Stormwater Management Manual for Eastern Washington

August 2019

DEPARTMENT OF ECOLOGY
State of Washington

Publication Number 18-10-044

Printed on recycled paper

Stormwater Management Manual for Eastern Washington

Prepared by:

Washington State Department of Ecology
Water Quality Program

August 2019
Publication Number 18-10-044

5.10 Oil and Water Separator BMPs

5.10.1 Introduction to Oil and Water Separator BMPs

This section provides a discussion of oil and water separators, including their application and design criteria. Best Management Practices (BMPs) are described for baffle-type and coalescing-plate-type (CP-type) separators.

5.10.2 Purpose

Oil and water separators remove oil and other water-insoluble hydrocarbons and settleable solids from stormwater runoff. Typical types include the American Petroleum Institute (API), also called the baffle-type, separator (API, 1990) or the CP-type separator using a gravity mechanism for separation. See Figure 5.27: API (Baffle-Type) Separator and Figure 5.28: Coalescing Plate Separator.

Oil and water separators typically consist of three bays; forebay, separator section, and the afterbay. The CP separators need considerably less space for separation of the floating oil due to the shorter travel distances between parallel plates.

Oil and water separators should be designed to remove oil and total petroleum hydrocarbons (TPH) down to 15 milligrams per liter (mg/L) at any time and 10 mg/L on a 24-hour average, and produce a discharge that does not cause an ongoing or recurring visible sheen in the stormwater discharge or in the receiving water (see also 5.2 Runoff Treatment BMP Selection Process).

Two BMPs are described in this section:

- BMP T5.100: API Separator Bay
- BMP T5.110: Coalescing Plate (CP) Separator Bay

Underground Injection Control (UIC) regulations do not apply to oil and water separators if the outlet structure discharges exclusively to a conveyance system and/or to surface water. However, the UIC regulations do apply to oil and water separators if the outlet structure discharges into the ground, and then—provided that the design and operation and maintenance criteria in this section are met—only the registration requirement would apply. See 5.6 Subsurface Infiltration (Underground Injection Control Wells).

Figure 5.27: API (Baffle-Type) Separator

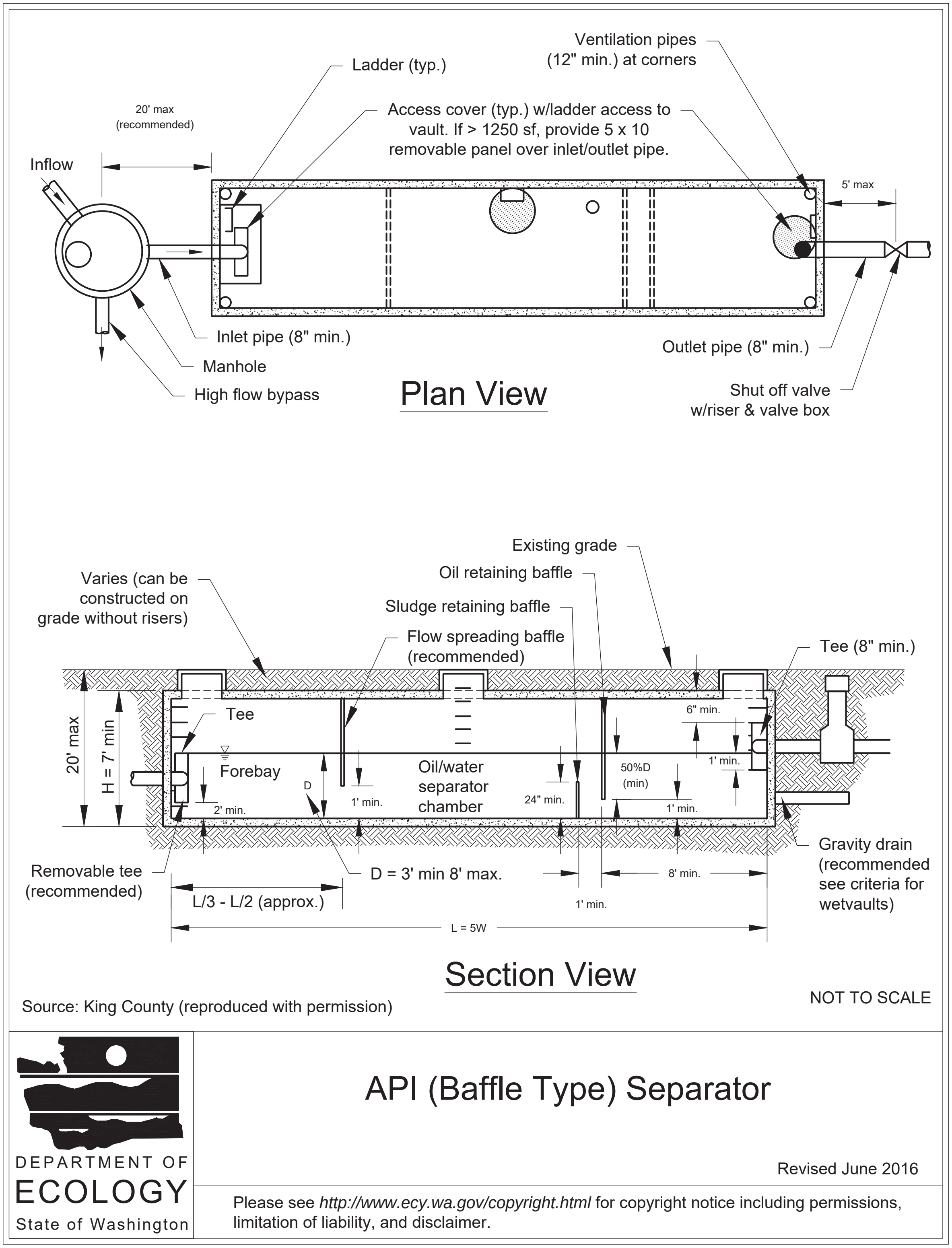
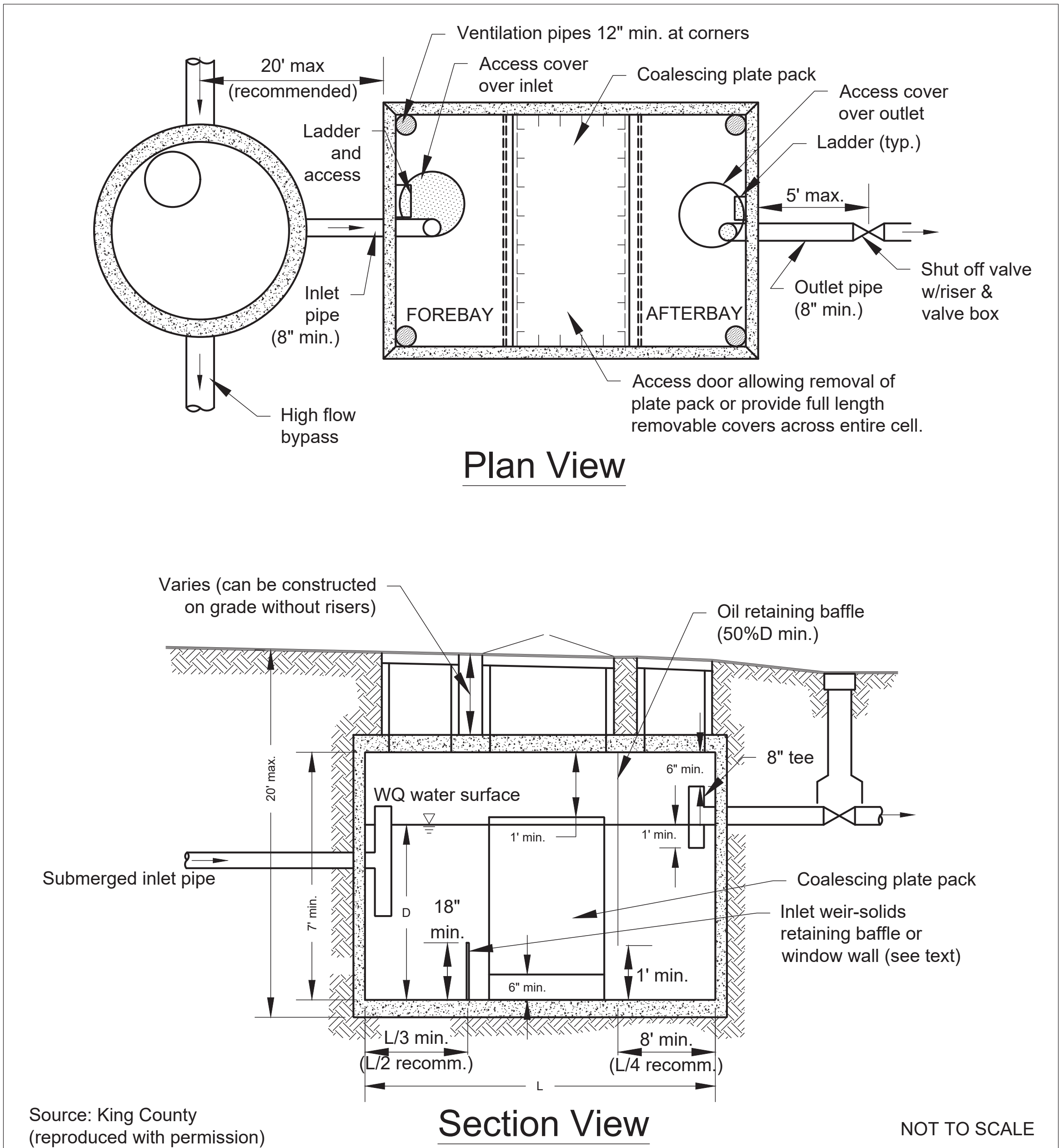


Figure 5.28: Coalescing Plate Separator



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Coalescing Plate Separator

Revised June 2016

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5.10.3 Application

The following are potential applications of oil and water separators where free oil is expected to be present at treatable high concentrations and sediment will not overwhelm the separator (Romano, 1990), (Watershed Protection Techniques, 1994), (King County, 2016). For low concentrations of oil, other treatments may be more applicable. These include sand filters (5.8 Filtration BMPs) and emerging technologies (5.11 Emerging Technologies). Table Table 5.33: Applicability of Oil and Water Separator BMPs for Runoff Treatment, Flow Control, and Conveyance summarizes the applicability of oil and water separator BMPs for runoff treatment, flow control, and conveyance.

Table 5.33: Applicability of Oil and Water Separator BMPs for Runoff Treatment, Flow Control, and Conveyance

BMP	Runoff Treatment					Flow Control	Conveyance
	Pretreatment	Basic	Metals	Oil Control	Phosphorus		
BMP T5.100: API Separator Bay				✓			
BMP T5.110: Coalescing Plate (CP) Separator Bay				✓			

Facilities that would require oil control BMPs under the high-use site definition in Chapter 2 - Core Elements for New Development and Redevelopment include parking lots at convenience stores, fast food restaurants, grocery stores, shopping malls, discount warehouse stores, banks, truck fleets, auto and truck dealerships, and delivery and commercial and industrial areas including petroleum storage yards, vehicle maintenance facilities, manufacturing areas, airports, utility areas (water, electric, gas), and fueling stations. High-ADT roadways and parking areas (defined in the glossary) also require oil control BMPs.

Without intense maintenance, oil and water separators may not be sufficiently effective in achieving oil and TPH removal down to required levels. See the recommended operation and maintenance criteria this section.

Pretreatment should be considered if the level of total suspended solids (TSS) in the inlet flow would cause clogging or otherwise impair the long-term efficiency of the separator.

For inflows from small contributing areas (fueling stations, maintenance shops, etc.), a CP-type separator is typically considered, due to space limitations. However, if plugging of the plates is likely, then a new design basis for the baffle-type API separator may be considered on an experimental basis (see “General Criteria” for the BMPs in 5.10.6 BMPs for Oil and Water Separation).

5.10.4 Cold Weather Climate Considerations

Check with the manufacturer on cold weather climate considerations.

5.10.5 Arid/Semiarid Climate Considerations

Check with the manufacturer on arid/semiarid climate considerations.

5.10.6 BMPs for Oil and Water Separation

BMP T5.100: API Separator Bay

General Criteria

Consider the following site characteristics for siting Best Management Practices (BMPs) using an American Petroleum Institute (API) separator bay:

- Sufficient land area
- Adequate total suspended solids (TSS) control or pretreatment capability
- Compliance with environmental objectives
- Adequate influent flow attenuation and/or bypass capability
- Sufficient access for operation and maintenance (O&M)

There is concern that oil and water separators used for stormwater treatment have not performed to expectations (Watershed Protection Techniques, 1994), (Schueler, 1992). Therefore, emphasis should be given to proper application (see 5.10.3 Application), design, O&M (particularly sludge and oil removal), and prevention of CP fouling and plugging (USACE, 1994). Other treatment systems, such as sand filters and emerging technologies, should be considered for the removal of insoluble oil and total petroleum hydrocarbons (TPH).

The following are design criteria applicable to API and coalescing plate (CP) oil and water separators:

- If practicable, determine oil/grease (or TPH) and TSS concentrations, lowest temperature, pH; and empirical oil rise rates in the runoff, and the viscosity, and specific gravity of the oil. Also determine whether the oil is emulsified or dissolved. Do not use oil and water separators for the removal of dissolved or emulsified oils such as coolants, soluble lubricants, glycols, and alcohols.
  - Locate the oil and water separator off-line and bypass flows in excess of the water quality design flow rate. For model time increments of 30 minutes or greater, the water quality design flow rate is the instantaneous peak flow rate calculated by the model.
  - For model time increments < 30 minutes (e.g., where the short-duration storm is applied), the water quality design flow rate is the average of the flow rates generated by the model over the peak 30-minute period.
- Use only impervious conveyances for oil-contaminated stormwater.
- Specify appropriate performance tests after installation and shakedown, and/or certification by a licensed engineer in the state of Washington that the separator is functioning in

accordance with design objectives. Expeditious corrective actions must be taken if it is determined the separator is not achieving acceptable performance levels.

- Add pretreatment for TSS that could cause clogging of the CP separator or otherwise impair the long-term effectiveness of the separator.

Separator Bays

- Size the separator bay for the water quality design flow rate as follows:
    - For model time increments of 30 minutes or greater, the water quality design flow rate is the instantaneous peak flow rate calculated by the model.
    - For model time increments < 30 minutes (e.g., where the short-duration storm is applied), the water quality design flow rate is the average of the flow rates generated by the model over the peak 30-minute period.
- To collect floatables and settleable solids, design the surface area of the forebay at 20 sf per 10,000 sf of area draining to the separator. The length of the forebay should be one-third to one-half the length of the entire separator. Include roughing screens for the forebay or upstream of the separator to remove debris, if needed. Screen openings should be about 0.75 inches.
- Include a submerged inlet pipe with a turn-down elbow in the first bay ≥ 2 feet from the bottom. The outlet pipe should be a tee, sized to pass the design peak flow and placed ≥ 12 inches below the water surface.
- Include a shutoff mechanism at the separator outlet pipe (King County, 2016).
- Use absorbents and/or skimmers in the afterbay as needed.

Baffles

- Oil-retaining baffles (top baffles) should be located ≥ at one-quarter the total separator length from the outlet and should extend down ≥ 50% of the water depth and ≥ 1 foot from the separator bottom.
- Baffle height to water depth ratios should be 0.85 for top baffles and 0.15 for bottom baffles.

Design Procedure

The design procedure for small drainages is based on the design velocity, oil rise rate, residence time, width, depth, and length considerations. The Washington State Department of Ecology (Ecology) modified the API criteria for treating stormwater runoff from small impervious contributing areas of ≤ 2 acres (e.g., fueling stations, commercial parking lots, etc.). Ecology's modified criteria differ from the API criteria as follows:

- Use the design hydraulic horizontal velocity (V_h) for the design V_h/V_t ratio, rather than the API minimum of $V_h/V_t = 15$,
- Use an oil droplet diameter (D) of 60 microns, rather than the API formula where D = (Q / (2 *

$V_h))^{1/2}$.

- Use a depth to width ratio (d/w) of 0.5, rather than the API range of 0.3 to 0.5.

Ecology considers the API criteria to be applicable for > 2 acres of impervious contributing area. Performance verification of this design basis must be obtained during at least one wet season using the test protocol referenced in Section 5.11 for new technologies.

Use Method 1 – Modified API Criteria for Small Impervious Contributing Areas for small impervious contributing areas of ≤ 2 acres and Method 2 – API Criteria for Large Impervious Contributing Areas for larger areas.

Method 1 – Modified API Criteria for Small Impervious Contributing Areas

The stepwise procedure for designing API separator bay BMPs using Ecology's modified API criterion for small impervious contributing areas of ≤ 2 acres includes the following:

1. Determine the oil rise rate (V_t) in cm/sec, using one of the following three options:
   - Stoke's Law (Water Pollution Control Federation, 1985)
   - Empirical determination
   - Default value of 0.033 feet per minute (ft/min) for a 60-micron droplet of oil

   The use of Stoke's Law or empirical rise rates is preferred over the default value because they account for the actual site-based oil droplet sizes and densities and better represent the actual site conditions.

   Stoke's Law equation for rise rate:

   ### Equation 5.11: API Separator Rise Rate (Stoke's Law) (Method 1)

   $$V_t = g * (\rho_w - \rho_o) * D^2 / (18 * \mu_w)$$

   where:

   V_t = rise rate of the oil droplet (centimeters per second [cm/sec])

   g = acceleration due to gravity (981 cm/sec²)

   ρ_w = density of water at the design temperature (0.999 gm/cc at 32 degrees Fahrenheit [°F])

   ρ_o = density of oil at the design temperature (gm/cc). Select conservatively high oil density, for example: if diesel oil @ σo = 0.85 gm/cc and motor oil @ σo = 0.90 can be present, then use σo = 0.90 gm/cc.

   D = oil droplet diameter (cm). Use oil droplet diameter d = 60 microns (0.006 cm).

   μ_w = absolute viscosity of the water (0.017921 poise at a water temperature of 32°F)

2. Use the following separator dimension criteria:

- Separator water depth (d) = ≥ 3 and ≤ 8 ft to minimize turbulence (API, 1990), (USACE, 1994)
- Separator width (w) = 6 to 20 ft (ASCE and WEF, 1998), (King County, 2016)
- Depth to width ratio (d/w) = 0.3 to 0.5 (API, 1990)

3. Calculate the minimum residence time of the separator at depth:

Equation 5.12: API Separator Minimum Residence Time (Method 1)

$$tm = d / Vt$$

where:

tm = minimum residence time (min)

d = depth (cm)

Vt = the rise rate of the oil droplet (cm/sec)

4. Calculate the horizontal velocity of the bulk fluid:

Equation 5.13: API Separator Horizontal Velocity of Bulk Fluid (Method 1)

$$V_h = Q / (d * w) = Q / A_v$$

where:

V_h = horizontal velocity of the bulk fluid (ft/min), maximum value < 2.0 ft/min (API, 1990)

Q = water quality design flow rate (cf/min), at minimum residence time (t_m)

A_v = vertical cross-sectional area (sf) = d * w

5. Determine the API turbulence and short-circuiting factor. Use Figure 5.29: Recommended Values of F for Various Values of Vh/Vt based on the ratio of the rise rate of the oil droplet to the horizontal velocity of the bulk fluid (V_h/V_t). F values range from 1.28 to 1.74. (API, 1990)

6. Calculate the minimum length of the separator section:

Equation 5.14: API Separator Minimum Length (Method 1)

$$l(s) = (F * Q * t_m) / (w * d) = F * (V_h/V_t) * d$$

Equation 5.15: API Separator Bay Length (Method 1, Equation 1)

$$l(t) = l(f) + l(s) + l(a)$$

Equation 5.16: API Separator Bay Length (Method 1, Equation 2)

$$l(t) = l(t)/3 + l(s) + l(t)/4$$

where:

l(s) = length of separator section (ft)

F = turbulence and short-circuiting factor (Figure 5.10.3)

Q = water quality design flow rate (cf/min), at minimum residence time (t_m)

t_m = minimum residence time (min)

V_h = horizontal velocity of the bulk fluid (ft/min)

V_t = oil rise rate (cm/sec)

l(t) = total length of three bays (ft)

l(f) = length of forebay (ft)

l(a) = length of afterbay (ft)

7. Calculate the minimum hydraulic design volume using:

Equation 5.17: API Separator Minimum Hydraulic Design Volume (Method 1)

$$V = l(s) * w * d = F * Q * t_m$$

where:

V = minimum hydraulic design volume (cf)

l(s) = length of separator section (ft)

w = width (ft)

d = depth (ft)

F = turbulence and short-circuiting factor (Figure 5.29: Recommended Values of F for Various Values of Vh/Vt)

Q = water quality design flow rate (cf/min), at minimum residence time (t_m)

t_m = minimum residence time (min)

8. Calculate the minimum horizontal area of the separator using:

Equation 5.18: API Separator Minimum Horizontal Area (Method 1)

$$A_h = w * l(s)$$

where:

A_h = minimum horizontal area of the separator (sf)w = width (ft)

l(s) = length of separator section (ft)

Table Table 5.34: Sizing Methods and Assumptions for BMP T5.100 API Separator Bay (Method 1) provides a summary of this sizing procedure and assumptions.

Table 5.34: Sizing Methods and Assumptions for BMP T5.100 API Separator Bay (Method 1)

Step	Variable	Methods and Assumptions	Notes/Sources
1	Oil rise rate (V_t)	Use Stoke's Law (Equation 5.11: API Separator Rise Rate (Stoke's Law) (Method 1)), empirical determination, or default value 0.033 ft/min for 60 micron droplet size oil.	Use of Stoke's Law or empirical rise rates is preferred over the default value in order to represent site conditions.
2	Separator water depth (d)	• Minimum = 3 feet • Maximum = 8 feet	(API, 1990), (USACE, 1994)
2	Separator width (w)	• Minimum = 6 feet • Maximum = 20 feet	(ASCE and WEF, 1998), (King County, 2016)
2	Depth to width ratio (d/w)	• Minimum = 0.3 • Maximum = 0.5	(API, 1990)
3	Minimum residence time (t_m)	Use Equation 5.12: API Separator Minimum Residence Time (Method 1)	(API, 1990)
4	Horizontal velocity of the bulk fluid (V_h)	• Use Equation 5.13: API Separator Horizontal Velocity of Bulk Fluid (Method 1) • Maximum < 2.0 ft/min	(API, 1990)
5	Turbulence and short-circuiting factor (F)	• Use Figure 5.29: Recommended Values of F for Various Values of Vh/Vt based on the ratio V_h/V_t • Minimum = 1.28 • Maximum = 1.74	(API, 1990)
6	Minimum length of the separator section (l(s))	Use Equation 5.14: API Separator Minimum Length (Method 1) to Equation 5.16: API Separator Bay Length (Method 1, Equation 2)	(API, 1990)
7	Minimum hydraulic design volume (V)	Use Equation 5.17: API Separator Minimum Hydraulic Design Volume (Method 1)	(API, 1990)
8	Minimum horizontal area of the separator (A_h)	Use Equation 5.18: API Separator Minimum Horizontal Area (Method 1)	(API, 1990)

Method 2 – API Criteria for Large Impervious Contributing Areas

For stormwater inflow from drainages > 2 acres, repeat Steps 1 through 8 in Method 1, above, using the following values:

Equation 5.19: API Separator Horizontal Velocity of Bulk Fluid (Method 2)

$$V_h = 15 * V_t$$

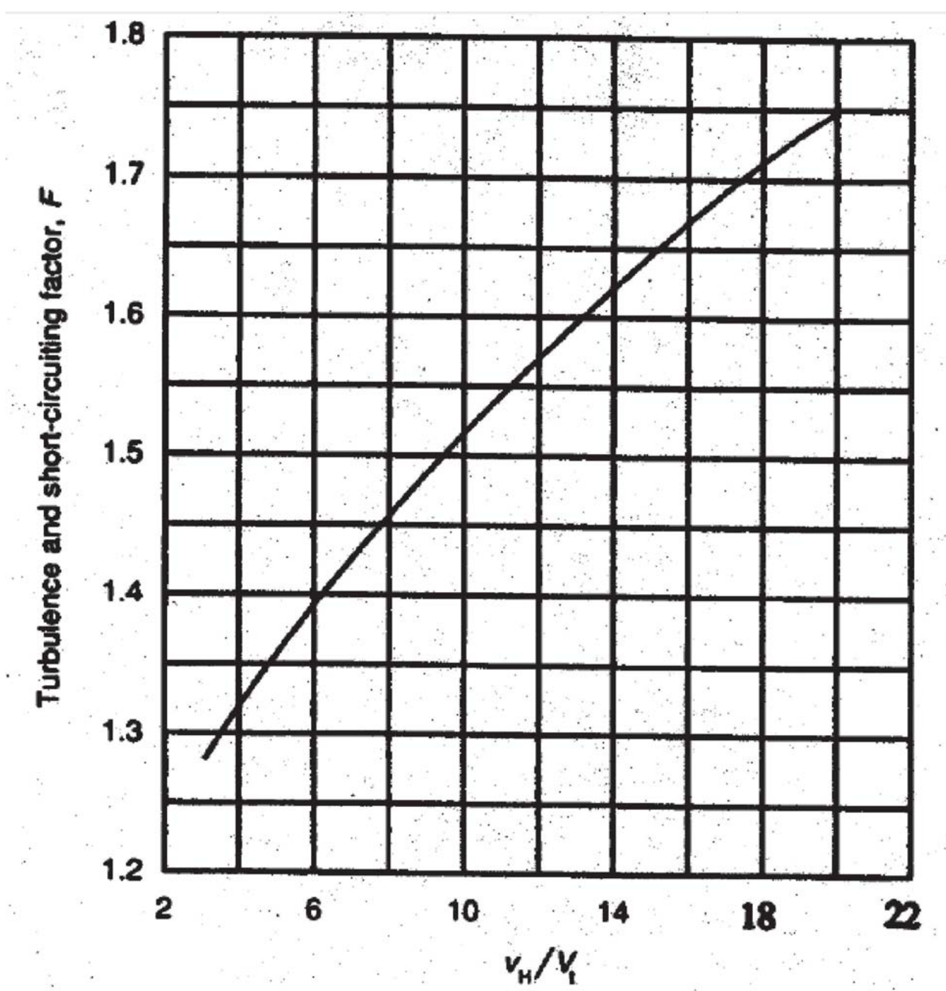
Equation 5.20: API Separator Oil Droplet Diameter (Method 2)

$$D = (Q / (2 x V_h))^{1/2}$$

Equation 5.21: API Separator Depth to Width Ratio (Method 2)

$$d/w = 0.5$$

Figure 5.29: Recommended Values of F for Various Values of V_h/V_t



v_H/V_t	Turbulence Factor (F_t)	$F = 1.2(F_t)$
20	1.45	1.74
15	1.37	1.64
10	1.27	1.52
6	1.14	1.37
3	1.07	1.28

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Recommended Values for *F* for Various Values of v_H/V_t

Revised June 2016

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Construction Criteria

Check with the manufacturer for construction criteria.

Operation and Maintenance Criteria

- Prepare, regularly update, and implement an operation and maintenance manual for the oil and water separators.
- Inspect oil and water separators monthly during the wet season of October 1 through June 30 (ASCE and WEF, 1998), (Woodward-Clyde, 1995) to ensure proper operation, and during and immediately after a large storm event of ≥ 1 inch per 24 hours. In Climate Region 2, it is most important to check these BMPs in the spring before the summer thunderstorm season begins; one annual check at this time of year should be sufficient for oil and water separators in Climate Region 2.
- Clean oil and water separators regularly to keep accumulated oil from escaping during storms. They must be cleaned by October 15 to remove material that has accumulated during the dry season (Woodward-Clyde, 1995), after all spills and after a significant storm. A Vactor truck may be used for extracting accumulated solids and oils (King County, 2016).
- Remove the accumulated oil when the thickness is ≥ 1 inch.
- Remove sediment deposits when the thickness is ≥ 6 inches (King County, 2016).
- Replace oil absorbent pads before their sorbed oil content reaches capacity.
- Train designated employees on appropriate oil and water separator operation, inspection, record keeping, and maintenance procedures.

See manufacturer's recommendations and Appendix 5-A: Recommended Maintenance Criteria for Runoff Treatment BMPs for recommended maintenance criteria.

BMP T5.110: Coalescing Plate (CP) Separator Bay

General Criteria

- Plate spacing should be a minimum of 0.75 inches (perpendicular distance between plates) (ASCE and WEF, 1998), (USACE, 1994), (USAF, 1991), (Jaisinghani and Sprenger, 1979).
- Select a plate angle between 45 and 60 degrees from the horizontal.
- Locate plate pack ≥ 6 inches from the bottom of the separator for sediment storage.
- Add 12 inches minimum head space from the top of the plate pack and the bottom of the vault cover.
- Design inlet flow distribution and baffles in the separator bay to minimize turbulence, short-circuiting, and channeling of the inflow especially through and around the plate packs of the coalescing plate (CP) separator. The Reynolds Number through the separator bay should be <500 (laminar flow).
- Include forebay for floatables and afterbay for collection of effluent (ASCE and WEF, 1998).

- The sediment-retaining baffle must be upstream of the plate pack at a minimum height of 18 inches (King County, 2016).
- Design plates for ease of removal and cleaning with high-pressure rinse or equivalent.

Design Procedure

Calculate the projected (horizontal) surface area of plates needed using the following equation:

Equation 5.22: CP Separator Horizontal Surface Area of Plates (Equation 1)

$$A_h = Q / V_t = Q / [0.00386 * (S_w - S_o/\mu_w)]$$

Equation 5.23: CP Separator Horizontal Surface Area of Plates (Equation 2)

$$A_h = A_a * (\text{cosine } b)$$

where:

A_h = horizontal surface area of the plates in square feet (sf)

Q = water quality design flow rate, cubic feet per minute (cf/min)

V_t = rise rate of the oil droplet, use 0.033 feet per minute (ft/min) or empirical determination, or based on Stoke's Law

0.00386 = unit conversion constant (dimensionless)

S_w = specific gravity of water at the design temperature (32 degrees Fahrenheit [ºF]) (dimensionless)

S_o = specific gravity of oil at the design temperature (32ºF) (dimensionless)

μ_w = absolute viscosity of the water at 32ºF (poise)

A_a = actual plate area in sf (one side only)

b = angle of the plates with the horizontal in degrees (usually varies from 45 to 60 degrees).

Construction Criteria

Check with the manufacturer for construction criteria.

Operation and Maintenance Criteria

- Prepare, regularly update, and implement an operation and maintenance manual for the oil and water separators.
- Inspect oil and water separators monthly during the wet season of October 1 through June 30 (ASCE and WEF, 1998), (Woodward-Clyde, 1995) to ensure proper operation, and during and immediately after a large storm event of ≥ 1 inch per 24 hours. In Climate Region 2, it is most important to check these BMPs in the spring before the summer thunderstorm season begins; one annual check at this time of year should be sufficient for oil and water separators

in Climate Region 2.

- Clean oil and water separators regularly to keep accumulated oil from escaping during storms. They must be cleaned by October 15 to remove material that has accumulated during the dry season (Woodward-Clyde, 1995), after all spills and after a significant storm. Coalescing plates may be cleaned in situ or after removal from the separator. A Vactor truck may be used for extracting accumulated solids and oils removal (King County, 2016).
- Remove the accumulated oil when the thickness is ≥ 1 inch.
- Remove sediment deposits when the thickness is ≥ 6 inches (King County, 2016).
- Replace oil absorbent pads before their sorbed oil content reaches capacity.
- Train designated employees on appropriate oil and water separator operation, inspection, record keeping, and maintenance procedures.

See manufacturer's recommendations and Appendix 5-A: Recommended Maintenance Criteria for Runoff Treatment BMPs for recommended maintenance criteria.