2F-1 Sand Filter

BENEFITS Low = <30% Medium = 30-65% High = 65-100%			
	Low	Med	High
Suspended Solids			■
Nitrogen	■		
Phosphorous		■	
Metals		■	
Bacteriological		■	
Hydrocarbons		■	

Description: A sand filter is a multi-chamber structure designed to treat stormwater runoff through filtration, using a sediment forebay and a sand bed as its primary filter media. In some cases, a third chamber may be used to collect filtered runoff. Typically, an underdrain is used to return the filtered runoff to the conveyance system.

Typical uses: High-density/ultra-urban location where available land is restricted, such as a receiving area for runoff from an impervious site.

Advantages/benefits:

- Stormwater filters have their greatest applicability for small development sites – drainage areas of up to 5 surface acres.
- Good for highly impervious areas.
- Good retrofit capability.
- Good for areas with extremely limited space.
- Can provide runoff quality control, especially for smaller storms; generally provide reliable rates of pollutant removal through careful design and regular maintenance.
- No restrictions on soils at installation site if filtered runoff is returned to the conveyance system.

Disadvantages/limitations:

- High maintenance burden.
- Not recommended for areas with high sediment content in stormwater or areas receiving significant clay/silt runoff.
- Relatively costly.
- Possible odor problems.
- Porous soil required at site, if filtered runoff is to be exfiltrated back into the soil.
- Not recommended for residential developments due to higher maintenance burden.

Maintenance requirements:

- Inspect for clogging – rake first inch of sand.
- Remove sediment from forebay/chamber.
- Replace sand filter media as needed.

A. Description

Sand filters are structural stormwater controls that capture and temporarily store stormwater runoff and pass it through a filter bed of sand. Most sand filter systems consist of two or three chambered structures. The first chamber is a sediment forebay or sedimentation chamber, which removes floatables and heavy sediments. The second is the main filtration chamber, which removes additional pollutants by filtering the runoff through a sand bed. A third chamber is sometimes utilized to collect the filtered runoff. The filtered runoff is typically returned to the conveyance system by an underdrain, though it can also be partially or fully exfiltrated into the surrounding soil in areas with porous soils. Because they have few site constraints besides head requirements, sand filters can be used on development sites where the use of other structural controls may be precluded. However, sand filter systems can be relatively expensive to construct and install.

There are three sand filter system design variants: the surface sand filter, perimeter sand filter, and underground sand filter. Descriptions of these filter systems are provided below:

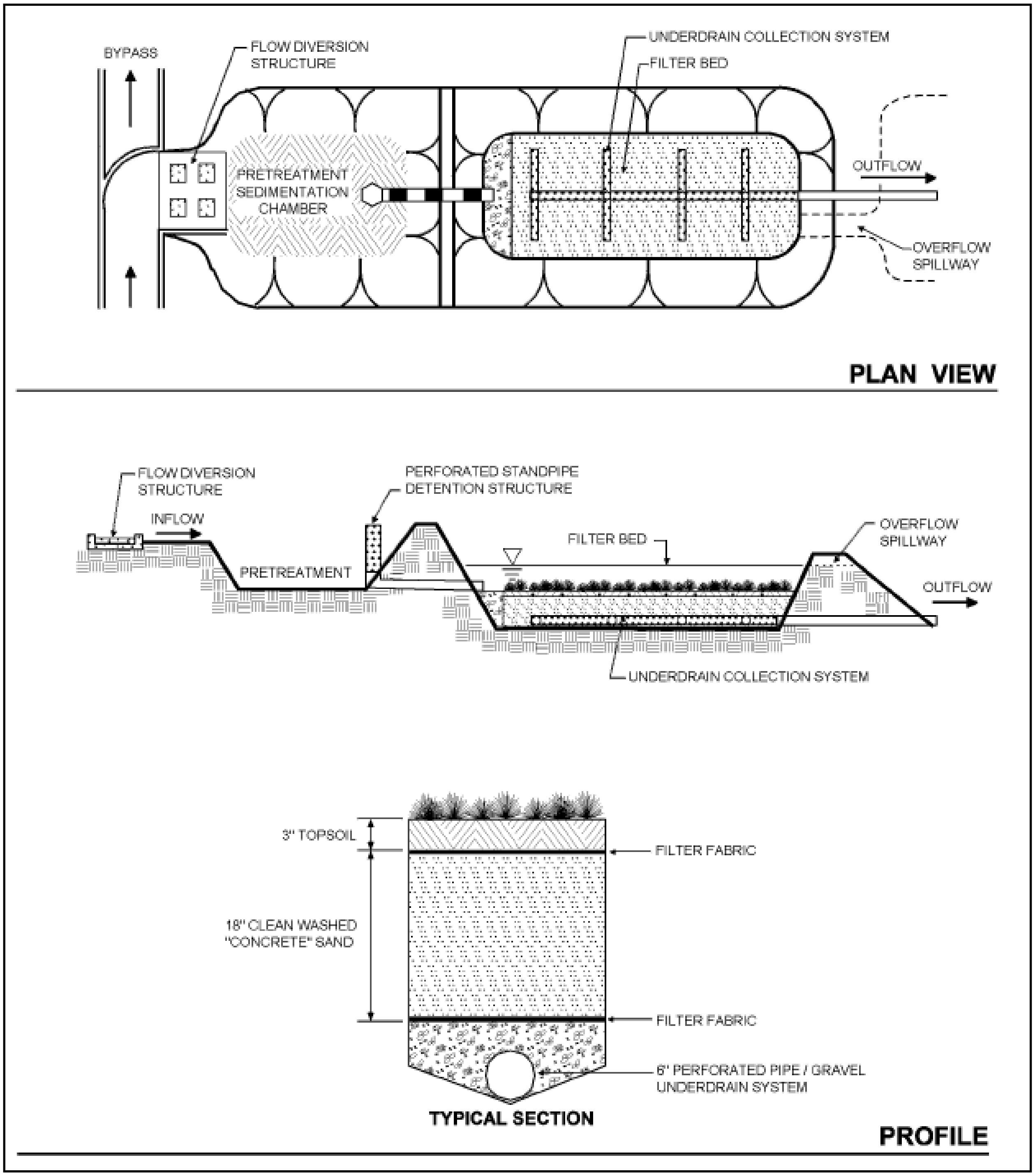
1. **Surface sand filter.** The surface sand filter is a ground-level open-air surface structure that consists of a pre-treatment sediment forebay and a filter bed chamber (Figures 1 and 2). This system is typically used to treat drainage areas 2-10 acres in size and is typically located off-line. Surface sand filters can be designed as an excavation with earthen embankments or as a concrete or block structure. A flow splitter is used to divert the first flush of runoff into an off-line sedimentation chamber. The chamber may be either wet or dry, and is used for pre-treatment. Coarse sediments drop out as the runoff velocities are reduced. Runoff is then distributed into the second chamber, which consists of 18-24-inch deep sand filter bed and temporary runoff storage above the bed. Pollutants are trapped or strained out at the surface of the filter bed. The filter bed surface may have optional sand or grass cover. A series of perforated pipes located in a gravel bed collect the runoff passing through the filter bed, and return it into the stream or channel at a downstream point. If underlying soils are permeable, and groundwater contamination unlikely, the bottom of the filter bed may have no lining, and all or part of the filtered runoff may be allowed to exfiltrate into the soil.

2. **Perimeter sand filter.** The perimeter sand filter is an enclosed filter system typically constructed just below grade in a vault along the edge of an impervious area such as a parking lot (Figure 3). First developed by Shaver and Baldwin (1991), the system consists of two parallel trench-like chambers installed along the perimeter of a parking lot. This system is usually used to treat drainage areas up to 2 acres in size, and consists of a sedimentation chamber and a sand bed filter. Runoff flows into the first chamber through a series of inlet grates located along the top of the control. The first trench provides pre-treatment through sedimentation in a shallow permanent pool of water before the runoff spills into the second trench, which consists of an 18-inch deep sand layer. During a storm event, runoff is temporarily detained above the normal pool and sand layer. When both chambers fill up to capacity, excess parking lot runoff is routed to a bypass drop inlet. The remaining runoff is filtered through the sand, collected by underdrain piping, and delivered to a protected outflow point.

3. **Underground sand filter.** The underground sand filter is intended primarily for extremely space-limited and high-density areas. In this design, the sand filter is placed in a three-chamber underground vault (either on-line or off-line) accessible by manholes or grate openings (Figure 4). The initial chamber, a sedimentation (pre-treatment) chamber, temporarily stores runoff and utilizes a wet pool to capture sediment. The sedimentation chamber is connected to the sand filter chamber by a submerged wall that protects the filter bed from oil and debris. The filter bed is 18-24 inches deep and may have a protective screen of gravel or permeable geotextile to limit clogging. During a storm, the water quality volume (WQv) is temporarily stored in both the first

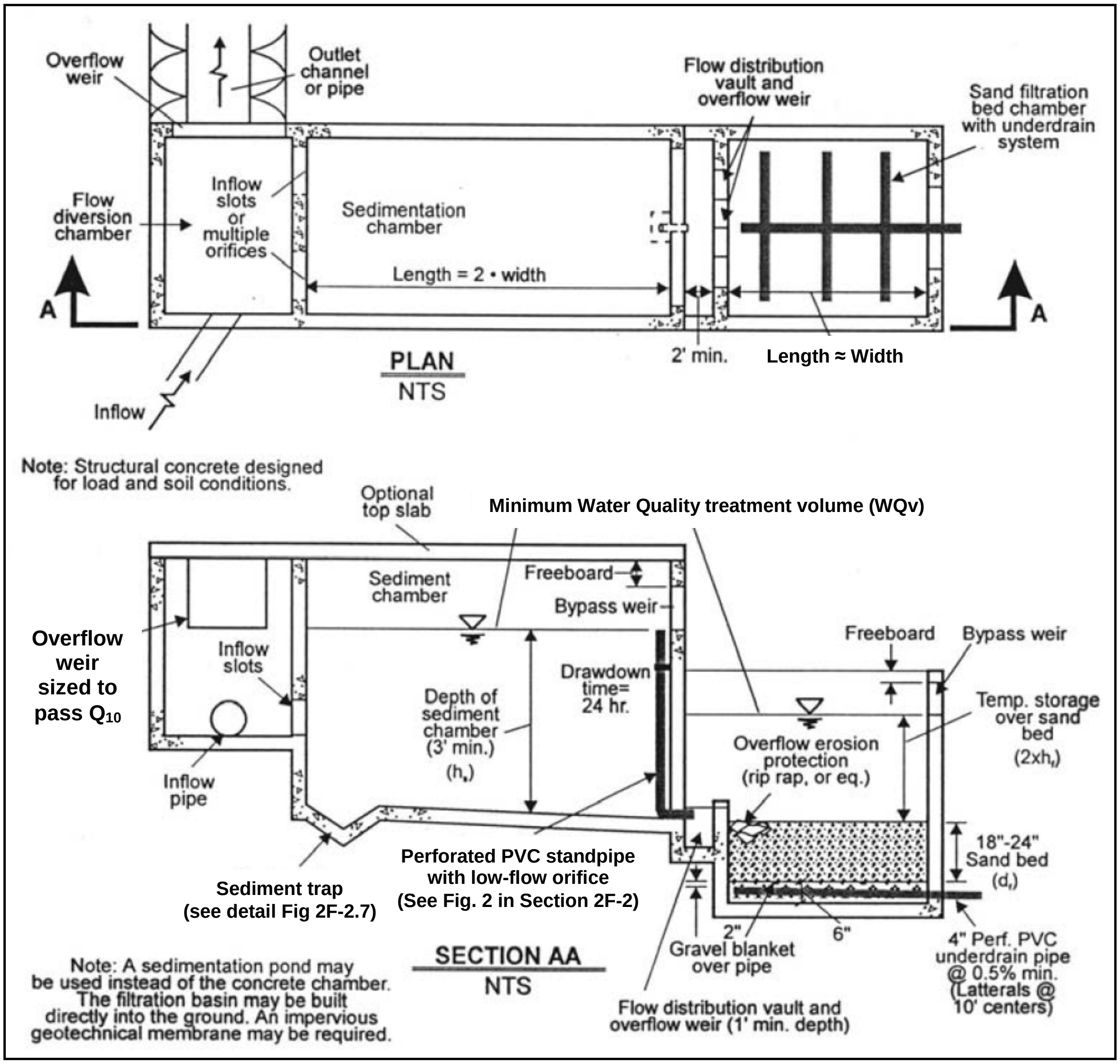
and second chambers. Flows in excess of the filter's capacity are diverted through an overflow weir. The sand filter chamber also includes an underdrain system with inspection and cleanout wells. Perforated drain piping under the sand filter bed extends into a third chamber that collects filtered runoff.

Figure 1: Surface sand filter (earthen structure)



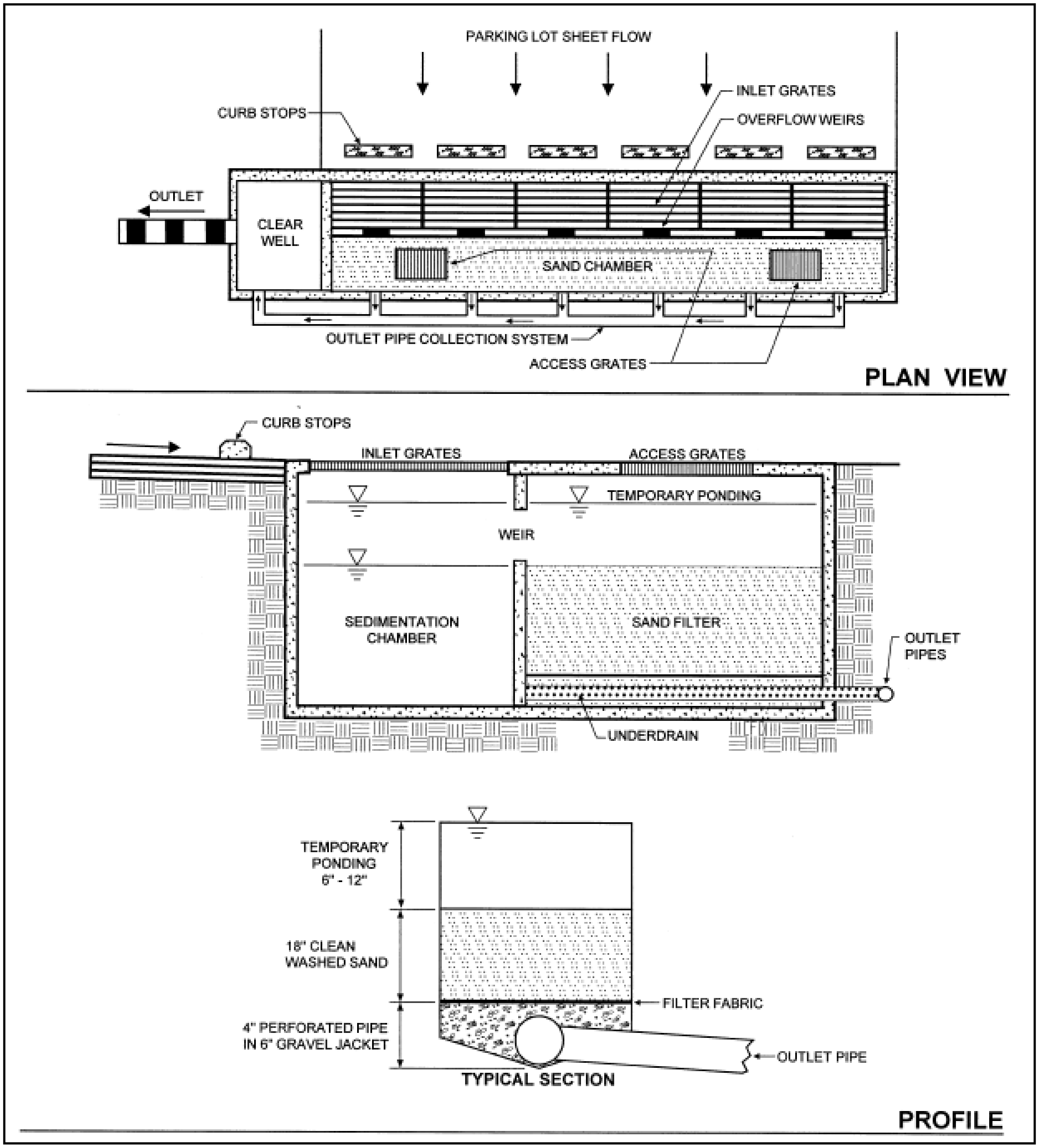
Source: Adapted from Claytor & Schueler, CWP, 1996

Figure 2: Surface sand filter (concrete structure)



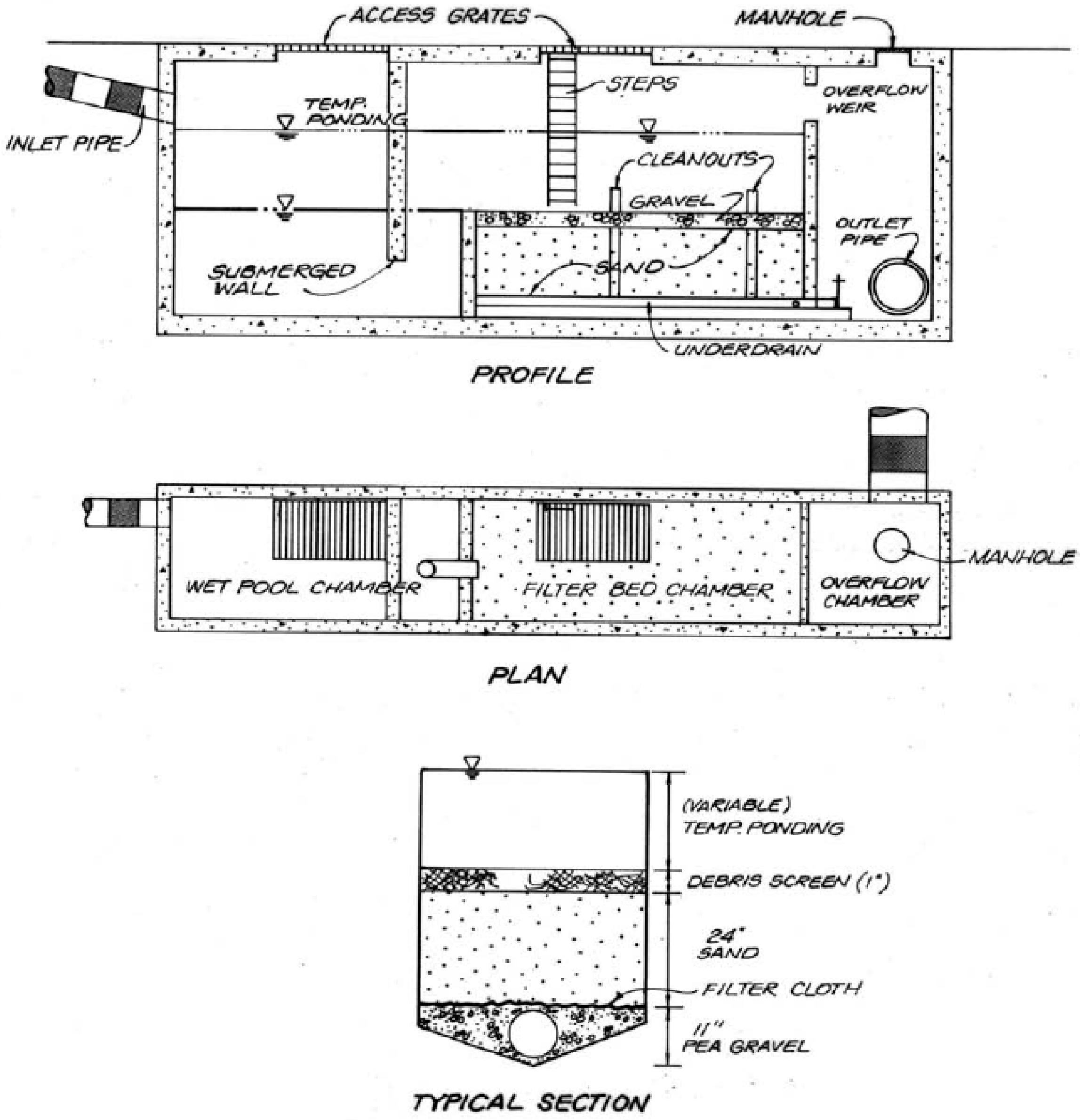
Source: Adapted from Claytor & Schueler, CWP, 1996

Figure 3: Perimeter sand filter



Source: Adapted from Claytor & Schueler, CWP, 1996

Figure 4: Underground sand filter



Source: Adapted from Claytor & Schueler, CWP, 1996

Figure 5: Surface sand filter

Figure 6: Perimeter sand filter

B. Stormwater management suitability

Sand filter systems are designed primarily as off-line systems for stormwater quality (i.e., the removal of stormwater pollutants) and will typically need to be used in conjunction with another structural control to provide downstream channel protection, overbank flood protection, and extreme flood protection, if required. However, under certain circumstances, filters can provide limited runoff quantity control, particularly for smaller storm events.

1. **Water quality.** In sand filter systems, stormwater pollutants are removed through a combination of gravitational settling, filtration, and adsorption. The filtration process effectively removes suspended solids and particulates, biochemical oxygen demand (BOD), fecal coliform bacteria, and other pollutants. Surface sand filters with a grass cover have additional opportunities for bacterial decomposition, as well as vegetation uptake of pollutants, particularly nutrients. See Pollutant Removal Capabilities for planning and design purposes.

2. **Channel protection.** For smaller sites, a sand filter may be designed to capture the entire channel protection volume, CPv, in either an off-line or on-line configuration. Given that a sand filter system is typically designed to completely drain over 40 hours, the requirement of extended detention of the 1-year, 24-hour storm runoff volume will be met. For larger sites or where only the WQv is diverted to the sand filter facility, another structural control must be used to provide Cpv extended detention.

3. **Overbank flood protection.** Another structural control must be used in conjunction with a sand filter system to reduce the post-development peak flow of the 25-year storm (Qp) to pre-development levels (detention).

4. **Extreme flood protection.** Sand filter facilities must provide flow diversion and/or be designed to safely pass extreme storm flows and protect the filter bed and facility.

C. Pollutant removal capabilities

The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes derived from sampling data, modeling, and professional judgment. In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or treatment train approach.

- Total suspended solids – 80%
- Total phosphorous – 50%
- Total nitrogen – 25%
- Fecal coliform – 40%
- Heavy metals – 50%

D. Application and feasibility

1. **General feasibility.**
   a. Suitable for Residential Subdivision Usage – no

   b. Suitable for High Density/Ultra Urban Areas – yes

   c. Regional Stormwater Control – no

2. **Physical feasibility – physical constraints at project site.**

   a. **Drainage area.** 10 acres maximum for surface sand filter; 2 acres maximum for perimeter sand filter.

   b. **Space required.** Function of available head at site.

   c. **Site slope.** No more than 6% slope across filter location.

   d. **Minimum head.** Elevation difference needed at a site from the inflow to the outflow: 5 feet for surface sand filters; 2-3 feet for perimeter sand filters.

   e. **Minimum depth to water table.** For a surface sand filter with exfiltration (earthen structure), 2 feet are required between the bottom of the sand filter and the elevation of the seasonally high water table.

   f. **Soils.** No restrictions; Group A soils generally required to allow exfiltration (for surface sand filter earthen structure).

   g. **Other constraints/considerations.** Aquifer protection: do not allow exfiltration of filtered hotspot runoff into groundwater.

E. Planning and design criteria

The following criteria are to be considered minimum standards for the design of a sand filter facility:

1. **Application and site feasibility criteria.** Sand filter systems are well-suited for highly impervious areas where land available for structural controls is limited. Sand filters should primarily be considered for new construction or retrofit opportunities for commercial, industrial, and institutional areas where the sediment load is relatively low, such as parking lots, parking ramps, driveways, loading docks, gas stations, garages, airport runways/taxiways, and storage yards. Sand filters may also be feasible and appropriate in some multi-family or higher density residential developments.

2. **Initial selection criteria.**

    a. Is the filter appropriate for the type of development being considered?

    b. Do site conditions such as space consumption, available head, cost, or maintenance consideration favor the use of the proposed design?

    c. How effective is the stormwater filter design in removing the key pollutants of concern?

The following physical constraints should be evaluated to ensure the suitability of a sand filter facility for meeting stormwater management objectives on a site or development:

3. **Location and siting.**

    a. Surface sand filters should have a contributing drainage area of 10 acres or less. The maximum drainage area for a perimeter sand filter is 2 acres.

    b. **Minimum head.** Elevation difference needed at a site from the inflow to the outflow: 5 feet for surface sand filters; 2-3 feet for perimeter sand filters.

    c. **Minimum depth to water table.** For a surface sand filter with exfiltration (earthen structure), 2 feet are required between the bottom of the sand filter and the elevation of the seasonally high water table.

    d. **Soils.** No restrictions; HSG A soils generally required to allow exfiltration (for surface sand filter earthen structure)

    e. **Pre-treatment**. Any disturbed areas within the sand filter facility drainage area should be identified and stabilized. Sites with less than 50% imperviousness or high clay/silt sediment loads must not use a sand filter without adequate pre-treatment due to potential clogging and failure of the filter bed. Filtration controls should only be constructed after the construction site is stabilized.

    f. **Hydraulic loading.**

        1) **Quantity**. Surface sand filters are generally used in an off-line configuration where water is diverted to the filter facility through the use of a flow diversion structure and flow splitter. Likewise, flow greater than the capacity of the surface sand filter is diverted to other controls or downstream using a flow diversion structure or flow splitter.

2) **Flow pattern.** Sand filter systems are designed for intermittent flow and must be allowed to drain and re-aerate between rainfall events. They should not be used on sites with a continuous flow from groundwater, sump pumps, or other sources.

g. Perimeter sand filters are typically sited along the edge, or perimeter, of an impervious area such as a parking lot.

F. Flow regulation

1. Since sand filters are designed to provide treatment for the WQv only, they should be located off-line from the primary conveyance/detention system.
2. Sand filters should be located where they can intercept as much of the site impervious area as possible and where discharge to the primary conveyance system is feasible.

3. Off-line designs are recommended for sand filter systems to avoid mixing with larger storm events which are likely to re-suspend settled solids within the sedimentation chamber, scour the filter bed, or otherwise compromise the pollutant removal effectiveness of these facilities.

4. The design objective is to capture and divert the WQv to the sand filter and bypass larger storms to the downstream storm drainage system or receiving water. WQv is computed based on the methods identified in Parts 2B and 2C.

5. In most Iowa jurisdictions, the enclosed conveyance systems are sized for the 5-10 year storm event. Open channel systems may be sized for larger events. A flow diversion structure must be able to accommodate these larger flows as well as the water quality storm.

6. Two methods for diverting the WQv include computing a peak discharge (Qp) for the water quality storm (See Section 2C-7), and

   a. Using an isolation/diversion structure upstream and within the drainage network as shown in Figure 7.

   b. Incorporating the isolation/diversion structure within the treatment practice itself as shown in Figure 6.

7. The preferred method for accomplishing a diversion is within the treatment practice itself, where the overflow (or bypass) weir elevation is set equal to the design WQv elevation within the adjacent practice. This method ensures larger inflows will overflow the bypass weir, thus minimizing mixing within the BMP. It is also a more reliable capture technique than reliance on computed Qp to size the diversion structure.

8. It is still necessary to compute the Qp to size the intake slots or openings. The openings directing runoff to the treatment practice should be slightly oversized to ensure that the entire WQv is treated.

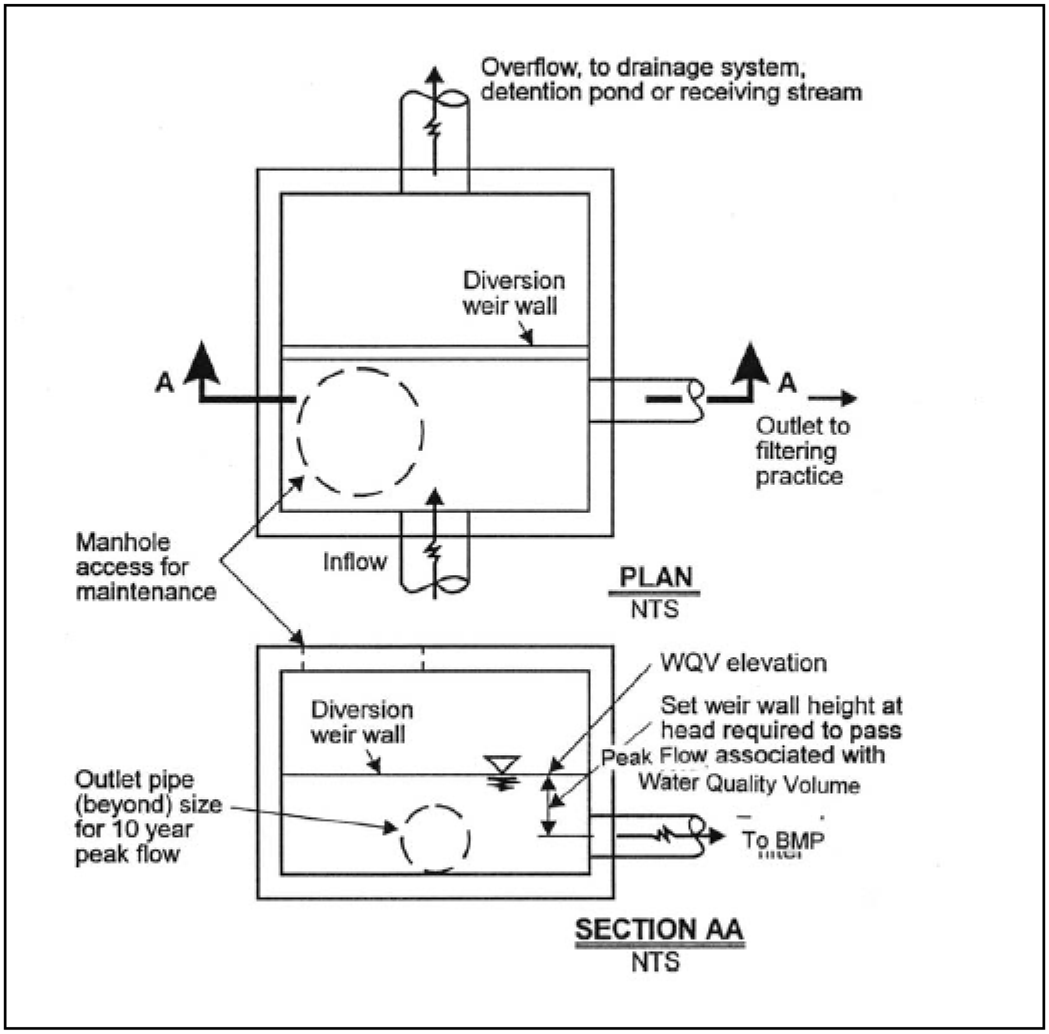
9. In many cases, however, it is not possible to maintain the necessary geometry and elevations to locate the isolation/diversion structure within the treatment practice itself. An alternative technique for isolation/diversion within the drainage network is described in Table 1.

Table 1: Design procedures for diversion of WQv within the drainage network

STEPS	CALCULATION
1	Peak discharge (Qp) for WQv is computed based on the methods presented in Parts 2B and 2C.
2	Qp for the bypass storm is computed (most jurisdictions use the 10-year frequency storm). Use the Rational Formula or NRCS WinTR-55.
3	Size diversion slots/openings or pipe utilizing the orifice equation: $Q = CA(2gh)^{0.5}$
4	Size overflow weir for bypass storm using the weir equation: $Q = CLh^{3/2}$ Size the outfall pipe, if provided, using the orifice equation (to check inlet condition flow capacity) and Manning's equation to check friction losses.

Source: Claytor and Schuler, 1996

Figure 7: Isolation/diversion structure



Source: Claytor and Schueler, 1996