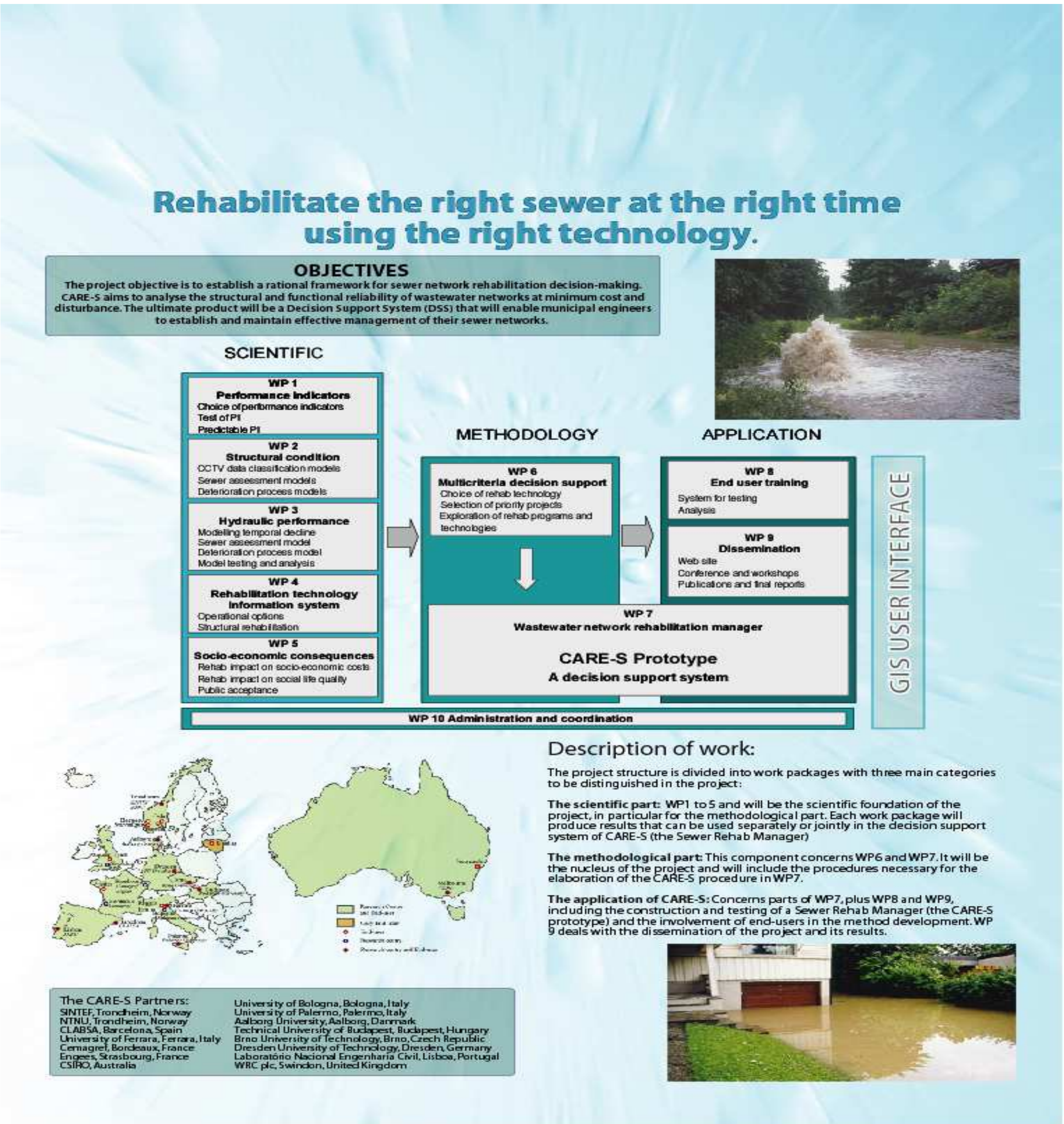


12. REHABILITATION OF SEWERS

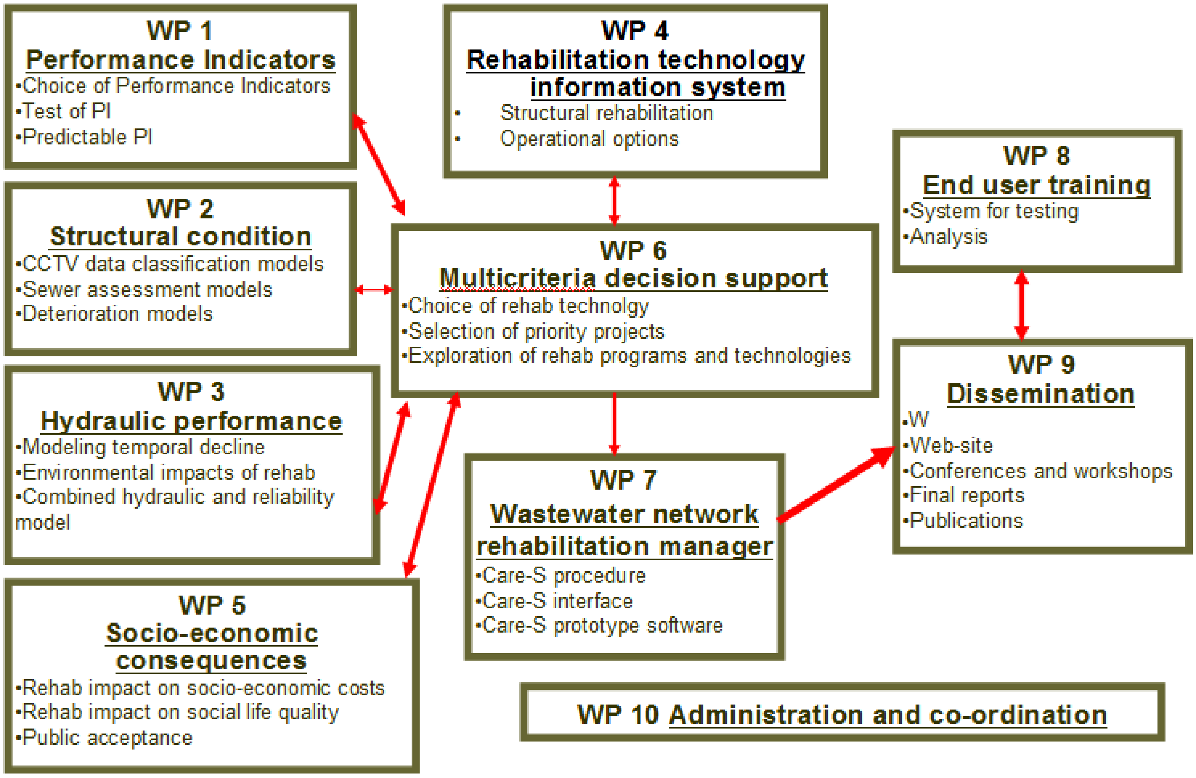
Sewer and storm water systems in cities worldwide suffer from insufficient capacity, construction failures and pipe deterioration. The consequences are structural damage and local floods leading to inflow of water into basements, traffic disturbances, street and surface erosion, and pollution of local receiving waters.

This challenge has to be met by systematic upgrading and preventive maintenance. It is necessary to analyze the current performance of the wastewater networks, to determine the system bottlenecks that cause system vulnerability on floods in city areas and pollution of receiving waters. The next task is then to use this information for selecting and ranking upgrading projects to improve the situation.

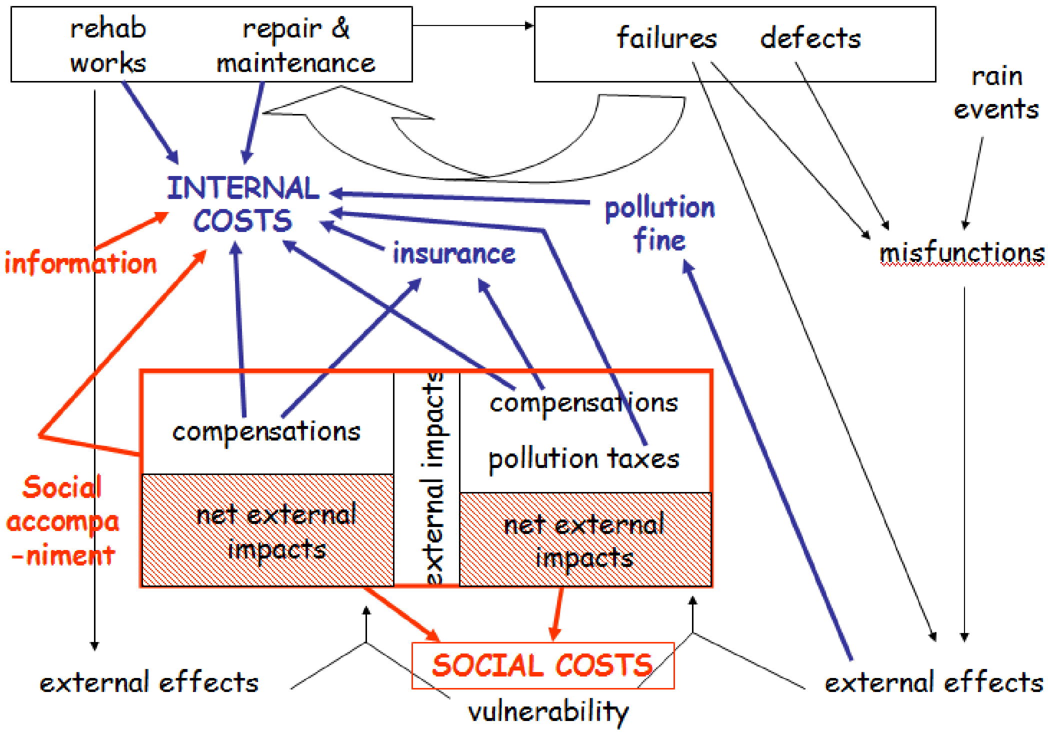
CARE-S is a computer based system developed to meet this challenge. It is designed for sewer and storm water network rehabilitation planning. It provides fundamental instruments for estimating the current and future condition of sewer networks, i.e. performance indicators, selecting and ranking of rehabilitation projects and long-term investment needs. The procedure for selection and ranking of projects is supported by tools for analysis of structural failures and hydraulic performance. Socio-economic issues are also included in the priority ranking process of CARE-S.


Rehabilitate the right sewer at the right time
using the right technology.
OBJECTIVES
The project objective is to establish a rational framework for sewer network rehabilitation decision-making. CARE-S aims to analyse the structural and functional reliability of wastewater networks at minimum cost and disturbance. The ultimate product will be a Decision Support System (DSS) that will enable municipal engineers to establish and maintain effective management of their sewer networks.
SCIENTIFIC
WP 1
Performance indicators
Choice of performance indicators
Test of PI
Predictable PI
WP 2
Structural condition
CCTV data classification models
Sewer assessment models
Deterioration process models
WP 3
Hydraulic performance
Modelling temporal decline
Sewer assessment model
Deterioration process model
Model testing and analysis
WP 4
Rehabilitation technology information system
Operational options
Structural rehabilitation
WP 5
Socio-economic consequences
Rehab impact on socio-economic costs
Rehab impact on social life quality
Public acceptance
METHODOLOGY
WP 6
Multicriteria decision support
Choice of rehab technology
Selection of priority projects
Exploration of rehab programs and technologies
APPLICATION
WP 8
End user training
System for testing
Analysis
WP 9
Dissemination
Web site
Conference and workshops
Publications and final reports
WP 7
Wastewater network rehabilitation manager
CARE-S Prototype
A decision support system
GIS USER INTERFACE
WP 10 Administration and coordination
Description of work:
The project structure is divided into work packages with three main categories to be distinguished in the project:
The scientific part: WP1 to 5 and will be the scientific foundation of the project, in particular for the methodological part. Each work package will produce results that can be used separately or jointly in the decision support system of CARE-S (the Sewer Rehab Manager)
The methodological part: This component concerns WP6 and WP7. It will be the nucleus of the project and will include the procedures necessary for the elaboration of the CARE-S procedure in WP7.
The application of CARE-S: Concerns parts of WP7, plus WP8 and WP9, including the construction and testing of a Sewer Rehab Manager (the CARE-S prototype) and the involvement of end-users in the method development. WP 9 deals with the dissemination of the project and its results.
The CARE-S Partners:
SINTEF, Trondheim, Norway
NTNU, Trondheim, Norway
CLABSA, Barcelona, Spain
University of Ferrara, Ferrara, Italy
Cemagref, Bordeaux, France
Engees, Strasbourg, France
CSIRO, Australia
University of Bologna, Bologna, Italy
University of Palermo, Palermo, Italy
Aalborg University, Aalborg, Danmark
Technical University of Budapest, Budapest, Hungary
Brno University of Technology, Brno, Czech Republic
Dresden University of Technology, Dresden, Germany
Laboratório Nacional Engenharia Civil, Lisboa, Portugal
WRC plc, Swindon, United Kingdom

12.1. Structure of CARE-S



12.2. Socio economic consequences of failures and of rehab works



12.3. Structural Condition

CCTV data classification models

Collect failure data from end-users
Identify and describe classification models
Apply and validate classification models
Comparison between models

Sewer assessment model

Identify and describe existing sewer condition assessment models
Test of existing sewer condition assessment models with data obtained from D3
Comparison between models

Deterioration process models

Development of a bio-chemical in-sewer process model
Development of a physical and structural failure model, including safety factors
Procedure for estimation of the probability for structural collapse, combining bio-chemical and physical-structural

Model testing and evaluation

Application of sewer assessment model by end users
Application of deterioration process models by end users
Comparison of results obtained

PRACTICAL MANUAL

FOREWORD

The aim of the subject is to have the students get acquainted with the dimension of the sanitary public works. They need to carry out 3 public works conceptual plans which are the water supply, sewage, storm water system on the given design area. The design methods are showed according the European Unions and Hungarians directives. The base data of the design is given in the worksheet. The design area is on the distributed map A4 and A3 format. The maps are found on the ftp site of the department (ftp://152.66.18.2/English). The method of the design follows the next steps:

1. Collection of the data
2. Determination of the loads
3. Determination of horizontal path of the public works
4. Determination of vertical path of the public works
5. Hydraulically design of the network
6. Hydraulically analysis of the network
7. The showing of the finally parameters and the calculated result (thematic layout maps, longitudinal sections)
8. Technical description of the network

Tasks to be completed in the given-in design work

- In a file folder with front page:
- The file folder contains the followings:
    - Work-sheet,
    - Table of contents,
    - Attachments,
    - Technical specification and detailed calculations,
    - Layout maps and longitudinal sections for designing

During the design process the student should consult with the practice lesson teacher at least 5 times, which is proved by the signature of the practice lesson teacher.

1. DETERMINATION OF DESIGNING WATER DEMAND (1ST PRACTICAL LESSON)

Every design task start the determination of the loads. The water demand depend on the type of the area, custom of the inhabitants. We need distinguish the design area. Is it a real area with water supply or new area without water supply? In first case we can determine the water demand from the real measured consumption and production. The calculation of peak water demand is important for the designing. We need distinguish the design area. It is a real area with water supply or new area without water supply. In first case we can determine the water demand from the real measured consumption and production. In this project we don't know the real consumption so we use the values of the directives. This data can be find in the datasheet. The load has three parts in this task:

- inhabitant,
- public institution and
- industrial water demands
- firefighting water (this is given).

DOMESTIC WATER DEMAND

The domestic water demands are the consumption of the inhabitants. It is a distributed load in most case not a concentrate. In this task we calculated for a bigger area, or for the blocks of the parcels.

Used definitions:

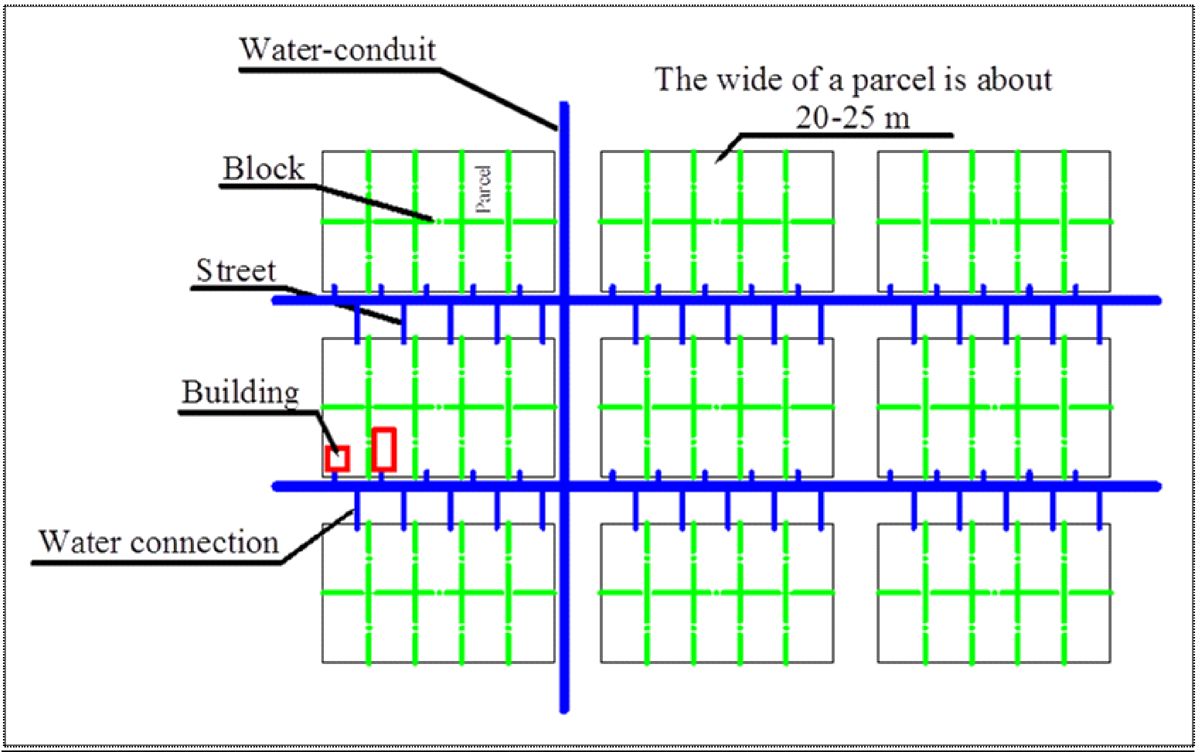


Figure 1.: Determination of the number of the connection pipe

Count of Connection: We have got some blocks in our designing area, the block is a border of grounds/building sites. The buildings are on these grounds. Every building has a water connection or binding in. The distance of the grounds is 15-20 meter between themselves. The connections join on the one hand to the ground, on the other hand to the water distribution pipe. The distance of connection depends on the type of settlement. This distance between two connections is larger in a village than in a city. So we have to determine the count of connection (Fig. 1).

Dweller density: shows us the number people who joins to the binding-in. For example so many people live in a flat in average.

Number of people: This number is calculated from dweller density, and from count of connections (multiply)

Specific water demand (q) is a feature value of the consumption on the actually area. This value depends on the habit of dweller. This value is higher in a rich settlement, than in a poor one.

Average daily water demand (Q_{avg}): This value applies to actually designing area. This value is yearly average daily water demand of an area.

Seasonal ratio (β) shows us the difference between the daily average and the daily peak water demand. Because we have higher water demand on summer, than all-year.

Peak water demand (Q_{max}): is highest water demand of people in a year. We can calculate this value from average water demand, and from seasonal ratio. (multiply)

Loss coefficient: Every system has loss so has the water supply system some water loss too. This loss is 10-30 percent in the Hungarian water system. So we have to put this loss to the peak water demand. This loss comes from break of pipe, from leak, from cleaning of system, disinfection of the system. This value is pertain of system.

Designing peak water demand (Q_{design}): is increased value of peak water demand by the loss. We use this value to calculate the needed pipe size.

Count of Connections (piece)	dweller density (person/binding-in)	people of designing area (head)	specific water demand (l/person/day)	average water demand (m3/day)	seasonal ratio $\beta(-)$	peak water demand (m3/day)	loss coefficient	designing peak water demand (m3/day)
600	3	1800	150	270	1.4	378	1.1	**415.8**

Table 1. Demand calculation of the inhabitants

PUBLIC INSTITUTIONS WATER DEMAND

We have a public institution on our planning area. We have to choose a block on our planning area, whereon we say that is a public institution. The public institution block has just one connection. We haven't got to add this blocks connection to the dweller connection. We assume there is a grammar school. So There are some workers and lot of students. The student and the teacher have got different water demand. In this part of task, we haven't got to define the people number, because it is available. The calculating of water demand is like the dweller demand.

Profession of people	Number of people	specific water demand (l/person/ day)	average water demand (m3/day)	seasonal ratio	peak water demand (m3/day)	loss coefficient	designing peak water demand (m3/day)
worker	60	150	9	1.2	10.8	1.1	**11.88**
student	450	130	58.5	1.2	70.2	1.1	**77.22**

Table 2. Water demand calculation of the public institution

THE INDUSTRIAL WATER DEMAND

We have an industrial area in our planning area. We have to choose a block on our planning area, whereon we say that is a industry. The industry block has just one connection. We haven't got to add this blocks connection to the dweller connection. The industry has two water demands one side technological demand other side the social water demand. The technological water is used to product fabricating. We calculate the social water demand as the dweller. We don't have to define the worker number because it is available. We assume in this task that the technological water demand doesn't vary in the year. It is fix. There are some branches of industry, where the seasonal ratio differs from 1.00 for example the cannery. The seasonal ratio of technological water demand is 1.00 in this task.

Technological water demand (m3/day)	Loss coefficient	designing peak water demand (m3/day)
1000	1.1	**1100**

Table 3. Industrial technical water demand

Number of People	specific water demand (l/person/day)	average water demand (m3/day)	seasonal ratio	peak water demand (m3/day)	loss coefficient	designing peak water demand (m3/day)
400	150	60	1.2	72	1.1	**79.2**

Table 4. Industrial social water demand

The full water demand of the design area: ***1672.22*** m3/d

2. PATH OF THE WATER SUPPLY NETWORK (2ND PRACTICAL LESSON)

The water supply system was built by transit, main, distribution, and connection pipe. Topology of the system can be branch or loop. In most case the main and distribution pipes create loops. The loops give higher safety level for the supply than it created from branches.

We design only one main-loop in our area. First we have to draw our one-loop main conduits line. The conduits must be laid down on the area of common use. We don’t lay it on the private area, or below the buildings. The main loop must touch the consumption centers and the concentrated big consumer as the public institution and industrial area. It must connect to the given inlet point, which will be a source in the hydraulic model.

3. TOPOLOGICAL MODEL OF THE WATER SUPPLY NETWORK (2ND PRACTICAL LESSON)

We have to divide the created main ring into some parts, about 7-8 parts if we want to create the hydraulic model. These parts join with nodes. We set the nodes at the breakpoint (but it isn’t necessary), and at the branch joint, and at the inlet node. (Fig. 2). We have to take on the nodes at every great consumer (for example the industry, the public institution), because they have concentrated consumption in our model. The water demands of the big consumers influence significantly the hydraulic state.

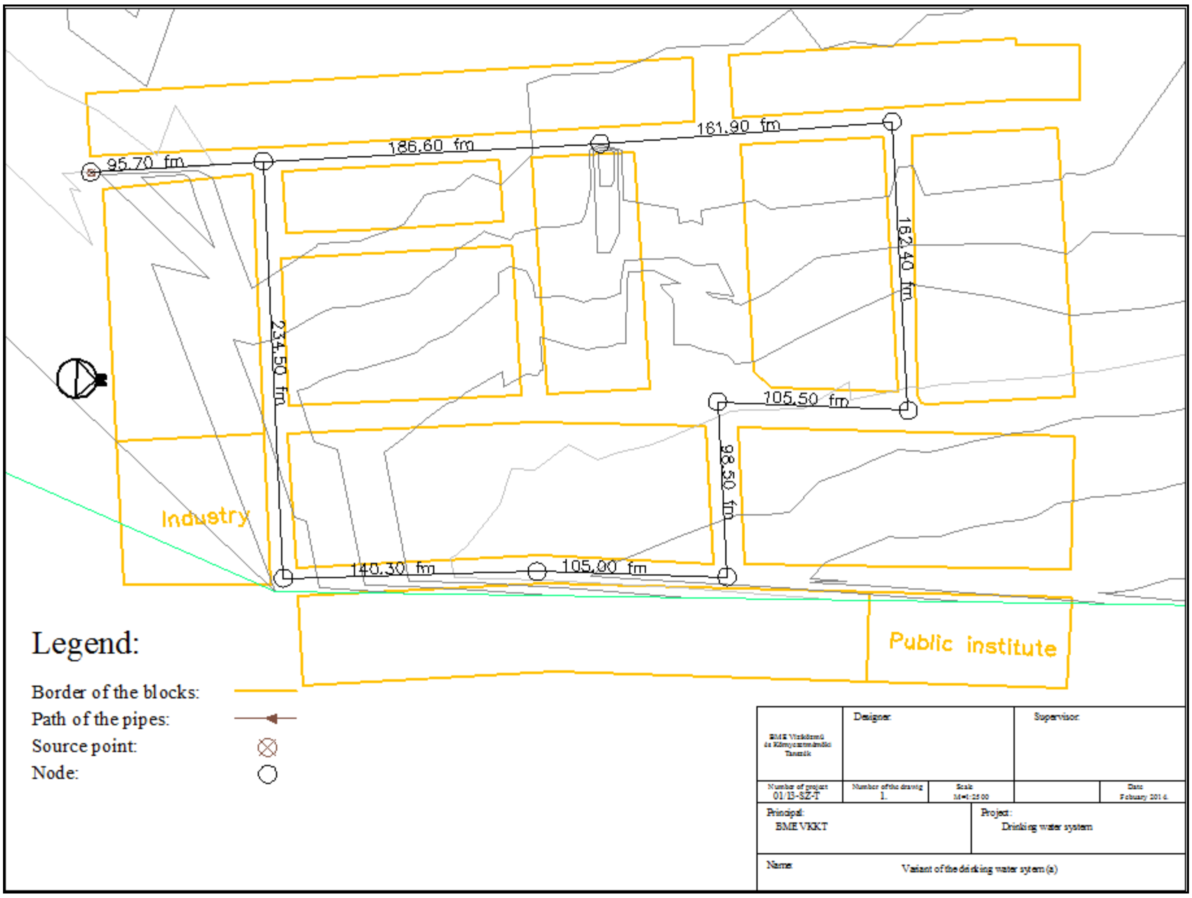


Figure 2. The path of the drinking water system (The main-loop)

We consider the communal consumption an uniform distributed water consumption on our main loop. We have to order this uniform distribution consumption to the nodes. We carry out this distribution on the basis of conduits length or the area which belongs to the current node. In this case we distribute the consumption (415.8 m^3/d) according to the length in our example. You can see this calculation in the table 5. We need to measure the length of the branches to the calculation. We assume that the water demand on the branch is uniformly. So we can order the half water demand to the one and the other half to the other node (Table.6).

Branches	Lenght (m)	Q branches (m3/d)	Q node 1	Q node 2
1-2	95	30.6	15.3	15.3
2-3	235	75.7	37.8	37.8
3-4	140	45.1	22.5	22.5
4-5	105	33.8	16.9	16.9
5-6	99	31.9	15.9	15.9
6-7	106	34.1	17.1	17.1
7-8	162	52.2	26.1	26.1
8-9	162	52.2	26.1	26.1
9-2	187	60.2	30.1	30.1
sum	1291	415.8		

Table 5. The order of the dweller consumption to the links

Node	Branch 1-2	2-3	3-4	4-5	5-6	6-7	7-8	8-9	9-2	Node (m3/d)
1	15.3									15.3
2	15.3	37.8							30.1	83.3
3		37.8	22.5							60.4
4			22.5	16.9						39.5
5				16.9	15.9					32.9
6					15.9	17.1				33.0
7						17.1	26.1			43.2
8							26.1	26.1		52.2
9								26.1	30.1	56.2

Table 6. The distribution of the dweller consumption to the nodes

Node	Qdweller m3/d	Qpublic ins. m3/d	Qind. Soc. m3/d	Qpeople m3/d	Qind. Tech. m3/d	Qfire l/min
1	15.3			15.3		
2	83.3			83.3		
3	60.4		200	260.4	1100	
4	39.5			39.5		
5	32.9	300		332.9		
6	33.0			33.0		
7	43.2			43.2		600
8	52.2			52.2		
9	56.2			56.2		
szum	416	300	200	916	1100	
				2016		

Table 5. The full daily water consumption at the nodes.

4. HYDRAULICAL MODEL OF THE WATER SUPPLY NETWORK (3RD PRACTICAL LESSON)

The water system has typical states, for example maximum and minimum consumption, fire event, burst in a water pipe. This event influences the behaviour of the water system (pressure, water velocity). The different states have different pressure value and flow quantity and transporting direction. The typical states are:

- Maximum demand
- Minimum demand
- Average demand (4,17%)+ fire water
- Pipe failure

We design our system for the standard state, which is the hourly peak demand in this case. (In some case the firefighting state is the standard). We assume that, the maximum hourly water demand is 8 percent of the daily water demand (table 6). (The water consumption value is changing during the day). So we multiply the daily people water demand by 8 per cent. We have to compute the nodes consumption in the typical states (Table 6, 7, 8.).

	Q people	Qind tech	Q fire	Q people	Qind. tech	Qfire	Qcsp
Node	m3/d	m3/d	l/perc	l/s			
1	15.7	0	0	0.04			0.04
2	81.5	0	0	0.23			0.23
3	261.2	1100	0	0.73	12.73		13.46
4	40.0	0	0	0.11			0.11
5	333.3	0	0	0.93			0.93
6	33.5	0	0	0.09			0.09
7	43.8	0	600	0.12			0.12
8	52.9	0	0	0.15			0.15
9	53.9	0	0	0.15			0.15
Qcons							15.27

Table 6. The minimum hourly water consumption at the nodes.

				peak consumption (8 %)			
	Q people	Qind tech	Q fire	Q people	Qind. tech	Qfire	Qcsp
Node	m3/d	m3/d	l/perc	l/s			
1	15.7	0	0	0.35			0.35
2	81.5	0	0	1.81			1.81
3	261.2	1100	0	5.80	12.73		18.53
4	40.0	0	0	0.89			0.89
5	333.3	0	0	7.40			7.40
6	33.5	0	0	0.74			0.74
7	43.8	0	600	0.97			0.97
8	52.9	0	0	1.17			1.17
9	53.9	0	0	1.20			1.20
Qcons							33.07

Table 7. The maximum hourly water consumption at the nodes.

				check (4.17 %)+fire			
	Q people	Qind tech	Q fire	Q people	Qind. tech	Qfire	Qcsp
Node	m3/d	m3/d	l/perc	l/s			
1	15.7	0	0	0.18			0.18
2	81.5	0	0	0.94			0.94
3	261.2	1100	0	3.02	12.73		15.76
4	40.0	0	0	0.46			0.46
5	333.3	0	0	3.86			3.86
6	33.5	0	0	0.39			0.39
7	43.8	0	600	0.51		10.00	10.51
8	52.9	0	0	0.61			0.61
9	53.9	0	0	0.62			0.62
Qcons							33.33

Table 8. The average hourly water and firefighting consumption at the nodes.

When we distributed the consumption upon the nodes we can determine the hydraulic parameters in the ring-mains. The hydraulic parameters are the next:

- pressure at the nodes
- flow quantity in the branches
- flow direction in the branches
- water velocity in the branhes

5. INITIAL WATER TRANSORT IN THE WATER SUPPLY NETWORK (3RD PRACTICAL LESSON)

The determination of the water transport and its direction are complicate in a water supply network. The cause of this thing is the looped network. The flow direction is not clear in the loop. We use the first Kirchoff's law to determine the initial water flow.

First Kirchoff's law (node balance): The sum of the waters quantities, what flows in the node and out the node that is null.

We put on a flow direction as we wish, but we have one regulation the first Kirchoff's law the low of node. So we get the flow quantity (fig. 3). We can make branches from the loop. (We cut a conduit between two nodes. So we can calculate the directions of the flows. The flow of the cut branch is null)

Branch	Qin (l/s)	Node	Qnode (l/s)	branches	Qbranch (l/s)
	33.07	1	0.35	1-2	32.72
1-2	32.72	2	1.81	2-3	15.45
2-3	15.45	3	18.53	3-4	-3.08
3-4	-3.08	4	0.89	4-5	-3.97
4-5	-3.97	5	7.40	5-6	-11.37
5-6	-11.37	6	0.74	6-7	-12.11
6-7	-12.11	7	0.97	7-8	-13.08
7-8	-13.08	8	1.17	8-9	-14.26
8-9	-14.26	9	1.20	9-2	-15.45
9-2	-15.45				

Table 9. Initial flow in peak flow

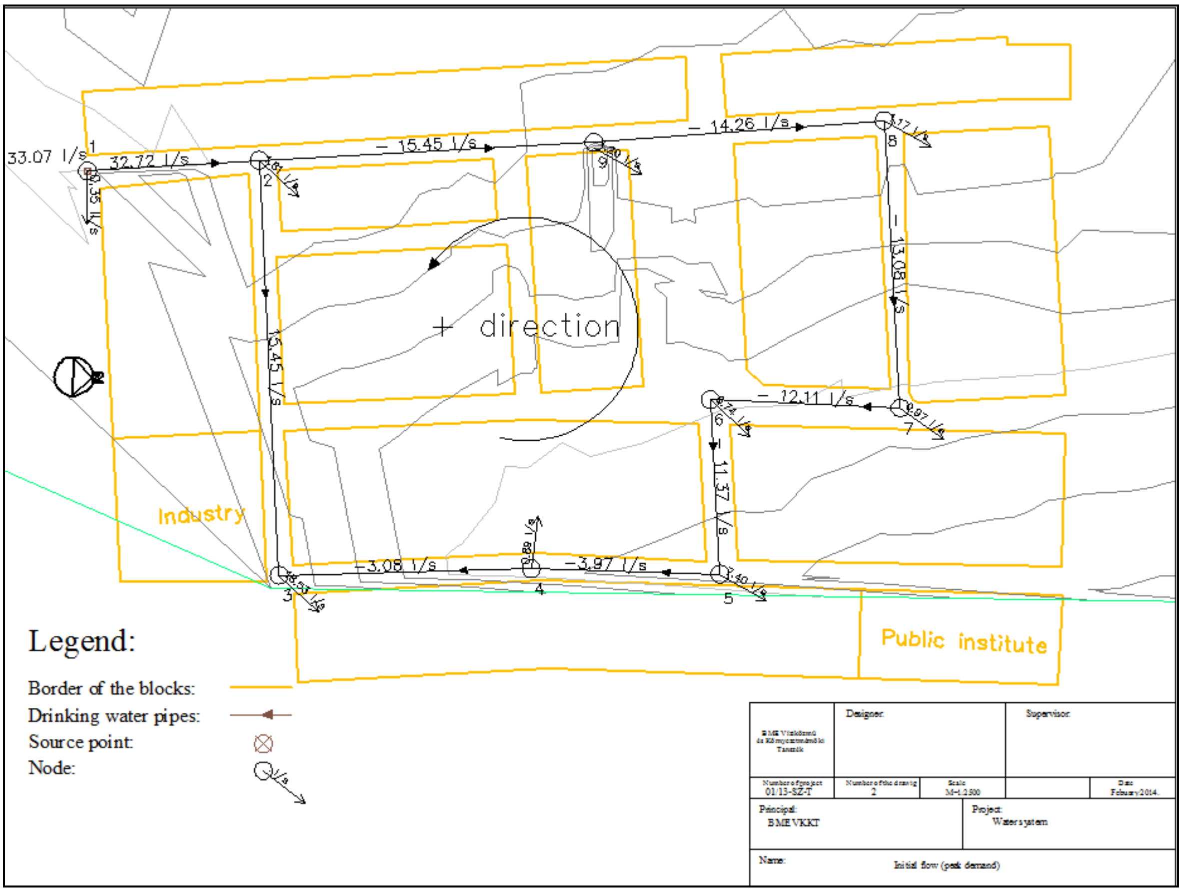


Figure 3. The initial water flow and direction

We set the initial diameter of conduits. We assume the velocity is 1 m/s in the pipes. We use the next equation:

$$Q = v * A$$

The minimum diameter is 100 mm in distribution system according the general rules (firefighting). If a node has two direction input, it can be 80 mm to.

6. HYDRAULIC PARAMETERS IN THE WATER SUPPLY NETWORK (4TH PRACTICAL LESSON)

The initial water flow is not the real flow. We need to calculate the real flow. We use the second Kirchoff's low.

Second Kirchoff's law: We take on a circuity direction in our loop. The sums of the signed flow pressure loss must be null along the loop.

The formula of flow pressure loss is in the next:

$$hv = \lambda * \frac{L}{D} * \frac{v^2}{2 * g}$$

$$v = Q / A$$

$$hv = L * \frac{16 * \lambda}{D^5 * \pi^2 * 2 * g} * Q^2$$

$$hv = L * c * Q^2$$

$$hv = C * Q^2$$

Where:

D: Diameter of pipe (m)
L: lenght of conduit (m)
v : velocity (m/s)
g : 9,81 m/s2
hv: local loss (in the pipe)
Q: water flow (m3/s)

The „c" values, what belongs to different pipe diameter you can see on ***table 9***.

λ= 0,033

Diameter (mm)	c
100	272,667353531
150	35,906811988
200	8,520854798
250	2,792113700
300	1,122087875
400	0,266276712
500	0,087253553
600	0,035065246
800	0,008321147
1000	0,002726674
1200	0,001095789
1400	0,000506982
1600	0,000260036
1800	0,000144301
2000	0,000085209

Table 9: *„c" values*

We analyse our loop that is it adequate for the second Kirchoff's law. We define the failure of the sum of the pressure flow loss. If it is not null then we correct our flows quantity (Table 10). Then we calculate the flows pressure loss again, until the failure will null, this is the Cross method (Table 11, 12). Finally we get the right flow direction, and quantity (Table 13). The result of the calculation is showed by table 14. We can see the right flow direction, the local flows pressure loss and the water velocity in the branches.

1. iteration

Branches	Lenght (m)	Diameter (mm)	main-ring	Sign	C=c*l [s2/m5]	Q[m3/s]	2abs(CQ)	C*Q*abs(Q)	Σ2absCQ	ΣCQ2	Dq
1-2	96	200	branch	1	818	0.0327	53.5271	0.8757			
2-3	235	200		1	2002	0.0155	61.8915	0.4782	61.8915	0.4782	
3-4	140	100		1	38173	-0.0031	234.9889	-0.3616	296.8804	0.1166	
4-5	105	100		1	28630	-0.0040	227.1144	-0.4504	523.9948	-0.3338	
5-6	99	100	one-loop	1	26994	-0.0114	613.7084	-3.4882	1137.7032	-3.8220	
6-7	106	100		1	28903	-0.0121	700.0743	-4.2393	1837.7775	-8.0612	
7-8	162	100		1	44172	-0.0131	1155.7825	-7.5604	2993.5600	-15.6216	
8-9	162	150		1	5817	-0.0143	165.8707	-1.1825	3159.4307	-16.8041	
9-2	168	150		1	6032	-0.0155	186.4517	-1.4407	3345.8824	-18.2448	0.0055
										failure	correction water quantity

Table 10: *The pressure loss in the loop (according to the initial flow)*

2. iteration

Q (m3/s)	Q[m3/s]	2abs(CQ)	C*Q*abs(Q)	∑2absCQ	∑CQ2	Dq
0.0327	0.0327					
0.0209	0.0209	83.7294	0.8753	83.7294	0.8753	
0.0024	0.0024	181.3238	0.2153	265.0531	1.0906	
0.0015	0.0015	85.1201	0.0633	350.1733	1.1539	
-0.0059	-0.0059	319.3159	-0.9443	669.4891	0.2096	
-0.0067	-0.0067	384.8661	-1.2812	1054.3552	-1.0717	
-0.0076	-0.0076	674.0493	-2.5714	1728.4045	-3.6431	
-0.0088	-0.0088	102.4326	-0.4509	1830.8371	-4.0940	
-0.0100	-0.0100	120.6640	-0.6034	1951.5011	-4.6974	0.0024

Table 11: *Second iteration*

3. iteration

Q (m3/s)	Q[m3/s]	2abs(CQ)	C*Q*abs(Q)	∑2absCQ	∑CQ2	Dq
0.0327	0.0327					
0.0233	0.0233	93.3693	1.0884	93.3693	1.0884	
0.0048	0.0048	365.0974	0.8730	458.4667	1.9614	
0.0039	0.0039	222.9503	0.4340	681.4170	2.3954	
-0.0035	-0.0035	189.3617	-0.3321	870.7787	2.0633	
-0.0043	-0.0043	245.7232	-0.5223	1116.5019	1.5411	
-0.0052	-0.0052	461.3969	-1.2049	1577.8988	0.3362	
-0.0064	-0.0064	74.4290	-0.2381	1652.3278	0.0981	
-0.0076	-0.0076	91.6233	-0.3479	1743.9511	-0.2498	0.0001

Table 12: *third iteration*

4. iteration

Q (m3/s)	Q[m3/s]	2abs(CQ)	C*Q*abs(Q)	∑2absCQ	∑CQ2	Dq
0.0327	0.0327					
0.0235	0.0235	93.9429	1.1018	93.9429	1.1018	
0.0049	0.0049	376.0330	0.9260	469.9759	2.0279	
0.0040	0.0040	231.1520	0.4666	701.1279	2.4944	
-0.0034	-0.0034	181.6286	-0.3055	882.7565	2.1889	
-0.0041	-0.0041	237.4434	-0.4877	1120.2000	1.7013	
-0.0051	-0.0051	448.7429	-1.1397	1568.9429	0.5616	
-0.0063	-0.0063	72.7626	-0.2275	1641.7055	0.3340	
-0.0075	-0.0075	89.8952	-0.3349	1731.6007	-0.0009	0.0000

Table 13: *Fourth iteration*

Branches	Lenght (m)	Diameter (mm)	Q (m3/s)	Q (l/s)	water velocity (m/s)	local loss C*Q*abs(Q) (m)	specific pressure flow loss %o
1-2	96	200	0.0327	32.72	1.04	0.8757	9.1
2-3	235	200	0.0235	23.46	0.75	1.1018	4.7
3-4	140	100	0.0049	4.93	0.63	0.9260	6.6
4-5	105	100	0.0040	4.04	0.51	0.4666	4.4
5-6	99	100	-0.0034	-3.36	-0.43	-0.3055	-3.1
6-7	106	100	-0.0041	-4.11	-0.52	-0.4877	-4.6
7-8	162	100	-0.0051	-5.08	-0.65	-1.1397	-7.0
8-9	162	150	-0.0063	-6.25	-0.35	-0.2275	-1.4
9-2	168	150	-0.0075	-7.45	-0.42	-0.3349	-2.0

Table 14: *The result of calculation*

Than we check the ring, is it adequate for the hydraulically criteria:

- The pressure must be about 45-60 meter (4,5-6,0 bar) above the surface.
- The water velocity must be about 0,5-1,50 m/s.
- the pressure loss must be less than 10‰ (10m/km)

We can get the pressure at the nodes, if we start from the connection node where the pressure is known, what is about 45-60 meter (4,5-6,0 bar) above the surface and we add the signed flow pressure loss on the path (table 15). The pressure decrease in that direction whither the water flows. The pressures must be higher than 20 meter or buildings height + 10 meter at the node above the surface. The smallest allowed conduit is 100 mm (80 mm) in the water supply system. If the water system is not adequate for the pressure demand or water velocity, we have to change the pipe diameter.

Node 1		Branches		Node 2		Surface	Pressure above the surface	Pressure demand	Pressure
	H (mBf)		C*Q*abs(Q)		H (mBf)	(mBf)	h (m)	H(m)	
1	190	1-2	0.8757	2	189.12	149.8	39.32	25	OK
2	189.12	2-3	1.1018	3	188.02	150.1	37.92	25	OK
3	188.02	3-4	0.9260	4	187.10	151.2	35.90	25	OK
4	187.10	4-5	0.4666	5	186.63	155.7	30.93	25	OK
5	186.63	5-6	-0.3055	6	186.94	156.5	30.44	25	OK
6	186.94	6-7	-0.4877	7	187.42	154.7	32.72	25	OK
7	187.42	7-8	-1.1397	8	188.56	155.5	33.06	25	OK
8	188.56	8-9	-0.2275	9	188.79	151.2	37.59	25	OK
9	188.79	9-2	-0.3349	2	189.13	151.3	37.83	25	OK

Table 15: *The result of pressure calculation*

If we determined the system parameters to the maximum hourly consumption than we have to check the behaviour of the system in the minimum consumption and average consumption + firefighting too. (We don't modify the diameters of the pipes).

The results are shown in pressure longitudinal profile and layout map.

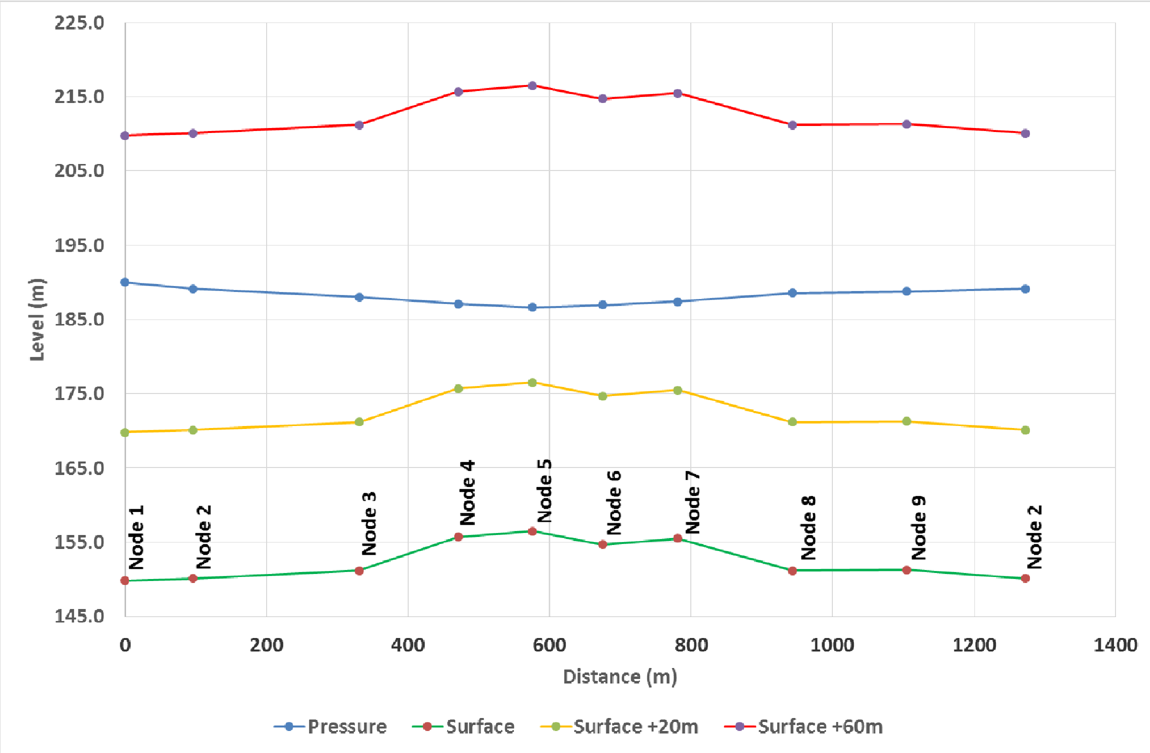


Figure 4. Pressure longitudinal profile

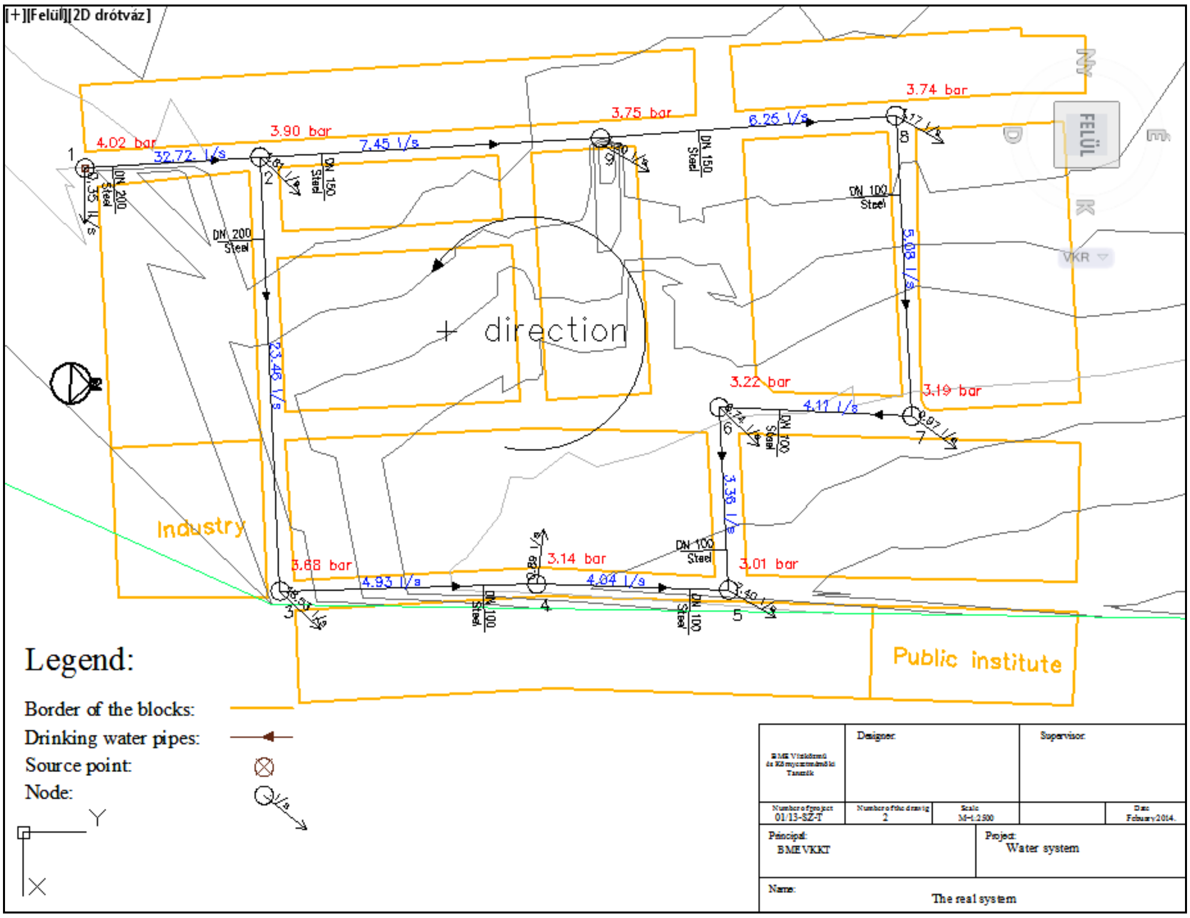


Figure 5. Final layout map

7. DOCUMENTATTION OF THE RESULTS(5TH PRACTICAL LESSON)

We have to present our results in our system. We have to make some thematic layout maps:

The final designed water supply system:

- The path of the pipes
- The types of the pipes (material, diameter)
- The nodes id number (according to the calculation)
- The absolute level of the nodes
- The consumption zones (industrial area, public institution, private area) with specific demand data

State of the water supply system (minimum, maximum, average + firefighting):

- The water demands at the nodes
- The right flow direction in the pipes
- The water velocity or quantity of water flow in the pipes
- The relative pressure at nodes
- The diameter of conduits

Longitudinal profile for the pressure

- Vertical axis is the height
- Horizontal axis the distance (with the nodes ID)
- Line of the surface
- Pressure lines in different state

8. WASTEWATER LOADS (6TH PRACTICAL LESSON)

Sewerage systems can be classified into combined sewerage and separate sewerage. Combined sewerage carries both stormwater and wastewater, while separate sewerage carries stormwater or wastewater separately. We plan a gravity separated sewerage system. First we have to determine the load of the sewer system on the area. The load derives from three different sources as the water supply system. The waste water was derived from the drinking water consumption. The waste water pipe is dimensioned for maximum waste water load. The maximum waste water load is calculated with following value:

- the peak water demand without loss
- waste-water fraction

- hourly-peak ratio

Waste water types	maximum water consumption (m3/day)	Waste water fraction / sewage ratio	Maximum waste water quantity (m3/day)	hourly-peak ratio	hourly maximum waste water quantity (m3/hour)
dweller	378	0.9	340.2	0.056	18.9
public institution	89.1	0.8	71.28	0.056	3.96
technological water	1100	0.6	660	0.042	27.5
social water	79.2	0.95	75.24	0.100	7.524

Table 16: *The wastewater loads*

The peak water demand: We use this value and not the designing water, because the loss of water won't waste water.

Waste-water fraction/sewage ratio: This value shows us how much proportion of water will waste water. It depends on the applications mode of water. This value is lower for example in a village, where the water is used for watering than in a downtown.

Hourly peak ratio/Peak flow coefficient show us how many proportion of daily waste water flows in the peak hour in the drainage. This value is varied by habits of the people. For example this value in a small village is 1/10 in a big city is 1/22.

9. PATH OF THE WASTEWATER SYSTEM (6TH PRACTICAL LESSON)

The sewer system was built by collector, main collector, and connection pipe. Topology of the system must be branch. We design only collector and main collector gravity pipe on our area. The principle of using gravity as the driving force for conveying wastewater in a sewerage system should be applied wherever possible, because this will minimise the cost of pumping. Catchment area is an area draining to a drain, sewer or watercourse (Standard EN 752:2008). Crossing a catchment boundary may mean that the water has to be unnecessarily pumped, requiring an energy source. In first step we need to draw the catchments and subcatchments according to the surface. The catchment is bounded by the watershed. We can draw the borderline of the catchment if we analyze the surface counter lines. First we have to draw our main collector conduits line. We need draw 2 path variant (Fig 4.).

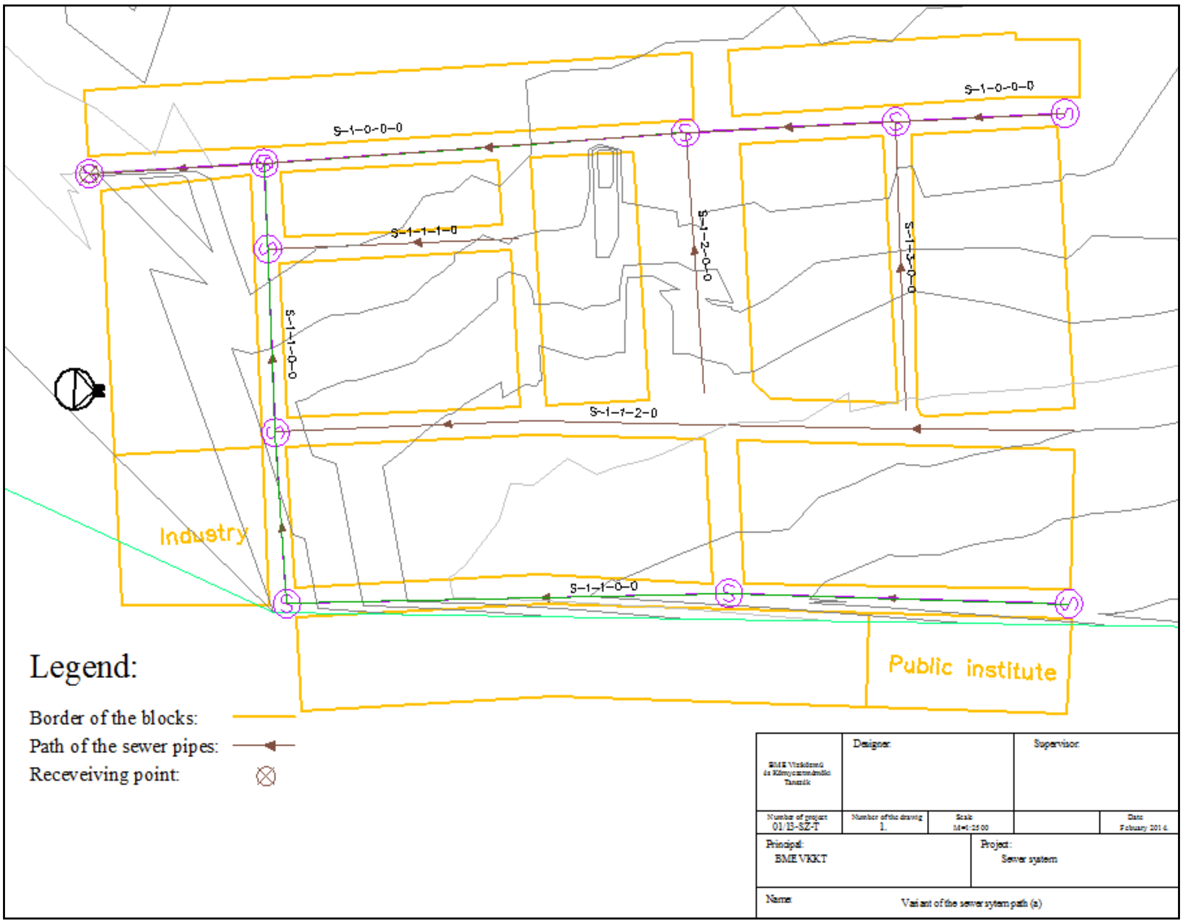


Figure 4. Path variant of the sewer sytem

The path of this pipe is in lowest level of the area. The collectors connect to the main pipe. The conduits must be laid down on the area of common use. We don't lay it on the private area, or below the buildings. The pipes must touch the consumption centers and the concentrated big consumer as the public institution and industrial area. It must connect to the given receiving point, which will be a output point in the hydraulic model.

If we drew the line of the pipes, we need to check the slope of the pipes because it is a gravity system. So we need to design some test longitudinal profile (Fig. 5). Then we assume a slope of the conduit. (we check the longitudinal section, is it proper for the surface?). The value of the slope must be between about 3 ‰ and 50 ‰. ($D/100 \leq I \leq D/1000$, D (mm))

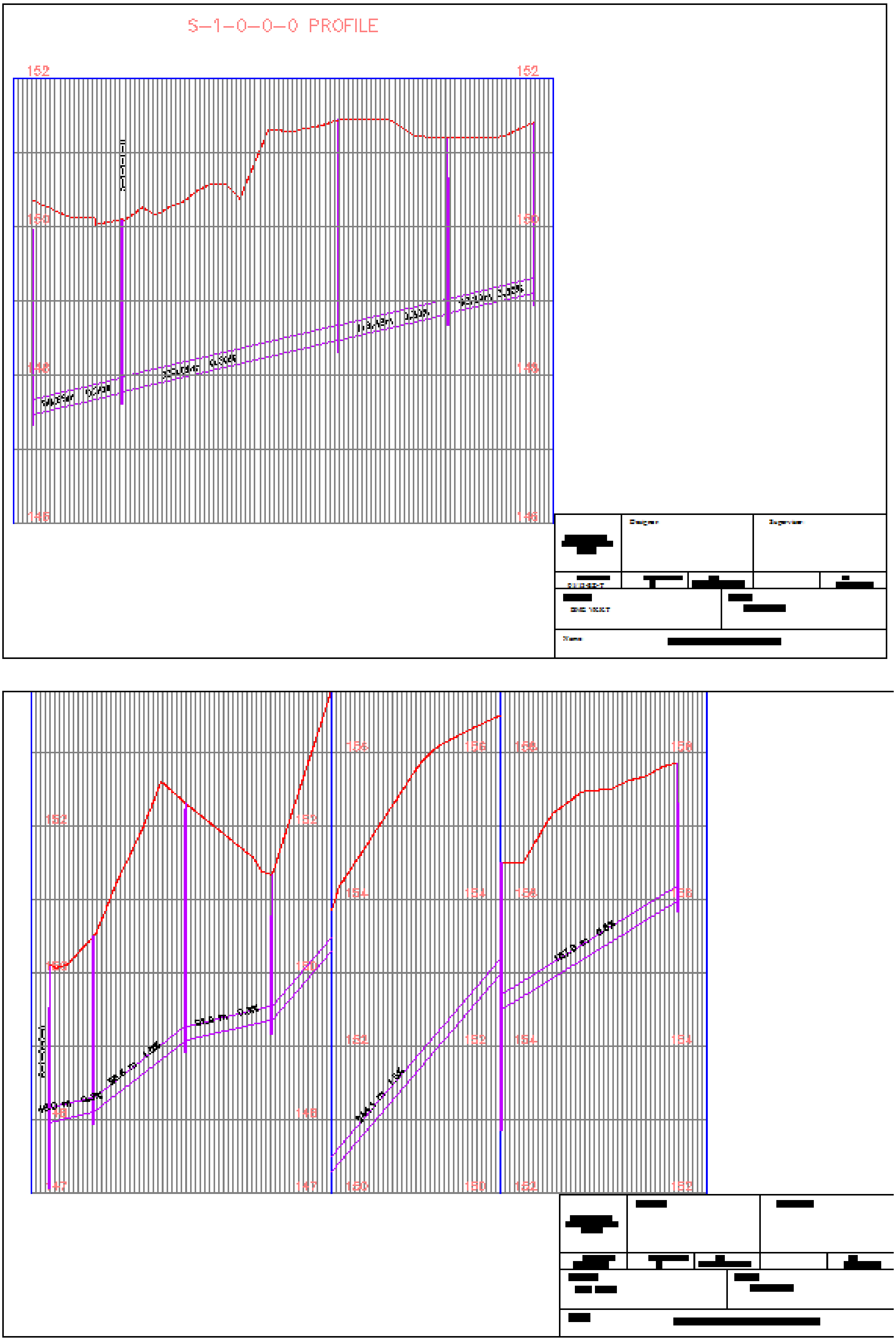


Figure 5. Longitudinal profile

If we have got the design waste water, and a slope we have to assume a pipe diameter. The pipe diameter must be larger than 200 mm. We give this minimum value by the public sewer, because this diameter can be cleaned with canal cleaner. If we have got a slope a diameter, we have to check is these values adequate for the waste water load. First we have to define the quantity of design waste water at the designing point. The designing point are at the:

- Receiving point
- Connection points
- After the big loads (public institution, industry)

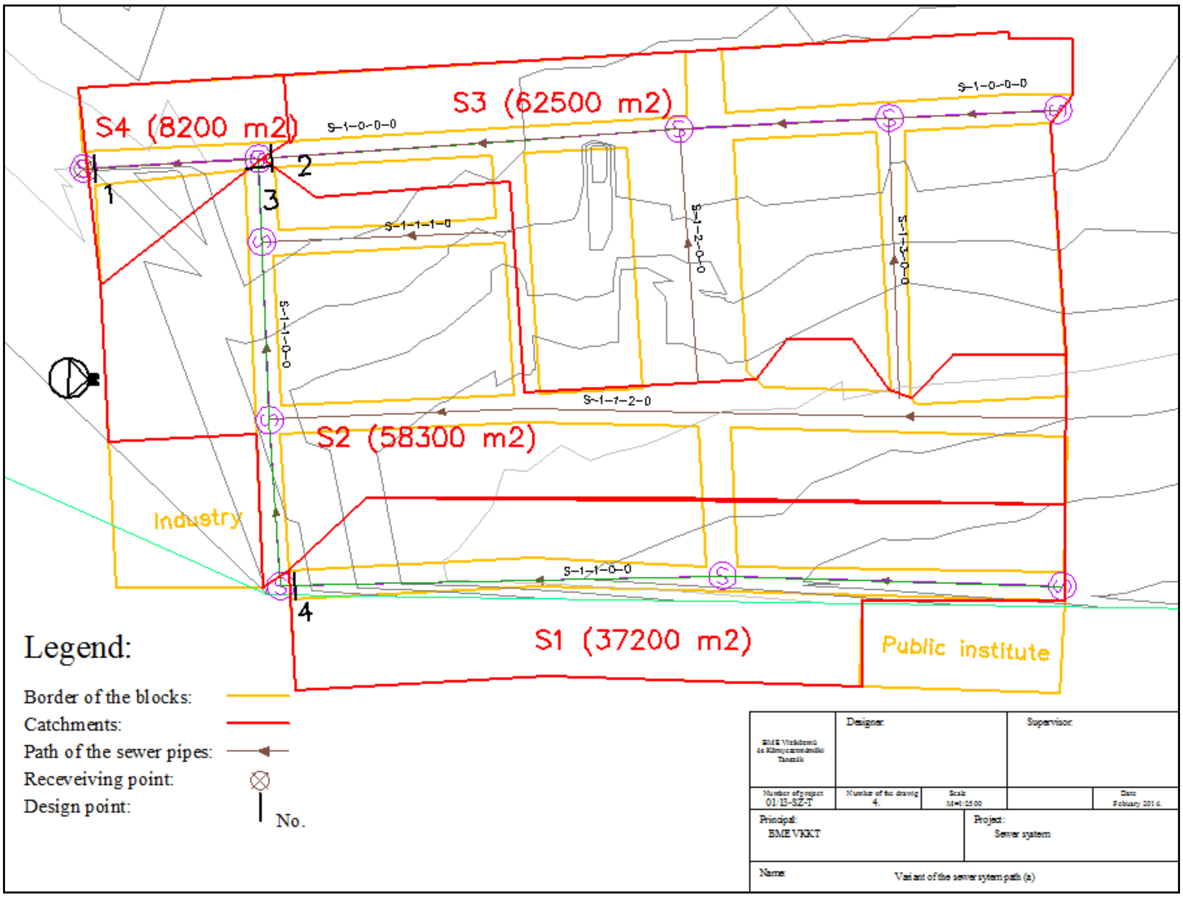


Figure 6. Catchments of the design points

The uniformly distributed loads as the dweller load is concentrated to the designing point according the catchment area. First we have to measure the catchment area of the designing points. We need 5-6 design point on our area.

Design point	Sign of the catchments	Catchment area (m2)	Wastewater load of the Inhabitants (m3/h)	wastewater of the public institution (m3/h)	wastewater of the industry (m3/h)	The design load (m3/h)
1	S1, S2, S3, S4	166 200	9.56	3.96	35.02	**48.54**
2	S3	62 500	3.60			**3.60**
3	S1, S2	95 500	5.49	3.96	35.02	**44.47**
4	S1	37 200	2.14		35.02	**37.16**
Sum:		**361 400**	**20.79**			

Table 17. Calculation of the wastewater load at the design points

10. PATH OF THE WASTEWATER SYSTEM (7TH PRACTICAL LESSON)

We use for the checking the Prandtl-Kármán-Colebrook formula, what gives us the velocity of the waste-water in the full-section pipe. This formula can be applied to the gravity sewers designing. The load results from water velocity ($Q = v \cdot A$), A is the cross-sectional area of the pipe).

$$v_{tot} = \left[-2\lg\left(\frac{2{,}51\upsilon}{d\sqrt{2gId}} + \frac{k}{3{,}71d} \right) \right] \bullet \sqrt{2gId} \qquad \text{1.1 formula}$$

v – the water velocity (m/s)

υ – the kinematic viscosity of the waste-water 1,31*10^{-6} m/s^2

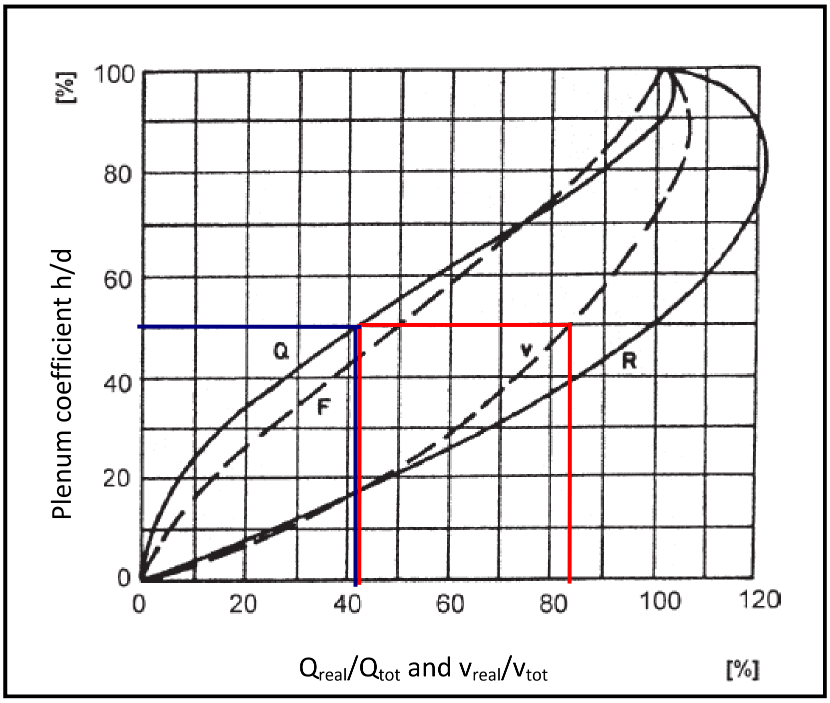
g – acceleration of gravity (9,81 m/s^2)

I – the slope of the conduit (m/m)

d – diameter of the pipe (m)

k – roughness of pipe wall (0,0025 m)

If we get the waste-water velocity, we have to check the velocity, and the minimal water depth in the sewer 3-4 cm, because the blockage or siltation. The real velocity of the waste-water must be 0,4-2,0 m/s. We can get the real water depth and the real velocity with next ***graph 1.1.***.



***1.1. graph:** Plenum curve*

If we want get the real water velocity, and real water depth we have to calculate the total transported quantity, what the pipe can transport.

$$Q_{tot} = v_{tot} \cdot A$$ 1.2. formula

Q_{tot} – water flow with full section (m^3/s)

v_{tot} – water velocity (m/s) derives from 1.1. formula

$A-$ cross sectional area of pipe (m^2)

Then we have to compute the next ratio:

$$\frac{Q_{real}}{Q_{tot}}$$ 1.3. formula

$Q_{real}-$ the planning flow volume at the designing point (m^3/s)

Q_{tot} – water flow with full section (m^3/s)

If we have the ratio of Q_{real}/Q_{tot} we have to search this value on the horizontal shaft of the plenum curve. We have to project this value to the curve „Q", then we have to project the intersection we got, to the curve „v" horizontal. Then we get another section, and we have to project this section to the horizontal shaft. The value we got on the horizontal shaft is the v_{real}/v_{tot}. This method can be seen on the ***graph 1.1.*** *(red line)*. We can calculate the real velocity from this ratio and from v_{tot} (velocity of the waste-water in the full-section pipe).

$$v_{real} = v_{tot} \cdot \frac{v_{real}}{v_{tot}}$$ 1.4. formula

Finally we have to calculate the water depth, the method can be seen on the ***graph 1.1.*** (blue line) We have to read the value h/d from the vertical shaft. We get the real water depth as it follows:

$$h = d\frac{h}{d}$$

d – pipe diameter

Finally we check the real water velocity, the real water depth, is it adequate for the rules, if the values aren't adequate we have to modify the slope or the pipe diameter until the result is satisfying.

Design point	Slope (‰)	Diameter (mm)	Roughness of the pipe (mm)	vtot (m/s)	Qtot (l/s)	Q design (l/s)	Qdesign/ Qtot	v/vtot	vreal (m/s)	h/d	h (cm)
1	3	200	0.4	0.69	21.55	13.48	0.63	1.15	0.72	0.65	13.00
2	3	200	0.4	0.69	21.55	1.00	0.05	0.42	0.02	0.18	3.60
3	3	200	0.4	0.69	21.55	12.35	0.57	1.07	0.61	0.63	12.60
4	15	200	0.4	1.56	49.04	10.32	0.21	0.84	0.18	0.33	6.60

Table 17. Calculation of the pipe diameter

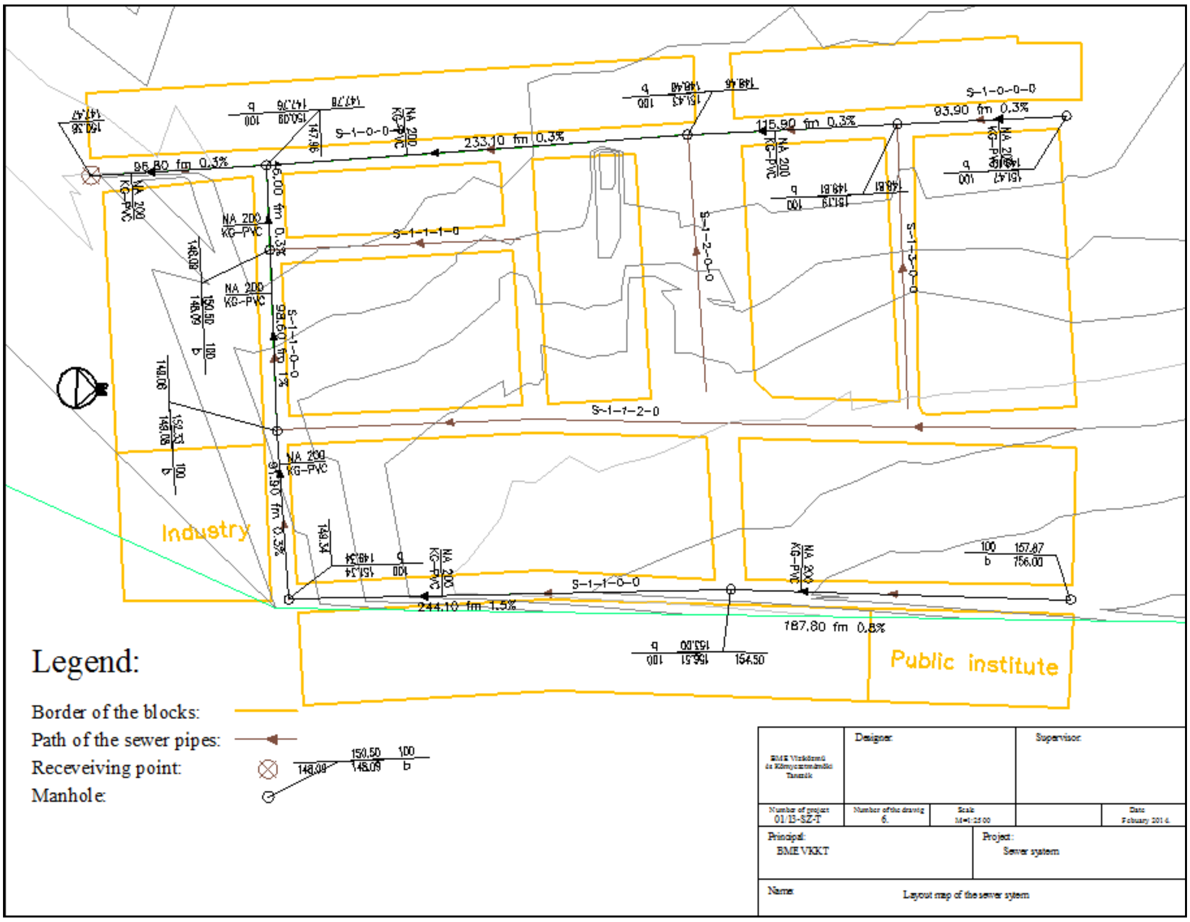
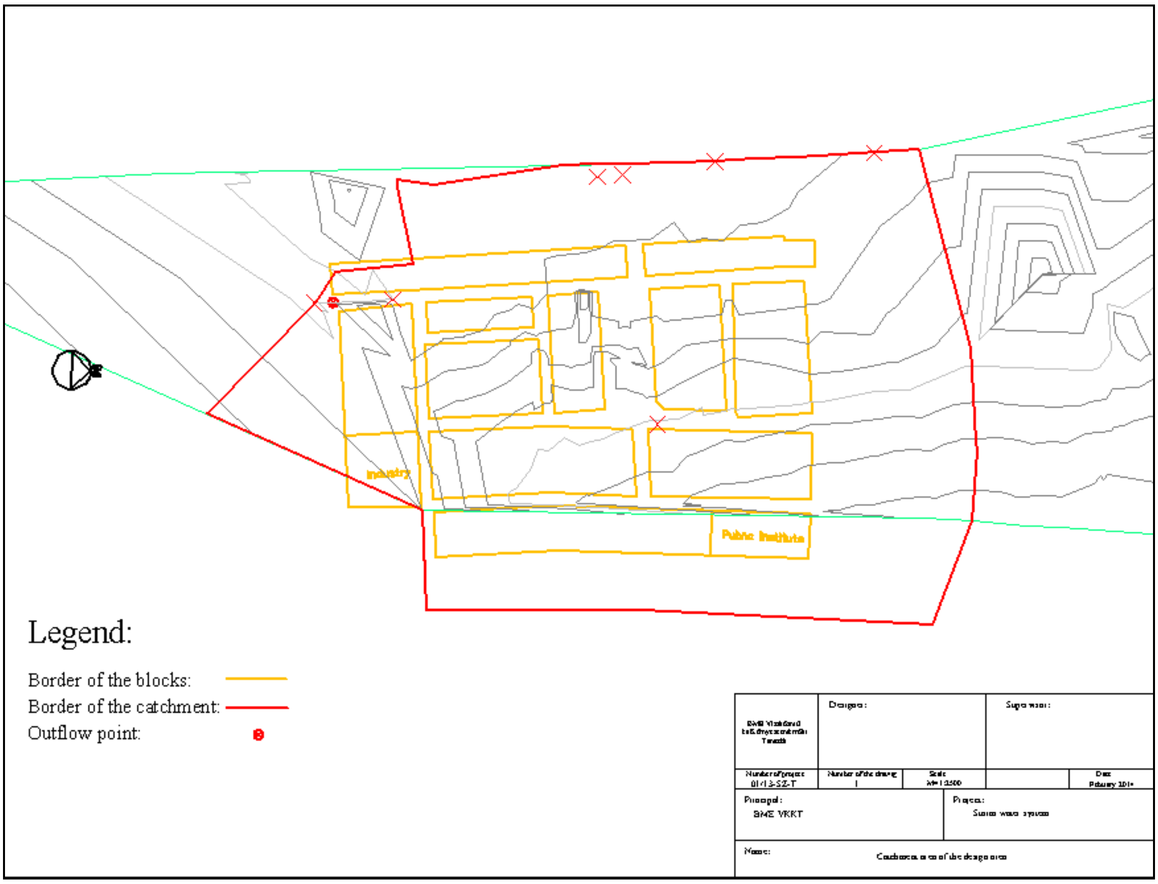


Figure 7. Final layout map of the sewer systems

11. PATH OF THE STORMWATER SYSTEM (8TH PRACTICAL LESSON)

The storm water is conveyanced in a gravity separated system. The design is similar to the wastewater, but the determination of the load is more complicate. It is not simply. First we have to determine the catchment area of the design area. We border the area, wherefrom the storm water flows to the designing point. The catchment can be larger than the design area. The catchment area can determined according to the surface (in this case the contour lines help us). The built surroundings can change the real catchment shape. Then we draw our sewer on the area. We can lay our sewer just on area of common use. We have to measure the sewers length.

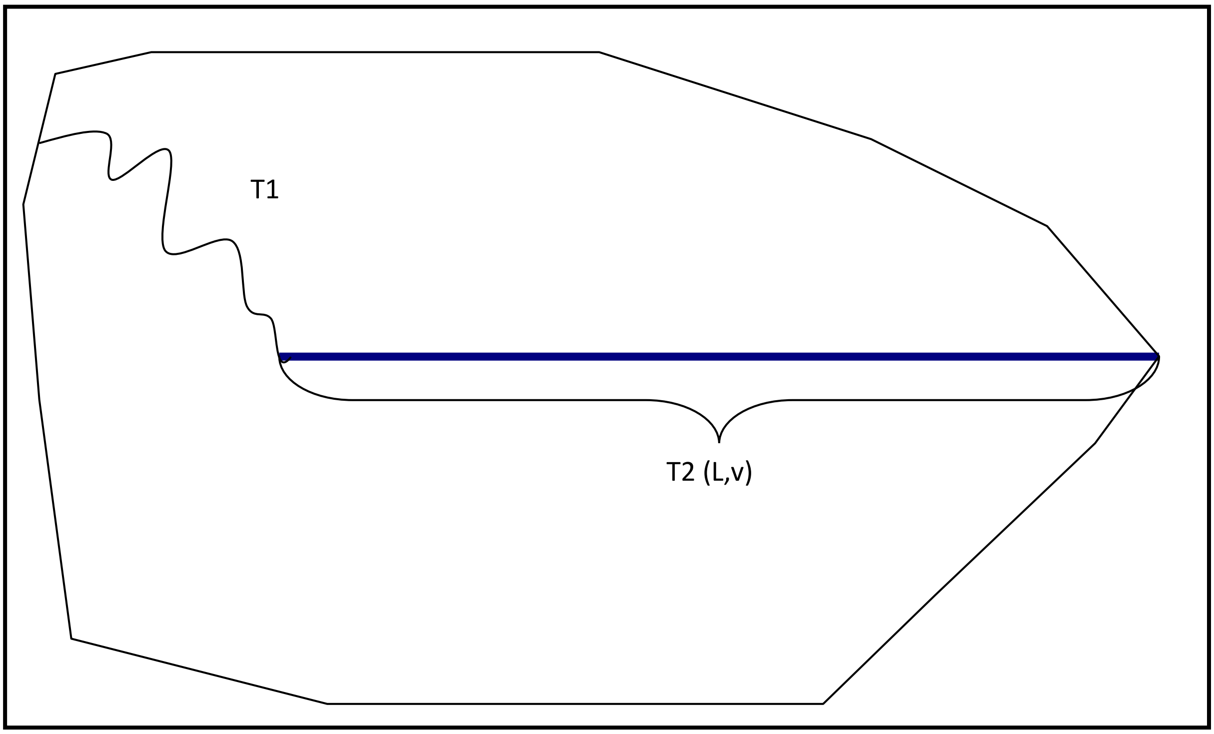


Border of the catchment

12. DIMENSION OF STORM WATER PIPE (9TH PRACTICAL LESSON)

The dimension of the storm water pipe is similar to the waste-water pipe. First we have to define the load of the storm water. We have to define the catchment, what belongs to the designing point. First we have to border the catchment. We use the rational method to the design. The theory of rational method is the next. The time of concentration is equal to the period of the design storm. The storm water, which falls in the outermost point, gets in the water conveyance at the design point. The time of concentration (T) has got two parts (***figure 2.1***.):

- the runoff on surface T_1
- the runoff in the storm water system T_2



2.1. figure

$T = T_1 + T_2$ (max)

We calculate the time of concentration from the farthest point. The farthest point was meant in time. The calculation start at the ends of the system. The times are summarised. The run off on surface is given on the worksheet. This value depends on the slop of the surface the length on the surface the quality of surface. We have to calculate the runoff in the storm water system if we assume the water velocity in the pipe 1 m/s (v) and we know the length of sewer (L).

$$T_2 = \frac{L}{v}$$

The next step we calculate precipitation intensity whit this formula:

$i_p = a \cdot (\frac{T}{10})^{-m}$ (l/s ha)

Where:

$T-$ the time of concentration (min)

$a, m-$ this value belong to rate of occurrence (see ***next table 2.1.***)

Rate of occurrence	a	m
1 year	133	0,69
2 years	203	0,71
4 years	270	0,72

2.1. table

We calculate the load of storm water at the design point with next formula:

$Q = i_p \cdot A \cdot \alpha$ (l/s)

Where:

$i_p -$ precipitation intensity

$A-$ area of catchment

$\alpha-$ run-off coefficient

The run-off coefficient depends on the surface for example run-off coefficient of the covered surface is higher value than uncovered. This value can be seen on the worksheet. The typical values are in the table x

Chapter 3 - Estimating Stormwater Runoff

SLOPE	LAND USE	SANDY SOILS		CLAYEY SOILS	
		MIN	MAX	MIN	MAX
Flat (0-2%)	Woodlands	0.10	0.15	0.15	0.20
	Pasture, grass, and farmland[b]	0.15	0.20	0.20	0.25
	Rooftops and pavement	0.95	0.95	0.95	0.95
	Pervious pavements[c]	0.75	0.95	0.90	0.95
	SFR: 1/2-acre lots and larger	0.30	0.35	0.35	0.45
	Smaller lots	0.35	0.45	0.40	0.50
	Duplexes	0.35	0.45	0.40	0.50
	MFR: Apartments, townhouses, etc.	0.45	0.60	0.50	0.70
	Commercial and Industrial	0.50	0.95	0.50	0.95
Rolling (2-7%)	Woodlands	0.15	0.20	0.20	0.25
	Pasture, grass, and farmland[b]	0.20	0.25	0.25	0.30
	Rooftops and pavement	0.95	0.95	0.95	0.95
	Pervious pavements[c]	0.80	0.95	0.90	0.95
	SFR: 1/2-acre lots and larger	0.35	0.50	0.40	0.55
	Smaller lots	0.40	0.55	0.45	0.60
	Duplexes	0.40	0.55	0.45	0.60
	MFR: Apartments, townhouses, etc.	0.50	0.70	0.60	0.80
	Commercial and Industrial	0.50	0.95	0.60	0.95
Steep (7%+)	Woodlands	0.20	0.25	0.25	0.30
	Pasture, grass, and farmland[b]	0.25	0.35	0.30	0.40
	Rooftops and pavement	0.95	0.95	0.95	0.95
	Pervious pavements[c]	0.85	0.95	0.90	0.95
	SFR: 1/2-acre lots and larger	0.40	0.55	0.50	0.65
	Smaller lots	0.45	0.60	0.55	0.70
	Duplexes	0.45	0.60	0.55	0.70
	MFR: Apartments, townhouses, etc.	0.60	0.75	0.65	0.85
	Commercial and Industrial	0.60	0.95	0.65	0.95

Source: FDOT (1987)

Table x Runoff coefficient

If we have the load of the sewer at the design point. We can calculate the diameter of the pipe with Prandtl-Kármán-Colbrook formula. Then we have to check the real water velocity, and water depth. See by the waste water design method. If the difference is between the calculated real water velocity and assumed water velocity more than 20 per cent we have to change the slope or diameter of pipe until the difference lower than 20 per cent. We have got other possibility to correct the failure, for example we can change the assume water velocity.