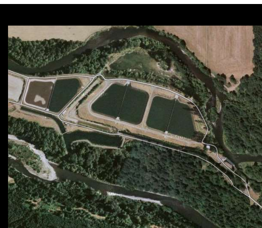
Astoria, OR
5 MGD

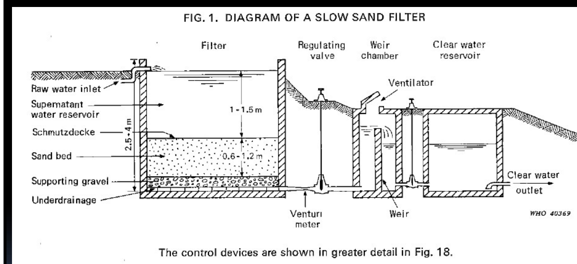
Springfield, OR
6.5 MGD



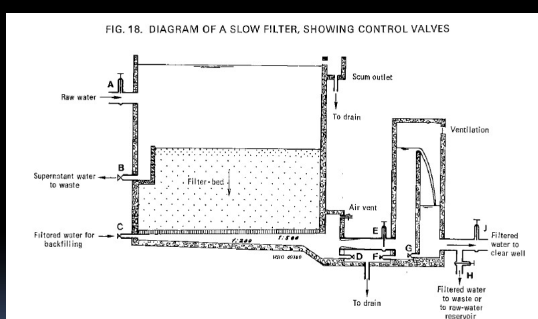
Salem, OR
62 MGD

DESIGN

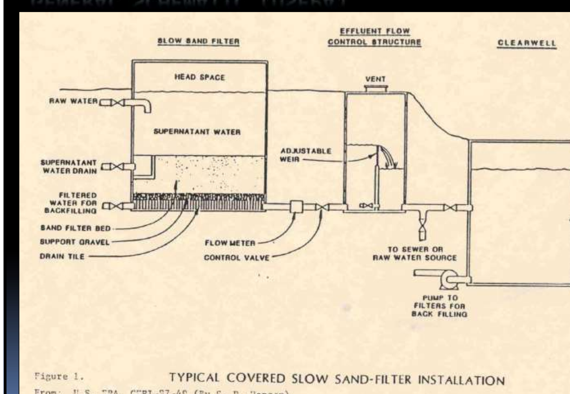
GENERAL SCHEMATIC (WHO, 1974)



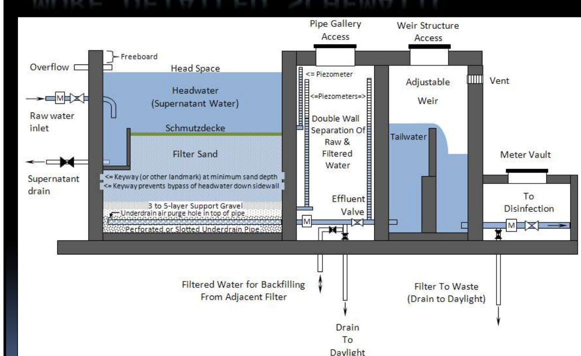
GENERAL SCHEMATIC (WHO, 1974)



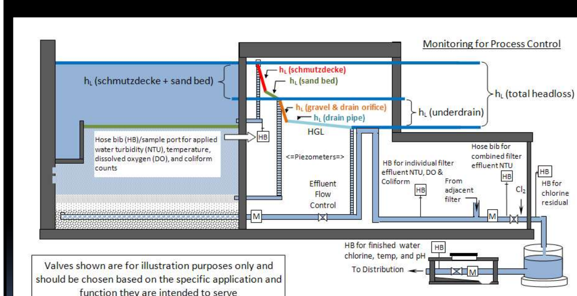
GENERAL SCHEMATIC (USEPA)



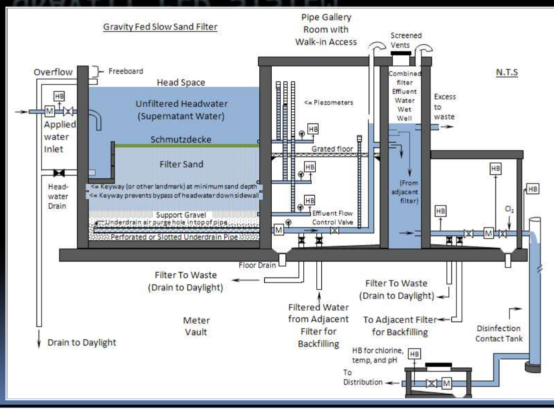
MORE DETAILED SCHEMATIC



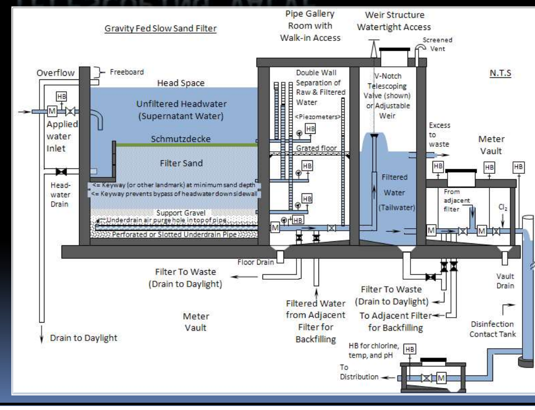
“GOOSENECK” WEIR



GRAVITY FED SYSTEM



TELESCOPING VALVE



DESIGN - SS VERSUS RAPID RATE

Parameter	Slow Sand Filters	Rapid Rate Filters
Influent Flow	Continuous	Intermittent
Filter Box	☑ - designed to overflow	☑ - not intended to overflow
Filter Media	☑- sand - GAC (rare)	☑ - sand - anthracite - GAC (more common)
Underdrain	☑	☑
"Backwash" mechanisms	☑ - slow filling from bottom of filter – removal of entrained air not media expansion.	☑ - high rate (and low rate) flow designed to suspend & wash the media
Surface Agitator (breaks up media during backwash)		☑

DESIGN - SS VERSUS RAPID RATE

Parameter	Slow Sand Filters	Rapid Rate Filters
Filtration Rate	0.03 – 0.1 gpm/ft²	2-4 gpm/ft²
Water Above Sand	~4-6 ft	~ 5 ft
Sand Bed Depth	~ 24-48 inches	~ 24-30 inches
Sand Effective Size (d_{10})	0.15 – 0.35 mm	0.45 – 0.55 mm
Retention Time above Sand	15 hrs	9 min
Retention Time in Sand Bed	3.2 hrs	2 min
Cycle Length	1-6 mo	1-4 days
Removal mechanisms	Chemical, physical, and biological (no chemicals)	Chemical and physical (depends on proper coagulation)
Turbidity Removal	Variable even if optimized < 5 NTU by regulation Not indicative of filter performance or pathogen removal. Sub micron particles are not readily removed.	< 0.1 NTU when optimized Good indicator of filter performance and pathogen removal. Coagulation/flocculation removes even sub-micron particles.
Giardia Removal	>3.0 log	>3.0 log
Raw Water Turbidity	<10 NTU	100+ NTU

COMMON DESIGN PITFALLS

Common Design Pitfalls

1. Inappropriate source water quality => inappropriate application
2. Not conducting a pilot study
3. Improperly designed under drains
4. Poorly designed filter piping
5. Inadequate flow control and air binding
6. Insufficient head loss allowed
7. Insufficient sand bed depth
8. Inappropriate filtration rate and variability
9. Poorly specified sand and gravel media (effective size, uniformity, etc.)
10. Poor access to filter bed for cleaning and re-sanding
11. Insufficient sample ports
12. Failure to have the operator involved in design process
13. Failure to provide a good O&M manual with filter cleaning/ripening protocols

DESIGN RECOMMENDATIONS - EXAMPLE

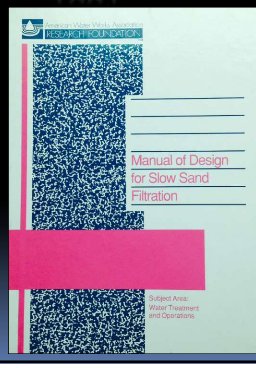
Design parameters	Recommended range of values
Filtration rate Area per filter bed	0.15 $m^3/m^2 \cdot h$ (0.1–0.2 $m^3/m^2 \cdot h$) Less than 200 m^2 (in small community water supplies to ease manual filter cleaning)
Number of filter beds	Minimum of two beds
Depth of filter bed	1 m (minmum of 0.7 m of sand depth)
Filter media	Effective size (ES) = 0.15–0.35 mm; uniformity coefficient (UC) = 2-3
Height of supernatant water	0.7–1 m (maximum 1.5 m)
Underdrain system Standard bricks Precast concrete slabs Precast concrete blocks with holes on the top Porous concrete Perforated pipes (laterals and manifold type)	Generally no need for further hydraulic calculations Maximum velocity in the manifolds and in laterals = .3 m/s Spacing between laterals = 1.5 m Spacing of holes in laterals = 0.15 m Size of holes in laterals =3 mm

Source: Vigneswaran, S. and C. Visvanathan. 1995
http://www.nesc.wvu.edu/ndwc/pdf/OT/TB/TB14_slowsand.pdf

DESIGN MANUAL - 1991

"Manual of Design for Slow Sand Filtration" . David Hendricks & American Water Works Association, 1991. ISBN 978-0898675511

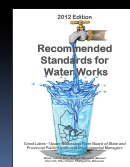
Excellent resource that covers design in great detail



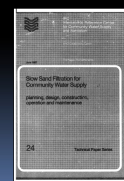
3 OTHER DESIGN REFERENCES

The 3 other main design references include:

1. Recommended Standards for Water Works (a.k.a., "Ten States Standards", 2012);
2. "Slow Sand Filtration for Community Water Supply", International Research Center for Community Water Supply and Sanitation (Visscher et al., 1987)
3. "Slow Sand Filtration", World Health Organization (Huisman & Wood), 1974;



http://10statesstandards.com/



http://www.irc.nl/page/4530

http://www.who.int/water_sanitation_health/publications/ssf/en/index.html

DESIGN CRITERIA – 3 OTHER REFERENCES

The design specifications for these 3 sources are summarized here

Comparison of Design Specifications
(Design Period, Operation, and Filtration Rate, # of Units, and Supernatant Depth)

Reference	WHO Manual (Huisman & Wood, 1974)	IRC Manual (Visscher et al., 1987)	Ten States Standards (2012)
Design Period	7-10 Years	10-15 years	Not Specified
Mode of Operation	Continuous	24 hr/day	Not Specified
Filtration Rate (flow rate ÷ filter area)	0.04 – 0.08 gpm/ft2 (0.1 – 0.2 m/hr)	0.04 – 0.08 gpm/ft2 (0.1 – 0.2 m/hr)	0.03 – 0.1 gpm/ft2
Filter Units (a.k.a., cells)	2 minimum	2 minimum	2 minimum
Supernatant Depth	39 – 59 in, 79 in max (100 – 150 cm, 200 cm max)	27 – 39 in, 60 in max (70 – 100 cm, 150 cm max)	36 – 72 in (91 – 183 cm)

DESIGN CRITERIA – 3 REFERENCES

Comparison of Design Specifications
(Minimum Sand Bed Depth)

Reference	WHO Manual (Huisman & Wood, 1974)	IRC Manual (Visscher et al., 1987)	Ten States Standards (2012)
Minimum Filter Bed Depth*	28 – 35 in (70 – 90 cm)	18 – 35 in (45 – 90 cm)	19 in (48 cm)

*The design should add these minimum sand bed depths to the amount of sand anticipated to be removed during cleanings throughout the design life of the filter (estimates of sand removal can be determined based on cleaning data obtained during pilot testing). Filters designed for harrowing only need to account for minor losses, since sand is not removed due to scraping when using this method of cleaning.

DESIGN CRITERIA – 3 REFERENCES

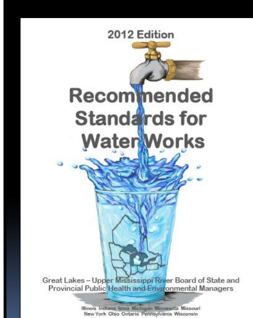
Comparison of Design Specifications
(Filter Sand Effective Size and Uniformity Coefficient)

Reference	WHO Manual (Huisman & Wood, 1974)	IRC Manual (Visscher et al., 1987)	Ten States Standards (2012)
Filter Sand Effective Size (d_{10})	0.15 – 0.35 mm	0.15 – 0.30 mm	0.15 – 0.30 mm
Uniformity Coefficient (U)	1.5 – 3	< 3 – 5	< 2.5

Other specifications include:

1. Percent of fines passing the #200 sieve < 0.3% by weight (can impact post sanding turbidity levels and length of filter to waste time needed to "wash" the fines out)
2. Acid solubility < 5% (can impact sand grain characteristics, effective size, and uniformity coefficient if acid soluble)
3. Apparent specific gravity > 2.55

TEN STATES STANDARDS



Ten States Standards
http://10statesstandards.com/index.html

Member States and Provinces	
Illinois	New York
Indiana	Ohio
Iowa	Ontario
Michigan	Pennsylvania
Minnesota	Wisconsin
Missouri	

TEN STATES STANDARDS
APPLICATION TO BE BASED ON STUDIES

4.3.4 Slow Sand Filters

The use of these filters shall require prior engineering studies to demonstrate the adequacy and suitability of this method of filtration for the specific raw water supply.

PILOT TESTING

Pilot testing

Recommend 1-year pilot study in order to account for seasonal variability of source water variables (required in some cases)

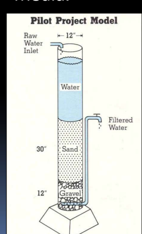
Pilot testing is to determine feasibility (i.e., "will it work when we need it to?"), not just to discover O&M issues.

2010. Walla Walla, WA Pilot filters

PILOT TESTING BENEFITS

Pilot testing

Pilot testing is relatively easy and can be used anytime to test cleaning procedures, model ripening times, or evaluate new media.



<< It can be done on a small scale (1991 - Alsea, OR)

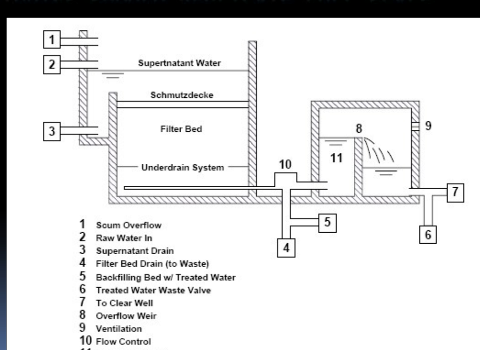
or a very large scale >> (2010 - Walla Walla, WA)

INFO GAINED BY PILOT TESTING

Pilot testing can yield valuable information such as:

1. The flow to be expected (will the proposed design be enough to meet demands or will more sand bed area be needed?).
2. Cleaning frequency. As sand is removed during cleaning, the frequency of cleaning can yield information about how many years the sand will last before re-sanding is needed.
3. O&M requirements that may change seasonally
4. If algae growth will have an adverse impact
5. Cold temperature effects (may require longer filter-to-waste times after ripening.
6. Ripening time (Use plots of turbidity and coliform)

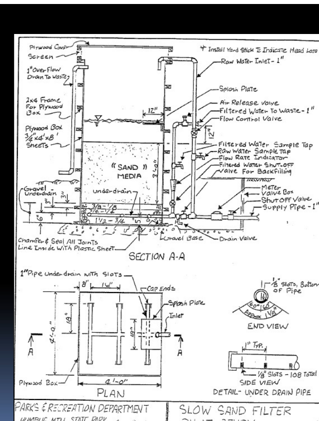
STUDIES SHOULD REPLICATE FULL SCALE



PILOT FILTER SCHEMATIC

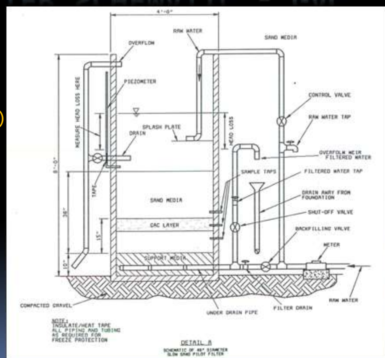
Intent is to replicate full-scale design.

Pilot testing schematics can be simple, but should clearly show key features that can simplify operation and improve data collection.

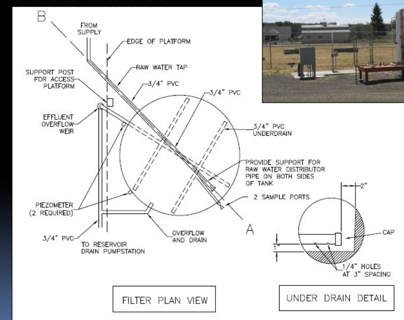


PILOT FILTER SCHEMATIC - GAC

This design is set up to evaluate a layer of granulated activated carbon (a.k.a. GAC sandwich)



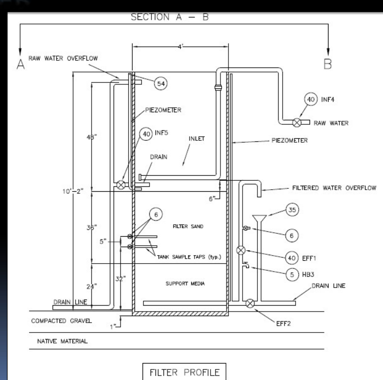
PILOT FILTER SCHEMATIC



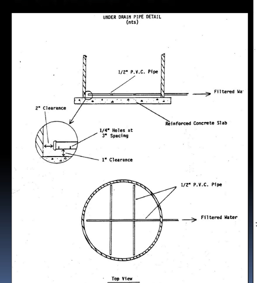
This is a plan view of a pilot filter (shown above) used by the City of Walla Walla in 2010-2012.

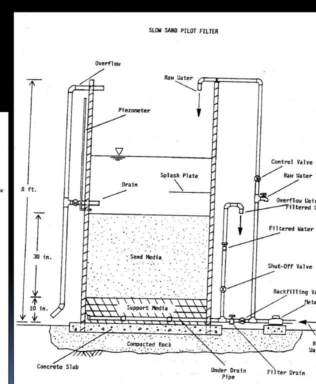
PILOT FILTER SCHEMATIC

This is a section view of the filter used by the City of Walla Walla, WA.



PILOT FILTER SCHEMATIC





PILOT FILTER COLUMN

Pilot Filter Material

1. PVC, concrete, fiberglass, etc. (5 gallon buckets have been used). Design some durability into it in order to retain filter for future studies

Pilot Filter Size

1. 8-12 ft high (replicate full scale filter)
2. 12 – 36 inch diameter
3. Diameter dictated by room needed to fit under drains, sample ports, etc. and accommodate cleaning. A joint constructed just above the sand bed can facilitate cleaning in small diameter filters. A lip below the sand surface can help eliminate side-wall effects (short-circuiting) of smaller diameter filters.

PILOT FILTER MEDIA

Pilot Filter Media

1. The media should be the same as that intended to be used in the full scale installation.
2. Multiple, identical filters should be used to evaluate various sources or specifications of sand.
3. Pilot filter media should be delivered and washed as would be done at full scale in order to help estimate the time needed to wash out fines and for the filter to fully mature.
4. The filter bed and support gravel layers should be installed to the same depth anticipated to be used at full scale.

COVERED PILOT FILTERS?

Pilot Filter – to cover or not to cover

1. Pilot filters should be covered if the intended full-scale design includes a cover. If not, it may be advantageous to have the ability to cover the pilot filter in order to observe differences in filter performance.
2. Note that covered filters may not develop a discernable schmutzdecke, rather they may exhibit a layer of darker sand at the surface when maturing.

Tillikum Retreat Center, OR – Covered "Blue Future" filters

PILOT FILTER SAMPLE PORTS

Note the sample ports at various locations to evaluate removal mechanisms throughout the filter bed.

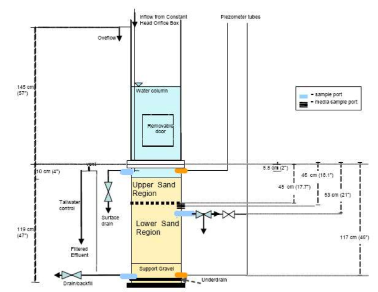


Figure 2. Schematic of Typical Pilot Slow Sand Filter Used in the Winthrop, ME Pilot Study

PILOT TEST MONITORING – RAW WATER

Raw Water

Sample location	Parameter	Sample frequency	Laboratory or field analysis needed
Raw water	Turbidity	Daily	Field
	Temperature	Daily	Field
	Apparent color	Weekly	Field
	pH	Weekly	Field
	Alkalinity	Weekly	Field
	Coliform (total and E. coli)	Weekly	Laboratory
	Dissolved oxygen	Weekly	Field
	UV 254 absorbance, TOC and/or THM formation potential	Monthly	Field or laboratory analysis
	Iron and Manganese	Monthly	Laboratory
	Algae identification and enumeration (toxins if indicated)	Quarterly or with algae blooms	Laboratory or field identification. Laboratory or field test strips for toxins.

PILOT TEST MONITORING – FILTER EFFLUENT

Filter Effluent

Sample location	Parameter	Sample frequency	Laboratory or field analysis needed
Filter effluent	Turbidity	Daily	Field
	Temperature	Daily	Field
	Apparent color	Weekly	Field
	pH	Weekly	Field
	Alkalinity	Weekly	Field
	Coliform (total and E. coli)	Weekly	Laboratory
	Dissolved oxygen	Weekly	Field
	UV 254 Absorbance, TOC and/or THM formation potential	Monthly	Field or laboratory analysis
	Iron and Manganese	Monthly	Laboratory
	Algal toxins	If indicated by raw water testing	Laboratory or field test strips for toxins.

PILOT TEST MONITORING – OTHER

Other

Sample location	Parameter	Sample frequency	Laboratory or field analysis needed
Other	Filter head loss	Daily	Field
	Flow rate	Daily and with changes	Field
	Filter run length	Record cumulative days	Field
	Cleaning frequency	Record events and unusual circumstances	Field
	Depth of Sand	Initial amount and amount remaining after each cleaning	Field

PILOT TEST CONCLUSIONS

Key pilot test conclusions that can influence design include…

1. <u>Flow</u>
   - Will it meet system demands?
   - What sand characteristics are most appropriate?
   - How much filter area do I need?
   - Do I need to account for slower flows due to cold temps or should they be covered?
2. <u>Cleaning</u>.
   - What frequency?
   - How much ripening time? Cold water effects?
   - How long can I go without a filter?
   - Will I need multiple smaller filters, rather than fewer large filters due to cleaning and ripening requirements?
   - How long will the filter last & how deep will the bed need to be to make it last given the cleaning required?

PILOT TEST PLAN AND REPORT

Document the pilot test plan and results for future reference

1.2 Study Goals and Testing Objectives

The goals of the pilot study are:

- Determine if SSF is a feasible filtration method to meet present and future regulatory requirements and other water quality goals.
- Determine the operating parameters that optimize treatment capacity and performance.
- Determine costs of the pilot facility that can be used to estimate net present value costs for construction, operation, and maintenance of a full-scale facility.

1.3 Scope and Testing Approach

The scope of the pilot study includes:

- Routine pilot facility operation and water sample collection over a 9-12 month period.
- Analyses of samples.
- Evaluations of the data and a final pilot study report.

CITY OF WALLA WALLA

CITY OF WALLA WALLA
SLOW SAND FILTRATION PILOT STUDY
WORK PLAN
DOH Submittal #10-0604
October 2010

Prepared by:
City of Walla Walla Engineering Division
Darin Christen, E.I.T.
Frank Nicholson, P.E.

TEN STATES STANDARDS
RAW WATER QUALITY

10 STATES STANDARDS (GLUMRB)

4.3.4.1 Quality of raw water

Slow rate gravity filtration shall be limited to waters having maximum turbidities of 10 units and maximum color of 15 units; such turbidity must not be attributable to colloidal clay. Microscopic examination of the raw water must be made to determine the nature and extent of algae growths and their potential adverse impact on filter operations.

RAW WATER QUALITY

Recommended Limits for Raw Water (Source Water Characteristics)	
Turbidity	< 10 NTU (colloidal clays are not desirable)
True Color	< 5 platinum color units
Coliform Bacteria	< 800 /100 ml (CFU or MPN)
Dissolved Oxygen (DO)	> 6 mg/l (filtered water DO $\geq$ 3 mg/l)
Total Organic Carbon (TOC)	< 3.0 mg/l (low TOC to prevent DBP issues)
Iron & Manganese	Both < 1 mg/l Each
Algae	< 200,000 cells/L (depends upon type)

TEN STATES STANDARDS
NUMBER OF FILTERS

10 STATES STANDARDS (GLUMRB)

4.3.4.2 Number

At least two units shall be provided. Where only two units are provided, each shall be capable of meeting the plant design capacity (normally the projected maximum daily demand) at the approved filtration rate. Where more than two filter units are provided, the filters shall be capable of meeting the plant design capacity at the approved filtration rate with one filter removed from service.

NUMBER OF FILTERS

How do you determine a reasonable filter area?

An individual filter should be small enough to allow it to be cleaned in 1 day. Determine the filter size as follows:

Area of 1 filter = (cleaning rate in ft²/person/hr) x (no. of people available for cleaning) x (hours allotted to cleaning)

Example:
Cleaning rate: 1,000 ft²/5 persons/hr (Cullen and Letterman, 1985) (1" of sand hand shoveled with hydraulic conveyance)

Number of people: 2 minimum (think safety)
Hours estimated for cleaning: 2.5 hrs (desired)
Area of 1 filter: 1,000 ft²/5 persons/hr x 2 people x 2.5 hrs = 1,000 ft² => 20 x 50-ft filter

NUMBER OF FILTERS

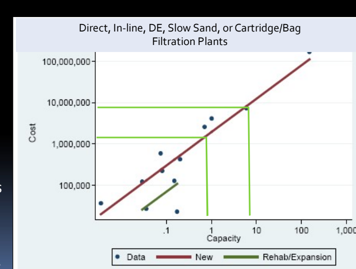
Is there such thing as too small?

The minimum size of a filter depends upon the:

1. Cleaning method and equipment access needs
2. System demands
3. If covers are needed
4. Construction costs

Huisman and Wood (1974) and Sharp et al (1994) indicate a minimum area for one filter of about 1,000 ft² (100 m²). This is due to construction costs being lower per ft² with larger filters (economy of scale).

Small modular units are common and can be very cost effective



NUMBER OF FILTERS

How do you determine the number of filters needed?

Equation for number of filters needed: N = 1 + (Q / (HLR * A))

Where:

1. HLR = hydraulic loading rate (gpm/ft^2)
2. Q = flow needed to meet demands (gpm)
3. A = The sand bed surface area of one filter bed (ft^2)
4. N = total number of filter beds needed (assumes 1 filter is taken off-line for cleaning and storage can meet peak hour demands)

Example: How many filters are needed, given a peak day demand of 250 gallons per capita per day and a community of 600 people. The peak design filtration rate is 0.1 gpm/ft^2. A minimum rate of 0.05 gpm/ft^2 has been identified through pilot testing for operation during cold conditions and to accommodate filters left in service that may be near the end of their filter run. There is also a desire to limit the size of each filter to 20'x50' in order to facilitate the cleaning:

$$1 + \left[\frac{250 \text{ gpcpd} \times 600 \text{ people} \times 1 \text{ day}/1440 \text{ minutes}}{0.05 \text{ gpm/ft}^2 \times (50\text{-ft} \times 20\text{-ft})}\right] = 3.08 = 3 \text{ filters}$$

NUMBER OF FILTERS

Are more filters better?

Equation for minimum number of filters needed: N = 1 + (Q / (HLR * A))

In the previous example, 3 filters were determined to be needed, any 2 of which are capable of meeting 100% of the peak day demand (PDD) to allow for 1 filter being taken out of service for cleaning. This means that each filter is able to meet 50% of the PDD.

3 filters x 50% of PDD = a plant capacity of 150% x PDD
(1 filter off-line leaves 2 filters to meet 100% of PDD)

If 4 smaller filters were constructed, each filter would only need to be capable of meeting ~33% of the peak day demand to allow for 1 being taken out of service.

4 filters x 33% of PDD = a plant capacity of 132% x PDD
(1 filter off-line leaves 3 filters to meet 100% of PDD)

The capital cost involved with fewer large filters should be carefully weighed against the benefits of having a higher number of smaller filters (smaller overall plant capacity, more operational flexibility, shorter time cleaning each filter, although more filters to construct and maintain)

SYSTEM DEMANDS

System demands and operation to consider…

1. 20-year planning horizon
2. Average day demands (ADD) – Design Goal
3. Peak day demands (PDD) – Design Goal
4. Peak hour demands (use storage)
5. Available storage (3 days ADD recommended)
6. Account for cleaning/ripening (min 2 filter beds) – ability to meet PDD with largest filter off-line.
7. Keep filtration rates below 0.1 gpm/ft^2
8. Avoid rapid flow changes (strive for weekly or monthly changes)
9. Plan for constant flow through filter (constant supply of nutrients for biological health)

Tank for City of Astoria, OR

TEN STATES STANDARDS

STRUCTURAL DETAILS & HYDRAULICS

4.3.4.3 Structural details and hydraulics

Slow rate gravity filters shall be so designed as to provide:

a. a cover,
b. headroom to permit normal movement by operating personnel for scraping and sand removal operations,
c. adequate access hatches and access ports for handling of sand and for ventilation,
d. an overflow at the maximum filter water level, and
e. protection from freezing.

FILTER BOX

Filter boxes and earthen cells

1. Water tight. Filter boxes should be watertight, not merely to prevent loss of treatment water, but to exclude ingress of groundwater, which might contaminate the treated effluent. If possible, ensure the floor is above the highest water table.
2. Allows for cleaning and re-sanding efforts.
3. Insulated from freezing (below ground, covered, or fully enclosed) .
4. Covered as needed to prevent algae blooms and exclude falling leaf litter.
5. Freeboard of 4 – 12" (10 – 30 cm) above overflow level.

FILTER WALLS - VERTICAL

Vertical Walls

Short circuiting of the filter-bed along vertical walls can be mitigated by using a keyway (6x8 cm), rough sloped walls, or a batter.

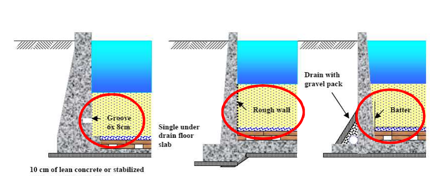


Figure 12: Method of preventing the short circuiting of the filter bed along the vertical wall (WHO)

FILTER WALLS - VERTICAL

City of Sumpter (Baker Co)

3 cells
360,000 gpd
completed
In the spring of 2003

FILTER WALLS - VERTICAL

Vertical Walls

Ramps allow to get equipment and new sand in and old sand out.

FILTER WALLS - VERTICAL

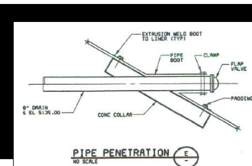
Vertical Walls

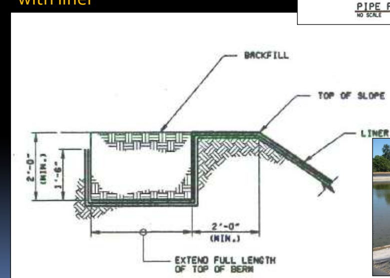
Removable stop "logs" allow access to the filters used by the City of Banks, OR.

Top of stop logs also serve as scum outlet/overflow.

FILTER WALLS – SLOPED

Design showing sloped walls with liner





COVERED FILTERS

If covered and/or housed in a filter building, make sure ample room exists to enable cleaning.

2012. Camp Yamhill in Yamhill County Oregon.

COVERED FILTERS

Protection from freezing

Even if the filters are enclosed, like these "Blue Future" filters, they may not provide enough protection from freezing temperatures. These filters were eventually enclosed in a building.

2009. Jewell School District #8, OR. "Blue Future" covered filter (left) and raw water control tank (right)

COVERED FILTERS
Wickiup Water District (Clatsop Co)

Two 80'x30' cells
120 gpm (0.025 gpm/sf)
Framework allows for shade cloth to be used during the summer

COVERED FILTERS
Thames Water (London England)

Positive air pressure support a plastic film cover at Thames Water.

Plate 2.2 - Internal view of a slow sand filter covered by plastic film supported by positive air-pressure at Walton, Thames Water

SLOW SAND DESIGN
UNCOVERED VS. COVERED

Note the difference in biomass development following scraping (Campos et. al, 2002/2006) – this should be considered in sizing system

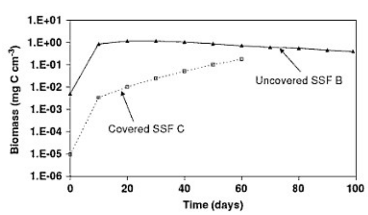


Figure 3 Development of biomass in (a) uncovered SSF B, and (b) covered SSF C (Note: Biomass concentration plotted on logarithmic scale).

SLOW SAND DESIGN
UNCOVERED VS. COVERED FILTERS

Parameter	Uncovered	Covered
Temperature	More exposed to lower temperatures which can adversely impact biological activity and increase filter ripening times.	Less susceptible to temperature effects
Algae	Algal growth/blooms in the headwaters can increase clogging	Not as susceptible to localized algae blooms.
Biomass Development	Filter has a higher biomass and develops a more noticeable schmutzdecke.	Overall biomass levels are lower and schmutzdecke formation may appear non-existent or present as an easily suspended, inert, black carbonaceous deposit of about 1 mm in thickness. Biomass is significantly correlated to bacteria counts.
Removal Efficiency	Equivalent	May be adversely impacted by lack of schmutzdecke layer

TEN STATES STANDARDS
FILTRATION RATE

4.3.4.4 Rates of filtration

The permissible rates of filtration shall be determined by the quality of the raw water and shall be on the basis of experimental data derived from the water to be treated. The nominal rate may be 45 to 150 gallons per day per square foot of sand area (1.8 - 6.1 m/day), with somewhat higher rates acceptable when demonstrated to the satisfaction of the approving authority.

45 – 150 gpd/ft^2
(0.031 – 0.10 gpm/ft^2)

FILTRATION RATE
(HYDRAULIC LOADING RATE)

Equation for Determine HLR: HLR = Q / (A * (N-1))

Where:

1. HLR = hydraulic loading rate (gpm/ft^2)
2. Q = flow needed to meet demands (gpm)
3. A = The sand bed surface area of one filter bed (ft^2)
4. N = total number of filter beds needed $\geq$ 2 ("N-1" is the total number of filters with 1 filter taken out of service for cleaning)

Example: Given a peak day demand of 250 gallons per capita per day and a community of 600 people served by two 50'x20' filters:

$$\frac{250\ \text{gpcpd} \times 600\ \text{people}}{(1{,}000\ \text{ft}^2/\text{filter} \times (2\ \text{filters} - 1\ \text{filter})} = 150\ \text{gpd/ft}^2\ (0.1\ \text{gpm/ft}^2)$$

FILTRATION RATE

Maximum
≤ 0.1 gpm/ft²

Rate may need to be ≤ 0.05 gpm/ft² when water temp <5 °C

Minimum
≥ 0.02 gpm/ft² to keep biota viable

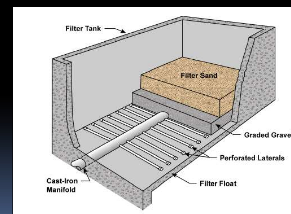
TEN STATES STANDARDS
UNDERDRAINS

4.3.4.5 underdrains

Each filter unit shall be equipped with a main drain and an adequate number of lateral underdrains to collect the filtered water.

The underdrains shall be placed as close to the floor as possible and spaced so that the maximum velocity of the water flow in the underdrain will not exceed 0.75 feet per second.

The maximum spacing of laterals shall not exceed 3 feet if pipe laterals are used.



UNDERDRAINS

underdrains are typically made using perforated pipe laterals (PVC, NSF-61) due to minimal head loss.

For larger installations, laterals are typically 4-8" in diameter, while main drains are 12-18" in diameter.

UNDERDRAIN CONFIGURATIONS

Common configurations include laterals that connect to a main drain system. Smaller filters will often have only 1 main drain like the one shown on the right.

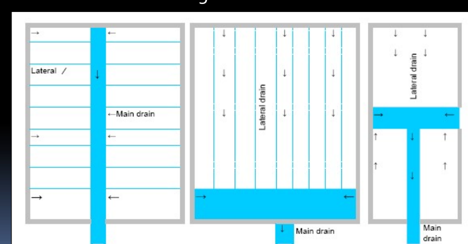
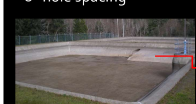


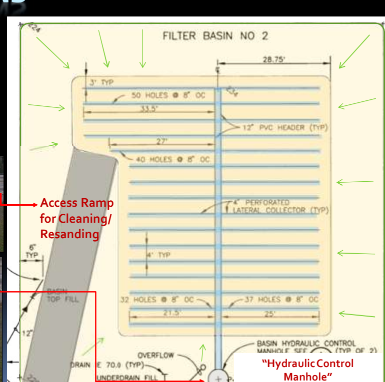
Figure 10: Common arrangements for the main drain of a slow sand filter

UNDERDRAINS

City of Cannon Beach

12" PVC header
4" laterals
48" lateral spacing
8" hole spacing

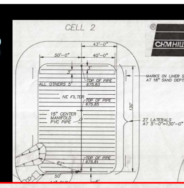


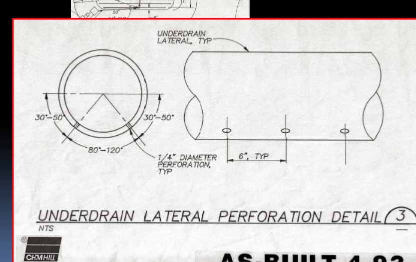


UNDERDRAINS

City of Astoria (5 MGD)

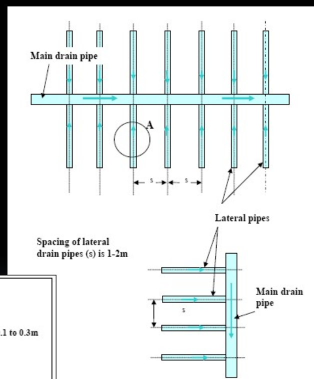
Filter Cell #2
1993 filter rebuild
15" PVC manifold
14" PVC header
6" laterals
60" lateral spacing
6" hole spacing
¼" drain holes

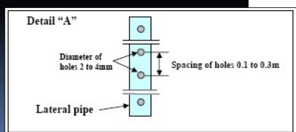




UNDERDRAINS

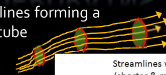
Velocity in laterals and main drain should not exceed 0.75 fps (0.23 m/sec.)



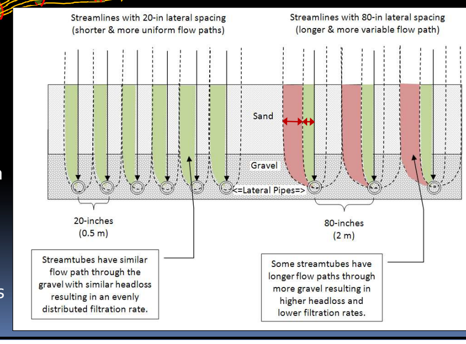


UNDERDRAINS – LATERAL SPACING

Streamlines forming a streamtube



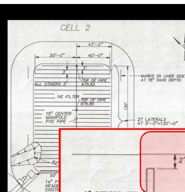
Closer lateral spacing leads to a more even distribution of headloss and more consistent filtration rates across the filter

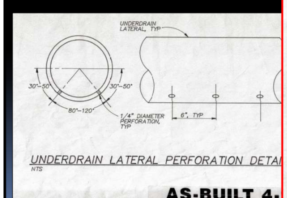


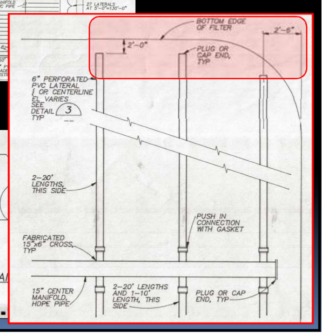
UNDERDRAINS

City of Astoria (5 MGD)

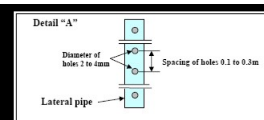
Filter Cell #2
1993 filter rebuild
Keep laterals spaced away from filter walls to avoid short-circuiting of raw water down the filter wall







UNDERDRAINS



Underdrain Design Parameters	Recommended Specification
Maximum Velocity in Laterals[1]	0.75 fps (0.23 m/sec)
Maximum Velocity in Main Drain[1]	0.75 fps (0.23 m/sec)
Spacing of lateral drain pipes[1]	36 inches (91.4 cm)
Spacing of bottom lateral drain holes[2]	4 – 12 inches (0.1 – 0.3 m) (include air release holes @ ends on top of laterals)
Diameter of drain holes[2]	5/64" – 5/32" (2-4 mm) (needs to be determined through hydraulic calculations)
Material	Non-Corrosive and meeting NSF-61 (e.g., PVC)

[1] Source: 2012 Edition of the Recommended Standards for Water Works (Ten States Standards). Visscher et., al. (see footnote 2) recommended 1.64 fps (0.5 m/sec).
[2] Source: Visscher, J.T., R. Paramasivam, A. Raman, and H.A. Heijnen. 1987. *Slow Sand Filtration for Community Water Supply, Planning, Design, Construction, Operation and Maintenance*. Technical Paper No. 24, The Hague, Netherlands: International Reference Center for Community Water Supply and Sanitation.

TEN STATES STANDARDS

FILTER MEDIA

4.3.4.6 Filter material

a. Filter sand shall be placed on graded gravel layers for a minimum depth of 30 inches.

b. The effective size shall be between 0.15 mm and 0.30 mm. Larger sizes may be considered by the reviewing authority; a pilot study may be required.

c. The uniformity coefficient shall not exceed 2.5.

d. The sand shall be cleaned and washed free from foreign matter.

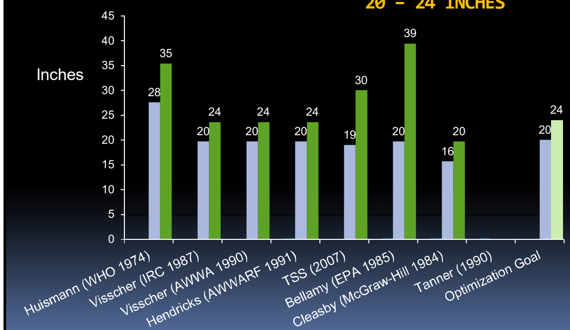
e. The sand shall be rebedded when scraping has reduced the bed depth to no less than 19 inches. Where sand is to be reused in order to provide biological seeding and shortening of the ripening process, rebedding shall utilize a "throw over" technique whereby new sand is placed on the support gravel and existing sand is replaced on top of the new sand.

FILTER MEDIA

Plan the work and provide an adequate budget so recommended media specifications and placement practices are able to be followed – it will pay off in the long run!

SAND BED DEPTH RECOMMENDATIONS

MINIMUM SAND DEPTH GUIDELINE
20 – 24 INCHES



SAND BED DEPTH

According to the WHO manual, biochemical and adsorption removal mechanisms are in effect immediately below the schmutzdecke down to a depth of around 24-inches.

Therefore the total bed thickness would need to be at least 24 inches in order for these two mechanisms to be fully effective.

Additional sand is needed to accommodate the amount of sand anticipated to be removed due to cleanings over the design life.

Freeboard	Air above water (4 – 12")
Headwater	Sedimentation (39-59")
Schmutzdecke	Biological (1-2 cm)
Filter Sand	Biochemical (12-16")
	Adsorption (8")
	Sand allowance for cleanings
Sand Support	Support Gravel (15-24")

SAND BED DEPTH - FORMULA

Formula for determining depth of sand:

$$D_i = [Y (R * f_{scraping})] + D_f$$

Re-arrange to find design life: $Y = (D_i – D_f) / (R * f_{scraping})$

Where:
Y = years of operation before sand bed needs rebuilding
D_i = initial sand bed depth (inches)
D_f = final sand bed depth before rebuilding (inches)
R = sand depth removal per scraping (inches/scraping)
$f_{scraping}$ = frequency of scraping (scrapings/year)

SAND BED DEPTH - EXAMPLE

Example: $D_i = [Y (R * f_{scraping})] + D_f$

Given:
1. D_i = initial sand bed depth (inches)
2. D_f = 24 inches
3. $f_{scraping}$ = 6 cleanings per year
4. R = Removal of 1.3 cm (1/2") of sand per cleaning
5. Y = 7-year design life (before re-sanding is needed)

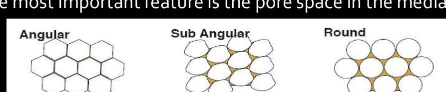
Di = 7 yrs * (0.5 in/scraping * 6 scrapings/year)] + 24 in
= 45 inches

Therefore, an additional 21 inches (53 cm) of sand is needed to allow for scraping over 7 years.

FILTER MEDIA - SILICA

Silica sand
- Durable
- Inexpensive
- Readily available

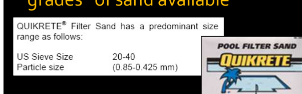
- The most important feature is the pore space in the media.



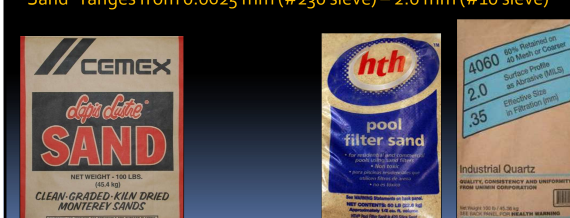
- Removal mechanisms occur in the pores where suspended solids are trapped, microorganisms grow, and air and water flow.
- Using media with an appropriate effective size and uniformity ensures an optimal pore space.

FILTER MEDIA – GRAIN SIZE

There are many different "grades" of sand available



"Sand" ranges from 0.0625 mm (#230 sieve) – 2.0 mm (#10 sieve)



FILTER MEDIA - SIEVE SIZES

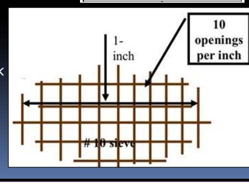
Sieves larger than the #4 sieve are designated by the size of the openings in the sieve.

Sieve Number	Opening (mm)
4	4.750
6	3.350
8	2.360
10	2.000
16	1.180
20	0.850
30	0.600
40	0.425
50	0.300
60	0.250
80	0.180
100	0.150
140	0.106
170	0.088
200	0.075
270	0.053

Smaller sieves are numbered according to the number of openings per inch.

Example: A #10 sieve is made with 0.0237" thick wire. What is the opening size?

9 wires/in x 0.0237"/wire = 0.213"
1" – 0.213" = 0.787"
Opening width = 0.787"/10 openings = 0.0787"
0.0787" = 2.0 mm

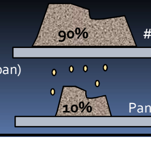


FILTER MEDIA - EFFECTIVE SIZE (D_{10})

Effective Size (D_{10})
Range should be 0.2 mm to 0.35 mm

- The effective size gives a good indication of the permeability characteristics of sand.
- D_{10} is the size of grain such that 10% by weight of the total sample is smaller. (i.e., 10% of the sand, by weight, is finer than a given grain size).

D_{10} = 0.2 mm (10% passes through to the pan)



#70 Sieve (70 openings/inch = 0.212 mm opening)

10% (by weight) of this sample is smaller than 0.2 mm

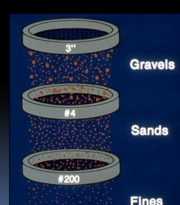
Pan

FILTER – DETERMINING D_{10}

Effective Size (D_{10})
Range should be 0.2 mm to 0.35 mm

A sieve analysis is done to determine D_{10} by:

1. Passing a known amount of media through a series of progressively smaller sieve sizes; and
2. Weighing the amount of media retained on each sieve.



FILTER MEDIA - DETERMINING D_{10}

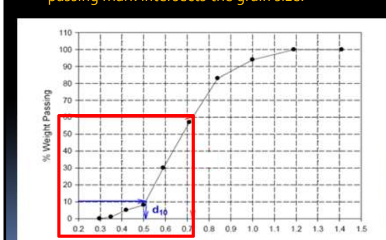
Percentage retained on any sieve:
= 100% x (weight of soil retained / total soil weight)
Cumulative percentage retained on any sieve:
= Σ percentage retained
Percentage passing the sieve:
= 100% - Σ percentage retained

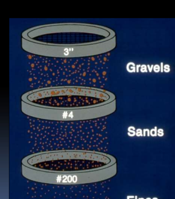
Sieve #	Diameter (mm)	Mass of soil retained on each sieve (g)	Percent retained (%)	Cumulative Retained (%)	Percent Passing (%)
20	0.850	5	1.00%	0.00%	100%
30	0.600	27.5	5.50%	5.50%	95%
40	0.425	85	17.00%	22.50%	78%
50	0.300	125	25.00%	47.50%	53%
70	0.212	128	25.50%	73.00%	27%
100	0.150	77.5	15.50%	88.50%	12%
140	0.106	40	8.00%	96.50%	4%
200	0.075	10	2.00%	98.50%	2%
Pan	N/A	2.5	0.50%	99.00%	1%
	Total =>	500 gram sample			

FILTER MEDIA – DETERMINING D_{10}

Effective Size (D_{10})
Range should be 0.2 mm to 0.35 mm

- The results are plotted (% passing vs. sieve/grain size (mm)).
- D10 is where a horizontal line drawn from the 10% passing mark intersects the grain size.





FILTER MEDIA - UC

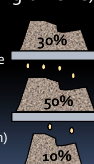
$$UC = \frac{D_{60}}{D_{10}}$$

Uniformity Coefficient (UC)
Range should be 1.5 – 3.0

- D_{60} is the size of grain such that 60% by weight of the total sample is smaller. (i.e., 60% of the sand, by weight, is finer than a given grain size).

D_{60} = 0.3 mm (50% on #100 sieve plus 10% in pan)

D_{10} = 0.15 mm (10% passes through to the pan)



#50 Sieve (50 openings/inch = 0.3 mm opening)

#100 Sieve (100 openings/inch = 0.15 mm opening)

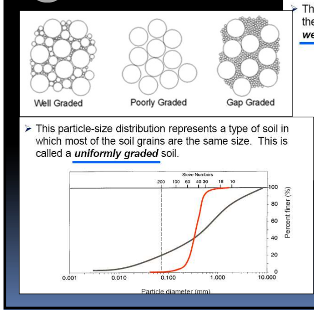
Pan

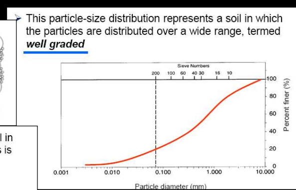
60% (by weight) of this sample is smaller than 0.3 mm (50% + 10%)
D_{60} = 0.3 mm
10% is smaller than 0.15 mm = d_{10}
UC = D_{60}/D_{10} = 0.3 mm/0.15 mm = 2.0

FILTER MEDIA - UC

Uniformity Coefficient (UC) = 1.5 – 3.0

$$UC = \frac{D_{60}}{D_{10}}$$





If the grain sizes vary greatly, the smaller ones will fill the spaces between the larger particles, making it easier for the filter to clog.

FILTER MEDIA – DETERMINING UC

Quiz:
What is D_{10}, D_{60} and UC for this sieve analysis?

Sieve #	Diameter (mm)	Mass of soil retained on each sieve (g)	Percent retained (%)	Cumulative Retained (%)	Percent Passing (%)
20	0.850	0	0.00%	0.00%	100%
30	0.600	30	30%	30%	70%
50	0.300	10	10%	40%	60%
70	0.212	40	40%	80%	20%
100	0.150	10	10%	90%	10%
200	0.075	5	5%	95%	5%
Pan	N/A	5	5%	100%	0%

FILTER MEDIA – DETERMINING UC

D10 = 0.15 mm
D60 = 0.3 mm
UC = d60/d10 = 0.3/0.15 = 2.0

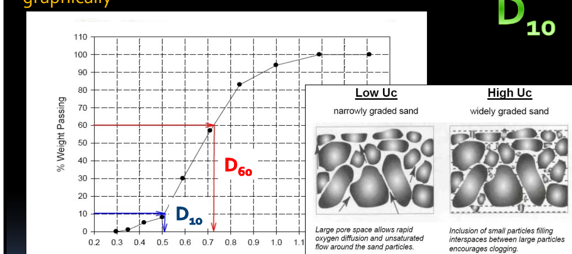
Cumulative percentage retained on any sieve:
= Σ percentage retained
Percentage passing the sieve:
= 100% - Σ percentage retained

Sieve #	Diameter (mm)	Mass of soil retained on each sieve (g)	Percent retained (%)	Cumulative Retained (%)	Percent Passing (%)	
20	0.850	0	0.00%	0.00%	100%	
30	0.600	30	30%	30%	70%	
50	0.300	10	10%	40%	60%	d60
70	0.212	40	40%	80%	20%	
100	0.150	10	10%	90%	10%	d10
200	0.075	5	5%	95%	5%	
Pan	N/A	5	5%	100%	0%	

FILTER MEDIA – DETERMINING UC

D_{10}, D_{60} and UC can also be determined graphically

$$UC = \frac{D_{60}}{D_{10}}$$

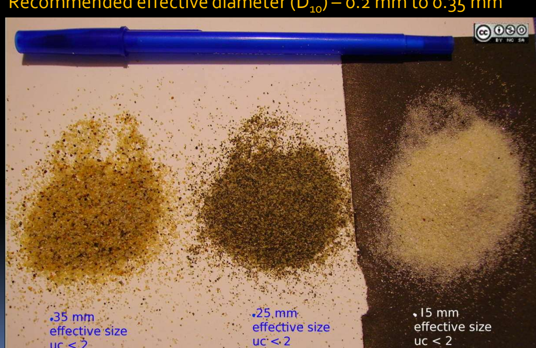


- D10 = Effective Size.
- D10 = Particle diameter such that 10% of the particles are finer.
- D30 = Particle diameter such that 30% of the particles are finer.
- D60 = Particle diameter such that 60% of the particles are finer.

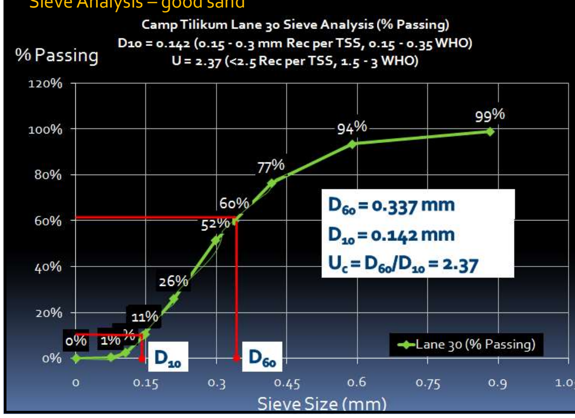
FILTER MEDIA

http://www.slowsandfilter.org

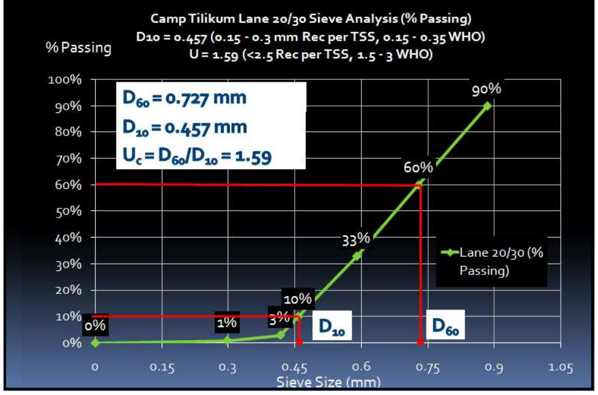
Recommended effective diameter (D_{10}) – 0.2 mm to 0.35 mm



Sieve Analysis – good sand

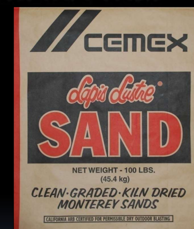


Sieve Analysis – not so good sand



OTHER MEDIA CONSIDERATIONS

1. % of fines passing #200 sieve
   < 0.3% by weight
2. Acid solubility
   < 5%
3. Apparent Specific Gravity
   ≥ 2.55
4. Minimum depth
   20-24 inches before re-sanding
5. Availability
   - Local supply options (keep transport costs low)
   - Redundant/backup supply (e.g. 2 or more quarries)
   - Ability to meet specifications
   - Consider ability to clean/stockpile scraped media
6. NSF-61 or equivalent (tested for contaminants)



Sources of Sand

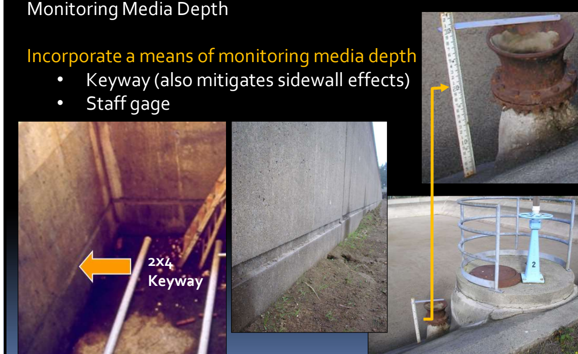
1. CEMEX, Vancouver, WA & Boardman, OR
2. Kleen Industrial Services, Danville, CA
3. Knife River Corporation, Corvallis, OR & Stayton, OR
4. Naselle Rock and Asphalt, Naselle, WA
5. Fazio Brothers, Vancouver, WA

Others???

OTHER MEDIA CONSIDERATIONS

Monitoring Media Depth

Incorporate a means of monitoring media depth
- Keyway (also mitigates sidewall effects)
- Staff gage

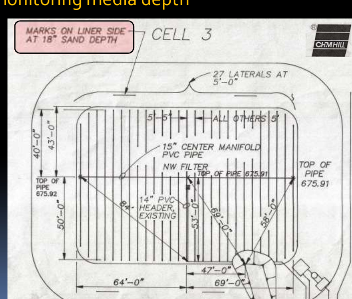


OTHER MEDIA CONSIDERATIONS

Monitoring Media Depth

Incorporate a means of monitoring media depth

"Marks on Liner Side"



RECOMMENDED MEDIA SPECS

Media specifications (silica sand) - summary

Filter Sand Specification	Recommended Range
Effective Diameter (d10)	0.2 – 0.35 mm
Uniformity Coefficient (U)	1.5 – 3.0
% fines passing #200 sieve	< 0.3% by Wt.
Acid Solubility	< 5%
Apparent Specific Gravity	≥ 2.55
Minimum Depth	20-24 inches
Delivery/Installation	Sand washed prior to installation
NSF/ANSI Standard 61	Certified or equivalent

SUPPORT GRAVEL

Support gravel prevents migration of sand down to underdrains, while allowing passage of filtered water.

Proper gradation is key to prevent migration
Rounded rock is used to promote drainage

Example shown* is for a rapid rate plant
(City of Grants Pass)

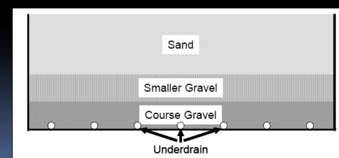
Top Layer 1	Filter sand (Silica sand w/ D_{10} = 0.45 mm- 0.55 mm)
Layer 2	#50 garnet sand
Layer 3	#12 garnet gravel
Layer 4	3/8″ x 3/16″ gravel
Layer 5	3/4″ x 3/8″ gravel
Bottom layer	1-1/2″ x ¾″ gravel

*Anthracite is on top of filter sand, but is not shown.

TEN STATES STANDARDS
SUPPORT GRAVEL

4.3.4.7 Filter gravel

The supporting gravel should be similar to the size and depth distribution provided for rapid rate gravity filters. See 4.2.1.6.f.2. (e.g. 4.3.1.6.e. – Support Media (for rapid rate gravity filters))



TEN STATES STANDARDS
SUPPORT GRAVEL, CONT.

4.3.1.6.e. – Support Media (for rapid rate gravity filters)

4.3.1.6.e.1. Torpedo sand (often used to backfill utility pipes)
A three-inch layer of torpedo sand shall be used as a supporting media for filter sand where supporting gravel is used, and shall have:

a. effective size of 0.8 mm to 2.0 mm (1/32″ – 5/64″)

b. uniformity coefficient not greater than 1.7.

TEN STATES STANDARDS
SUPPORT GRAVEL, CONT.

4.3.1.6.e.2. Gravel - Gravel, when used as the supporting media shall consist of cleaned and washed, hard, durable, rounded silica particles and shall not include flat or elongated particles. The coarsest gravel shall be 2.5 inches in size when the gravel rests directly on a lateral system, and must extend above the top of the perforated laterals. Not less than four layers of gravel shall be provided in accordance with the following size and depth distribution:

Size	Depth
3/32 to 3/16 inches	2 to 3 inches
3/16 to 1/2 inches	2 to 3 inches
1/2 to 3/4 inches	3 to 5 inches
3/4 to 1 ½ inches	3 to 5 inches
1 ½ to 2 ½ inches	5 to 8 inches

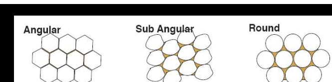
Reduction of gravel depths and other size gradations may be considered upon justification to the reviewing authority for slow sand filtration or when proprietary filter bottoms are specified.

SAND & GRAVEL

ASTM E11 standard sizes for woven wire test sieve cloth

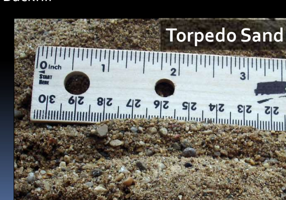
No.	Mesh Size (mm)	No.	Mesh Size (mm)	No.	Mesh Size (mm)	No.	Mesh Size (mm)
1″	25.0	7	2.80	20	0.85	60	0.250
¾″	19.0	8	2.36	25	0.71	80	0.180
½″	12.5	10	2.00	30	0.60	100	0.150
3/8″	9.5	12	1.70	35	0.50	120	0.125
4	4.75	14	1.40	40	0.425	140	0.106
5	4.00	16	1.18	45	0.355	170	0.090
6	3.35	18	1.00	50	0.300	200	0.075

SUPPORT SAND

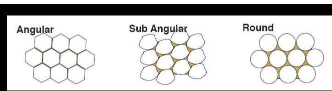


Concrete Sand
(a.k.a. "Torpedo Sand")

- Fine Aggregate grade 1 or 2 (FA-1 or 2)
- Angular to sub-angular
- 3/8″ x #100 mesh (9.5 x 0.15 mm)
- Washed and screened
- Used in production of ready mixed concrete
- Commonly used for pipe bedding & Backfill
- Meets ASTM C33 standard



SUPPORT GRAVEL

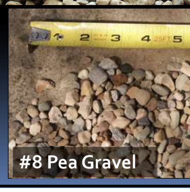


Pea Gravel (CA-16)

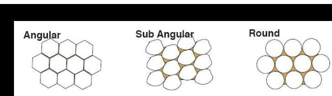
- Round to sub-angular river rock
- 3/8" x #16 (9.5 x 1.18 mm)
  (1.18 mm ~ 3/64")
- Washed but may contain smaller sediment
- Commonly used for decorative landscaping,
- retaining wall backfill, or where finer aggregates are needed when drainage through stone is
- desired.

#8 Gravel (a.k.a. #8 pea gravel)

3/8" x #8 (9.5 x 2.36 mm) (2.36 mm ~ 3/32")



FILTER MEDIA



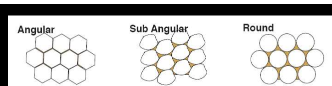
#57 gravel

1" x #4 (25.0 x 4.75 mm)   (4.75 mm ~ 3/16")

#4 gravel

1-1/2" x 3/4" (37.5 x 19 mm)

FILTER MEDIA



3/4" washed Gravel (CA11)

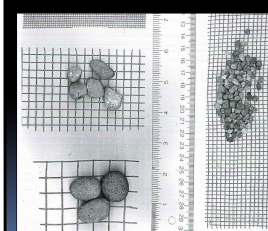
1-1/2" Washed Gravel (CA5)

SUPPORT MEDIA

City of Salem, OR

Filter sand D_{10} = 0.27 – 0.33 mm
4" Top Layer #4 x #8 sieve
4" Middle Layer 1/2" x #4 sieve (3/16")
10" Bottom Layer 7/8" x 1/2"

Gravel Layer	d_{10} Size	d_{90} Size
Top 4 inches	No. 8 sieve (2.36 mm)	No. 4 sieve (4.75 mm)
Middle 4 inches	No. 4 sieve (4.75 mm)	0.5 inches
Bottom 10 inches	0.5 inches	0.875 inches



SUPPORT MEDIA

3 layers of support gravel can be adequate, but 4 or more layers is recommended due to product and placement uncertainties.

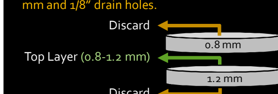
Layer	D10 (mm)	D90 (mm)	Depth (inches)
Top Layer	3/64" (1.0 mm)	1/16" (1.4 mm)	6
Middle Layer	5/32" (4.0 mm)	7/32" (5.6 mm)	6
Bottom Layer	5/8" (16 mm)	29/32" (23 mm)	6
Each successive layer should be graded so that its smaller (D_{10}) particle diameters are not more than four times smaller than those of the layer immediately below.			
The grains of the bottom layer should have an effective diameter of at least twice the size of the drain holes or slots.			

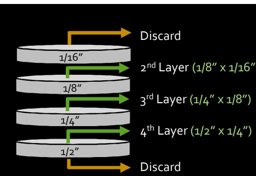
<u>Considerations</u>
Durability
Cost
Availability

* The gravel support using three layers as specified will work if the orifices into the under drain pipe are less than 8 mm in diameter. If the orifices are larger, more than three layers of gravel may be needed.

SUPPORT MEDIA

Example of a 4 layer support media for use with a filter sand with an effective size (D10) of 0.2 mm and 1/8" drain holes.





Support media for use with a filter sand with an effective size (d10) of 0.2 – 0.35 mm and 1/8" underdrain holes (for ¼" underdrain holes a fifth layer of ¾" x ½" or 1" x ½" gravel is needed).

Layer	Size Range		Depth (inches)	Specification
<u>Top Layer</u>	1/32" (0.8 mm)	1/21" (1.2 mm)	3	Largest Size/Smallest Size = 1.5 Smallest Size in Top Layer /D_{10} Filter Sand = 4.0
<u>2nd Layer</u> 1/8" x 1/16"	1/16" (1.588 mm)	1/8" (3.175 mm)	3	Largest Size/Smallest Size = 2.00 Largest Size/Smallest Size of Top Layer = 3.97
<u>3rd Layer</u> 1/4" x 1/8"	1/8" (3.175 mm)	1/4" (6.35 mm)	3	Largest Size/Smallest Size = 2.00 Largest Size/Smallest Size of 2nd Layer = 4.00
<u>4th Layer</u> 1/2" x 1/4"	1/4" (6.35 mm)	1/2" (12.7 mm)	Embed and bury underdrain piping with 1" of cover	Largest Size/Smallest Size = 2.00 Largest Size/Smallest Size of 3rd Layer = 4.00 Smallest Size = 2x Drain Diameter

SUPPORT MEDIA

4-5 Layer Option

Filter sand D_{10} = 0.2 mm
3" Top Layer #20 sand
3" Second Layer 1/8" x 1/16"
3" Third Layer 1/4" x 1/8"
3" Fourth Layer ½" x ¼" (4 layers work with 1/8" drain holes)
Bottom Layer ¾" x ½" (5 layers are needed with ¼" drain holes)

4-5 Layer Option	d10 (mm)	d90 (mm)	d10 (in)	d90 (in)	AWWA B100-09 & WHO d10 > 2xDrain?	AWWA B100-09 d10 top gravel between 4 and 4.5 times d10 sand	WHO (Huisman & Wood) d10 lower/d10 upper (≤3 where d90/d10 of same layer ≤ 2 or ≤ 4 if d90/d10 of same layer ≤ 1.4)	AWWA B100-09 d90 lower/d10 upper (≤4)	AWWA B100-09 d90/d10 same layer (≤2) (≤ 1.4, WHO)
Sand	0.2	N/A			N/A	N/A	N/A	N/A	N/A
Top Gravel	0.8	1.2	1/32	1/21	No	4.00	4.00	N/A	1.50
2nd Gravel	1.5875	3.175	1/16	1/8	No	N/A	1.98	3.97	2.00
3rd Gravel	3.175	6.35	1/8	1/4	No	N/A	2.00	4.00	2.00
4th Gravel	6.35	12.7	1/4	1/2	Yes	N/A	2.00	4.00	2.00
5th Gravel	12.7	19.05	1/2	3/4	Yes	N/A	2.00	3.00	1.50
Drain	3.175	N/A	1/8		N/A	N/A	N/A	N/A	N/A

SUPPORT MEDIA

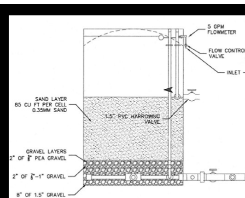
Rapid Rate Filter (City of Grants Pass)

Top Layer 1 (#50 garnet sand w/ D_{10} = 0.25 mm)
Layer 2 #12 garnet gravel
Layer 3 3/8" x 3/16" gravel
Layer 4 3/4" x 3/8" gravel
Bottom layer 1-1/2" x ¾" gravel

Grants Pass using Garnet Sand as Filter Medium	d10 (mm)	d90 (mm)	d10 (in)	d90 (in)	AWWA B100-09 & WHO d10 > 2xDrain?	AWWA B100-09 d10 top gravel between 4 and 4.5 times d10 sand	WHO (Huisman & Wood) d10 lower/d10 upper (≤3 where d90/d10 of same layer ≤ 2 or ≤ 4 if d90/d10 of same layer ≤ 1.4)	AWWA B100-09 d90 lower/d10 upper (≤4)	AWWA B100-09 d90/d10 same layer (≤2) (≤ 1.4, WHO)
Sand	0.25	N/A			N/A	N/A	N/A	N/A	N/A
Top Gravel	1.18	1.7	2/43	1/15	No	4.72	4.72	N/A	1.44
2nd Gravel	4.7625	9.5	3/16	3/8	No	N/A	4.04	8.05	1.99
3rd Gravel	9.5	19.05	3/8	3/4	No	N/A	1.99	4.00	2.01
4th Gravel	19.05	38.1	3/4	1 1/2	Yes	N/A	2.01	4.01	2.00
5th Gravel			0	0	No	N/A	0.00	0.00	#DIV/0!
Drain	6.35	N/A	1/4		N/A	N/A	N/A	N/A	N/A

SUPPORT MEDIA

Opal Creek, OR (Blue Future Filters)



Filter sand D_{10} = 0.3 mm
2" Top Layer 3/8" x 3/16"
2" Middle Layer 1" x 7/8" (or 1" x 1/2")
8" Bottom Layer 1-1/2" x 3/4"
Drain orifice = ¼" slots

Opal Creek, Oregon (Blue Future Filters)	d10 (mm)	d90 (mm)	d10 (in)	d90 (in)	AWWA B100-09 & WHO d10 > 2xDrain?	AWWA B100-09 d10 top gravel between 4 and 4.5 times d10 sand	WHO (Huisman & Wood) d10 lower/d10 upper (≤3 where d90/d10 of same layer ≤ 2 or ≤ 4 if d90/d10 of same layer ≤ 1.4)	AWWA B100-09 d90 lower/d10 upper (≤4)	AWWA B100-09 d90/d10 same layer (≤2) (≤ 1.4, WHO)
Sand	0.35	N/A			N/A	N/A	N/A	N/A	N/A
Top Gravel	3.175	9.525	1/8	3/8	No	9.071429	9.07	N/A	3.00
2nd Gravel	22.25	25.4	7/8	1	Yes	N/A	7.01	8.00	1.14
3rd Gravel	19.05	38.1	3/4	1 1/2	Yes	N/A	0.86	1.71	2.00
4th Gravel			0	0	No	N/A	0.00	0.00	#DIV/0!
5th Gravel			0	0	No	N/A	#DIV/0!	#DIV/0!	#DIV/0!
Drain	6.35	N/A	1/4		N/A	N/A	N/A	N/A	N/A

SUPPORT MEDIA

City of Salem, OR

Filter sand D_{10} = 0.27 – 0.33 mm
4" Top Layer #4 x #8 sieve
4" Middle Layer 1/2" x #4 sieve (3/16")
10" Bottom Layer 7/8" x 1/2"

Gravel Layer	d_{10} Size	d_{90} Size
Top 4 inches	No. 8 sieve (2.36 mm)	No. 4 sieve (4.75 mm)
Middle 4 inches	No. 4 sieve (4.75 mm)	0.5 inches
Bottom 10 inches	0.5 inches	0.875 inches

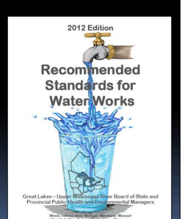
City of Salem, Oregon	d10 (mm)	d90 (mm)	d10 (in)	d90 (in)	AWWA B100-09 & WHO d10 > 2xDrain?	AWWA B100-09 d10 top gravel between 4 and 4.5 times d10 sand	WHO (Huisman & Wood) d10 lower/d10 upper (≤3 where d90/d10 of same layer ≤ 2 or ≤ 4 if d90/d10 of same layer ≤ 1.4)	AWWA B100-09 d90 lower/d10 upper (≤4)	AWWA B100-09 d90/d10 same layer (≤2) (≤ 1.4, WHO)
Sand	0.27	N/A			N/A	N/A	N/A	N/A	N/A
Top Gravel	2.36	4.75	4/43	3/16	No	8.740741	8.74	N/A	2.01
2nd Gravel	4.75	12.7	3/16	1/2	No	N/A	2.01	5.38	2.67
3rd Gravel	12.7	22.25	1/2	7/8	Yes	N/A	2.67	4.68	1.75
4th Gravel			0	0	No	N/A	0.00	0.00	#DIV/0!
5th Gravel			0	0	No	N/A	#DIV/0!	#DIV/0!	#DIV/0!
Drain	6	N/A	17/72		N/A	N/A	N/A	N/A	N/A

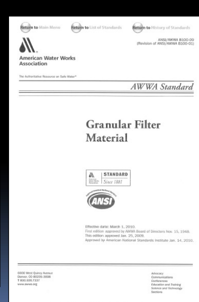
SUPPORT MEDIA

More layers of support gravel is often needed, due to product cost and availability.

For material size and layer depth, follow the latest:

1. Guidelines in Appendix D of ANSI/AWWA B100 Standard; or
2. Ten States Standards for slow sand filter construction

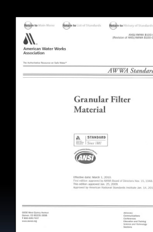




SUPPORT MEDIA

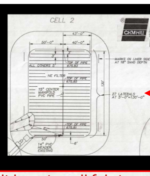
Support Media Installation

1. For material washing/handling/delivery/installation recommendations, follow the ANSI/AWWA B100 Standard
3. Desired layer elevations should be marked on filter wall and each layer added and screeded level and even with the mark.
4. The elevation of the top surface of each layer shall be checked using water that is introduced into the filter as a guide with the media within + 0.5 inch of the desired level and the areas above and below the desired level within 10% of each other.
5. Support gravel should washed prior to placement of filter sand (see AWWA B100 Standard).



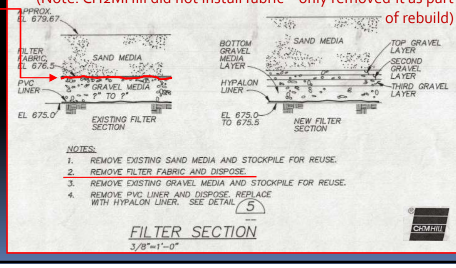
FILTER FABRIC?

City of Astoria
Filter Cell #2
(1993 filter rebuild)



Filter fabric between sand and gravel often gets clogged as in this case. This fabric was discarded and is not needed with proper gravel gradations

(Note: CH2MHill did not install fabric – only removed it as part of rebuild)



TEN STATES STANDARDS

SUPERNATANT WATER (HEADWATER)

4.3.4.8 Depth of water on filter beds

Design shall provide a depth of at least 3 – 6 feet of water above the sand. Influent water shall not scour the sand surface.

Wickiup Water District, OR

HEADWATER

- Purpose is to provide driving head
- Provides retention/settling
- Little benefit to exceeding a depth of 4-5 feet
- Shallow levels may increase algae due to sunlight penetration
- Important to include:
  1. Side stream influent piping if harrowing
  2. Overflow
  3. Drain
  4. Backflush piping

Headwater	Sedimentation 4 – 5 ft (48-60")
Schmutzdecke	Biological (1-2 cm)

INFLUENT ENERGY DISSIPATION

"Influent water shall not scour the sand surface"
Energy Dissipation (to avoid sand scouring)

Energy dissipation helps to keep sand from scouring and erosion of the filter cell liner.

2011. City of Corbett, OR

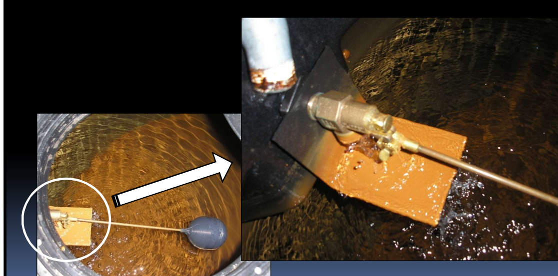
INFLUENT ENERGY DISSIPATION

Jewell School District #8 (Clatsop Co)

3 cells (Blue Future)
18 gpm (0.1 gpm/sf)
Completed in 2010
Cleaned using wet harrowing

INFLUENT ENERGY DISSIPATION

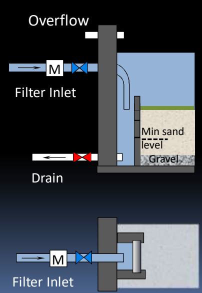
Energy Dissipation ("Splash Plate") for Jewell SD #8

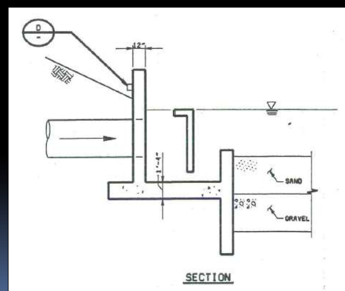


2012. Jewell School District #8, OR

INFLUENT ENERGY DISSIPATION

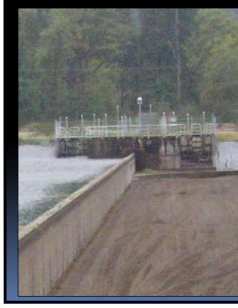
Sections showing influent baffles

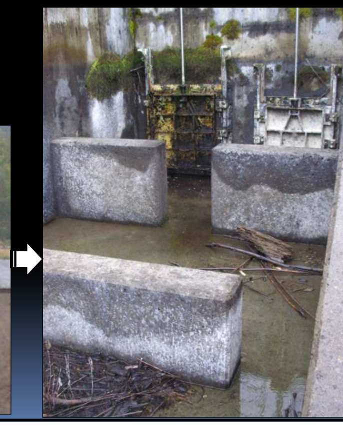




INFLUENT ENERGY DISSIPATION

City of Salem, Oregon influent baffles





TEN STATES STANDARDS
MONITORING & INFLUENT CONTROLS

4.3.4.9 Control appurtenances

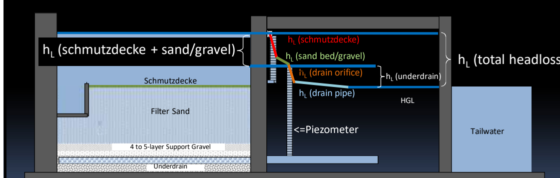
Each filter shall be equipped with:

a. Influent and effluent sampling taps;
b. An indicating loss of head gauge or other means to measure head loss;
c. An indicating rate-of-flow meter. A modified rate controller that limits the rate of filtration to a maximum rate may be used. However, equipment that simply maintains a constant water level on the filters is not acceptable, unless the rate of flow onto the filter is properly controlled. A pump or flow meter in each filter effluent line may be used as the limiting device for the rate of filtration only after consultation with the reviewing authority.

HEADLOSS MEASUREMENT

Piezometers

Measurement of head loss can be accomplished with simple piezometers mounted outside the filter and tailwater structures.



TEN STATES STANDARDS
EFFLUENT CONTROLS

4.3.4.9 Control appurtenances, continued

Each filter shall be equipped with:

d. Provisions for filtering to waste with appropriate measures for cross connection control;
e. An orifice, Venturi, or other suitable means of discharge measurement installed on each filter to control the rate of filtration.
f. An effluent pipe designed to maintain the water level above the top of the filter sand.

KEY FLOW CONTROL ELEMENTS

Key flow control elements:

1. Effluent weir or controls to prevent air entrainment
2. Ability to fill from the top with raw water or the bottom with filtered water from another cell – a flow meter is needed to control this flow to a rate of 0.3 – 0.6 ft of filter bed per hour (0.0374 – 0.0748 gpm/ft^2).
3. Continuous operation (constant supply of nutrients)
4. Gradual flow rate changes (ideally no more often than weekly or monthly)
5. Flexibility to change sources or use various combinations of filter beds

FILTRATION RATE

Filtration rate should be continuous

1. Good for dissolved oxygen
2. Good for nutrient supply
3. Good for biological mechanisms
4. Influent flow should not scour sand surface
5. 0.1 gpm/ft² maximum filtration rate
6. 0.03 gpm/ft² minimum filtration rate
7. Cold temperatures may need lower filtration rates (e.g., 0.05 gpm/ft² when water temp < 5°C)
8. Controls should be in place to prevent the tail water (effluent side) from dropping below the sand bed during operation (e.g., an effluent weir) – this helps prevent vacuum conditions and air entrainment.

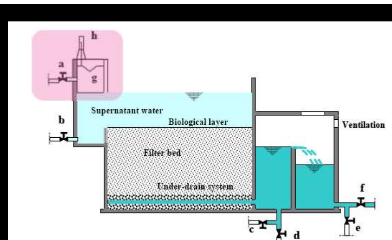
FLOW CONTROL –INLET VS OUTLET

Flow control can be practiced at the inlet or outlet. Inlet flow control can be either operated as constant rate or declining rate modes.

1. Inlet flow Control – Constant Rate
   Uses a throttling valve plus a flowmeter or V-notch weir prior to each filter. The operator uses the flow control valve to set the desired filtration rate. As the resistance of the filter bed increases, the water level rises. When the headwater level approaches the overflow pipe the bed should be cleaned.
   - Requires less operator involvement
   - Ensures a more constant rate of filtration
   - Allows operator to see headloss development as headwater rises
   - Low headwater at the beginning of filter runs may make filters more vulnerable to freezing in the winter if filters are not covered or insulated
2. Inlet Flow Control – Declining Rate
   Uses a hydraulic control valve with a flowmeter and valve at the raw water line prior to each filter that regulates flow while maintaining a constant water surface elevation above the filter. Effluent flow decreases as the filter plugs.
   - Headwater level is not indicative of headloss development (piezometers or pressure gages are needed)
   - Decline in effluent rate or approach to terminal headloss indicates cleaning

INLET FLOW CONTROL

Inlet (Influent) Control

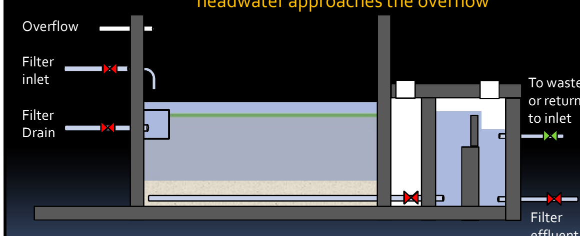


Basic components of an inlet controlled slow sand filter

a. Valve for raw water inlet and regulation of filtration rate
b. Valve for draining supernatant water layer
c. Valve for backfilling the filter bed with clean water
d. Valve for draining the filter bed and outlet chamber
e. Filter to waste valve
f. Valve for delivery of treated water to the disinfection clear well
g. Inlet weir
h. Calibrated flow indicator

CONSTANT RATE INLET CONTROL

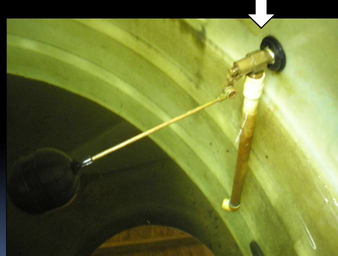
- Starts off with a lower headwater level
- Influent valve is set to the desired rate (e.g., 0.03-0.1 gpm/ft²)
- Outlet valve is fully open
- The filter will need to be cleaned when the headwater approaches the overflow



What goes into the filter will go out of the filter (filter effluent or to waste/inlet)
Headloss builds up towards the end of the filter run as it plugs up causing headwater to rise
Cleaning unplugs filter allowing headwater to drop
Excess water produced is re-circulated (pumped) to influent or sent to waste (gravity)

DECLINING RATE INLET CONTROL

Inlet float control valve



Some systems use influent float control valves in order to control the headwater level above the sand. This shows the location of the inlet float control valve on the inside of a small package filter.

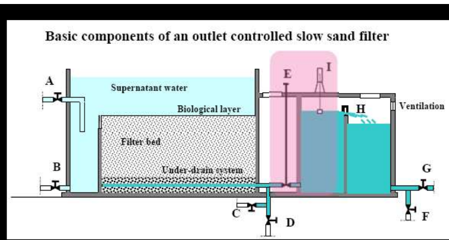
2012. Camp Yamhill in Yamhill County Oregon.

FLOW CONTROL –INLET VS OUTLET

3. Outlet Flow Control (declining rate)
   Uses a control valve and flowmeter on the outlet pipe from each filter. As the filter plugs, the filtration rate will decrease, even if the headwater level is increased. The level of water on top of the filter can be controlled by using float switches to turn on and off raw water pumps or control inlet control valves. Excess water can also be diverted out an overflow and directed back to the source.
   - Most common.
   - Fairly simple control method although operator involvement is higher if no automation is used.
   - Higher rates may be implemented faster for emergency situations, since you don't have to wait for headwater to rise as with constant rate influent control.
   - Ability to maintain higher headwater level provides better protection from freezing.
   - Higher headwater level provides raw water storage should influent flows be interrupted due to power failure or intake shutdown due to damage or to avoid high turbidity events.
   - Headwater level is not indicative of headloss development (piezometers or pressure gages are needed)

OUTLET FLOW CONTROL

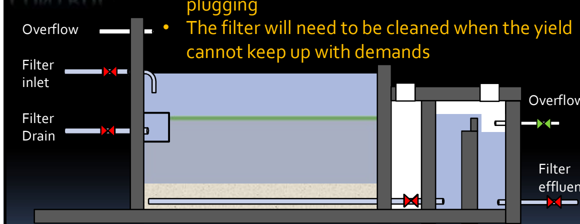
Outlet (effluent) control is most common



A. Raw water inlet valve
B. Valve for draining supernatant water layer
C. Valve for backfilling the filter bed with clean water
D. Valve for draining the filter bed and outlet chamber
E. Valve for regulation of the filtration rate
F. Filter to waste valve
G. Valve for delivery of treated water to the disinfection clear well
H. Outlet weir
I. Calibrated flow indicator

DECLINING RATE OUTLET CONTROL

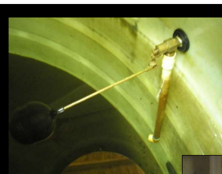
- Starts off with a higher headwater level
- Influent valve is adjusted to keep filter from overflowing
- Outlet valve is partially closed at first and then is gradually opened as the yield drops due to filter plugging
- The filter will need to be cleaned when the yield cannot keep up with demands



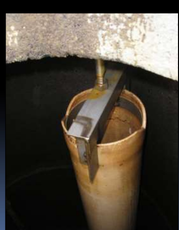
What goes into the filter will go out of the filter (Excess can be overflowed if needed)
Headloss builds up towards the end of the filter run as it plugs up causing headwater to rise
Cleaning unplugs filter allowing yield to recover
Influent water is balanced with effluent or excess can be overflowed from headwater

VALVES

Select valves for the purpose they are intended to serve and the pressures they are needed to withstand



Float control valve. Camp Yamhill in Yamhill Co. Oregon. 2012.



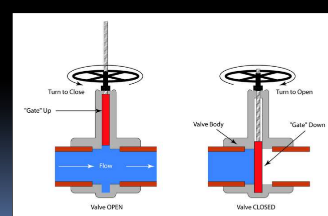
Telescoping Valve. City of Cannon Beach in Clatsop Co. Oregon. 2013.

Butterfly valves. City of Banks in Washington Co. Oregon. 2011.

GATE VALVES - ISOLATION OR THROTTLING

GATE VALVES

Gate valves contain a solid gate that is lowered for closing and raised for opening. This gate may be in the form of a square, rectangle, circle, oval, or ellipse. There is very little pressure loss through a gate valve and because they operate slowly, they are unlikely to cause water hammer. In the fully closed position, gate valves provide a positive seal under pressure. However, under very low pressure, i.e. 5 psi, light seepage would not be considered abnormal with this kind of valve. Gate valves should always be left fully open or fully closed. Throttling or fine controlling of gate valves, which places the gate into the flow of the liquid, can cause serious erosion of the gate. Most sedimentation basin inlet valves are gate valves. Gate valves are also commonly used as main raw water intake valves at the heads of water treatment plants.



BALL VALVES - ISOLATION

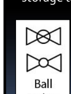
BALL VALVES

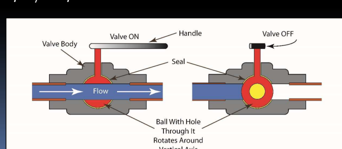
Description - Ball valves are very similar to plug valves, except have a ball-shaped plug with a hole bored through its center that can be rotated to throttle flow. Ball valves are relatively simple and trouble free, have low pressure drops, and open and close quickly, although opening or closing a ball valve too quickly can cause water hammer.

Isolation – Allow quick, quarter turn on-off operation, making them good for isolation. With the development of Teflon seals, ball valves have grown in popularity.

Throttling – Generally have poor throttling characteristics. Ball valves have a ported ball that can be rotated to throttle the flow of clear water, however, they should be operated either fully open or fully closed with any liquid containing particles that could scratch the ball.

Common Uses – They can be used for high or low pressure applications. Most water treatment plant storage tank, day tank, and chemical feed line valves are ball valves.





BUTTERFLY VALVES - ISOLATION OR THROTTLING

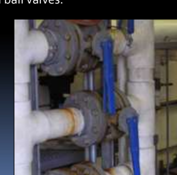
BUTTERFLY VALVES

Description - Butterfly valves, like ball valves, operate with an adjustable circular disc mounted on a shaft in the center of the valve that can be opened or closed with just a 1/4 turn.

Isolation – Not normally rated as bubble tight.

Throttling – Can be used for throttling, but should not be used for throttling for extended periods of time.

Common uses - They are often used for backwash, filter-to-waste, and filter effluent valves. They are generally used for handling large flows of gases or liquids, including slurries. Butterfly valves are also commonly used as large water line valves because they are less expensive than similarly sized ball valves. They are also very compact relative to flanged gate and ball valves.



GLOBE VALVES – PRECISE THROTTLING

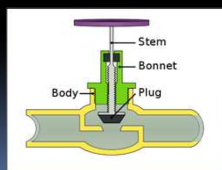
GLOBE VALVES

Description - Globe valves have a casing that historically has been shaped more globe-like than today's models. Globe valves have a plug that fits into a seat within the main cavity area of the globe. Like a gate, globe valves close slowly to prevent fluid hammer.

Isolation – Not typically used for isolation

Throttling - You can throttle the flow and they will not leak under low pressure when they are shut off, but have relatively high head loss.

Common Uses - Flow and pressure control valves as well as hose bibs generally use the globe pattern. The disadvantage of this design is that the "Z" pattern restricts flow more than the gate, ball, or butterfly valves.



PLUG VALVES – ISOLATION OR THROTTLING

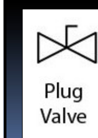
PLUG VALVES

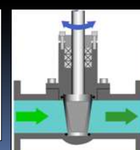
Description - Like the gate valve, a plug valve has an unobstructed flow, yet requires only a 90 degree turn to open it. It also requires very little headroom. Stem corrosion is minimal because there are no screw threads. Almost all plug valves now are furnished with an elastomer-coated plug and will seal off drip-tight.

Isolation – Plug valves can seal well and have a tight shutoff, however, some plug valves are made with a reduced port, which means the valve is smaller than the adjoining pipe's cross-sectional area, leading to higher pressure drop – look for full bore plug valves if you need them.

Throttling – Not typically used for throttling, but they have been used for throttling.

Common Uses - Plug valves are available in much larger sizes than ball valves and are highly suitable for use in wastewater plants.

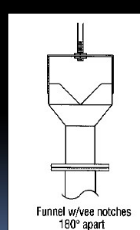


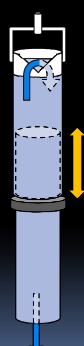


TELESCOPING VALVES

TELESCOPING VALVES

Telescoping valves use a gasketed slip pipe to allow the outlet to be raised or lowered. They can be fitted without weirs or with V-notch weirs.





TELESCOPING VALVES

TELESCOPING VALVES

Image to the right shows:

1. Traditional hand wheel
2. Self locking bevel gear
3. Clear acrylic stem cover tube
4. Remote (electric) actuator
5. Valve position indicator

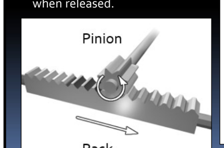
TELESCOPING VALVES

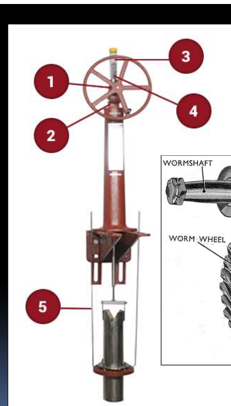
TELESCOPING VALVES

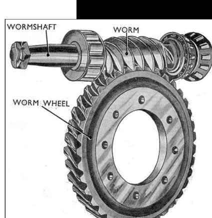
Image to the right shows:

1. Rack and pinion
2. Worm gear box
3. Acrylic rack cover tube
4. Depth indication markings
5. Slip tube lubrication system

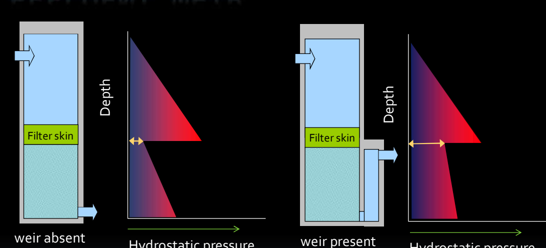
In a work gear, the worm can move the wheel, but the wheel cannot move the worm. In that way the weight of the slip pipe will not turn the hand wheel when released.







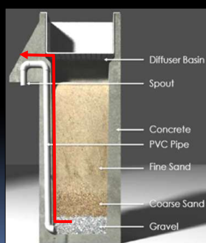
EFFLUENT WEIR



Effluent weir prevents air binding caused by a drop in hydrostatic pressures low enough to cause a partial vacuum in the filter media below the schmutzdecke . This can seriously impact water quality because algal activity causes the supernatant water to become supersaturated with oxygen, which would be released as tiny bubbles in the partial vacuum below the schmutzdecke – the condition known as "air binding". If air binding occurs in a part of the filter, the remaining filter can become overloaded. If air binding is more widespread, the hydrostatic head above the filter can greatly increase, causing a rupture in the schmutzdecke and breakthrough of pathogens.

EFFLUENT WEIR

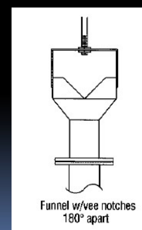
Effluent piping can be configured to simulate weir in order to prevent unplanned bed dewatering and air binding

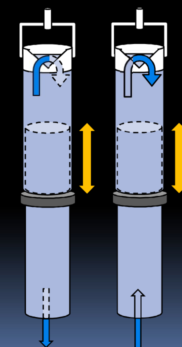


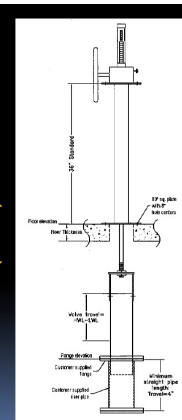
BioSand Filter (Dr. David Manz)

EFFLUENT WEIR

Telescoping valve with a V-notch weir serves the same function as an effluent weir.





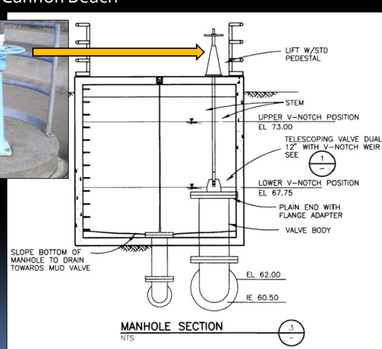


Latanick Equipment, Inc.

EFFLUENT WEIR

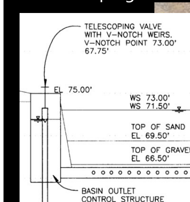
Telescoping Valve – Cannon Beach

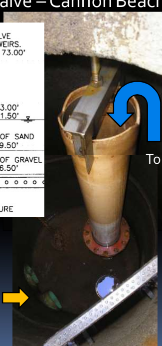
City of Cannon Beach, Oregon



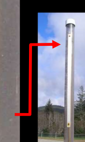
EFFLUENT WEIR

Telescoping Valve – Cannon Beach





To Clearwell

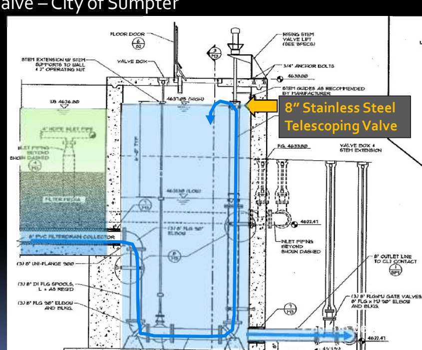


Cannon Beach, Oregon

Filter Effluent Pipes (2 filters)

EFFLUENT WEIR

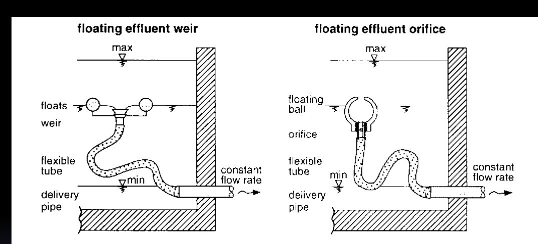
Telescoping Valve – City of Sumpter



City of Sumpter, Oregon =>

EFFLUENT WEIR

Floating effluent weirs



TEN STATES STANDARDS
FILTER RIPENING

4.3.4.10 Ripening

Slow sand filters shall be operated to waste after scraping or rebedding during a ripening period until the filter effluent turbidity falls to consistently below the regulated drinking water standard established for the system.

RIPENING NEW FILTERS

Basic steps to ripening a new filter are as follows:

1. Backfill slowly to displace air pockets at a rate of 0.3 – 0.6 feet of filter bed depth per hour (0.0374 – 0.0748 gpm/ft²) until the inlet jets are covered.
2. Set the weir plate with the crest at the level of influent jets
3. Begin top filing through the inlet jets and begin filtering to waste.
4. The water in the filter box will rise slowly due to the Schmutzdecke buildup and when the level reaches twice the distance between the sand bed and influent jets, lower the weir plate slowly so that the crest is at the level of the sand bed surface.
5. Continue filter-to-waste until the filter is ripened as indicated by turbidity $\leq$ 1 NTU and coliform $\leq$ 10 CFU/100 ml.

FILTER TO WASTE

1. Allows for cleaning newly sanded beds.
2. Allows for ripening without public health risk.
3. Air-gap is recommended to prevent cross-contamination.

DESIGN FOR WET HARROWING

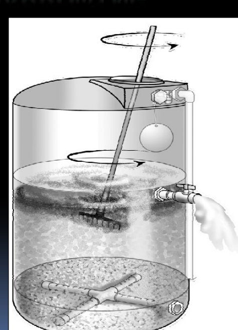
Facilities Needed:

1. Access for harrowing equipment
2. Harrowed water influent distribution system
   - Cross-flow (raw water)
   - Up-flow (filtered water)
3. Harrowed wastewater collection system
4. Holding lagoon for the harrowed wastewater
5. Filter-to-waste piping
6. Provisions to prevent equipment from contaminating filter bed

DESIGN FOR WET HARROWING

Wet Harrowing

Wet harrowing is a common method of cleaning small filters.

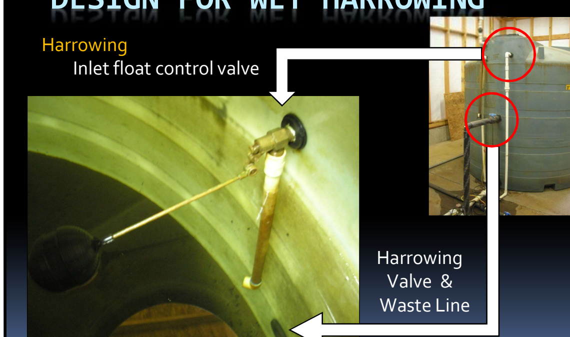


Basic process:

1. Lower water level to ~6" above the top of the sand.
2. Use a rake or rake-like Mechanism
3. agitate top 2"-3" of sand while slowly backflushing with filtered, but unchlorinated water
4. Wastewater is collected through A harrowing valve and waste piping

DESIGN FOR WET HARROWING

Harrowing



2012. Camp Yamhill in Yamhill County Oregon.

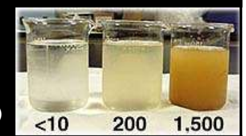
SLOW SAND DESIGN SCRAPED VS. HARROWING

Parameter	Scraped	Harrowed (wet harrowed)
Biomass Development	Biomass and schmutzdecke take longer to develop due to the removal of biomass	Biomass and schmutzdecke restore at a faster rate, however, the sudden release of nutrients can cause dissolved oxygen to dip as microbial grazing intensifies. Keeping influent water flowing and filtering to waste at a higher initial rate can help to replenish depleted oxygen levels.
Removal Efficiency	Equivalent once filter is properly ripened	Equivalent once a filter is properly ripened – usually takes less time to accomplish this.
Filter life	Impacted by removal of top ~2 cm of plugged sand layer	Little media loss leads to longer filter life. Media is more susceptible to deep bed clogging if not done properly.

OTHER DESIGN CONSIDERATIONS

Additional treatment may be needed for challenging waters

Examples:
Roughing Filters (turbidity)
Calcite Contactors (pH)
Ozone (DBP precursors)
Granular activated carbon (TOC/Color)
Filter mat (schmutzdecke removal)
Aeration (low dissolved oxygen)



Michigan Environmental Education Curriculum

City of Astoria, OR
Middle Lake Source 8-28-13
Photo by Gary McLauchlin
Aphanizomenon flos-aquae

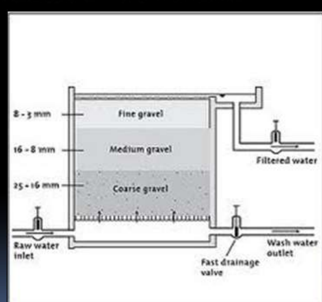
OTHER – ROUGHING FILTERS

Roughing Filters

Indicated with pilot test results.

May be required in the future due to changes In source water quality.

Pre-planning ensures flexibility

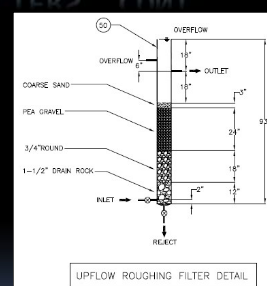


ROUGHING FILTERS, CONT.

Roughing Filters

Reduces the algae and sediment load to the filters

As with slow sand filters, biological maturity is key to optimal performance



Effectiveness
90% removal of particles > 10 microns (medium silt and larger)
72% removal of 2-5 micron particles (Cryptosporidium size particles)

ROUGHING FILTERS, CONT.

Roughing Filters

- Can be upflow, downflow, or horizontal
- Filtration rates of 0.12 – 0.62 gpm/ft²
- Cleaned by flushing at high hydraulic rates. Hydraulic surges can be generated by rapid openings and closings of the inlet and outlet valves
- Horizontal flow roughing filters are considered to have greater silt storage capacity and lower hydraulic cleaning needs than upflow or downflow roughing filters.

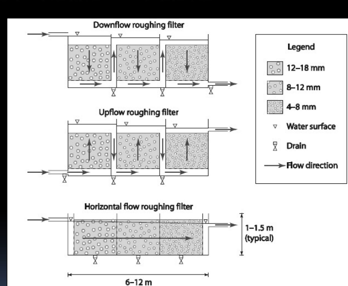
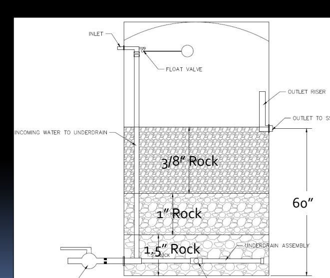


Figure 2.1 Typical roughing filter configurations (Collins et al., 1994)

ROUGHING FILTERS, CONT.

Roughing Filters

- Gravel size range from 0.2 – 2 in.



OTHER – PH CONTROL

Calcite Contactors

- Used to increase the pH in Corrosive waters
- Limestone can work well

Privately owned slow sand filter & limestone calcite contactor Photos by Stephen Tanner

OTHER - OZONE

Ozone

- Used prior to or after filtration for organics removal (DBP precursors)
- Oxidizes iron and manganese
- Reduces some algal toxins
- Removes color, taste, and odor causing compounds
- Increased O&M due to shorter filter runs

Large water system ozone

OTHER – ACTIVATED CARBON

Granular Activated Carbon

- Removes color, taste, and odor causing compounds.
- Needs to be replaced when depleted (i.e., deactivated)

Comparison of Slow Sand with and without a layer of GAC

Parameter	SSF w/out GAC	SSF with GAC
Cleaning Frequency	30 days	No change
Color Removal	20%	50%
TOC reduction	20%	35-40%
TTHM Formation Potential Reduction (24-hr contact time)	130 µg/L	60 g/L

OTHER – FILTER MATS

Nonwoven Synthetic Filter Mats

- Nonwoven synthetic fabric helps to concentrate the macro-particle removals on the fabric layers, thereby avoiding the need to remove sand.
- Fabric increase filter runs due to lower head loss development.
- Filter cleaning involves removal and cleaning of fabric
- Typically for filters smaller than about 300 ft^2 due to logistics of cleaning the mat. Limit thickness to 1-1.5 inches (2-3 cm).
- Properties of Nonwoven Synthetic Fabrics:
  - Thickness of 0.36 – 20 mm
  - Bulk density 0.02 – 0.4 g/ml
  - Mean fiber diameter 27-48 µm
  - Porosity 0.56-0.99
  - Specific surface area 13,000 – 14,000 m^2/m^3

OTHER – AERATION

Aeration

May be needed if DO < 6 mg/l

May be required in the future due to changes in source water quality.

Pre-planning ensures flexibility

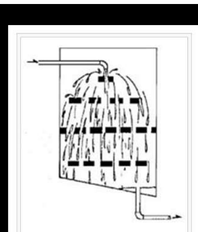
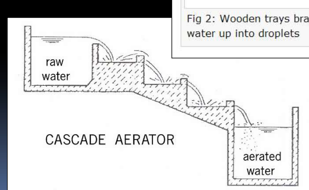


Fig 2: Wooden trays brake water up into droplets



MONITORING POINTS

The recommended minimum location points for recording and monitoring include:

Source water for:
- Turbidity
- Flow
- Temperature
- pH
- Grab sampling of coliform, TOC, or other water quality parameters

Supernatant for:
- Level
- Headloss
- Grab sampling of coliform, TOC, or other water quality parameters

MONITORING

Individual filter effluent for:
- •Flow rate and quantity
- •Turbidity
- •Grab sampling of coliform, TOC, or other water quality parameters

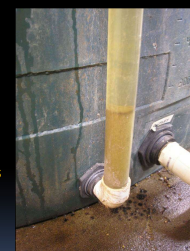
Combined filter effluent for:
- •Flow rate and quantity
- •Turbidity
- •Grab sampling of coliform, TOC, or other water quality parameters

Finished water (post disinfection and storage used for disinfection contact time) for:
- •Flow rate and quantity
- •pH
- •Temperature
- •Chlorine residual
- •Grab sampling of coliform, TOC, or other water quality parameters

Finished water storage for:
- •Effluent flows
- •Level

MONITORING HEAD LOSS

Head loss Measurement



On smaller facilities, routine visual observation of the supernatant depth and recording of the flow rate may be sufficient to monitor filter head loss development.

On larger facilities, screened probes at the top and bottom of the filter sand can allow easy measurement of head loss with simple piezometers mounted outside the filter, or through the use of a differential pressure transducer connected to the facility's SCADA system.

Tracking this data will allow the operator to predict and plan filter cleanings.

O&M MANUAL

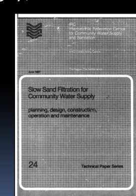
Frequency and tasks are adapted from WHO, 1996. *Fact Sheets on Environmental Sanitation, Fact Sheet 2.12: Slow Sand Filtration*

Frequency	Labor (person hours)	Slow Sand Filter Maintenance Task
Daily	1 - 3	Check raw water intake Check/adjust filtration rate Check water level in filter Check water level in clear well Sample & check water quality (raw/finished NTU, raw temp) Check pumps Enter observations in logbook
Weekly	1 - 3	Check & grease any pumps & moving parts Check/re-stock fuel Sample & check water quality (coliform) Enter observations in logbook
1 – 2 months	5 / 1,000 ft2 50 / 1,000 ft2 /12 inches of sand for re-sanding (Letterman & Cullen, 1985)	Scrape filter beds Wash scrapings & store retained sand Check & record sand bed depth Enter observations in logbook

KEY REFERENCES – 1974, 1987

1. "Slow Sand Filtration", World Health Organization (Huisman & Wood), 1974;
2. "Slow Sand Filtration for Community Water Supply", International Research Center for Community Water Supply and Sanitation (Visscher et al., 1987)

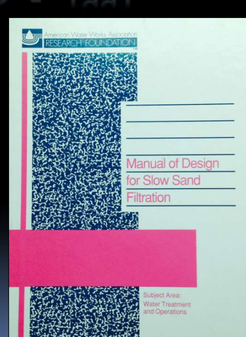
http://www.who.int/water_sanitation_health/publications/ssf/en/index.html



http://www.irc.nl/page/4530

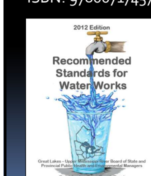
KEY REFERENCES - 1991

"Manual of Design for Slow Sand Filtration" . David Hendricks & American Water Works Association, 1991. ISBN 978-0898675511

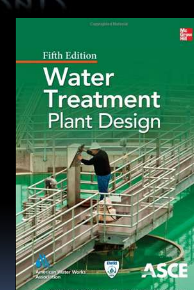


KEY REFERENCES - 2012

"Water Treatment Plant Design, 5th Edition". Stephen J. Randtke, Ph.D., P.E.; Michael B. Horsley, P.E. Co-published by the American Water Works Association; Environmental and Water Resources Institute of American Society of Civil Engineers; McGraw-Hill Professional. 2012. ISBN: 9780071745727



Recommended Standards for Water Works (a.k.a., "Ten States Standards", 2012);



http://10statesstandards.com/

QUESTIONS ABOUT DESIGN?