Sustainable Water Integrated Management - Support Mechanism (SWIM- SM)

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CSEI Catania
Centro Studi di Economia applicata all'Ingegneria

**STUDY TOUR ON WASTEWATER MANAGEMENT
USING NATURAL TREATMENT SYSTEMS (NTS) IN RURAL AREAS**

Construction, operation and maintenance of NTSs

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Introduction

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  - Operation and maintenance
- Waste Stabilization Ponds
  - Design and construction
  - Operation and maintenance
- Wastewater storage reservoir
  - Design and construction
  - Operation and maintenance

General design of natural wastewater system

- Implementation of a natural wastewater system must be based on a thorough technical design, ideally including:
  - Knowledge of **wastewater flow and wastewater characteristics** such as pH, temperature, and content of organic solids, suspended solids, and pathogens (hydraulic surface load, organic or pathogens areal loading rates)
  - Knowledge of the treatment efficiency of **treatment stages ahead** of the natural system (mean removal efficiency)
  - Knowledge of the **use of the effluent** treated (further treatments, discharged, reused, stored,..)
  - Selection of the **system type** and its configuration
  - Selection of **site**: Selecting an appropriate location can save significant costs. Site selection should consider land use and access, the availability of the land, site topography, soils, the environmental resources of the site and possible effects on any neighbours. The site should be located as close to the source of the wastewater as possible, and down gradient if at all possible so that water can move through the system by gravity.
  - Knowledge of **Permits and Regulations**: The appropriate agency(ies) must be contacted to determine the regulatory requirements for a proposed natural system and its discharge.

Constructed wetlands

Construction, operation and maintenance of NTSs

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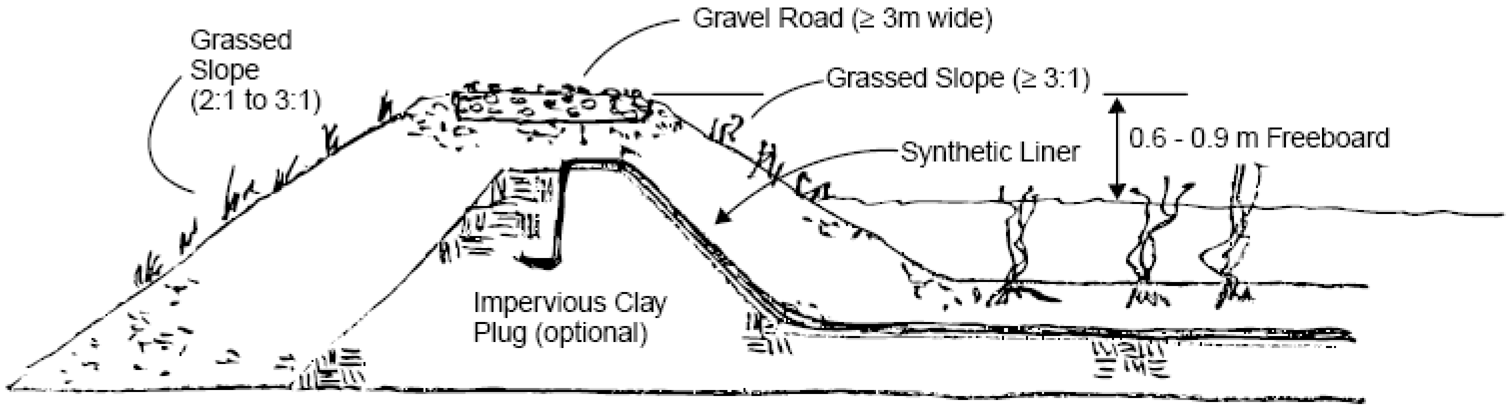
Construction of wetland

- Most of the equipment and procedures needed for construction of wetland the are the same as those employed for construction of pond, reservoir, and similar containment basins
- **Basin construction**: involves common earth moving, excavating and backfilling. A bottom slope of 0.5-1% in direction to the outlet is important.
- **Basin liner:** basin must be sealed to avoid possible contamination of groundwater and also to prevent groundwater from infiltrating into the wetland. Where on-site soils or clay provide an adequate seal, compaction of these materials may be sufficient to line the wetland. If not, synthetic liners, the same as those typically used for reservoir and ponds, include:
    - Polyvinyl chloride (PVC)
    - Polyethylene (PE)
    - Polypropylene or high-density polyethylene (HDP)
  - The liner must be strong, thick, and smooth to prevent root attachment or penetration. If the site soils contain angular stones, sand bedding or geotextile cushions should be placed under the liner to prevent punctures.

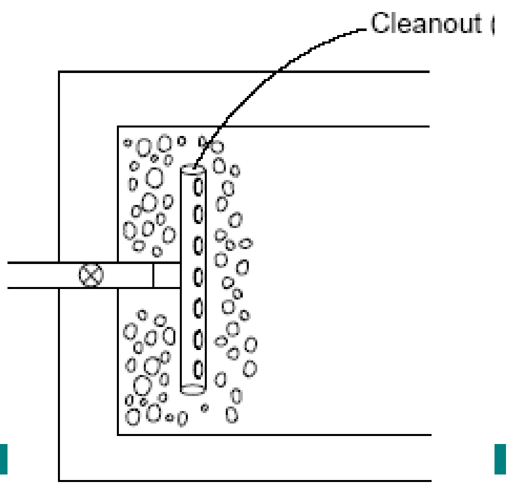
Berms

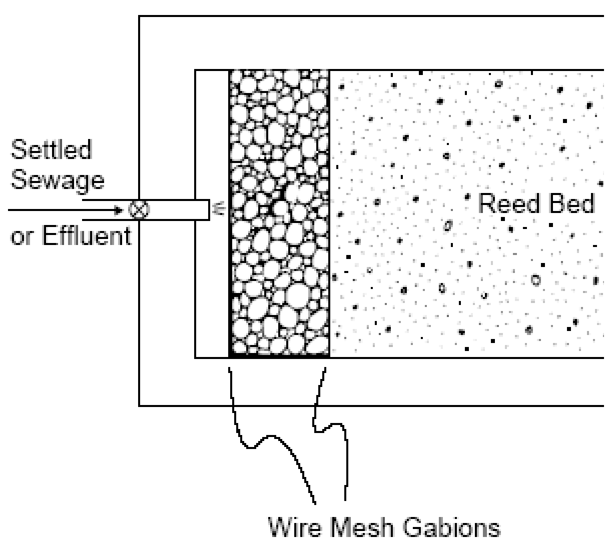
- Berms in constructed wetlands contain water within specific flow paths. Exterior berms are designed to prevent unregulated flow releases. Interior berms are used to augment flow distribution.
- External berms are typically built to provide 0.6 to 1 m (2–3 ft) of freeboard with a width at least 3 m (10 ft) at the top to permit service vehicle access.
- Side slopes should be a maximum of 3:1; however, slopes of 2:1 have been used for internal side slopes, particularly when liners or erosion control blankets are used.

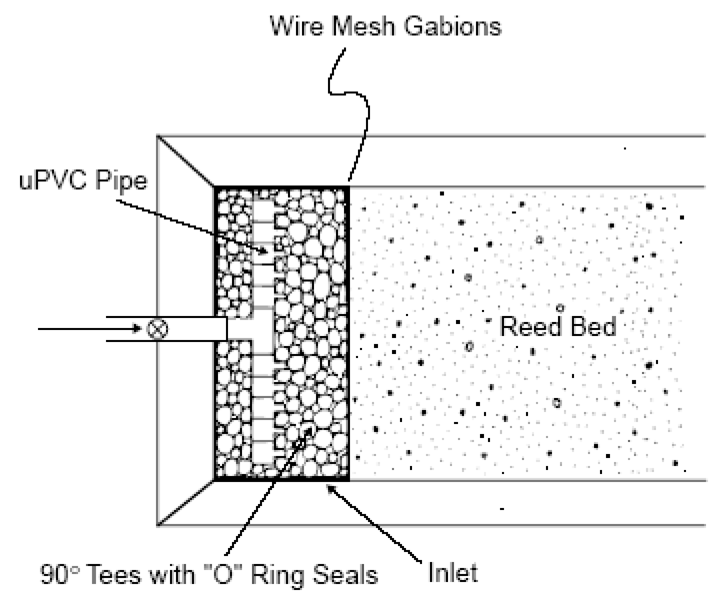


Inlet/Outlet Structures

- Inlet and outlet structures distribute the flow into the wetland, control the flow path through the wetland, and control the water depth
- Two types of inlet/outlet structures are commonly used in FWS and HSF constructed wetlands:
  - In small- to medium-sized wetlands, perforated PVC pipe can be used for both inlet and outlet structures. Perforated PVC pipe are length approximately equal to the wetland width, with uniform perforations (orifices) drilled along the pipe. It is important that the orifices be large enough to minimize clogging with solids.
  - For a wide wetland cell multiple weirs, or drop boxes are generally used for inlet and outlet structures. The weir boxes also can be used for measuring the influent flow.
- the inlet structure discharge could be located below or above the wetland water surface
- All inlet distribution systems should be accessible for cleaning and inspection

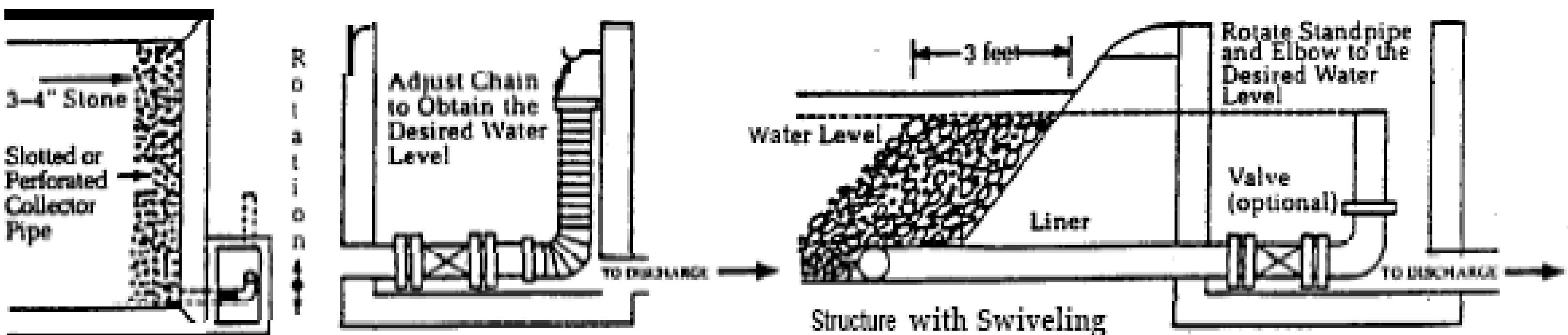






Outlets Structures

- At SSF, FW and VF wetlands, outlets include subsurface manifold, and weir boxes or similar gated structures. If submerged outlet manifolds are used, they must be connected to a level control device that permits the operator to adjust the water depth in the wetland.
- The water level is controlled by the outlet structure, which can be:
  - A variable height weir, such as a box with removable stop logs, allows the water levels to be adjusted easily.
  - Spillways are simple to construct but are not adjustable; incorrect water levels can lead to wetland failure and correcting spillway height can be difficult.
  - Adjustable riser pipes or flexible hoses offer simple water level control. A PVC elbow attached to a swivel offers easy control of the water level
- The use of an adjustable outlet, which is recommended to maintain an adequate hydraulic gradient in the bed, can also have significant benefits in operating and maintaining the wetland. It is important that any outlet structure be designed so that the wetland can be completely drained, if required



Plan View of Outlet Structure with Swiveling Standpipe

Structure with Collapsible Tubing

Structure with Swiveling Standpipe

Media

- A soil medium is necessary as a matrix FWS,HS and VF wetlands for supporting emergent vegetation. Hard, durable stone (river gravel or crushed stone) is recommended. Crushed limestone, which is soft and easily disintegrates, should be avoided.
- the hydraulic conductivity and porosity of the material should be determined in the field or laboratory, prior to system design.
- The use of smaller rock sizes has a number of advantages in that there is more surface area available on the media for treatment, and the smaller void spaces are more compatible with development of the roots and rhizomes of the vegetation, and the flow conditions should be closer to laminar.
- In FWS and HS beds the use of a coarser rock with larger void spaces and a higher hydraulic conductivity should be use at inlet zone, to ensures rapid infiltration and prevents ponding, and at outlet zone to favourite flow collection .
- In HS beds since some clogging can occur in these systems, It is recommended to utilize no more than 70 percent of the potential hydraulic gradient available in the proposed bed.

Type	Effective Size D_{10} mm	n^a Porosity %	k_s^b Hydraulic Conductivity $m^3/m^2/d$
Coarse Sand	2	32	1,000
Gravelly Sand	8	35	5,000
Fine Gravel	16	38	7,500
Medium Gravel	32	40	10,000
Coarse Rock	128	45	100,000

a. The porosity is used to determine the actual flow velocity in the void spaces, and in equations (3) and (5) to determine the size of the SF bed. Porosity is equal to Void Volume/Total Volume, and is expressed as a percent.

b. Assuming non turbulent, near laminar flow conditions, with clean water

HF: hydraulic conductivity and porosity of medium

Vegetation Establishment

- Establishing vegetation within a constructed wetland involves the planting of suitable vegetative materials at the appropriate time. The higher the density, the more rapid the development of the system, but with an increased construction cost. For plant establishment within a constructed wetlands to be successful, the following must occur (WERF, 2006)
  - Plant Species must be matched to the regime of the wetland;
  - Plant material must be viable at the time of the planting;
  - Water level management during startup must be compatible with the needs of plants.
- For SF type constructed wetlands, the water level should just cover the top of the rooting material. As the plants grown taller the water level may be raised (WERF, 2006).
- Plants may be obtained from the following sources:
  - Commercially available planting stocks;
  - Donor plants from another treatment wetland;
  - Onsite plant nursery; or
  - Natural wetlands.

design for VF

- Basic design recommendations for VF are:
  - The top surface of the filter has to be kept level and the distribution pipes are often covered with gravel to prevent open water accumulation during the pumping periods.
  - The distribution pipes should be designed in such way that they achieve an even distribution of the pre-treated wastewater on the entire constructed wetland bed. This is ensured by selecting the right diameter of the distribution pipes, length of pipes, diameter of holes and spacing between holes in the distribution pipes.
  - The distance between drainage pipes is based on the detailed design but may be around 5 m. The drainage pipes are covered with gravel to enable good drainage.
  - A bottom slope of 0.5-1% in direction to the outlet is important for large VF.
  - The depth of the sand filter beds should be at least 50 cm, with an additional 20 cm of gravel at the base to cover the drainage pipes, 10 cm gravel on the top of the bed and 15 cm freeboard for water accumulation. The gravel on top prevents free water accumulation on the surface, and could in fact be omitted if there is no access to the CW for members of the public.

CW Operation and maintenance

- The following are the most critical items in which operator input is necessary (US EPA, 2000):
  - **1. Adjustment of water levels:** Changes in water level will effect hydraulic retention time, atmospheric oxygen diffusion into the water and plant cover. Observed changes in the water level should be investigated immediately, as they may be due to leaks, clogging or other issues
  - **2. Maintaining uniformity of flow:** Water is introduced into a wetland system through the inlet control device and removed through the outlet control device. Short-circuiting of a wetland system occurs when clogging or other issues create non-uniform preferential flow paths. To help mitigate against this potential, the inlet and outlet control devices should be inspected routinely.
  - **3. Management of vegetation:** Routine maintenance of wetland vegetation is not required for systems operating within their design parameters. Harvested vegetation can be burned, chopped and composted, chopped and used as mulch or digested

CW Operation and maintenance

- **4. Odor Control:** FW and HSF constructed wetlands may contain anaerobic zones that release hydrogen sulfide or other compounds. Decreasing the water depth, thus increasing the overall amount of dissolved oxygen within the water column may help reduce the anaerobic conditions that lead to these odors.
- **5. Mosquito Control:** The goal of mosquito control in FWS design is to create conditions favorable for mosquito larvae predators, such that very few of the eggs that hatch survive to become adult mosquitoes. Predators of mosquito larvae include crustaceans (copepods, triops, swamp crayfish), coleopterans (whirligig beetles, hydrophilid and dytiscide beetle larvae), dragon fly although the most commonly used predator is the mosquitofish (*Gambusia holbrooki)*.

Waste Stabilization Ponds

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Design and Construction Practice for Waste Stabilization Ponds

- **Lining Materials**: bentonite, asphalt, soil cement liners, thin membrane liners. Lining must be placed on a stable soil foundation or structure.
- **Cover Material:** Placing cover material over buried membranes is the most expensive part of the procedure. The cover material should, therefore, be as thin as possible, while still providing adequate protection for the membrane. the depth of coverage should be greater than 25 cm
- **Inlet and Outlet Configuration:**
  - a single pipe, usually located toward the center of the pond. Hydraulic and performance studies have shown that the use of centralized inlet structures is an inefficient method of introducing wastewater to a pond, often resulting in less than ideal residence time.
  - Multiple inlet arrangements are preferred, even in small ponds (<0.5 ha) and preferably by means of a long splitter box with multiple outlets large enough to avoid plugging by influent solids.
  - The inlets and outlets should be placed so that flow through the pond has a uniform velocity profile between the next inlet and outlet

Operation and maintenance of an anaerobic pond

- A well-operating anaerobic pond is covered entirely with a dense scum blanket which helps to keep the pond anaerobic and minimizes foul odors.
- **Important Operation Considerations**
  - Keep the pond *p*H at or near neutral (*p*H = 7).
  - Keep records of flow, HRT, *p*H, BOD5 and TSS.
  - Include information on volatile acids, scum and sludge depth.
- Maintaining an aerobic pond in good condition requires full-time operator attention. These activities should be performed on a regular schedule and as needed:
  - Maintain mechanical equipment
  - Keep pipelines, diversion boxes and screens clean
  - Collecting samples
  - Run lab tests
  - Solids accumulate in the pond bottom and require removal infrequently (5-10 years), depending on the amount of inert material in the influent and the temperature.
  - Sludge depth should be measured annually.

Operation and Maintenance of facultative ponds

- During the start-up phase of the facultative and maturation ponds, the ponds should be filled with freshwater (from tap, river or wells), thereby allowing the gradual development of algae and heterotrophic bacteria population.
- General maintenance guidelines of facultative ponds:
  - To maintain wave action, a pond should be free of weeds in the water or tall weeds on thebanks.
  - Dikes should be well seeded with grasses above the water line. Grass should be mowed regularly to prevent soil erosion and insect problems.
  - Riprap, broken concrete rubble or a poured concrete erosion pad should be placed at the water's edge to prevent erosion of dikes.
  - Inlet and outlet structures should be cleaned regularly to remove any floating debris, caked scum, or other trash that might produce odors or be unsightly.
  - Mechanical equipment should be maintained according to a regular schedule.
  - Maintenance records should be kept and be readily accessible.
  - All pond operations should be listed on a posted schedule. The plant records should include weather data and basic test results such as flow, *p*H, DO, BOD5, TSS and chlorine residuals.

Operation and Maintenance of Maturation ponds

- Maturation ponds require the same daily inspections and maintenance as any other treatment ponds.

Maintenance of the ponds

- Maintenance of the ponds should be carried out regularly to avoid odors, flies and mosquito nuisances. The routine maintenance includes:
  - Removing screenings and grit from the inlet and outlet works;
  - Cutting grasses on the embankment, and removing it so that it does not fall in the ponds;
  - Removing floating scum and floating macrophytes from the surface of the maturation and facultative ponds;
  - Spraying scum on the surface of the anaerobic ponds and not removing it, since this will help the treatment processes;
  - Removing any accumulated solids in the inlet and outlet works;
  - Repairing any damaged embankment as soon as possible; and
  - Repairing any damage of the fences or gates.

Wastewater storage reservoir

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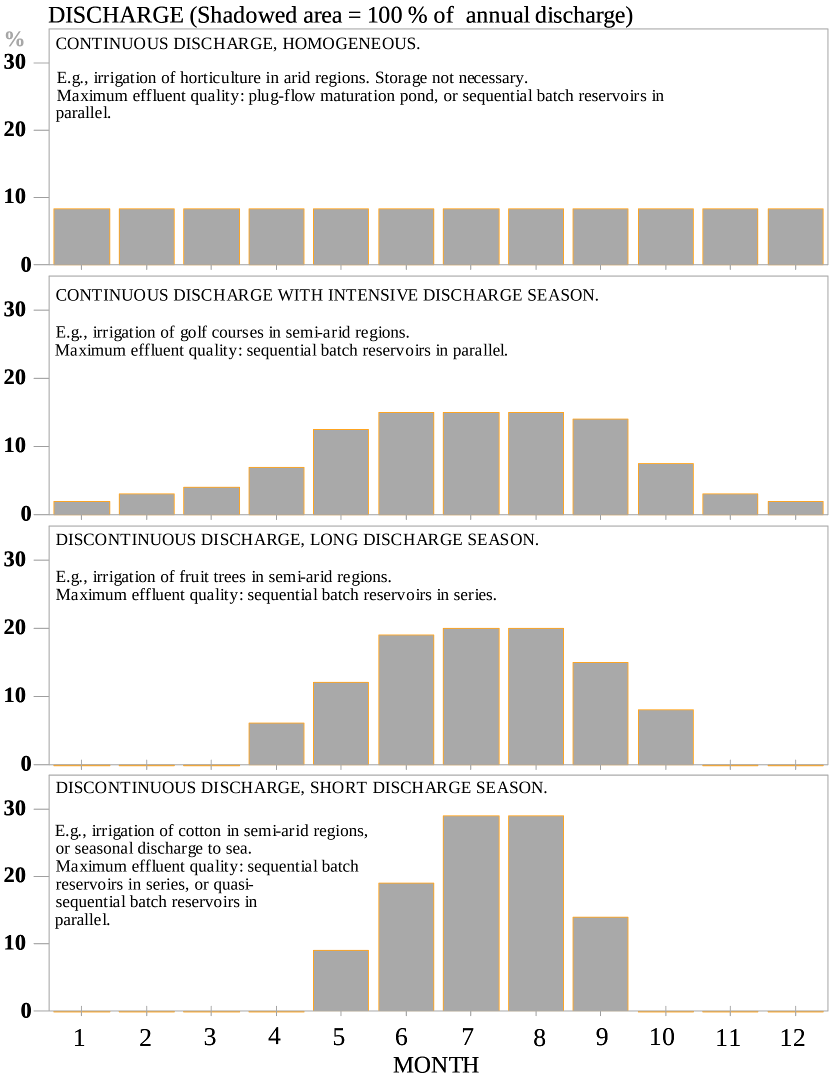
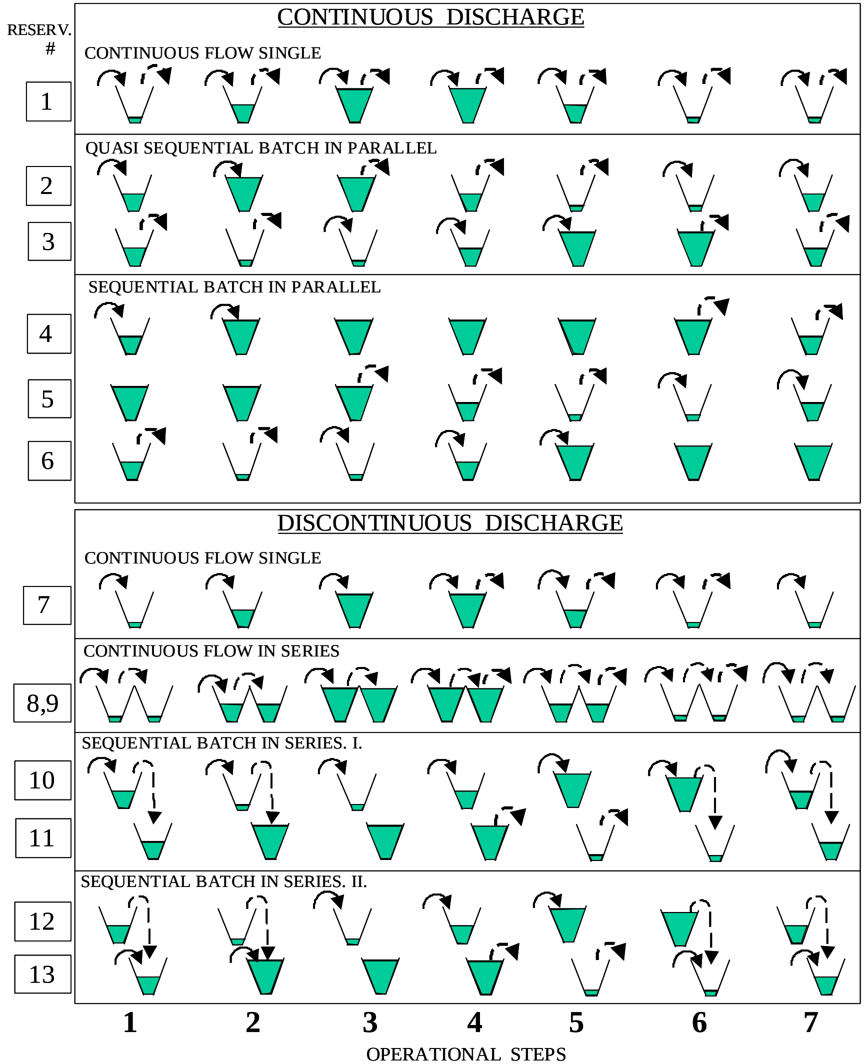
OPERATION OF WASTEWATER RESERVOIRS





Wastewater storage reservoir

- Operation modalities could be:
  - continuous flow: constant inflow, no outflow in the fall–winter season, and outflow higher than inflow in the summer; mean residence time varies between 50 and 180 days;
  - batch storage: inflow in a short time, no outflow until effluent withdrawal; mean residence time varies between 30 and 50 days. In general, it is more efficient than the previous one.
  - *Residence Time*, usually varies between 30-50 days (for operation modalities in batch) and between 50-180 days (for operation on a continuous cycle)
  - *PFE* (*Percentage of Fresh Effluents*) is a measurement of the amount of fresh effluents within the reactor, i.e., PFE5 is the percentage of fresh effluents having 5 or less days (within the reactor. In generally, PEF5< should be less than 5-10% of the total storage volume (for operation modalities in continuous flow).
  - WSRs depth is usually up to 15 m in order to minimize water loss due to evaporation, but there are several examples around the world where the depth is about 4-5 m (cirelli et al., 2008).
  - Basins are usually lined with impervious membranes in order to prevent wastewater infiltration.

Maintenance

- the algae removal is necessary in irrigation use before water distribution, because algae could cause clogging problems to irrigation systems (filters, emitters, distribution pipes, ..);
- the sludge, accumulated at the bottom of the basin, have to be remove about every 5-10 years;
- large areas are required; so this "natural technology" is particularly preferable to wastewater treatments in rural areas, where sufficient land of suitable feature is generally available;
- low energy and maintenance is required for both construction and O&M