Design Manual Revision Summaries
Design Policy and Standards Revisions
May 2003 Revision
The revision starts after page 2 of this document

The Design Office is launching a new service of providing a summary of the most recent revisions to the *Design Manual*.

Design Manual

Reminder: Revision marks are used throughout to highlight content changes. This is primarily demonstrated through the use of sidebars and underlining. Manual users should periodically check the *Design Manual* Errata webpage located on the Design Policy page under "What's New". Manual users should report all undocumented errors to ensure all errors are documented.

General
- Review and update references, definitions, titles, & acronyms as appropriate.
- Clean up references to metric units of measure
- The "Documentation" subheadings are revised to direct the reader to the Documentation Check List on line.

***Design Manual* Supplements**

In alignment with the major *Design Manual* revision packages, an occasional *Design Manual* supplement may be issued. There have been three issued since May 2003. They are listed with the chapters that are affected.

Chapter 430 DM Supplement "Urban Roadways", dated 7/22/2003
Chapter 440 DM Supplement "Urban Roadways", dated 7/22/2003
Chapter 640 DM Supplement "Urban Roadways", dated 7/22/2003

Chapter 700 Roadside Safety – (May 2003)

This chapter was rewritten to:
- Incorporate the *Design Manual* Supplement - Design Clear Zone
- Provided clarification on responsibilities for establishing design clear zone – differentiating between managed and limited access, within and outside of incorporated cities and towns
- Consideration for removal of fixed objects even though outside R.O.W.
- Expanded list of fixed objects that may require mitigation

- Added policy for use Shoulder Rumble Strips on undivided highways

Chapter 1050 High Occupancy Vehicle Facilities – (May 2003)

This chapter was completely rewritten to:

- Revise and clarify terminology and references
- Revise guidance on hours of operation
- Remove guidance on Direct Access Ramps, directing the reader to use the *HOV Direct Access Design Guide*
- Rather than being recommended, Direct Access HOV connections may now be considered for an inside HOV lane
- Pros and cons of 24 hour a day HOV operation noted
- Add guidance on Barrier Separated/Separated Roadway HOV facilities
- Present design criteria for Arterial Street HOV lanes
- Revise the design of 2-lane ramp meter with bypass
- Revise figures depicting ramp configurations and flyovers

Chapter 1130 Retaining Walls and Steep Reinforced Slopes – (May 2003)

Minor revisions to this chapter included:

- Clarification on documentation required for sole source proprietary wall

Chapter 1140 Noise Barriers – (May 2003)

Minor revisions to this chapter included:

- Additional considerations for the designing and locating a noise barriers
- Added guidance on fall protection
- Added reference to the Roadside Manual for guidance on vegetation on berms and redirectional land forms

STANDARD PLAN REVISIONS
APRIL 7, 2003
46 new or revised standard plans

Significant additions

- Dowel bar retrofit details for rehabilitating cement concrete pavement
- Details for repairing cement concrete pavement
- Thrie-beam guardrail bull-nose for median installations
- Cement concrete curb designs conforming with AASHTO "Green Book"
- ADA-compliant sidewalk ramps with detectable warning strips
- ADA-compliant concrete driveway entrances
- New shoulder rumble strip plans for undivided highways
- New MUTCD-compliant work zone traffic control plans for local agencies

Washington State Department of Transportation

Publications Transmittal

Transmittal Number	Date
PT 03-034	May 2003
Publication Distribution To: All English *Design Manual* holders	
Publication Title *Design Manual* (English) Revision 2002-2	Publication Number M 22-01
Originating Organization Environmental and Engineering Service Center, Design Office, Design Policy, Standards, and Safety Research Unit through Engineering Publications	

Remarks and Instructions

Remarks:

Additional copies may be purchased from:
Washington State Department of Transportation
Finance and Administration
Directional Documents and Engineering Publications
PO BOX 47408
Olympia, WA 98504-7408

Phone: (360) 705-7430
Fax: (360) 705-6861
E-mail: engrpubs@wsdot.wa.gov

Instructions:

Page numbers and corresponding sheet-counts are given in the table below to indicate portions of the *Design Manual* that are to be removed and inserted to accomplish this revision.

Chapter	Remove		Insert	
	Pages	Sheets	Pages	Sheets
Letter's List	N/A	1	N/A	1
Contents	1 – 24	12	1 – 24	12
700, "Roadside Safety"	1 – 16	8	1 – 17	9
1050, "High Occupancy Vehicles"	1 – 36	18	1 – 16	8
1130, "Retaining Walls and Steep Slopes"	1 – 30	15	1 – 30	15
1140, "Noise Barriers"	1 – 4	2	1 – 4	2
Index	1 – 18	9	1 – 18	9

Distributed By	Phone Number	Signature
Directional Documents and Engineering Publications	(360) 705-7430 FAX: 705-6861	Stephanie Williams

Washington State Department of Transportation

Design Manual Supplements and Instructional Letters

May 2003

In Effect	Chapter	Date	Type	Subject/Title
No	**150**	**01/18/99**	**IL 4015.00**	**Right of Way Plan Development Process Improvements**
No	330			(Chapter 330 revised June 1999)
No	1410			(Chapter 1410 revised June 1999)
Yes	HOV*	9/28/99	DM Supplement	Left-Side HOV Direct Access Connections
No	940			(Chapter 940 revised September 2002)
No	**1050**			(Chapter 1050 revised May 2003)
Yes	HOV*	05/03/00	DM Supplement	Left-Side HOV Parallel On-Connection
No	**1050**			(Chapter 1050 revised May 2003)
Yes	710	08/01/01	DM Supplement	Median Barrier Guidelines
No	**700**	Revised 11/15/01		(Chapter 700 revised May 2003)
Yes	650	10/09/02	DM Supplement	Stopping Sight Distance
No	**700**	**11/01/02**	**DM Supplement**	**Design Clear Zone**
No	**325**	**1/22/2003**	**Instructional Letter 4053.00**	**Jurisdiction Over State Highways Within Cities (Revised May 5, 2003)**
No	**330**			
No	**440**			
No	**640**			
No	**700**			
Yes	325	5/5/2003	Instructional Letter 4053.00	Jurisdiction Over State Highways Within Cities
Yes	330			
Yes	440			
Yes	640			
No	**700**			(Chapter 700 revised May 2003)

* The *HOV Direct Access Design Guide*, Draft M 22-98

Notes:

- Changes since the last revision to the *Design Manual* are shown in bold print.
- Items with **No** in the **In Effect** column were superseded by the latest revision and will be dropped from the next printing of this list.
- The listed items marked *yes* have been posted to the web at the following location:

http://www.wsdot.wa.gov/fasc/engineeringpublications/DesignLettersMemInstruction.htm

Contents

Division 3 Project Documentation

Division 4 Project Design Criteria

Division 5 Soils and Paving

Division 6 Geometrics

Division 7 Roadside Safety Elements

Division 8 Traffic Safety Elements

Division 10 Auxiliary Facilities

Division 11 Structures

Division 14 Right of Way and Access Control

Figures

700.01 General

Roadside safety addresses the area outside of the roadway and is an important component of total highway design. There are numerous reasons why a vehicle leaves the roadway. Regardless of the reason, a forgiving roadside can reduce the seriousness of the consequences of a roadside encroachment. From a safety perspective, the ideal highway has roadsides and median areas that are flat and unobstructed by hazards.

Elements such as side slopes, fixed objects, and water are potential hazards that a vehicle might encounter when it leaves the roadway. These hazards present varying degrees of danger to the vehicle and its occupants. Unfortunately, geography and economics do not always allow ideal highway conditions. The mitigative measures to be taken depend on the probability of an accident occurring, the likely severity, and the available resources.

In order of preference, mitigative measures are: removal, relocation, reduction of impact severity (using breakaway features or making it traversable), and shielding with a traffic barrier. Consider cost (initial and life cycle costs) and maintenance requirements in addition to accident severity when selecting a mitigative measure. Use traffic barriers only when other measures cannot reasonably be accomplished. See Chapter 710 for additional information on traffic barriers.

700.02 References

A Policy on Geometric Design of Highways and Streets (Green Book), AASHTO, 2001

Revised Code of Washington (RCW) 47.24.020(2), "Jurisdiction, control"

RCW 47.32.130, "Dangerous objects and structures as nuisances"

City and County Design Standards (contained in the *Local Agency Guidelines,* M 36-63), WSDOT

Roadside Design Guide, AASHTO, 2002

Roadside Manual, M 25-30, WSDOT

Standard Plans for Road, Bridge, and Municipal Construction (Standard Plans), M 21-01, WSDOT

700.03 Definitions

ADT The average daily traffic for the design year under consideration.

clear run-out area The area beyond the toe of a nonrecoverable slope available for safe use by an errant vehicle.

clear zone The total roadside border area, starting at the edge of the traveled way, available for use by errant vehicles. This area may consist of a shoulder, a recoverable slope, a nonrecoverable slope, and/or a clear run-out area. The clear zone cannot contain a critical fill slope.

Design Clear Zone The minimum target value used in highway design.

critical fill slope A slope on which a vehicle is likely to overturn. Slopes steeper than 3H:1V are considered critical fill slopes.

hazard A side slope, a fixed object, or water that, when struck, can result in unacceptable impact forces on the vehicle occupants or place the occupants in a hazardous position. A hazard can be either natural or manmade.

nonrecoverable slope A slope on which an errant vehicle will continue until it reaches the bottom, without having the ability to recover control. Fill slopes steeper than 4H:1V, but no steeper than 3H:1V, are considered nonrecoverable.

recoverable slope A slope on which the driver of an errant vehicle can regain control of the vehicle. Slopes of 4H:1V or flatter are considered recoverable.

recovery area The minimum target value used in highway design when a fill slope between 4H:1V and 3H:1V starts within the Design Clear Zone.

traffic barrier A longitudinal barrier, including bridge rail or an impact attenuator, used to redirect vehicles from hazards located within an established Design Clear Zone, to prevent median crossovers, to prevent errant vehicles from going over the side of a bridge structure, or (occasionally), to protect workers, pedestrians, or bicyclists from vehicular traffic.

traveled way The portion of the roadway intended for the movement of vehicles, exclusive of shoulders and lanes for parking, turning, and storage for turning.

700.04 Clear Zone

A clear roadside border area is a primary consideration when analyzing potential roadside and median hazards (as defined in 700.05). The intent is to provide as much clear, traversable area for a vehicle to recover as practical. The Design Clear Zone is used to evaluate the adequacy of the existing clear area and proposed modifications of the roadside. When considering the placement of new objects along the roadside or median, evaluate the potential for impacts and try to select locations with the least likelihood of an impact by an errant vehicle.

(1) Design Clear Zone on All Limited Access State Highways and Other State Highways Outside Incorporated Cities and Towns

Evaluate the Design Clear Zone when the Clear Zone column on the design matrices (see Chapter 325) indicates evaluate upgrade (EU) or Full Design Level (F) or when considering the placement of a new fixed object on the roadside or median. Use the Design Clear Zone Inventory form (Figures 700-2a & 2b) to identify potential hazards and propose corrective actions.

Guidance for establishing the Design Clear Zone for highways outside of incorporated cities is provided in Figure 700-1. This guidance also applies to limited access state highways within the city limits. Providing a clear recovery area that is consistent with this guidance does not require any additional documentation. However, there might be situations where it is not practical to provide these recommended distances. In these situations, document the decision as a deviation as discussed in Chapter 330.

For additional Design Clear Zone guidance relating to roundabouts, see Chapter 915.

While not required, the designer is encouraged to evaluate potential hazards even when they are beyond the Design Clear Zone distances.

For state highways that are in an urban environment but outside of an incorporated city, evaluate both median and roadside clear zones as discussed above using Figure 700-1. However, there might be some flexibility in establishing the Design Clear Zone in urbanized areas adjacent to incorporated cities and towns. To achieve this flexibility, an evaluation of the impacts including safety, aesthetics, the environment, economics, modal needs, and access control can be used to establish the Design Clear Zone. This discussion, analysis, and agreement must take place early in the consideration of the median and roadside designs. An agreement on the responsibility for these median and roadside sections must be formalized with the city and/or county. The justification for the design decision for the selected Design Clear Zone must be documented as part of a project or corridor analysis. (See Chapter 330.)

(2) Design Clear Zone Inside Incorporated Cities and Towns

For managed access state highways within an urban area, it is recognized that in many cases it will not be practical to provide the Design Clear Zone distances shown in Figure 700-1. Roadways within an urban area generally have curbs and sidewalks and might have objects such as trees, poles, benches, trash cans, landscaping, and transit shelters along the roadside.

(a) **Roadside.** For managed access state highways, it is the city's responsibility to establish an appropriate Design Clear Zone in accordance with guidance contained in the *City and County Design Standards*. Document, in the Design Documentation Package, the Design Clear Zone established by the city.

(b) **Median.** For managed access state highways with raised medians, the median's Design Clear Zone is evaluated using Figure 700-1. In some instances, a median analysis will show that certain median designs provide significant benefits to overall corridor or project operations. In these cases, flexibility in establishing the Design Clear Zone is appropriate. To achieve this flexibility, an evaluation of the impacts (including safety, aesthetics, the environment, economics, modal needs, and access control) can be used to establish the median clear zone. This discussion, analysis, and agreement must take place early in the consideration of the flexible median design. An agreement on the responsibility for these median sections must be formalized with the city. The justification for the design decision for the selected Design Clear Zone must be documented as part of a project or corridor analysis. (See Chapter 330.)

(3) Design Clear Zone and Calculations

The Design Clear Zone guidance provided in Figure 700-1 is a function of the posted speed, side slope, and traffic volume. There are no distances in the table for 3H:1V fill slopes. Although fill slopes between 4H:1V and 3H:1V are considered traversable if free of fixed objects, these slopes are defined as nonrecoverable slopes. A vehicle might be able to begin recovery on the shoulder, but will be unable to further this recovery until reaching a flatter area (4H:1V or flatter) at the toe of the slope. Under these conditions, the Design Clear Zone distance is called a recovery area. The method used to calculate the recovery area and an example are shown in Figure 700-3.

For ditch sections, the following criteria determine the Design Clear Zone:

(a) For ditch sections with fore slopes 4H:1V or flatter (see Figure 700-4, Case 1, for an example) the Design Clear Zone distance is the greater of the following:

- The Design Clear Zone distance for a 10H:1V cut section based on speed and the average daily traffic (ADT).
- A horizontal distance of 5 ft beyond the beginning of the back slope.

When a back slope steeper than 3H:1V continues for a horizontal distance of 5 ft beyond the beginning of the back slope, it is not necessary to use the 10H:1V cut slope criteria.

(b) For ditch sections with foreslopes steeper than 4H:1V, and back slopes steeper than 3H:1V the Design Clear Zone distance is 10 ft horizontal beyond the beginning of the back slope. (See Figure 700-4, Case 2, for an example.)

(c) For ditch sections with foreslopes steeper than 4H:1V and back slopes 3H:1V or flatter, the Design Clear Zone distance is the distance established using the recovery area formula (Figure 700-3). (See also Figure 700-4, Case 3, for an example.)

700.05 Hazards to Be Considered for Mitigation

There are three general categories of hazards: side slopes, fixed objects, and water. The following sections provide guidance for determining when these obstacles present a significant hazard to an errant motorist. In addition, several conditions require special consideration:

- Locations with high accident rate histories.
- Locations with pedestrian and bicycle usage. See Chapters 1020, "Bicycle Facilities," and 1025, "Pedestrian Design Considerations."
- Playgrounds, monuments, and other locations with high social or economic value might require mitigation such as a barrier.

Use of a traffic barrier for hazards other than those described below requires justification in the Design Documentation Package.

(1) Side Slopes

(a) **Fill Slopes.** Fill slopes can present a hazard to an errant vehicle with the degree of severity dependant upon the slope and height of the fill. Providing fill slopes that are 4H:1V or flatter can mitigate this hazard. If flattening the slope is not feasible or cost effective, the installation of a barrier might be appropriate. Figure 700-5 represents a selection procedure used to determine whether a fill side slope constitutes a hazard for which a barrier is a cost-effective mitigation. The curves are based on the severity indexes and represent the points where total costs associated with a traffic barrier are equal to the predicted accident cost associated with selected slope heights without traffic barrier. If the ADT and height of fill intersect on the "Barrier Recommended" side of the embankment slope curve, then provide a barrier if flattening the slope is not feasible or cost effective. Do not use Figure 700-5 for slope design. Design guidance for slopes is in Chapters 430 and 640. Also, if the figure indicates that barrier is not recommended at an existing slope, that result is not justification for a deviation.

For example, if the ADT is 4000 and the embankment height is 10 ft, barrier will be cost effective for a 2H:1V slope, but not for a 2.5H:1V slope.

This process only addresses the potential hazard of the slope. Obstacles on the slope can compound the hazard. Where barrier is not cost effective, use the recovery area formula to evaluate fixed objects on critical fill slopes less than 10 ft high.

(b) **Cut Slopes.** A cut slope is usually less of a hazard than a traffic barrier. The exception is a rock cut with a rough face that might cause vehicle snagging rather than providing relatively smooth redirection.

Analyze the potential motorist risk and the benefits of treatment of rough rock cuts located within the Design Clear Zone. A cost-effectiveness analysis that considers the consequences of doing nothing, removal, or smoothing of the cut slope, and all other viable options to reduce the severity of the hazard, can be used to determine the appropriate treatment. Some potential options are:

- Redirectional land form.
- Flexible barrier.
- More rigid barrier.
- Rumble strips.

Conduct an individual investigation for each rock cut or group of rock cuts. Select the most cost-effective treatment.

(2) Fixed Objects

Consider the following objects for mitigation:

- Wooden poles or posts with cross sectional area greater than 16 square inches that do not have breakaway features.
- Nonbreakaway steel sign posts.
- Nonbreakaway light standards.
- Trees having a diameter of 4 in or more measured at 6 in above the ground surface.
- Fixed objects extending above the ground surface by more than 4 in; for example, boulders, concrete bridge rails, signal and electrical cabinets, piers, and retaining walls.
- Existing guardrail that does not conform to current design guidance. (See Chapter 710.)
- Drainage items, such as culvert and pipe ends.

Mitigate hazards that exist within the Design Clear Zone when feasible. Although limited in application, there may be situations where removal of hazard outside of the R.O.W is appropriate. The possible mitigative measures are listed below in order of preference.

- Remove.
- Relocate.
- Reduce impact severity (using a breakaway feature).
- Shield the object by using redirectional landform, longitudinal barrier, or impact attenuator.

(a) **Trees**. When evaluating new plantings or existing trees, consider the maximum allowable diameter of 4 in measured at 6 in above the ground when the tree has matured. When removing trees within the Design Clear Zone, complete removal of stumps is preferred. However, to avoid significant disturbance of the roadside vegetation, larger stumps may be mitigated by grinding or cutting them flush to the ground and grading around them. See the *Roadside Manual* for further guidance on the treatment of the disturbed roadside.

(b) **Mailboxes**. Ensure that all mailboxes located within the Design Clear Zone have supports and connections as shown in the Standard Plans. The height from the ground to the bottom of the mailbox is 3 ft 3 in. This height may vary from 3 ft 3 in to 4 ft if requested by the mail carrier. Include a note in the contract plans that gives the height desired if it is to be different from 3 ft 3 in. See Figure 700-6 for installation guidelines.

In urban areas where sidewalks are prevalent, contact the postal service to determine the most appropriate mailbox location. Locate mailboxes on limited access highways in accordance with the "Limited Access" Chapter in Division 14. A turnout, as shown on Figure 700-6, is not required on limited access highways with shoulders of 6 ft or more where only one mailbox is to be installed. On managed access highways, mailboxes must be on the right-hand side of the road in the direction of travel of the postal carrier. Avoid placing mailboxes along high-speed, high-volume highways. Locate Neighborhood Delivery and Collection Box Units (NDCBUs) outside the Design Clear Zone.

(c) **Culvert Ends.** Provide a traversable end treatment when the culvert end section or opening is on the roadway side slope and within the Design Clear Zone. This can be accomplished for small culverts by beveling the end to match the side slope, with a maximum of 4 in extending out of the side slope.

Bars might be necessary to provide a traversable opening for larger culverts. Place bars in the plane of the culvert opening in accordance with the Standard Plans when:

1. Single cross culvert opening exceeds 40 in measured parallel to the direction of travel.
2. Multiple cross culvert openings that exceed 30 in each, measured parallel to the direction of travel.
3. Culvert approximately parallel to the roadway that has an opening exceeding 24 in measured perpendicular to the direction of travel.

Bars are permitted where they will not significantly affect the stream hydraulics and where debris drift is minor. Consult the regional Maintenance Office to verify these conditions. If debris drift is a concern, consider options to reduce the amount of debris that can enter the pipe. (See the *Hydraulics Manual*). Other treatments are extending the culvert to move the end outside the Design Clear Zone or installing a traffic barrier.

(d) **Sign Posts.** Whenever possible, locate signs behind existing or planned traffic barrier installations to eliminate the need for breakaway posts. Place them at least 25 ft from the end of the barrier terminal and with the sign face behind the barrier. When barrier is not present, use terrain features to reduce the likelihood of an errant vehicle striking the sign posts. Whenever possible, depending on the type of sign and the sign message, adjust the sign location to take advantage of barrier or terrain features. This will reduce accident potential and, possibly, future maintenance costs. See Chapter 820 for additional information regarding the placement of signs.

Sign posts with cross sectional areas greater than 16 square inches that are within the Design Clear Zone and not located behind a barrier must have breakaway features as shown in the Standard Plans.

(e) **Traffic Signal Standards/Posts/Supports.** Breakaway signal posts generally are not practical or desirable. Since these supports are generally located at intersecting roadways, there is a higher potential for a falling support to impact vehicles and/or pedestrians. In addition, signal supports that have overhead masts may be too heavy for a breakaway design to work properly. Other mitigation such as installing a traffic barrier is also very difficult. With vehicles approaching the support from many different angles, a barrier would have to surround the support and would be subject to impacts at high angles. Therefore, barrier is generally not an option. However, since speeds near signals are generally lower and drivers are more alert, the potential for a severe impact is reduced. For these reasons, the only mitigation is to locate the support as far from the traveled way as possible.

In locations where signals are used for ramp meters, the supports can be made breakaway as shown on the Standard Plan.

(f) **Fire Hydrants.** Fire hydrants that are made of cast iron can be expected to fracture on impact and can therefore be considered a breakaway device. Any portion of the hydrants that will not be breakaway must not extend more then 4 in above the ground. In addition, the hydrant must have a stem that will shut off water flow in the event of an impact. Mitigate all other hydrants.

(g) **Utility Poles.** Since utilities often share the right of way, utility objects such as poles will often be located along the roadside. It is undesirable/impractical to install barrier for all of these objects so mitigation is usually in the form of relocation (underground or to the edge of the right of way) or delineation. In some instances where there is a history of impacts with poles and relocation is not possible, a breakaway design might be appropriate. Contact Headquarters Design for information on breakaway features. Coordinate with the Utilities Office where appropriate.

(h) **Light Standards.** Provide breakaway light standards unless fixed light standards can be justified. Fixed light standards may be appropriate in areas of extensive pedestrian concentrations, such as adjacent to bus shelters. Document the decision to use fixed bases in the Design Documentation Package.

(3) Water

Water with a depth of 2 ft or more and located with a likelihood of encroachment by an errant vehicle must be considered for mitigation on a project-by-project basis. Consider the length of time traffic is exposed to this hazard and its location in relationship to other highway features such as curves.

Analyze the potential motorist risk and the benefits of treatment of bodies of water located within the Design Clear Zone. A cost-effectiveness analysis that considers the consequences of doing nothing versus installing a longitudinal barrier can be used to determine the appropriate treatment.

700.06 Median Considerations

Medians must be analyzed for the potential of an errant vehicle to cross the median and encounter oncoming traffic. Median barriers are normally used on limited access, multilane, high-speed, high traffic volume highways. These highways generally have posted speeds of 45 mph or greater. Median barrier is not normally placed on collectors or other state highways that do not have limited access control. Providing access through median barrier requires openings and, therefore, end-treatments.

Provide median barrier on full access control, multilane highways with median widths of 50 ft or less and posted speeds of 45 mph or more. Consider median barrier on highways with wider medians or lower posted speeds when there is a history of cross median accidents.

When installing a median barrier, provide left-side shoulder widths as shown in Chapters 430 and 440 and shy distance as shown in Chapter 710. Consider a wider shoulder area where the barrier will cast a shadow on the roadway and hinder the melting of ice. See Chapter 640 for additional criteria for placement of median barrier. See

Chapter 710 for information on the types of barriers that can be used. See Chapter 650 for lateral clearance on the inside of a curve to provide the required stopping sight distance.

When median barrier is being placed in an existing median, identify the existing crossovers and enforcement observation points. Provide the necessary median crossovers in accordance with Chapter 960, considering enforcement needs.

700.07 Other Roadside Safety Features

(1) Rumble Strips

Rumble strips are grooves or rows of raised pavement markers placed perpendicular to the direction of travel to alert inattentive drivers.

There are three kinds of rumble strips:

(a) **Roadway rumble strips** are placed across the traveled way to alert drivers approaching a change of roadway condition or a hazard that requires substantial speed reduction or other maneuvering. Examples of locations where roadway rumble strips may be used are in advance of:

- Stop controlled intersections.
- Port of entry/customs stations.
- Lane reductions where accident history shows a pattern of driver inattention.

They may also be placed at locations where the character of the roadway changes, such as at the end of a freeway.

Contact the Headquarters Design Office for additional guidance on the design and placement of roadway rumble strips.

Document justification for using roadway rumble strips.

(b) **Shoulder rumble strips** are placed on the shoulders just beyond the traveled way to warn drivers when they are entering a part of the roadway not intended for routine traffic use. Shoulder rumble strips may be used when an analysis indicates a problem with run-off-the-road accidents due to inattentive or fatigued drivers. A comparison of rolled-in and milled-in Shoulder Rumble Strips (SRS) has determined that milled-in rumble strips, although more expensive, are more cost effective. Milled-in rumble strips are recommended.

When SRS are used, discontinue them where no edge stripe is present such as at intersections and where curb and gutter are present. Where bicycle travel is allowed, discontinue SRS at locations where shoulder width reductions can cause bicyclists to move into or across the area where rumble strips would normally be placed, such as shoulders adjacent to bridges with reduced shoulder widths.

SRS patterns vary depending on the likelihood of bicyclists being present along the highway shoulder, and whether they are placed on divided or undivided highways. Rumble strip patterns for undivided highways are shallower and may be narrower than patterns used on divided highways. They also provide gaps in the pattern, providing opportunities for bicycles to move across the pattern without having to ride across the grooves. There are four shoulder rumble strip patterns. Consult the Standard Plans for the patterns and construction details.

1. **Divided Highways**

SRS are required on both the right and left shoulders of rural Interstate highways. Consider them on both shoulders of rural divided highways. Use the Shoulder Rumble Strip Type 1 pattern on divided highways.

Omitting SRS on rural highways is a design exception (DE) under any one of the following conditions:

- When another project scheduled within two years of the proposed project will overlay or reconstruct the shoulders or will use the shoulders for detours.
- When a pavement analysis determines that installing SRS will result in inadequate shoulder strength.
- When overall shoulder width will be less than 4 ft wide on the left and 6 ft wide on the right.

2. **Undivided Highways**

SRS are not required on undivided highways, but may be used where run-off-the-road accident experience is high. SRS usage on the shoulders of undivided highways demands strategic application because bicycle usage is more prevalent along the shoulders of the undivided highway system. Rumble strips affect the comfort and control of bicycle riders; consequently, their use is to be limited to highway corridors that experience high levels of run-off-the-road accidents. Apply the following criteria in evaluating the appropriateness of rumble strips on the shoulders of undivided highways.

- Use on rural roads only.
- Ensure shoulder pavement is structurally adequate to support milled rumble strips.
- Posted speed is 45 mph or greater.
- Ensure that at least 4 feet of useable shoulder remains between the rumble strip and the outside edge of shoulder. If guardrail or barrier is present, increase the dimension to 5 feet of useable shoulder.
- Preliminary evaluation indicates a run-off-the-road accident experience of approximately 0.6 crashes per mile per year, or approximately 34 crashes per 100 million miles of travel. (These values are intended to provide relative comparison of crash experience and are not to be used as absolute guidance on whether rumble strips are appropriate.)
- Do not place shoulder rumble strips on downhill grades exceeding 4% for more than 500 ft in length along routes where bicyclists are frequently present.
- An engineering analysis indicates a run-off-the-road accident experience considered correctable by shoulder rumble strips.
- Consult the regional members of the Washington Bicycle and Pedestrian Advisory Committee to determine bicycle usage along a route, and involve them in the decision-making process when considering rumble strips along bike touring routes or other routes where bicycle events are regularly held.

The Shoulder Rumble Strip Type 2 or Type 3 pattern is used on highways with minimal bicycle traffic. When bicycle traffic on the shoulder is high, the Shoulder Rumble Strip Type 4 pattern is used.

Shoulder rumble strip installation considered at any other locations must involve the WSDOT Bicycle and Pedestrian Advisory Committee as a partner in the decision-making process.

Consult the following website for guidance on conducting an engineering analysis:

http://www.wsdot.wa.gov/EESC/Design/Policy/RoadsideSafety/Chapter700/Chapter700B.htm

(c) **Center line rumble strips** are placed on the center line of undivided highways to alert drivers that they are entering the opposing lane. They are a countermeasure for crossover accidents. Consult the Headquarters Design Office and the region's Traffic Engineer for guidance on center line rumble strips.

(2) Headlight Glare Considerations

Headlight glare from opposing traffic can cause safety problems. Glare can be reduced by the use of wide medians, separate alignments, earth mounds, plants, concrete barriers, and by devices known as glare screens specifically designed to reduce glare. Consider long term maintenance when selecting the treatment for glare. When considering earth mound and planting to reduce glare, see the *Roadside Manual* for additional guidance. When considering glare screens, see Chapter 650 for lateral clearance on the inside of a curve to provide the required stopping sight distance. In addition to reducing glare, taller concrete barriers also provide improved crash performance for larger vehicles such as trucks.

Glare screen is relatively expensive and its use must be justified and documented. It is difficult to justify the use of glare screen where the median width exceeds 20 ft, the ADT is less than 20,000 vehicles per day, or the roadway has continuous lighting. Consider the following factors when assessing the need for glare screen:

- Higher rate of night accidents compared to similar locations or statewide experience.
- Higher than normal ratio of night to day accidents.
- Unusual distribution or concentration of nighttime accidents.
- Over representation of older drivers in night accidents.
- Combination of horizontal and vertical alignment, particularly where the roadway on the inside of a curve is higher than the roadway on the outside of the curve.
- Direct observation of glare.
- Public complaints concerning glare.

The most common glare problem is between opposing main line traffic. Other conditions for which glare screen might be appropriate are:

- Between a highway and an adjacent frontage road or parallel highway, especially where opposing headlights might seem to be on the wrong side of the driver.
- At an interchange where an on-ramp merges with a collector distributor and the ramp traffic might be unable to distinguish between collector and main line traffic. In this instance, consider other solutions, such as illumination.
- Where headlight glare is a distraction to adjacent property owners. Playgrounds, ball fields, and parks with frequent nighttime activities might benefit from screening if headlight glare interferes with these activities.

There are currently three basic types of glare screen available: chain link (see Standard Plans), vertical blades, and concrete barrier. (See Figure 700-7.)

When the glare is temporary (due to construction activity), consider traffic volumes, alignment, duration, presence of illumination, and type of construction activity. Glare screen may be used to reduce rubbernecking associated with construction activity, but less expensive methods, such as plywood that seals off the view of the construction area, might be more appropriate.

700.08 Documentation

A list of documents that are required to be preserved in the Design Documentation Package (DDP) or the Project File (PF) is on the following website:

http://www.wsdot.wa.gov/eesc/design/projectdev/

<u>Design</u> Clear Zone Distances <u>for State Highways Outside Incorporated Cities</u>**
(In feet from edge of traveled way*)**

Posted Speed mph	Average Daily Traffic	Cut Section (Back Slope) (H:V) 3:1	4:1	5:1	6:1	8:1	10:1	Fill Section (H:V) 3:1	4:1	5:1	6:1	8:1	10:1
35 or Less	The Design Clear Zone-distance is 10 feet												
40	Under 250	10	10	10	10	10	10	*	13	12	11	11	10
	251-800	11	11	11	11	11	11	*	14	14	13	12	11
	801-2000	12	12	12	12	12	12	*	16	15	14	13	12
	2001-6000	14	14	14	14	14	14	*	17	17	16	15	14
	Over 6000	15	15	15	15	15	15	*	19	18	17	16	15
45	Under 250	11	11	11	11	11	11	*	16	14	13	12	11
	251-800	12	12	13	13	13	13	*	18	16	14	14	13
	801-2000	13	13	14	14	14	14	*	20	17	16	15	14
	2001-6000	15	15	16	16	16	16	*	22	19	17	17	16
	Over 6000	16	16	17	17	17	17	*	24	21	19	18	17
50	Under 250	11	12	13	13	13	13	*	19	16	15	13	13
	251-800	13	14	14	15	15	15	*	22	18	17	15	15
	801-2000	14	15	16	17	17	17	*	24	20	18	17	17
	2001-6000	16	17	17	18	18	18	*	27	22	20	18	18
	Over 6000	17	18	19	20	20	20	*	29	24	22	20	20
55	Under 250	12	14	15	16	16	17	*	25	21	19	17	17
	251-800	14	16	17	18	18	19	*	28	23	21	20	19
	801-2000	15	17	19	20	20	21	*	31	26	23	22	21
	2001-6000	17	19	21	22	22	23	*	34	29	26	24	23
	Over 6000	18	21	23	24	24	25	*	37	31	28	26	25
60	Under 250	13	16	17	18	19	19	*	30	25	23	21	20
	251-800	15	18	20	20	21	22	*	34	28	26	23	23
	801-2000	17	20	22	22	23	24	*	37	31	28	26	25
	2001-6000	18	22	24	25	26	27	*	41	34	31	29	28
	Over 6000	20	24	26	27	28	29	*	45	37	34	31	30
65	Under 250	15	18	19	20	21	21	*	33	27	25	23	22
	251-800	17	20	22	22	24	24	*	38	31	29	26	25
	801-2000	19	22	24	25	26	27	*	41	34	31	29	28
	2001-6000	20	25	27	27	29	30	*	46	37	35	32	31
	Over 6000	22	27	29	30	31	32	*	50	41	38	34	33
70	Under 250	16	19	21	21	23	23	*	36	29	27	25	24
	251-800	18	22	23	24	26	26	*	41	33	31	28	27
	801-2000	20	24	26	27	28	29	*	45	37	34	31	30
	2001-6000	22	27	29	29	31	32	*	50	40	38	34	33
	Over 6000	24	29	31	32	34	35	*	54	44	41	37	36

* When the fill section slope is steeper than 4H:1V but not steeper than 3H:1V, the Design Clear Zone distance <u>is</u> modified by the recovery area formula (Figure 700-3) and is referred to as the recovery area. The basic philosophy behind the recovery area formula is that a vehicle can traverse these slopes but cannot recover (control steering) and, therefore, the horizontal distance of these slopes is added to the <u>Design</u> Clear Zone distance to form the recovery area.

<u>** This figure also applies to limited access state highways in cities and median areas on managed access state highways in cities. See 700.04 for guidance on managed access state highways within incorporated cities.</u>

<u>*** See 700.03 for definition of traveled way.</u>

Design Clear Zone Distance Table

Figure 700-1

Washington State
Department of Transportation

Design Clear Zone Inventory

Region	SR	Control Section	MP	to MP	Date
Project Number	Project Title		Responsible Unit		

Item Number	MP to MP	Distance From Traveled Way L	Distance From Traveled Way R	Description	Corrective Actions Considered (2)	Estimated Cost to Correct	Correction Planned (1) Yes	Correction Planned (1) No

(1) Only one "Yes" or "No" per item number. Corrections not planned must be explained on reverse side.
(2) A list of Location 1 & 2 Utility Objects to the forwarded to the region Utility Office for coordination per Control Zone Guidelines.

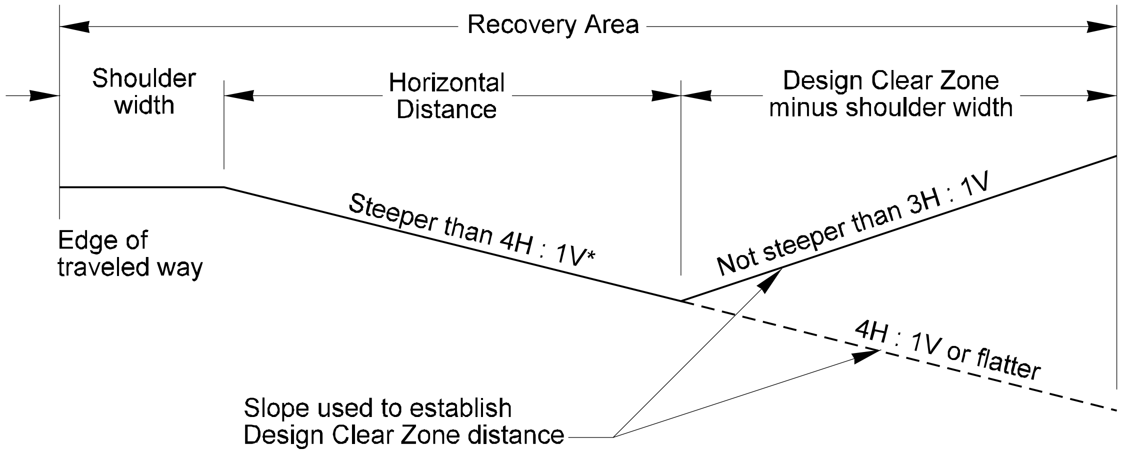
DOT Form 410-026 EF
Revised 9/02

Design Clear Zone Inventory Form
Figure 700-2a

Item Number	Reasons for Not Taking Corrective Action

DOT Form 410-026 EF
Revised 9/02

Design Clear Zone Inventory Form
Figure 700-2b

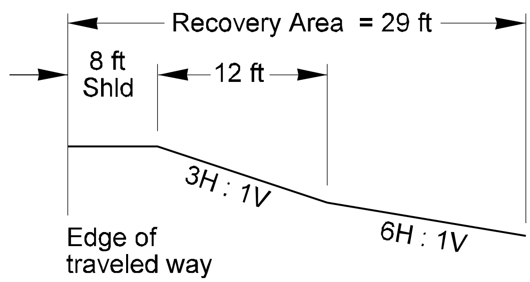


*Recovery area normally applies to slopes steeper than 4H:1V but no steeper than 3H:1V. For steeper slopes, the recovery area formula may be used as a guide if the embankment height is 10 ft or less.

Formula:

Recovery area = (shoulder width) + (horizontal distance)
+ (Design Clear Zone distance - shoulder width)

Example:



Fill section (slope 3H:1V or steeper)

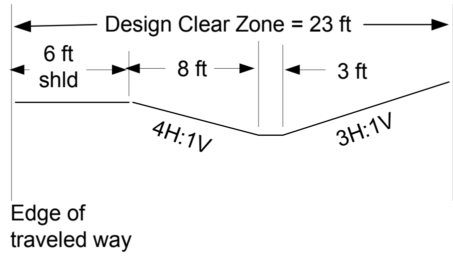
Conditions: Speed - 45 mph
Traffic - 3000 ADT
Slope - 3H:1V

Criteria: Slope 3H:1V - use
Recovery area formula

Recovery area = (shoulder width) + (horizontal distance)
+ (Design Clear Zone distance - shoulder width)
= 8 + 12 + (17 - 8)
= 29 ft

Recovery Area
Figure 700-3

Cut section with ditch (foreslope 4H:1V or flatter)



Conditions: Speed - 55 mph

Traffic - 4200 ADT

Slope - 4H:1V

Criteria: Greater of

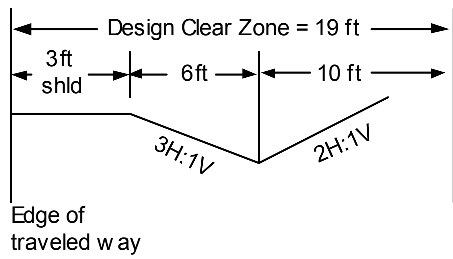
(1) Design Clear Zone for 10H:1V Cut Section, 23 ft

(2) 5 ft horizontal beyond beginning of back slope, 22 ft

Design Clear Zone = 23 ft

Case 1

Cut section with ditch (foreslope 3H:1V or steeper and back slope steeper than 3H:1V)



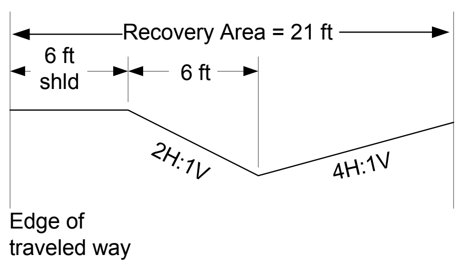
Conditions: NA

Criteria: 10 ft horizontal beyond beginning of back slope

Design Clear Zone = 19 ft

Case 2

Cut section with ditch (foreslope 3H:1V or steeper and back slope not steeper than 3H:1V)



Conditions: Speed - 45 mph

Traffic - 3000 ADT

Foreslope - 2H:1V

Back slope 4H:1V

Criteria: Use recovery area formula

Recovery Area = (shoulder width) + (horizontal distance) + (Design Clear Zone distance - shoulder width)

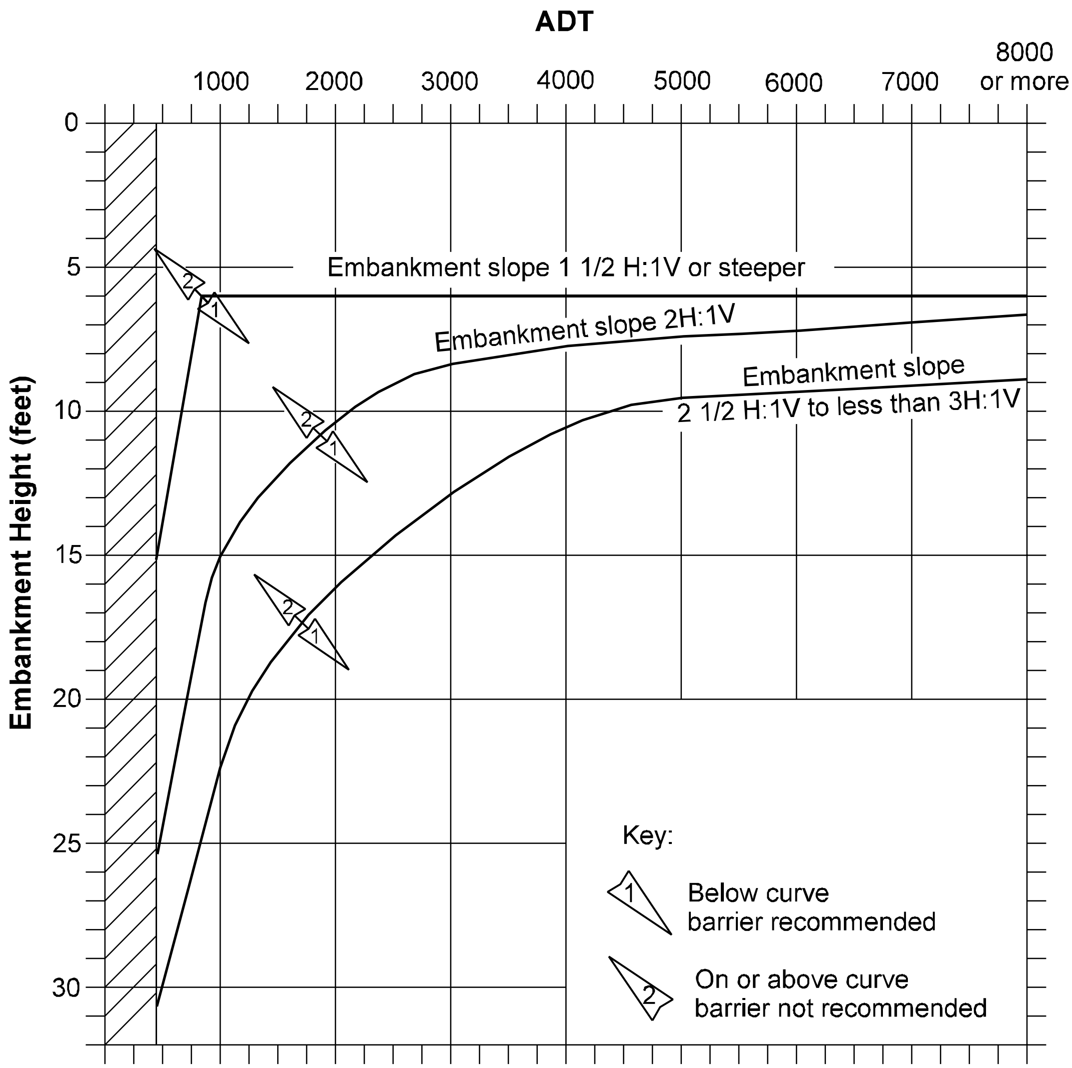
= 6 + 6 + (15 - 6)

= 21 ft

Case 3

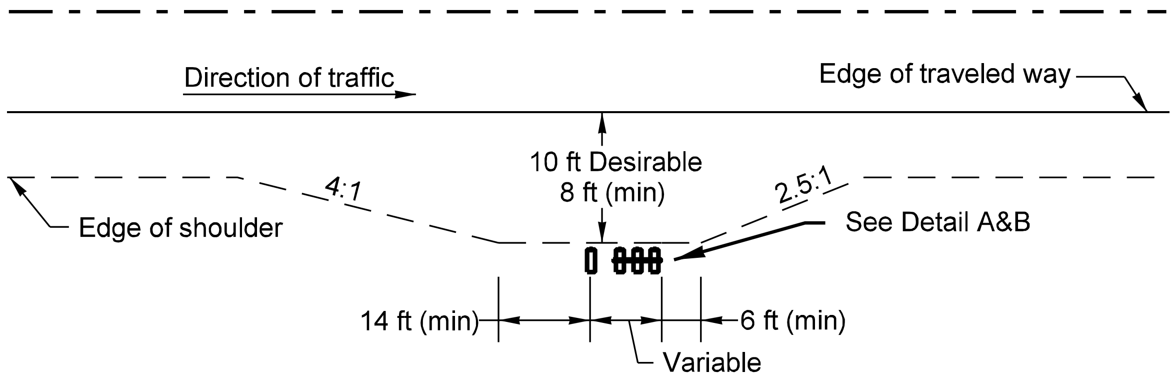
Design Clear Zone for Ditch Sections

Figure 700-4

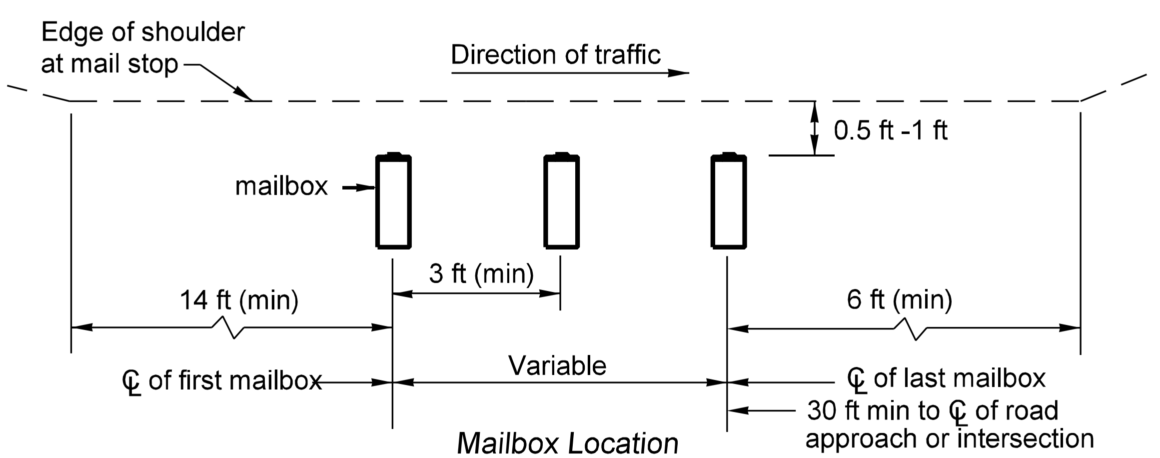


Note: Routes with ADTs under 400 may be evaluated on a case by case basis.

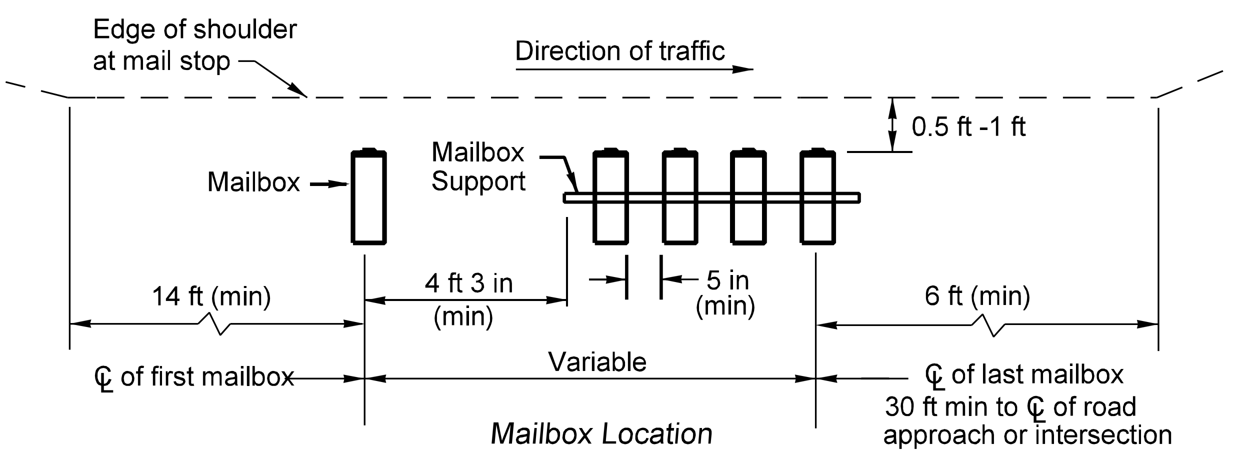
Guidelines for Embankment Barrier
Figure 700-5



Mailbox Turnout

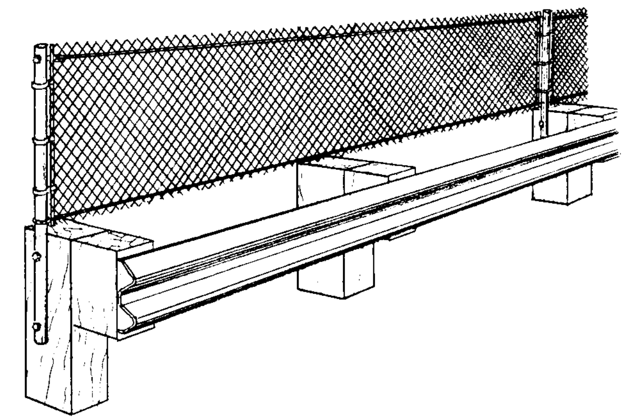


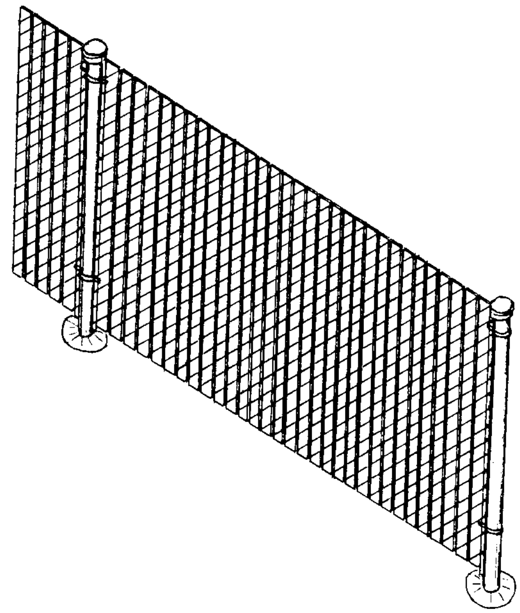
Mailbox Location
Single Box Design
Detail A



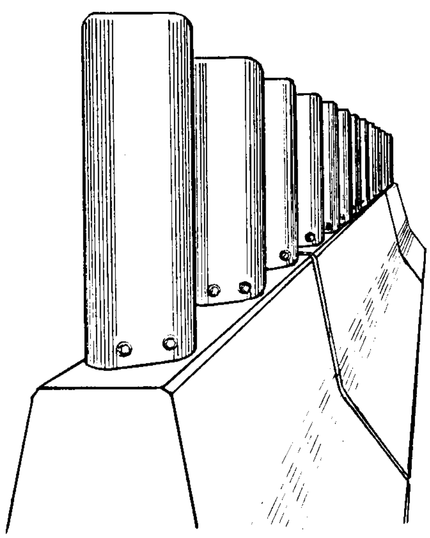
Mailbox Location
Multiple Box Design
Detail B

Mailbox Location and Turnout Design
Figure 700-6

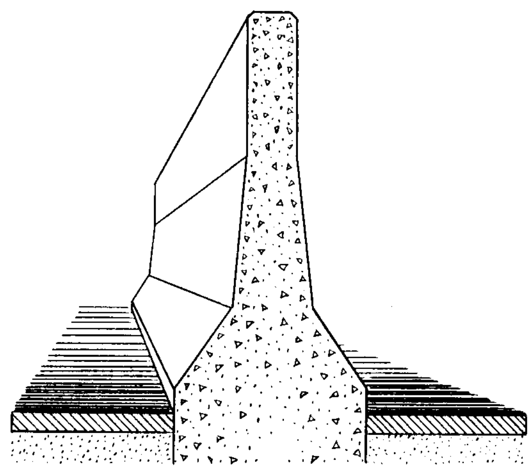




Chain Link



Vertical Blades



Concrete Barrier

Glare Screens
Figure 700-7

1050.01 General

High occupancy vehicle (HOV) facilities include separate HOV roadways, HOV lanes, transit lanes, HOV direct access ramps, and flyer stops. The objectives for the HOV facilities are:

- Improve the capability of corridors to move more people by increasing the number of people per vehicle.
- Provide travel time savings and a more reliable trip time to HOV lane users.
- Provide safe travel options for HOVs without adversely affecting the safety of the general-purpose lanes.

Plan, design, and construct HOV facilities that ensure intermodal linkages. Give consideration to future highway system capacity needs. Whenever possible, design HOV lanes so that the level of service for the general-purpose lanes will not be degraded.

In urban corridors that do not currently have planned or existing HOV lanes, complete an analysis of the need for HOV lanes before proceeding with any projects for additional general-purpose lanes. In corridors where both HOV and general-purpose facilities are planned, construct the HOV lane before or simultaneously with the construction of new general-purpose lanes.

See the following chapters for additional information:

Chapter	Subject
430	general-purpose roadway widths for modified design level
440	general-purpose roadway widths for full design level
640	general-purpose turning roadway widths and other cross section data

1050.02 References

Revised Code of Washington (RCW) 46.61.165, High-occupancy vehicle lanes

RCW 47.52.025, Additional powers — Controlling use of limited access facilities — High-occupancy vehicle lanes

Washington Administrative Code (WAC) 468-510-010, High occupancy vehicles (HOVs)

Standard Plans for Road, Bridge, and Municipal Construction (Standard Plans), M 21-01, Washington State Department of Transportation (WSDOT)

HOV Direct Access Design Guide, Draft, M 22-98, WSDOT

Manual on Uniform Traffic Control Devices for Streets and Highways (MUTCD), 2000, U.S. Department of Transportation, Federal Highway Administration; including the *Washington State Modifications to the MUTCD*, M 24-01, WSDOT

Traffic Manual, M 51-02, WSDOT

Guide for the Design of High Occupancy Vehicle Facilities, American Association of State Highway and Transportation Officials (AASHTO)

Design Features of High Occupancy Vehicle Lanes, Institute of Traffic Engineers (ITE)

High-Occupancy Vehicle Facilities: Parsons Brinkerhoff, Inc.

NCHRP Report 414, *HOV Systems Manual*

1050.03 Definitions

buffer-separated HOV lane An HOV lane that is separated from the adjacent same direction general-purpose freeway lanes by a designated buffer.

bus rapid transit (BRT) An express rubber tired transit system operating predominantly in roadway managed lanes. It is generally characterized by separate roadway or buffer-separated HOV lanes, HOV direct access ramps, and a high occupancy designation (3+ or higher).

business access transit (BAT) lanes A transit lane that allows use by other vehicles to access abutting businesses.

enforcement area A place where vehicles may be stopped for ticketing by law enforcement. It also may be used as an observation point and for emergency refuge.

enforcement observation point A place where a law enforcement officer may park and observe traffic.

flyer stop A transit stop inside the limited access boundaries.

high occupancy toll (HOT) lane A managed lane that combines a high occupancy vehicle lane and a toll lane.

high occupancy vehicle (HOV) A vehicle that fits one of the following:

(1) Rubber tired municipal transit vehicles.

(2) Buses with a carrying capacity of sixteen or more persons, including the operator.

(3) Motorcycles.

(4) Recreational vehicles that meet the occupancy requirements of the facility.

(5) All other vehicles that meet the occupancy requirements of the facility, except trucks in excess of 10,000 lb gross vehicle weight.

HOV direct access ramp An on or off ramp exclusively for the use of HOVs that provides access between a freeway HOV lane and a street, transit support facility, or another freeway HOV lane without weaving across general-purpose lanes.

HOV facility A priority treatment for HOVs.

level of service A qualitative measure describing operational conditions within a traffic stream, incorporating factors of speed and travel time, freedom to maneuver, traffic interruptions, comfort and convenience, and safety.

managed lane A lane that increases efficiency by packaging various operational and design actions. Lane management operations may be adjusted at any time to better match regional goals.

nonseparated HOV lane An HOV lane that is adjacent to and operates in the same direction as the general-purpose lanes with unrestricted access between the HOV lane and the general-purpose lanes.

occupancy designation The minimum number of occupants required for a vehicle to use the HOV facility.

separated HOV facility An HOV roadway that is physically separated from adjacent general-purpose lanes by a barrier, median, or on a separate right of way.

single occupant vehicle (SOV) Any motor vehicle other than a motorcycle carrying one occupant.

transit lane A lane for the exclusive use of transit vehicles.

violation rate The total number of violators divided by the total number of vehicles on an HOV facility.

1050.04 Preliminary Design and Planning

(1) Planning Elements for Design

In order to determine the appropriate design options for an HOV facility, the travel demand and capacity must first be established; identify suitable corridors, evaluate the HOV facility location and length, and estimate the HOV demand. A viable HOV facility will satisfy the following criteria:

- Be part of an overall transportation plan.
- Have the support of the community and public.

- Respond to demonstrated congestion or near-term anticipated congestion: Level of Service E or F for at least one hour of peak period (traffic approaching a capacity of 1,700 to 2,000 vehicles per hour per lane) or average speeds less than 30 mph during peak periods over an extended distance.
- Except for a bypass of a local bottleneck, be of sufficient length to provide a travel time saving of at least 5 minutes during the peak periods.
- Have sufficient numbers of HOV users for a cost-effective facility and to avoid the perception of under utilization. (HOV volumes of 400 to 500 vehicles per hour on nonseparated lanes and 600 to 800 on separated facilities.)
- Provide a safe, efficient, and enforceable operation.

A queue or bottleneck bypass can be effective without satisfying all of the above. An isolated bypass can be viable when there is localized, recurring traffic congestion, and such treatment will provide a travel time saving to an adequate number of HOV users.

The efficiency of the HOV facility can be affected by the access provisions. Direct access between park and ride/transit facilities and an HOV lane is the most desirable, but it is also an expensive alternative. Direct access options are discussed in the *HOV Direct Access Design Guide*.

Document the need for the HOV lane and how the proposed lane will meet those needs.

(2) HOV Facility Type

Make a determination as to the type of HOV lane. The three major choices are separated roadway, buffer-separated lane, and nonseparated HOV lane.

(a) **Separated Roadway.** The separated roadway can be either a one-way reversible or a two-way operation. The directional split in the peak periods, space available, and operating logistics are factors to be considered. A separated HOV roadway may be located in the median of the freeway, next to the freeway, or on an independent alignment. Separated HOV facilities are more effective for:

- Large HOV volumes.
- Large merging and weaving volumes.
- Long-distance HOV travel.

Reversible, separated roadways operate effectively where there are major directional splits during peak periods. Consider potential changes in this traffic pattern and designing the facility to accommodate possible conversion to two-way operation. The separated roadway is normally more efficient, provides for the higher level of safety, and is more easily enforced. However, it is generally the most expensive type of HOV facility to implement.

(b) **Buffer-Separated.** A buffer-separated HOV lane is similar to a freeway nonseparated HOV lane on the left, but with a buffer between the HOV lane and the general-purpose lanes. The addition of a buffer provides better delineation between the lanes and controls access between the HOV lane and general-purpose lanes to improve operation.

(c) **Nonseparated.** Nonseparated HOV lanes operate in the same direction and immediately adjacent to the general-purpose lanes. They are located either to the left (preferred) or to the right of the general-purpose lanes. Nonseparated HOV lanes are normally cheaper, easier to implement, and provide more opportunity for frequent access. However, the ease of access can create more problems for enforcement and a higher potential for conflicts.

(3) Freeway Operational Alternatives

For an HOV lane on a limited access facility, consider the following operational alternatives:

- Inside (preferred) or outside HOV lane.
- Lane conversion.
- Use of existing shoulder (not recommended for permanent operations).
- HOV direct access ramps.
- Queue bypasses.
- Flyer stops.
- Hours of operation.

When evaluating alternatives, consider a combination of alternatives to provide the best solution for the corridor. Also, incorporate flexibility into the design in order not to preclude potential changes in operation, such as outside-to-inside lane and reversible to two-way operations. Access, freeway-to-freeway connections, and enforcement will have to be accommodated for such changes. Document the operational alternatives.

(a) **Inside Versus Outside HOV Lane.** System continuity and consistency of HOV lane placement along a corridor are important and influence facility development decisions. Other issues include land use, trip patterns, transit vehicle service, HOV volume, ramp volume, congestion levels, safety, enforcement, and direct access to facilities.

The inside (left) HOV lane is most appropriate for a corridor with long distance trip patterns, such as a freeway providing mobility to and from a large activity center. These trips are characterized by long distance commuters and express transit service. Maximum capacity for an effective inside HOV lane is approximately 1,500 vehicles per hour. When the HOVs weaving across the general-purpose lanes cause severe congestion, consider implementing HOV direct access ramps, separated HOV roadways, or a higher occupancy designation. Inside lanes are preferred for HOV lanes on freeways.

The outside (right) HOV lane is most appropriate for a corridor with shorter, widely dispersed trip patterns. These trip patterns are characterized by transit vehicle routes that exit and enter at nearly every interchange. The maximum capacity for an effective outside HOV lane is reduced and potential conflicts are increased by heavy main line congestion and large entering and exiting general-purpose volumes.

(b) **Conversion of a General-Purpose Lane.** The use of an existing general-purpose lane for an HOV lane is not a preferred option; however, conversion of a lane to an HOV lane might be justified when the conversion provides greater people-moving capability on the roadway. Use of an existing freeway lane as an HOV lane will be considered only with a deviation.

Given sufficient existing capacity, converting a general-purpose lane to an HOV lane will provide for greater people moving capability in the future without significantly affecting the existing roadway operations. The fastest and least expensive method for providing an HOV lane is through conversion of a general-purpose lane. Restriping and signing are sometimes all that is needed. Converting a general-purpose lane to HOV use will likely have environmental benefits. This method, however, is controversial from a public acceptance standpoint. Public support might be gained through an effective public involvement program. See Chapter 210, Public Involvement and Hearings.

Lane conversion of a general-purpose lane to an HOV lane must enhance the corridor's people moving capacity. It is critical that an analysis be conducted that includes:

- Public acceptance of the lane conversion.
- Present and long-term traffic impacts on the adjacent general-purpose lanes and the HOV lane.
- Impacts to the neighboring streets and arterials.
- Legal, environmental, and safety impacts.

(c) **Use of Existing Shoulder.** When considering the alternatives in order to provide additional width for an HOV lane, the use of the existing shoulder is not a preferred option. Use of the shoulder on a freeway or freeway ramp as an HOV lane will be considered only with a deviation.

Consider shoulder conversion to an HOV lane when traffic volumes are heavy and the conversion is a temporary measure. Another alternative is to use the shoulder as a permanent measure to serve as a transit-only or queue bypass lane during peak hours and then revert to a shoulder in off peak hours. The use of the shoulder creates special signing, operational, and enforcement problems. An agreement is required with the transit agency to ensure that transit vehicles will only use the shoulder during peak hours. The use of the shoulder must be clearly defined by signs. Institute special operations to ensure the shoulder is clear and available for the designated hours.

The existing shoulder pavement is often not designed to carry heavy volumes of vehicles, especially transit vehicles. As a result, repaving and reconstruction of the shoulder might be required.

(d) **HOV Direct Access Ramps.** To improve the efficiency of an HOV system, exclusive HOV access connections for an inside HOV lane may be considered. See the *HOV Direct Access Design Guide* for information on HOV direct access connections. Direct access reduces the need for HOVs to cross the general-purpose lanes from right side ramps. Transit vehicles will be able to use the HOV lane and provide service to park and ride lots, flyer stops, or other transit stops by the HOV direct access ramps.

(e) **Queue Bypass Lanes.** A queue bypass lane allows HOVs to save time by avoiding congestion at an isolated bottleneck. An acceptable time saving for a queue bypass is one minute or more. Typical locations for queue bypasses are at ramp meters, signalized intersections, toll plaza or ferry approaches, and locations with isolated main line congestion. By far the most common use is with ramp metering. Queue bypass lanes can be built along with a corridor HOV facility or independently. In most cases, they are relatively low cost and easily implemented. Where practical, include HOV bypasses on ramp metering sites or make provisions for their future accommodation, unless specific location conditions dictate otherwise.

(f) **Flyer Stops.** Flyer stops reduce the time required for express transit vehicles to serve intermediate destinations. However, passengers must travel greater distances to reach the loading platform. For information on flyer stops, see the *HOV Direct Access Design Guide*.

(g) **Hours of Operation.** HOV designation on freeway HOV lanes 24 hours a day provides benefits to users during off peak periods, minimizes potential confusion, makes enforcement easier, and simplifies signing and striping. However, 24-hour operation also might result in a lane not used during off peak periods, negative public opinion, and the need for full time enforcement.

(4) Arterial Street Operational Alternatives

Arterial street HOV lanes also have a variety of HOV alternatives to be considered. Some of these alternatives are site specific or have limited applications. Arterial HOV lanes differ from freeway HOV lanes in slower speeds, little access control (turning traffic can result in right angle conflicts), and traffic signals. Arterial HOV lanes are occasionally designated for transit vehicles only, especially in cities with a large concentration of transit vehicles. When evaluating alternatives consider traffic signal queues and managed access highway class. The alternatives include:

- Type of lane.
- Left side or right side HOV lane.
- Hours of operation.
- Spot treatments.
- Bus stops.

When evaluating alternatives, consider a combination of alternatives to provide the best solution for the corridor. Also, incorporate flexibility into the design in order not to preclude potential changes in operation. Document the operational alternatives.

(a) **Type of lane.** Lanes can be transit only or include all HOVs. Transit only lanes are desirable where bus volumes are high with a high level of congestion. They will increase the speed of transit vehicles through congested areas and improve the reliability of the transit service. Lanes that allow use by all HOVs are appropriate on corridors with high volumes of carpools and vanpools. They can collect carpools and vanpools in business and industrial areas and connect them to the freeway system.

(b) **Left side or right side HOV lane.** Continuity of HOV lane location along a corridor is an important consideration when making the decision whether to locate an arterial street HOV lane on the left or right side of the street. Other issues include land use, trip patterns, transit vehicle service, safety, enforcement, and presence of parking.

The right side is the preferred location for arterial street HOV lanes on transit routes with frequent stops. It is the most convenient for passenger boarding at transit stops. It is also the most common location for HOV lanes on arterial streets. General-purpose traffic must cross the HOV lane to make a right-turn at intersections and to access driveways. These turns across the HOV lane can create conflicts. Minimizing access points that create these conflict locations is recommended. Other issues to consider are on street parking, stopping area for delivery vehicles, and enforcement areas.

Left side arterial street HOV lanes are less common than right side lanes. HOV lanes on the left eliminate the potential conflicts with driveway access, on street parking, and stopping area for delivery vehicles. The result is fewer delays and higher speeds making left side arterial street HOV lanes appropriate for longer distance trips. Disadvantages are the difficulty providing transit stops and the need to provide for left turning general-purpose traffic.

(c) **Hours of operation.** An arterial street HOV lane can either operate as an HOV lane 24 hours a day or during peak hours only. Factors to consider in determining which to use include type of HOV lane, level of congestion, continuity, and enforcement.

HOV lanes operating 24 hours a day are desirable when congestion and HOV demand exists for extended periods throughout the day. The 24 hour operation provides benefits to users during off peak periods, minimizes potential confusion, makes enforcement easier, and simplifies signing and striping. Disadvantages are negative public opinion if the lane is not used during off peak periods, the need for full time enforcement, and the loss of on street parking.

Peak period HOV lanes are appropriate for arterial streets with HOV demand or congestion existing mainly during the peak period. Peak period HOV lanes provide HOV priority at the critical times of the day, lessen the negative public perception of the HOV lane, and allow on street parking or other shoulder uses at other times. The disadvantages include possible confusion to the drivers, more difficult enforcement, increased signing, and the need to institute special operations to ensure the shoulder or lane is clear and available for the designated period.

(d) **Spot Treatments.** A spot HOV treatment is used to give HOVs priority around a bottleneck. It can provide time savings, travel time reliability, and improve access to other facilities. Examples include a short HOV lane to provide access to a freeway on-ramp, one lane of a dual turn-lane, a priority lane at ferry terminals, and priority at traffic signals.

Signal priority treatments that alter the sequence or duration of a traffic signal are techniques for providing preferential treatment for transit vehicles. The priority treatments can range from timing and phasing adjustments to signal preemption. Consider the overall impact on traffic. Preemption would normally not be an appropriate treatment where traffic signal timing and coordination are being utilized or where there are high volumes on the cross streets.

(e) **Bus stops.** Normally, with arterial HOV lanes, there is not a shoulder suitable for a bus to use while stopped to load and unload passengers without blocking the lane. Therefore, bus stops are either in-lane or in a pullout. In-lane bus stops are the simplest type of bus stop. However, stopped buses will block the HOV lane; therefore, in-lane bus stops are only allowed in transit lanes. Bus pullouts provide an area for buses to stop without blocking the HOV lane. Disadvantages include higher cost, reduced width for the sidewalk or other roadside area, and possible difficulty reentering the HOV lane. See Chapter 1060 for additional information on bus stop location and design.

1050.05 Operations

(1) Vehicle Occupancy Designation

Select the vehicle occupancy designation to provide the maximum movement of people in a corridor, provide free-flow HOV operations, reduce the empty lane perception, provide for the ability to accommodate future HOV growth within a corridor, and be consistent with the regional transportation plan and the policies adopted by the metropolitan planning organization (MPO).

An initial occupancy designation must be established. It is WSDOT policy to use the 2+ designation as the initial occupancy designation. Consider a 3+ occupancy designation if it is anticipated during initial operation that the volumes will be 1,500 vehicles per hour for a left-side HOV lane, or 1,200 vehicles per hour for a right-side HOV lane, or that a 45 mph operating speed cannot be maintained for more than 90 percent of the peak hour.

(2) Enforcement

Enforcement is necessary for the success of an HOV facility. Coordination with the Washington State Patrol (WSP) is critical when the operational characteristics and design alternatives are being established. This involvement ensures that the project is enforceable and will receive their support.

Provide both enforcement areas and observation points for all high-speed HOV lanes and ramp facilities.

Barrier-separated facilities, because of the limited access, are the easiest facilities to enforce. Shoulders provided to accommodate breakdowns may also be used for enforcement. Reversible facilities have ramps for the reverse direction that may be used for enforcement. Gaps in the barrier may be needed so emergency vehicles can access barrier-separated HOV lanes.

Buffer-separated and nonseparated HOV lanes allow violators to easily enter and exit the HOV lane. For this reason, providing strategically located enforcement areas and observation points is essential.

Consider the impact on safety and visibility for the overall facility during the planning and design of enforcement areas and observation points. Where HOV facilities do not have enforcement areas, or where officers perceive that the enforcement areas are inadequate, enforcement on the facility will be difficult and less effective.

(3) Intelligent Transportation Systems

The objective of intelligent transportation systems (ITS) is to make more efficient use of our transportation network. This is done by collecting data, managing traffic, and relaying information to the motoring public.

It is important that an ITS system is incorporated into the HOV project and that the HOV facility fully utilize the ITS features available. This includes providing a strategy of incident management since vehicle breakdowns and accidents have a significant impact on the efficient operation of the HOV facilities. See Chapter 860 for more information on ITS.

1050.06 Design Criteria

(1) Design Procedures

See the design matrices (Chapter 325) for the required design level for the elements of an HOV project.

(2) Design Considerations

HOV lanes are designed to the same criteria as the facilities they are attached. Design nonseparated and buffer-separated HOV lanes to match the vertical alignment, horizontal alignment, and cross slope of the adjacent lane. A deviation is required when any proposed or existing design element does not meet the applicable design level for the project.

(3) Adding an HOV Lane

The options for adding an HOV lane are reconstruction, restriping, combined reconstruction and restriping, and possibly lane conversion.

Reconstruction involves creating roadway width. Additional right of way may be required. Restriping involves reallocating the existing paved roadway to create enough space to provide an additional HOV lane. Restriping of lane or shoulder widths to less than for the design level and functional class of the highway is a design deviation and approval is required.

Reconstruction and restriping can be combined to maximize use of the available right of way. For example, a new lane can be created through a combination of median reconstruction, shoulder reconstruction, and lane restriping. Each project will be handled on a case by case basis. Generally consider the following reductions in order of preference:

(a) Reduction of the inside shoulder width, provided the enforcement and safety mitigation issues are addressed. (Give consideration not to preclude future HOV direct access ramps by over reduction of the available median width.)

(b) Reduction of the interior general-purpose lane width to 11 ft.

(c) Reduction of the outside general-purpose lane width to 11 ft.

(d) Reduction of the HOV lane to 11 ft.

(e) Reduction of the outside shoulder width to 8 ft.

If lane width adjustments are necessary, old lane markings must be thoroughly eradicated. It is desirable that longitudinal joints (new or existing) not conflict with tire track lines. If they do, consider overlaying the roadway before restriping.

(4) Design Criteria for Types of HOV Facilities

(a) **Separated Roadway HOV Facilities.** The separated HOV facility can be single lane or multilane and directional or reversible. (See Figure 1050-2.)

1. **Lane Widths.** See Figure 1050-1 for traveled way width (W_R) on turning roadways.

2. **Shoulder Widths.** The shoulder width requirements are as follows:

- The minimum width for the sum of the two shoulders is 12 ft for one-lane facilities and 14 ft for two-lane facilities.
- One of the shoulders must have a width of at least 10 ft for disabled vehicles. The minimum for the other shoulder is 2 ft for one-lane facilities and 4 ft for two-lane facilities.
- The wider shoulder may be on the left or the right as needed to best match the conditions. Maintain the wide shoulder on the same side throughout the facility.

3. **Total Widths.** To reduce the probability of blocking the HOV facility, make the total width (lane width plus paved shoulders) wide enough to allow an A-BUS to pass a stalled A-BUS. For single lane facilities, the traveled way widths (W_R), given in Figure 1050-1, plus the 12 ft total shoulder width will provide for this passing for radii (R) 100 ft or greater. For R of 75 ft, a total roadway width of 33 ft is needed and for R of 50 ft, a total roadway width of 41 ft is needed to provide for the passing.

R (ft)[1]	W_R (ft) 1-Lane	W_R (ft) 2-Lane
3001 to Tangent	13[2]	24
3000	14	24
2000	14	25
1000	15	26
500	15	27
300	15	28
200	16	29
150	17	31
100	18	34
75	19	37
50	22	45

(1) Radius (R) is on the outside edge of traveled way on 1-lane and center line on 2-lane roadways.
(2) May be reduced to 12 ft on tangent.

Minimum Traveled Way Widths for Articulated Buses
Figure 1050-1

(b) **Nonseparated Freeway HOV Lanes.** For both inside and outside HOV lanes, the minimum lane width is 12 ft and the minimum shoulder width is 10 ft. (See Figure 1050-2.)

When a left shoulder less than 10 ft wide is proposed for distances exceeding 1.5 mi, enforcement and observation areas must be provided at 1- to 2-mi intervals. See 1050.06(7).

Where left shoulders less than 8 ft wide are proposed for lengths of roadway exceeding 0.5 mi, safety refuge areas must be provided at 0.5- to 1-mi intervals. These can be in addition to or in conjunction with the enforcement areas.

Allow general-purpose traffic to cross HOV lanes at on-and off-ramps.

(c) **Buffer-Separated HOV lanes.** Design buffer-separated HOV lanes the same as for inside nonseparated HOV lanes, except for a buffer 2 to 4 ft in width or 10 ft or greater in width with pavement marking, with supplemental signing, to restrict crossing. For buffer-separated HOV lanes with a buffer at least 4 ft wide, the left shoulder may be reduced to 8 ft. Buffer widths between 4 and 10 ft are not desirable since they may be used as a refuge area for which the width is not adequate. Provide gaps in the buffer to allow access to the HOV lane.

(d) **Arterial Street HOV Lanes.** The minimum width for an arterial street HOV lane is 12 ft. Allow general-purpose traffic to cross the HOV lanes to turn at intersections and to access driveways. (See Figure 1050-2.)

For right side HOV lanes adjacent to curbs, provide a 4 ft shoulder between the HOV lane and the face of curb. The shoulder may be reduced to 2 ft with justification.

For HOV lanes on the left, a 1 ft left shoulder between the HOV lane and the face of curb is required. When concrete barrier is adjacent to the HOV lane, the minimum shoulder is 2 ft.

(e) **HOV Ramp Meter Bypass.** The HOV bypass may be created by widening an existing ramp, construction of a new ramp where right of way is available, or reallocation of the existing pavement width provided the shoulders are full depth.

Ramp meter bypass lanes may be located on the left or right of metered lanes. Typically, bypass lanes are located on the left side of the ramp. Consult with local transit agencies and the region's Traffic Office for direction on which side to place the HOV bypass.

Consider the existing conditions at each location when designing a ramp meter bypass. Design a single lane ramp with a single metered lane and an HOV bypass as shown on Figure 1050-4a. Make the total width of the metered and bypass lanes equal to a 2-lane ramp (Chapters 640 and 940). Design a ramp with two metered lanes and an HOV bypass as shown on Figure 1050-4b. Make the width of the two metered lanes equal to a 2-lane ramp (Chapters 640 and 940) and the width of the bypass lane as shown on Figure 1050-3. The design shown on Figure 1050-4b requires that the ramp operate as a single lane ramp when the meter is not in operation.

Both Figures 1050-4a and 4b show an observation point/enforcement area. Document any other enforcement area design as a design exception. One alternative (a design exception) is to provide a 10-ft outside shoulder from the stop bar to the main line.

(5) HOV Direct Access Ramps

HOV direct access ramps provide access between an HOV lane and another freeway, a local arterial street, a flyer stop, or a park and ride facility. Design HOV direct access ramps in accordance with the *HOV Direct Access Design Guide*.

(6) HOV Lane Termination

Locate the beginning and end of an HOV lane at logical points. Provide decision sight distance, signing, and pavement markings at the termination points.

The preferred method of terminating an inside HOV lane is to provide a straight through move for the HOV traffic, ending the HOV restriction and dropping a general-purpose lane on the right. However, analyze volumes for both the HOV lanes and general-purpose lanes, and the geometric conditions, to optimize the overall operational performance of the facility.

(7) Enforcement Areas

Enforcement of the inside HOV lane can be done with a minimum 10 ft inside shoulder. For continuous lengths of barrier exceeding 2 mi, a 12 ft shoulder, for the whole length of the barrier, is recommended.

For inside shoulders less than 10 ft, locate enforcement and observation areas at 1- to 2-mi intervals or based on the recommendations of the WSP. These areas can also serve as safety refuge areas for disabled vehicles. See Figures 1050-5a and 5b.

Provide observation points approximately 1300 ft before enforcement areas. They can be designed to serve both patrol cars and motorcycles or motorcycles only. Coordinate with the WSP during the design stage to provide effective placement and to ensure utilization of the observation points. Median openings give motorcycle officers the added advantage of being able to quickly respond to emergencies in the opposing lanes. (See Figure 1050-5b.) The ideal observation point places the motorcycle officer 3 ft above the HOV lane and outside the shoulder so the officer can look down into a vehicle.

Locate the enforcement area on the right side for queue bypasses and downstream from the stop bar so the officer can be an effective deterrent (Figures 1050-4a and 4b).

An optional signal status indicator for enforcement may be placed at HOV lane installations that are metered. The indicator faces the enforcement area so that a WSP officer can determine if vehicles are violating the ramp meter. The indicator allows the WSP officer to simultaneously enforce two areas, the ramp meter and the HOV lane. Consult with the WSP for use at all locations.

See the *Traffic Manual* regarding HOV metered bypasses for additional information on enforcement signal heads.

(8) Signs and Pavement Markings

(a) **Signs.** Provide post-mounted HOV preferential lane signs next to the HOV lane or overhead mounted over the HOV lane. Make the sign wording clear and precise, stating which lane is restricted, the type of HOVs allowed, and the HOV vehicle occupancy designation for that section of road. The sign size, location, and spacing are dependent upon the conditions under which the sign is used. Roadside signs can also be used to convey other HOV information such as the HERO program, carpool information telephone numbers, and violation fines. Some situations may call for the use of variable message signs.

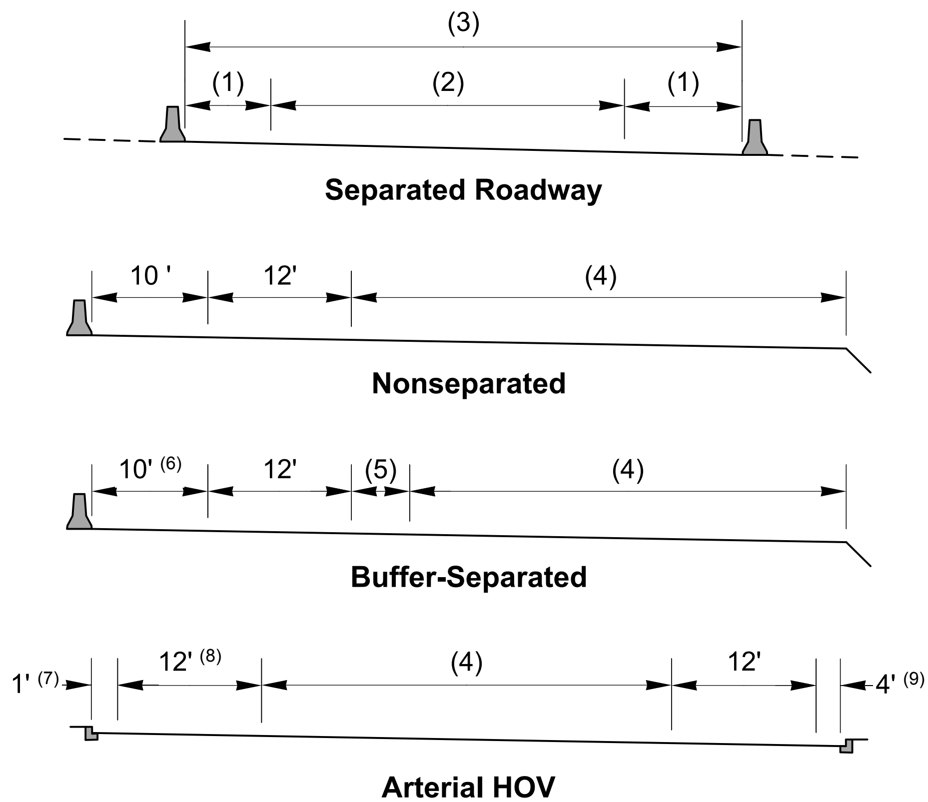
Place overhead signs directly over the HOV lane to provide maximum visibility. Use a sequence of overhead signs at the beginning and end of all freeway HOV facilities. Overhead signs can also be used in conjunction with roadside signs along the roadway.

(b) **Pavement Markings.** Provide pavement markings that conform to the *Traffic Manual* and the Standard Plans.

(c) **Interchanges.** In the vicinity of interchange on and off connections where merging or exiting traffic crosses an HOV lane, make provisions for general-purpose traffic using the HOV lane. These provisions include signing and striping that clearly show the changes in HOV versus general traffic restrictions. See the Standard Plans for pavement markings and signing.

1050.07 Documentation

A list of the documents that are to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following web site: http//www.wsdot.wa.gov/eesc/design/projectdev/



Notes:

(1) The sum of the two shoulders is 12 ft for one-lane and 14 ft for two-lane facilities. One of the shoulders must have a width of at least 10 ft for disabled vehicles. The wider shoulder may be on the left or the right as needed to best match the conditions. Maintain the wide shoulder on the same side throughout the facility. See 1050.06(4)(a)2.

(2) 12 ft minimum for single lane, 24 ft minimum for two lanes. Wider width is required on curves. See 1050.06(4)(a)1. and Figure 1050-1.

(3) For total width requirements see 1050.06(4)(a)3.

(4) Width as required for the design level, functional class, and the number of lanes.

(5) Buffer 2 to 4 ft or 10 ft or more.

(6) When buffer width is 4 ft or more, may be reduced to 8 ft.

(7) 2 ft when adjacent to concrete barrier.

(8) Arterial HOV lanes on the left operate in the same direction as the adjacent general-purpose lane.

(9) May be reduced to 2 ft with justification.

Typical HOV Lane Sections

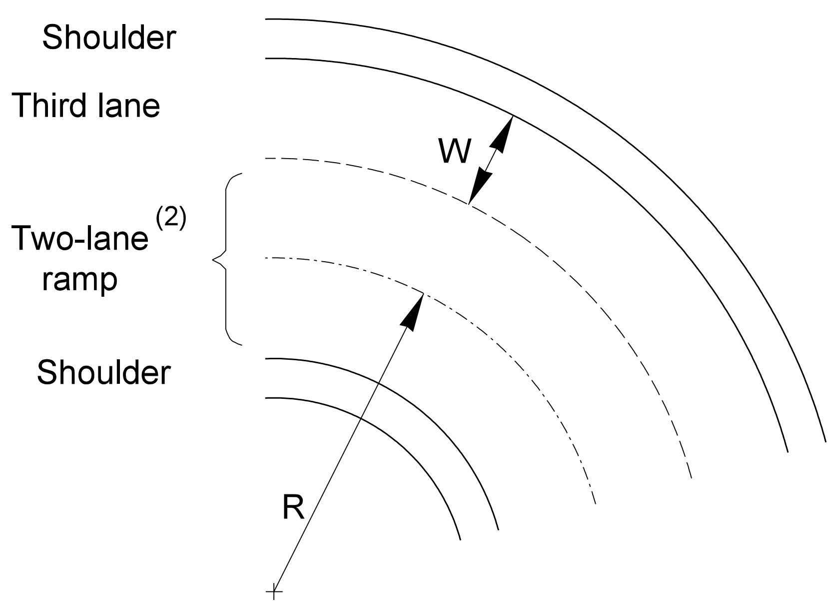
Figure 1050-2

Radius of Two-Lane Ramp R (ft)	Design Width of Third Lane(1) W (ft)
1000 to Tangent	12
999 to 500	13
499 to 250	14
249 to 200	15
199 to 150	16
149 to 100	17

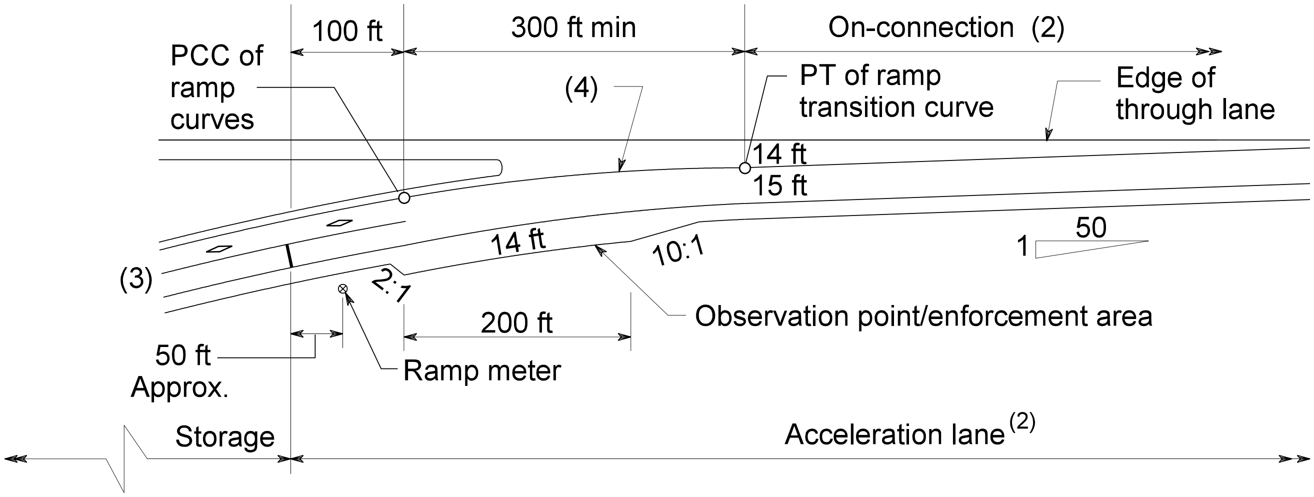
Notes:

(1) Apply additional width to 2-lane ramp widths.

(2) See traveled way width for two-lane one-way turning roadways in Chapter 640 for turning roadway widths.



Roadway Widths for Two-Lane Ramps with an HOV Lane
Figure 1050-3



Notes:

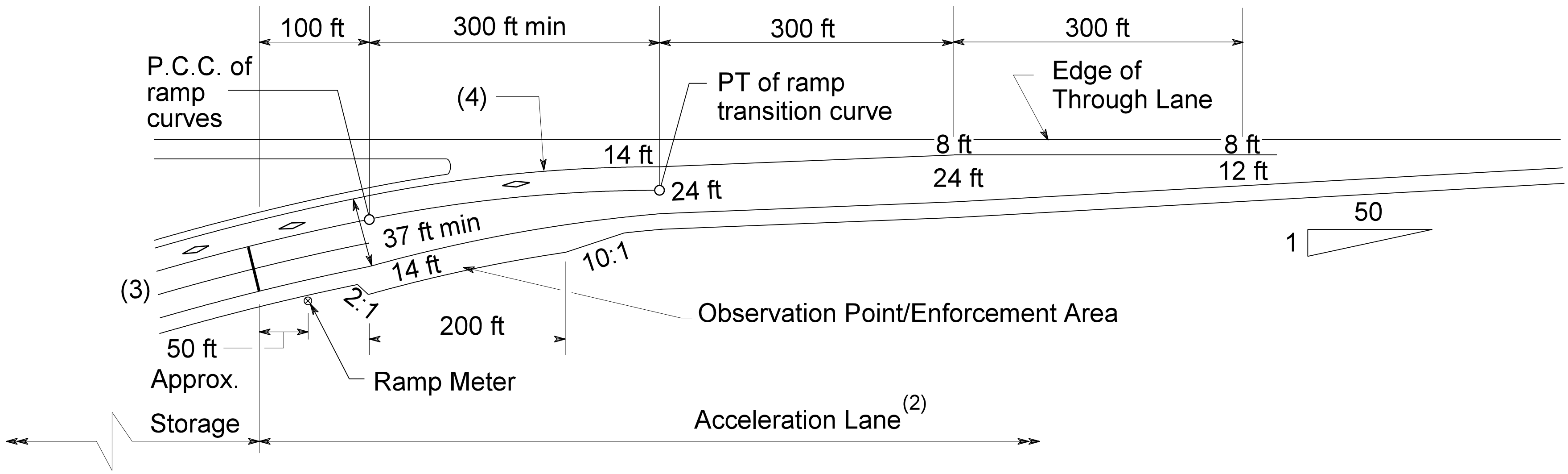
(1) See Standard Plans for striping details.

(2) See Chapter 940 for on-connection details and for acceleration lane length.

(3) See Chapters 940 & 640 for ramp lane and shoulder widths for a 2-lane ramp.

(4) A transition curve with a minimum radius of 3,000 ft is desirable. The minimum length is 300 ft. When the main line is on a curve to the left, the transition may vary from a 3,000 ft radius to tangent to the main line.

Single-Lane Ramp Meter With HOV Bypass
Figure 1050-4a



NOTES

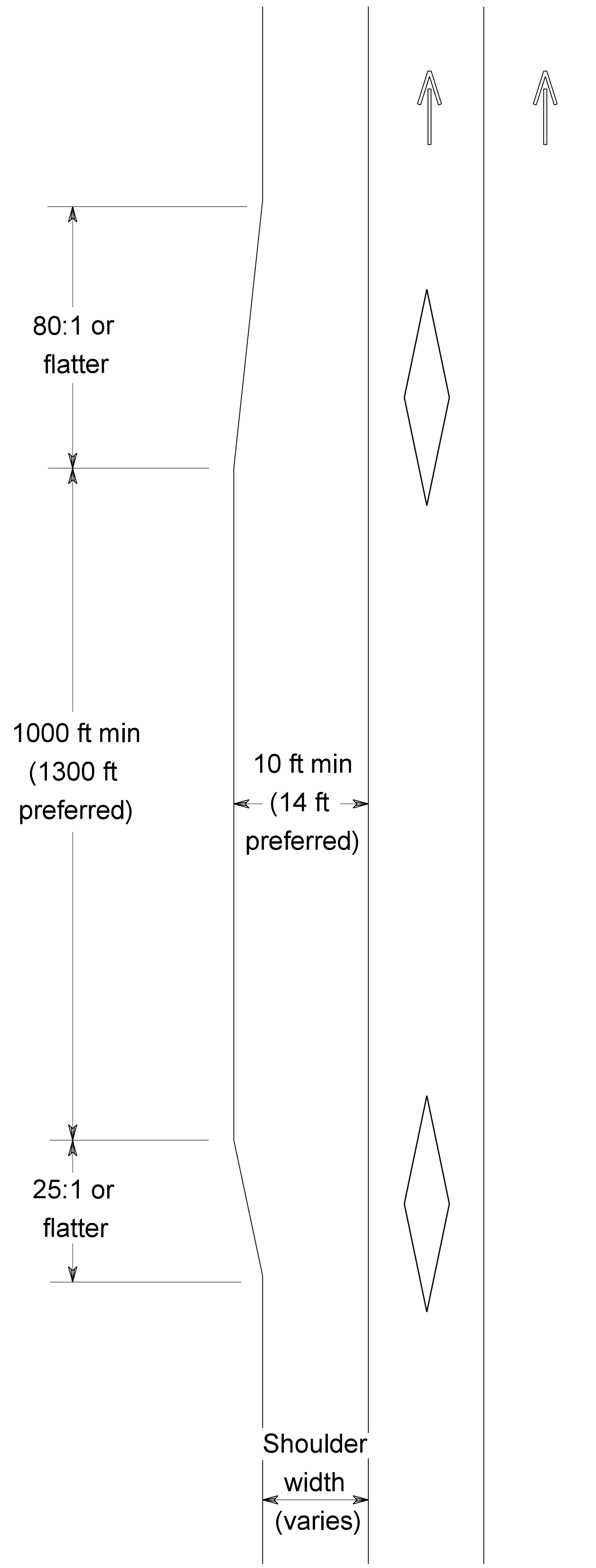
(1) See Standard Plans for Striping Details.

(2) See Chapter 940 for acceleration lane length.

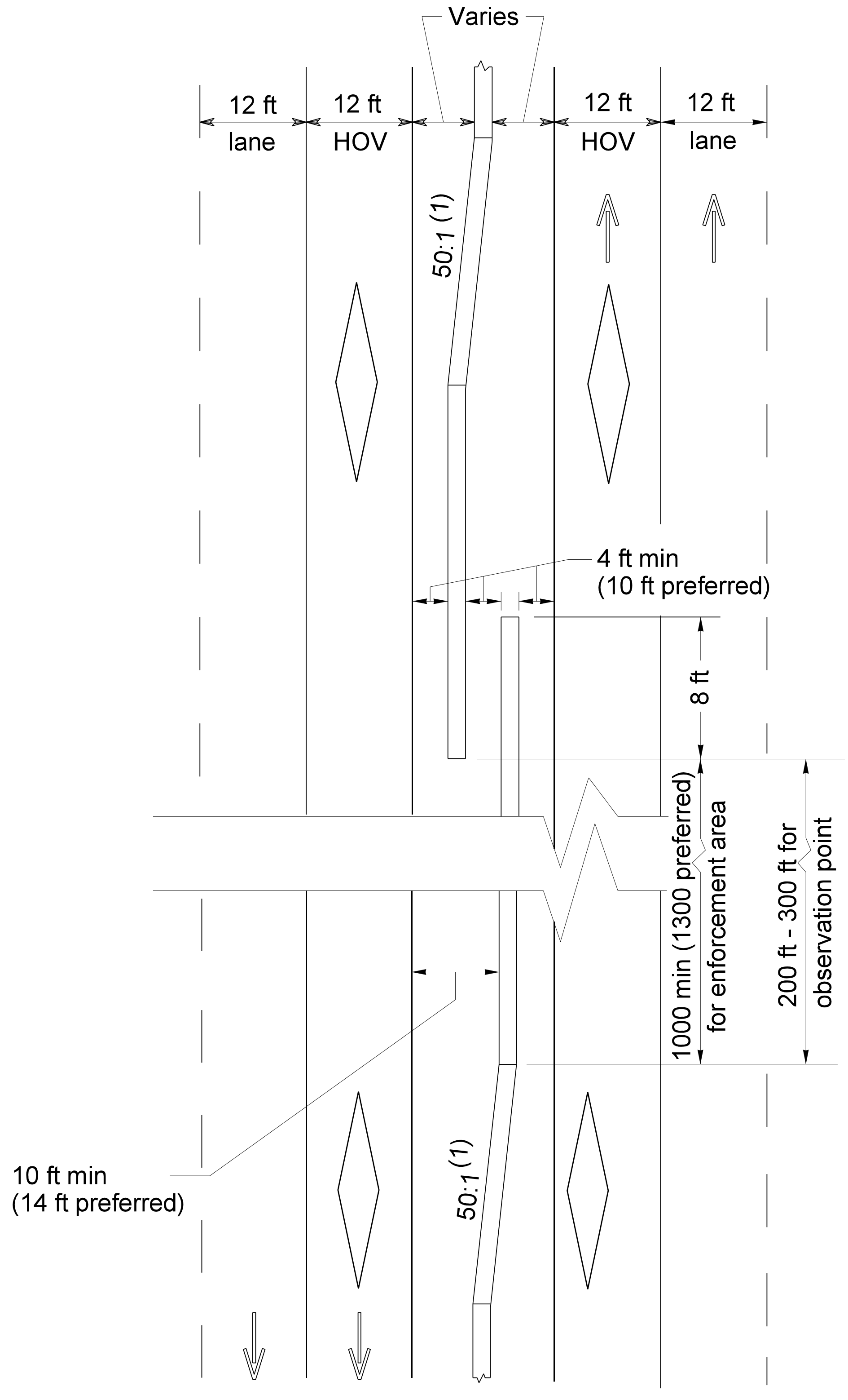
(3) See Chapters 940 & 640 for 2-lane ramp lane and shoulder widths. See Figure 1050-3 for 3rd lane width.

(4) A transition curve with a minimum radius of 3,000 ft is desirable. The minimum length is 300 ft. When the main line is on a curve to the left, the transition may vary from a 3,000 ft radius to tangent to the main line.

Two-Lane Ramp Meter With HOV Bypass
Figure 1050-4b



Enforcement Area (One Direction Only)
Figure 1050-5a



Notes:

(1) See Chapter 620 for median width transition.

Enforcement Area (Median)

Figure 1050-5b

Chapter 1130 Retaining Walls and Steep Reinforced Slopes

1130.01 References

Bridge Design Manual, M 23-50, WSDOT

Standard Plans for Road, Bridge, and Municipal Construction (Standard Plans), M 21-01, WSDOT

Plans Preparation Manual, M 22-31, WSDOT

Roadside Manual, M 25-39, WSDOT

1130.02 General

The function of a retaining wall is to form a nearly vertical face through confinement and/or strengthening of a mass of earth or other bulk material. Likewise, the function of a reinforced slope is to strengthen the mass of earth or other bulk material such that a steep (up to 1H:2V) slope can be formed. In both cases, the purpose of constructing such structures is to make maximum use of limited right of way. The difference between the two is that a wall uses a structural facing whereas a steep reinforced slope does not require a structural facing. Reinforced slopes typically use a permanent erosion control matting with low vegetation as a slope cover to prevent erosion. See the *Roadside Manual* for more information.

To lay out and design a retaining wall or reinforced slope, consider the following items:

- Functional classification
- Highway geometry
- Design Clear Zone requirements (Chapter 700)
- The amount of excavation required
- Traffic characteristics
- Constructibility
- Impact to any adjacent environmentally sensitive areas
- Impact to adjacent structures
- Potential added lanes
- Length and height of wall
- Material to be retained
- Foundation support and potential for differential settlement
- Ground water
- Earthquake loads
- Right of way costs
- Need for construction easements
- Risk
- Overall cost
- Visual appearance

If the wall or toe of a reinforced slope is to be located adjacent to the right of way line, consider the space needed in front of the wall/slope to construct it.

(1) Retaining Wall Classifications

Retaining walls are generally classified as gravity, semigravity, nongravity cantilever, or anchored. Examples of the various types of walls are provided in Figures 1130-1a through 1c.

Gravity walls derive their capacity to resist lateral soil loads through a combination of dead weight and sliding resistance. Gravity walls can be further subdivided into rigid gravity walls, prefabricated modular gravity walls, and Mechanically Stabilized Earth (MSE) gravity walls.

Rigid gravity walls consist of a solid mass of concrete or mortared rubble and use the weight of the wall itself to resist lateral loads.

Prefabricated modular gravity walls consist of interlocking soil or rock filled concrete, steel, or wire modules or bins (gabions, for example). The combined weight resists the lateral loads from the soil.

MSE gravity walls use strips, bars, or mats of steel or polymeric reinforcement to reinforce the soil and create a reinforced soil block behind the face. The reinforced soil block then acts as a unit and resists the lateral soil loads through the dead weight of the reinforced mass. MSE walls may be constructed as fill walls, with fill and reinforcement placed in alternate layers to create a reinforced mass, or reinforcement may be drilled into an existing soil/rock mass using grouted anchor technology to create a reinforced soil mass (soil nail walls).

Semigravity walls rely more on structural resistance through cantilevering action of the wall stem. Generally, the backfill for a semigravity wall rests on part of the wall footing. The backfill, in combination with the weight of the wall and footing, provides the dead weight for resistance. An example of a semigravity wall is the reinforced concrete wall provided in the Standard Plans.

Nongravity cantilever walls rely strictly on the structural resistance of the wall in which vertical elements of the wall are partially embedded in the soil or rock to provide fixity. These vertical elements may consist of piles (soldier piles or sheet piles, for example), caissons, or drilled shafts. The vertical elements may form the entire wall face or they may be spanned structurally using timber lagging or other materials to form the wall face.

Anchored walls derive their lateral capacity through anchors embedded in stable soil or rock below or behind all potential soil/rock failure surfaces. Anchored walls are similar to nongravity cantilevered walls except that anchors embedded in the soil/rock are attached to the wall facing structure to provide lateral resistance. Anchors typically consist of deadmen or grouted soil/rock anchors.

Reinforced slopes are similar to MSE walls in that they also use fill and reinforcement placed in alternate layers to create a reinforced soil mass. However, the face is typically built at a 1.2H:1V to 1H:2V slope.

Rockeries (rock walls) behave to some extent like gravity walls. However, the primary function of a rockery is to prevent erosion of an oversteepened but technically stable slope. Rockeries consist of large well-fitted rocks stacked on top of one another to form a wall.

An example of a rockery and reinforced slope is provided in Figure 1130-1d.

The various wall types and their classifications are summarized in Table 1(a-f).

1130.03 Design Principles

The design of a retaining wall or reinforced slope consists of seven principal activities:

- Developing wall/slope geometry
- Adequate subsurface investigation
- Evaluation of loads and pressures that will act on the structure
- Design of the structure to safely withstand the loads and pressures
- Design of the structure to meet aesthetic requirements
- Wall/slope constructibility
- Coordination with other design elements

The structure and adjacent soil mass must also be stable as a system, and the anticipated wall settlement must be within acceptable limits.

1130.04 Design Requirements

(1) Wall/Slope Geometry

Wall/slope geometry is developed considering the following:

- Geometry of the transportation facility itself
- Design Clear Zone requirements (Chapter 700)
- Flare rate and approach slope when inside the Design Clear Zone (Chapter 710)

- Right of way constraints
- Existing ground contours
- Existing and future utility locations
- Impact to adjacent structures
- Impact to environmentally sensitive areas
- For wall/slope geometry, also consider the foundation embedment and type anticipated, which requires coordination among the various design groups involved.

Retaining walls must not have anything (such as bridge columns, light fixtures, or sign supports) protruding in such a way as to present a potential for snagging vehicles.

Provide a traffic barrier shape at the base of a new retaining wall constructed 12 ft or less from the edge of the nearest traffic lane. The traffic barrier shape is optional at the base of the new portion when an existing vertical-faced wall is being extended (or the existing wall may be retrofitted for continuity). Standard Concrete Barrier Type 4 is recommended for both new and existing walls except when the barrier face can be cast as an integral part of a new wall. Deviations may be considered but require approval as prescribed in Chapter 330. For deviations from the above, deviation approval is not required where sidewalk exists in front of the wall or in other situations where the wall face is otherwise inaccessible to traffic.

(2) Investigation of Soils

All retaining wall and reinforced slope structures require an investigation of the underlying soil/rock that supports the structure. Chapter 510 provides guidance on how to complete this investigation. A soil investigation is critical for the design of any retaining wall or reinforced slope. The stability of the underlying soils, their potential to settle under the imposed loads, the usability of any existing excavated soils for wall/reinforced slope backfill, and the location of the ground water table are determined through the geotechnical investigation.

(3) Geotechnical and Structural Design

The structural elements of the wall or slope and the soil below, behind, and/or within the structure must be designed together as a system. The wall/slope system is designed for overall external stability as well as internal stability. Overall external stability includes stability of the slope of which the wall/reinforced slope is a part and the local external stability (overturning, sliding, and bearing capacity). Internal stability includes resistance of the structural members to load and, in the case of MSE walls and reinforced slopes, pullout capacity of the structural members or soil reinforcement from the soil.

(4) Drainage Design

One of the principal causes of retaining wall/slope failure is the additional hydrostatic load imposed by an increase in the water content in the material behind the wall or slope. This condition results in a substantial increase in the lateral loads behind the wall/slope since the material undergoes a possible increase in unit weight, water pressure is exerted on the back of the wall, and the soil shear strength undergoes a possible reduction. To alleviate this, adequate drainage for the retaining wall/slope must be considered in the design stage and reviewed by the region's Materials Engineer during construction. The drainage features shown in the Standard Plans are the minimum basic requirements. Underdrains behind the wall/slope must daylight at some point in order to adequately perform their drainage function. Provide positive drainage at periodic intervals to prevent entrapment of water.

Native soil may be used for retaining wall and reinforced slopes backfill if it meets the requirements for the particular wall/slope system. In general, use backfill that is free-draining and granular in nature. Exceptions to this can be made depending on the site conditions as determined by the Geotechnical Services Branch of the Headquarters (HQ) Materials Laboratory.

A typical drainage detail for a gravity wall (in particular, an MSE wall) is shown in Figure 1130-2. Always include drainage details with a wall unless otherwise recommended to be deleted by the region's Materials Engineer or HQ Geotechnical Services Branch.

(5) Aesthetics

Retaining walls and slopes can have a pleasing appearance that is compatible with the surrounding terrain and other structures in the vicinity. To the extent possible within functional requirements and cost effectiveness criteria, this aesthetic goal is to be met for all visible retaining walls and reinforced slopes.

Aesthetic requirements include consideration of the wall face material, the top profile, the terminals, and the surface finish (texture, color, and pattern). Where appropriate, provide planting areas and irrigation conduits. These will visually soften walls and blend walls with adjacent areas. Avoid short sections of retaining wall or steep slope where possible.

In higher walls, variations in slope treatment are recommended for a pleasing appearance. High, continuous walls are generally not desirable from an aesthetic standpoint, as high, continuous walls can be quite imposing. Consider stepping high or long retaining walls in areas of high visibility. Plantings may be considered between wall steps.

Approval from the State Bridge and Structures Architect is required on all retaining wall aesthetics including finishes, materials, and configuration.

(6) Constructibility

Consider the potential effect that site constraints might have on the constructibility of the specific wall/slope. Constraints to be considered include, but are not limited to, site geometry, access, time required to construct the wall, environmental issues, and impact on traffic flow and other construction activities.

(7) Coordination with Other Design Elements

(a) **Other Design Elements.** Retaining wall and slope designs must be coordinated with other elements of the project that might interfere with or impact the design and/or construction of the wall/slope. Also consider drainage features, utilities, luminaire or sign structures, adjacent retaining walls or bridges, concrete traffic barriers, and beam guardrails. Locate these design elements in a manner that will minimize the impacts to the wall elements. In general, locate obstructions within the wall backfill (such as guardrail posts, drainage features, and minor structure foundations) a minimum of 3 ft from the back of the wall facing units. Greater offset distances may be required depending on the size and nature of the interfering design element. If possible, locate these elements to miss reinforcement layers or other portions of the wall system. Conceptual details for accommodating concrete traffic barriers and beam guardrails are provided in Figure 1130-3.

Where impact to the wall elements is unavoidable, the wall system must be designed to accommodate these impacts. For example, it may be necessary to place drainage structures or guardrail posts in the reinforced backfill zone of MSE walls. This may require that holes be cut in the upper soil reinforcement layers, or that discrete reinforcement strips be splayed around the obstruction. This causes additional load to be carried in the adjacent reinforcement layers due to the missing soil reinforcement or the distortion in the reinforcement layers.

The need for these other design elements and their impact on the proposed wall systems must be clearly indicated in the wall site data that is submitted so that the walls can be properly designed. Contact the Bridge and Structures Office (or the Geotechnical Services Branch, for geosynthetic walls/slopes and soil nail walls) for assistance regarding this issue.

(b) **Fall Protection.** Department of Labor and Industries regulations require that, when employees are exposed to the possibility of falling from a location 10 ft or more above the roadway (or other lower area), the employer is to ensure that fall restraint or fall arrest systems are provided, installed, and implemented.

Consider fall protection when a wall retains 10 ft or more of material. Any need for maintenance of the wall's surface or the area at the top can expose employees to a possible fall. If the area at the top will be open to the public, see Chapter 1025, "Pedestrian Design Considerations," and Chapter 1460, "Fencing."

For maintenance of a tall wall's surface, consider harness tie-offs if other protective means are not provided.

For maintenance of the area at the top of a tall wall, a fall restraint system is required when all of the following conditions will exist:

- The wall is on a cut slope.
- A possible fall will be of 10 ft or more.
- Periodic maintenance will be performed on the area at the top.
- The area at the top is not open to the public.

Recommended fall restraint systems are:

- Wire rope railing with top and intermediate rails of one-half inch diameter steel wire rope.
- Brown vinyl coated chain link fencing.
- Steel pipe railing with one and one-half inch nominal outside diameter pipe as posts and top and intermediate rails.
- Concrete as an extension of the height of the retaining wall.

A fall restraint system must be 36 in to 42 in high, measured from the top of the finished grade, and capable of withstanding a 200 lb force from any direction, at the top, with minimal deflection. Post spacing is no more than 8 ft on centers.

During rail system selection, the designer is to contact Maintenance regarding debris removal considerations.

Contact the Bridge and Structures Office for design details for any retrofit to an existing retaining wall and for any attachments to a new retaining wall.

1130.05 Guidelines for Wall/Slope Selection

Wall/slope selection is dependent on the following considerations:

- Whether the wall/slope will be located primarily in a cut or fill (how much excavation/shoring will be required to construct the wall or slope?)
- If located in a cut, the type of soil/rock present
- The need for space between the right of way line and the wall/slope or easement
- The amount of settlement expected
- The potential for deep failure surfaces to be present
- The structural capacity of the wall/slope in terms of maximum allowable height
- The nature of the wall/slope application
- Whether or not structures or utilities will be located on or above the wall
- Architectural requirements
- Overall economy

(1) Cut and Fill Considerations

Due to the construction technique and base width required, some wall types are best suited for cut situations whereas others are best suited for fill situations. For example, anchored walls and soil nail walls have soil reinforcements drilled into the in-situ soil/rock and, therefore, are generally used in cut situations. Nongravity cantilevered walls are drilled or cut into the in-situ soil/rock, have narrow base widths, and are also well suited to cut situations. Both types of walls are constructed from the top down. Such walls are also used as temporary shoring to allow other types of walls or other structures to be constructed where considerable excavation will otherwise be required.

MSE walls and reinforced slopes, however, are constructed by placing soil reinforcement between layers of fill from the bottom up and are therefore best suited to fill situations. Furthermore, the base width of MSE walls is typically on the order of 70 percent of the wall height, which requires considerable excavation in a cut situation. Therefore, in a cut situation, base width requirements usually make MSE structures uneconomical and possibly unconstructible.

Semigravity (cantilever) walls, rigid gravity walls, and prefabricated modular gravity walls are free-standing structural systems built from the bottom up but they do not rely on soil reinforcement techniques (placement of fill layers with soil reinforcement) to provide stability. These types of walls generally have a narrower base width than MSE structures, (on the order of 50 percent of the wall height). Both of these factors make these types of walls feasible in fill situations as well as many cut situations.

Reinforced slopes generally require more room overall to construct than a wall because of the sloping face, but are typically a feasible alternative to a combination wall and fill slope to add a new lane. Reinforced slopes can also be adapted to the existing ground contours to minimize excavation requirements where fill is placed on an existing slope. Reinforced slopes might also be feasible to repair slopes damaged by landslide activity or deep erosion.

Rockeries are best suited to cut situations, as they require only a narrow base width, on the order of 30 percent of the rockery height. Rockeries can be used in fill situations, but the fill heights that they support must be kept relatively low as it is difficult to get the cohesive strength needed in granular fill soils to provide minimal stability of the soil behind the rockery at the steep slope typically used for rockeries in a cut (such as 1H:6V or 1H:4V).

The key considerations in deciding which walls or slopes are feasible are the amount of excavation or shoring required and the overall height. The site geometric constraints must be well defined to determine these elements. Another consideration is whether or not an easement will be required. For example, a temporary easement might be required for a wall in a fill situation to allow the contractor to work in front of the wall. For walls in cut situations, especially anchored walls and soil nail walls, a permanent easement may be required for the anchors or nails.

(2) Settlement and Deep Foundation Support Considerations

Settlement issues, especially differential settlement, are of primary concern for selection of walls. Some wall types are inherently flexible and can tolerate a great deal of settlement without suffering structurally. Other wall types are inherently rigid and cannot tolerate much settlement. In general, MSE walls have the greatest flexibility and tolerance to settlement, followed by prefabricated modular gravity walls. Reinforced slopes are also inherently very flexible. For MSE walls, the facing type used can affect the ability of the wall to tolerate settlement. Welded wire and geosynthetic wall facings are the most flexible and the most tolerant to settlement, whereas concrete facings are less tolerant to settlement. In some cases, concrete facing can be placed, after the wall settlement is complete, such that the concrete facing does not limit the wall's tolerance to settlement. Facing may also be added for aesthetic reasons.

Semigravity (cantilever) walls and rigid gravity walls have the least tolerance to settlement. In general, total settlement for these types of walls must be limited to approximately 1 in or less. Rockeries also cannot tolerate much settlement, as rocks can shift and fall out. Therefore, semigravity cantilever walls, rigid gravity walls, and rockeries are not used in settlement prone areas.

If very weak soils are present that will not support the wall and that are too deep to be overexcavated, or if a deep failure surface is present that results in inadequate slope stability, the wall type selected must be capable of using deep foundation support and/or anchors. In general, MSE walls, prefabricated modular gravity walls, and some rigid gravity walls are not appropriate for these situations. Walls that can be pile supported such as concrete semigravity cantilever walls, nongravity cantilever walls, and anchored walls are more appropriate for these situations.

(3) Feasible Wall and Slope Heights and Applications

Feasible wall heights are affected by issues such as the capacity of the wall structural elements, past experience with a particular wall, current practice, seismic risk, long-term durability, and aesthetics.

See Table 1 for height limitations.

(4) Supporting Structures or Utilities

Not all walls are acceptable to support other structures or utilities. Issues that must be considered include the potential for the wall to deform due to the structure foundation load, interference between the structure foundation and the wall components, and the potential long-term durability of the wall system. Using retaining walls to support other structures is considered to be a critical application, requiring a special design. In general, soil nail walls, semigravity cantilever walls, nongravity cantilever walls, and anchored walls are appropriate for use in supporting bridge and building structure foundations. In addition to these walls, MSE and prefabricated modular gravity walls may be used to support other retaining walls, noise walls, and minor structure foundations such as those for sign bridges and signals. On a project specific basis, MSE walls can be used to support bridge and building foundations, as approved by the Bridge and Structures Office.

Also consider the location of any utilities behind the wall or reinforced slope when making wall/slope selections. This is mainly an issue for walls that use some type of soil reinforcement and for reinforced slopes. It is best not to place utilities within a reinforced soil backfill zone because it <u>will</u> be impossible to access the utility from the ground surface without cutting through the soil reinforcement layers, thereby compromising the integrity of the wall.

Sometimes utilities, culverts, pipe arches, etc. must penetrate the face of a wall. Not all walls and facings are compatible with such penetrations. Consider how the facing can be formed around the penetration so that backfill soil cannot pipe or erode through the face. Contact the Bridge and Structures Office for assistance regarding this issue.

(5) Facing Options

Facing selection depends on the aesthetic and the structural needs of the wall system. Wall settlement may also affect the feasibility of the facing options. More than one wall facing may be available for a given system. The facing options available must be considered when selecting a particular wall.

For MSE walls, facing options typically include the following:

- Precast modular panels
- In some cases, full height precast concrete panels. (Full height panels are generally limited to walls with a maximum height of 20 ft placed in areas where minimal settlement is expected.)
- Welded wire facing
- Timber facing
- Shotcrete facing with various treatment options that vary from a simple broom finish to a textured and colored finish
- Segmental masonry concrete blocks
- Cast-in-place concrete facing with various texturing options.

Plantings on welded wire facings can be attempted in certain cases. The difficulty is in providing a soil at the wall face that is suitable for growing plants and meets engineering requirements in terms of soil compressibility, strength, and drainage. If plantings in the wall face are attempted, use only small plants, vines, and grasses. Small bushes <u>may</u> be considered for plantings between wall steps. Larger bushes or trees are not considered in these cases due to the loads on the wall face that they can create.

Geosynthetic facings are not acceptable for permanent facings due to potential facing degradation when exposed to sunlight. For permanent applications, geosynthetic walls must have some type of timber, welded wire, or concrete face. (Shotcrete, masonry concrete blocks, cast-in-place concrete, welded wire, or timber are typically used for geosynthetic wall facings.)

Soil nail walls can use either architecturally treated shotcrete or a cast-in-place facia wall textured as needed to produce the desired appearance.

For prefabricated modular gravity walls, the facing generally consists of the structural bin or crib elements used to construct the walls. For some walls, the elements can be rearranged to form areas for plantings. In some cases, textured structural elements might also be feasible. This is also true of rigid gravity walls, though planting areas on the face of rigid gravity walls are generally not feasible. The concrete facing for semigravity cantilever walls can be textured as needed to produce the desired appearance.

For nongravity cantilevered walls and anchored walls, a textured cast-in-place or precast facia wall is usually installed to produce the desired appearance.

(6) Cost Considerations

Usually, more than one wall type is feasible for a given situation. Consider cost throughout the selection process. Decisions in the selection process that may affect the overall cost might include the problem of whether to shut down a lane of traffic to install a low cost gravity wall system that requires more excavation room or to use a more expensive anchored wall system that will minimize excavation requirements and impacts to traffic. In this case, determine if the cost of traffic impacts and more excavation justifies the cost of the more expensive anchored wall system.

Decisions regarding aesthetics can also affect the overall cost of the wall system. In general, the least expensive aesthetic options use the structural members of the wall as facing (welded wire, concrete or steel cribbing or bins, for example), whereas the most expensive aesthetic options use textured cast-in-place concrete facias. In general, concrete facings increase in cost in the following order: shotcrete, segmental masonry concrete blocks, precast concrete facing panels, full height precast concrete facing panels, and cast-in-place concrete facing panels. Special architectural treatment usually increases the cost of any of these facing systems. Special wall terracing to provide locations for plants will also tend to increase costs. Therefore, the value of the desired aesthetics must be weighed against costs.

Other factors that affect costs of wall/slope systems include wall/slope size and length, access at the site and distance to the material supplier location, overall size of the project, and competition between wall suppliers. In general, costs tend to be higher for walls or slopes that are high, but short in length, due to lack of room for equipment to work. Sites that are remote or have difficult local access increase wall/slope costs. Small wall/slope quantities result in high unit costs. Lack of competition between materials or wall system suppliers can result in higher costs as well.

Some of the factors that increase costs are required parts of a project and are, therefore, unavoidable. Always consider such factors when estimating costs because a requirement may not affect all wall types in the same way. Current cost information can be obtained by consulting the *Bridge Design Manual* or by contacting the Bridge and Structures Office.

(7) Summary

For wall/slope selection, consider factors such as the intended application, the soil/rock conditions in terms of settlement, need for deep foundations, constructibility, impact to traffic, the overall geometry in terms of wall/slope height and length, location of adjacent structures and utilities, aesthetics, and cost. Table 1 provides a summary of many of the various wall/slope options available, including their advantages, disadvantages, and limitations. Note that specific wall types in the table may represent multiple wall systems, some or all of which will be proprietary.

1130.06 Design Responsibility and Process

(1) General

The retaining walls available for a given project include standard walls, nonstandard walls, and reinforced slopes.

Standard walls are those walls for which standard designs are provided in the WSDOT Standard Plans. Standard plans are provided for reinforced concrete cantilever walls up to 35 ft in height. The internal stability design, and the external stability design for overturning and sliding stability, have already been completed for these standard walls. However, overall slope stability and allowable soil bearing capacity (including settlement considerations) must be determined for each standard-design wall location.

Nonstandard walls may be either proprietary (patented or trademarked) or nonproprietary. Proprietary walls are designed by a wall manufacturer for internal and external stability, except bearing capacity, settlement, and overall slope stability which are determined by WSDOT. Nonstandard nonproprietary walls are fully designed by WSDOT.

The geosynthetic soil reinforcement used in nonstandard nonproprietary geosynthetic walls is considered to be proprietary. It is likely that more than one manufacturer can supply proprietary materials for a nonstandard nonproprietary geosynthetic wall.

Reinforced slopes are similar to nonstandard nonproprietary walls in terms of their design process.

Some proprietary wall systems are preapproved. Preapproved proprietary wall systems have been extensively reviewed by the Bridge and Structures Office and the Geotechnical Services Branch. Design procedures and wall details for preapproved walls have already been agreed upon between WSDOT and the proprietary wall manufacturers, allowing the manufacturers to competitively bid a particular project without having a detailed wall design provided in the contract plans.

Note that proprietary wall manufacturers might produce several retaining wall options, and not all options from a given manufacturer have necessarily been preapproved. For example, proprietary wall manufacturers often offer more than one facing alternative. It is possible that some facing alternatives are preapproved, whereas other facing alternatives are not preapproved. WSDOT does not preapprove the manufacturer, but specific wall systems by a given manufacturer can be preapproved.

It is imperative with preapproved systems that the design requirements for all preapproved wall alternatives for a given project be clearly stated so that the wall manufacturer can adapt the preapproved system to specific project conditions. For a given project, coordination of the design of all wall alternatives with all project elements that impact the wall (such as drainage features, utilities, luminaires and sign structures, noise walls, traffic barriers, guardrails, or other walls or bridges) is critical to avoid costly change orders or delays during construction.

In general, standard walls are the easiest walls to incorporate into project plans, specifications, & estimate (PS&E), but they may not be the most cost effective option. Preapproved proprietary walls provide more options in terms of cost effectiveness and aesthetics and are also relatively easy to incorporate into a PS&E. Nonstandard state-designed walls and nonpreapproved proprietary walls generally take more time and effort to incorporate into a PS&E because a complete wall design must be developed. Some nonstandard walls (state-designed geosynthetic walls, for example) can be designed relatively quickly, require minimal plan preparation effort, and only involve the region and the Geotechnical Services Branch. Other nonstandard walls such as soil nail and anchored wall systems require complex designs, involve both the Bridge and Structures Office and the Geotechnical Services Branch, and require a significant number of plan sheets and considerable design effort.

The Bridge and Structures Office maintains a list of the proprietary retaining walls that are preapproved. The region consults the Bridge and Structures Office for the latest list. The region consults the Geotechnical Services Branch for the latest geosynthetic reinforcement list to determine which geosynthetic products are acceptable if a critical geosynthetic wall or reinforced slope application is anticipated.

Some proprietary retaining wall systems are classified as experimental by the FHWA. The Bridge and Structures Office maintains a list of walls that are classified as experimental. If the wall intended for use is classified as experimental, a work plan must be prepared by WSDOT and approved by the FHWA.

An approved public interest finding, signed by the State Design Engineer, is required for the use of a sole source proprietary wall.

Gabion walls are nonstandard walls that must be designed for overturning, sliding, overall slope stability, settlement, and bearing capacity. A full design for gabion walls is not provided in the Standard Plans. Gabion baskets are typically 3 ft high by 3 ft wide, and it is typically safe to build gabions two baskets high (6 ft) but only one basket deep, resulting in a wall base width of 50 percent of the wall height, provided soil conditions are reasonably good (medium dense to dense granular soils are present below and behind the wall).

(2) Responsibility and Process for Design

A flow chart illustrating the process and responsibility for retaining wall/reinforced slope design is provided in Figure 1130-4a. As shown in the figure, the region initiates the process, except for walls developed as part of a preliminary bridge plan. These are initiated by the Bridge and Structures Office. In general, it is the responsibility of the design office initiating the design process to coordinate with other groups in the department to identify all wall/slope systems that are appropriate for the project in question. Coordination between the region, Bridge and Structures Office, Geotechnical Services Branch, and the State Bridge and Structures Architect must occur as early in the process as possible.

HQ or region consultants, if used, are considered an extension of the HQ staff and must follow the process summarized in Figure 1130-4a. All consultant designs, from development of the scope of work to the final product, must be reviewed and approved by the appropriate HQ offices.

(a) **Standard Walls.** The regions are responsible for detailing retaining walls for which standard designs are available.

For standard walls greater than 10 ft in height, and for all standard walls where soft or unstable soil is present beneath or behind the wall, a geotechnical investigation must be conducted, or reviewed and approved, by the Geotechnical Services Branch. Through this investigation, provide the foundation design including bearing capacity requirements and settlement determin-ation, overall stability, and the selection of the wall types most feasible for the site.

For standard walls 10 ft in height or less where soft or unstable soils are not present, it is the responsibility of the region materials laboratory to perform the geotechnical investigation. If it has been verified that soil conditions are adequate for the proposed standard wall that is less than or equal to 10 ft in height, the region establishes the wall footing location based on the embedment criteria in the *Bridge Design Manual*, or places the bottom of the wall footing below any surficial loose soils. During this process, the region also evaluates other wall types that may be feasible for the site in question.

Figure 1130-5 provides design charts for standard reinforced concrete cantilever walls. These design charts, in combination with the Standard Plans, are used to size the walls and determine the applied bearing stresses to compare with the allowable soil bearing capacity determined from the geotechnical investigation. The charts provide two sets of bearing pressures: one for static loads, and one for earthquake loads. Allowable soil bearing capacity for both the static load case and the earthquake load case can be obtained from the Geotechnical Services Branch for standard walls over 10 ft in height and from the region materials laboratories for standard walls less than or equal to 10 ft in height. If the allowable soil bearing capacity exceeds the values provided in Figure 1130-5, the Standard Plans can be used for the wall design. If one or both of the allowable soil bearing capacities does not exceed the values provided in Figure 1130-5, the Standard Plans cannot be used for wall design and the Bridge and Structures Office must be contacted for a nonstandard wall design.

If the standard wall must support surcharge loads from bridge or building foundations, other retaining walls, noise walls, or other types of surcharge loads, a special wall design is required. The wall is considered to be supporting the surcharge load and is treated as a nonstandard wall if the surcharge load is located within a 1H:1V slope projected up from the bottom of the back of the wall. Contact the Bridge and Structures Office for assistance

The Standard Plans provide six types of reinforced concrete cantilever walls (which represent six loading cases). Reinforced concrete retaining wall Types 5 and 6 are not designed to withstand earthquake forces and are not used in Western Washington (west of the Cascade crest).

Once the geotechnical and architectural assessment have been completed, the region completes the PS&E for the standard wall option(s) selected including a generalized wall profile and plan, a typical cross-section as appropriate, details for desired wall appurtenances, drainage details, and other details as needed.

Metal bin walls, Types 1 and 2, have been deleted from the Standard Plans and are therefore no longer standard walls. Metal bin walls are seldom used due to cost and undesirable aesthetics. If this type of wall is proposed, contact the Bridge and Structures Office for plan details and toe bearing pressures. The applied toe bearing pressure will then have to be evaluated by the Geotechnical Services Branch to determine if the site soil conditions are appropriate for the applied load and anticipated settlement.

(b) **Preapproved Proprietary Walls.** Final design approval of preapproved proprietary walls, with the exception of geosynthetic walls, is the responsibility of the Bridge and Structures Office. Final approval of the design of preapproved proprietary geosynthetic walls is the responsibility of the Geotechnical Services Branch. It is the region's responsibility to coordinate the design effort for all preapproved wall systems.

The region materials laboratory performs the geotechnical investigation for preapproved proprietary walls 10 ft in height or less that are not bearing on soft or unstable soils. In all other cases, it is the responsibility of the Geotechnical Services Branch to conduct, or review and approve, the geotechnical investigation for the wall. The region also coordinates with the State Bridge and Structures Architect to ensure that the wall options selected meet the aesthetic requirements for the site.

Once the geotechnical and architectural assessments have been completed and the desired wall alternatives selected, it is the responsibility of the region to contact the suppliers of the selected preapproved systems to confirm in writing the adequacy and availability of the systems for the proposed use.

A minimum of three different wall systems must be included in the PS&E for any project with federal participation that includes a proprietary wall system unless specific justification is provided. Standard walls can be alternatives.

Once confirmation of adequacy and availability has been received, the region contacts the Bridge and Structures Office for special provisions for the selected wall systems and proceeds to finalize the contract PS&E in accordance with the *Plans Preparation Manual*. Provide the allowable bearing capacity and foundation embedment criteria for the wall, as well as backfill and foundation soil properties, in the special provisions. In general, assume that gravel borrow or better quality backfill material will be used for the walls when assessing soil parameters.

Complete wall plans and designs for the proprietary wall options will not be developed until after the contract is awarded, but will be developed by the proprietary wall supplier as shop drawings after the contract is awarded. Therefore, include a general wall plan, a profile showing neat line top and bottom of the wall, a final ground line in front of and in back of the wall, a typical cross-section, and the generic details for the desired appurtenances and drainage requirements in the contract PS&E for the proprietary walls. Estimate the ground line in back of the wall based on a nominal 1.5 ft facing thickness (and state this on the wall plan sheets). Include load or other design acceptance requirements for these appurtenances in the PS&E. Contact the Bridge and Structures Office for assistance regarding this.

It is best to locate catch basins, grate inlets, signal foundations, and the like outside the reinforced backfill zone of MSE walls to avoid interference with the soil reinforcement. In those cases where conflict with these reinforcement obstructions cannot be avoided, the location(s) and dimensions of the reinforcement obstruction(s) relative to the wall must be clearly indicated on the plans. Contact the Bridge and Structures Office for preapproved wall details and designs for size and location of obstructions, and to obtain the generic details that must be provided in the plans. If the obstruction is too large or too close to the wall face, a special design may be required to accommodate the obstruction, and the wall is treated as a nonpreapproved proprietary wall.

A special design is required if the wall must support structure foundations, other retaining walls, noise walls, signs or sign bridges, luminaires, or other types of surcharge loads. The wall is considered to be supporting the surcharge load if the surcharge is located within a 1H:1V slope projected from the bottom of the back of the wall. For MSE walls, the back of the wall is considered to be the back of the soil reinforcement layers. If this situation occurs, the wall is treated as a nonpreapproved proprietary wall.

For those alternative wall systems that have the same face embedment criteria, the wall face quantities depicted in the plans for each alternative must be identical. To provide an equal basis for competition, the region determines wall face quantities based on neat lines.

Once the detailed wall plans and designs are available as shop drawings after contract award, the Bridge and Structures Office will review and approve the wall shop drawings and calculations, with the exception of geosynthetic walls which are reviewed and approved by the Geotechnical Services Branch.

(c) **Nonpreapproved Proprietary Walls.** Final design approval authority for nonpreapproved proprietary walls is the same as for preapproved proprietary walls. The region initiates the design effort for all nonpreapproved wall systems by submitting wall plan, profile, cross-section, and other information for the proposed wall to the Bridge and Structures Office, with copies to the Geotechnical Services Branch and the <u>State Bridge and Structures</u> Architect. The Bridge and Structures Office coordinates the wall design effort.

Once the geotechnical and architectural assessments have been completed and the desired wall types selected, the Bridge and Structures Office contacts suppliers of the nonpreapproved wall systems selected to obtain and review detailed wall designs and plans to be included in the contract PS&E.

To ensure fair competition between all wall alternatives included in the PS&E, the wall face quantities for those wall systems subject to the same face embedment requirements <u>must</u> be identical.

The Bridge and Structures Office develops the special provisions and cost estimates for the nonpreapproved proprietary walls and sends the wall PS&E to the region for inclusion in the final PS&E in accordance with the *Plans Preparation Manual*.

(d) **Nonstandard Nonproprietary Walls.** With the exception of rockeries over 5 ft high, nonproprietary geosynthetic walls and reinforced slopes, and soil nail walls, the Bridge and Structures Office coordinates with the Geotechnical Services Branch and the <u>State Bridge and Structures</u> Architect to carry out the design of all nonstandard, nonproprietary walls. In this case, the Bridge and Structures Office develops the wall preliminary plan from site data provided by the region, completes the wall design, and develops the nonstandard nonproprietary wall PS&E package for inclusion in the contract.

For rockeries over 5 ft high, nonproprietary geosynthetic walls and reinforced slopes, and soil nail walls, the region develops wall/slope profiles, plans, and cross-sections and submits them to the Geotechnical Services Branch to complete a detailed wall/slope design.

For geosynthetic walls and slopes, and for rockeries, the region provides overall coordination of the wall/slope design effort, including coordination with the State Bridge and Structures Architect regarding aesthetics and finishes, and the region's or HQ Landscape Architect if the wall uses vegetation on the face. The Geotechnical Services Branch has overall design approval authority. Once the wall design has been completed, the Geotechnical Services Branch, and in some cases the Bridge and Structures Office, provides geotechnical and structural plan details to be included in the region plan sheets and special provisions for the PS&E. The region then completes the PS&E package.

For soil nail walls, once the Geotechnical Services Branch has performed the geotechnical design, the Bridge and Structures Office, in cooperation with the Geotechnical Services Branch, coordinates the design effort and completes the PS&E package.

(3) Guidelines for Wall/Slope Data Submission for Design

(a) **Standard Walls, Proprietary Walls, Geosynthetic Walls/Slopes, and Soil Nail Walls.** Where HQ involvement in retaining wall/slope design is required (as for standard walls and preapproved proprietary walls over 10 ft in height, gabions over 6 ft in height, rockeries over 5 ft in height, all nonpreapproved proprietary walls, geosynthetic walls/slopes, and all soil nail walls), the region submits the following information to the Geotechnical Services Branch or Bridge and Structures Office as appropriate:

- Wall/slope plans.
- Profiles showing the existing and final grades in front of and behind the wall.
- Wall/slope cross-sections (typically every 50 ft) or CAiCE files that define the existing and new ground-line above and below the wall/slope and show stations and offsets.
- Location of right of way lines as well as other constraints to wall/slope construction.
- Location of adjacent existing and/or proposed structures, utilities, and obstructions.
- Desired aesthetics.
- Date design must be completed.
- Key region contacts for the project.

Note that it is best to base existing ground measurements, for the purpose of defining the final wall geometry, on physical survey data rather than solely on photogrammetry. In addition, the region must complete a Retaining Wall/Reinforced Slope Site Data Check List, DOT Form 351-009 EF, for each wall or group of walls submitted.

(b) **Nonstandard Walls, Except Geosynthetic Walls/Slopes and Soil Nail Walls.** In this case, the region must submit site data in accordance with Chapter 1110. Additionally, a Retaining Wall Site Data Check List, DOT351-009EF, for each wall or group of walls must be completed by the region.

1130.07 Documentation

A list of the documents that are required to be preserved [in the Design Documentation Package (DDP) or the Project File (PF)] is on the following web site:

http://www.wsdot.wa.gov/eesc/design/projectdev/

Specific Wall Type	Advantages	Disadvantages	Limitations
Steel soil reinforcement with full height precast concrete panels	Relatively low cost	Can tolerate little settlement; generally requires high quality backfill; wide base width required (70% of wall height)	Applicable primarily to fill situations; maximum feasible height is approximately 20 ft
Steel soil reinforcement with modular precast concrete panels	Relatively low cost; flexible enough to handle significant settlement	Generally requires high quality backfill; wide base width required (70% of wall height)	Applicable primarily to fill situations; maximum height of 33 ft; heights over 33 ft require a special design
Steel soil reinforcement with welded wire and cast in place concrete face	Can tolerate large short-term settlements	Relatively high cost; cannot tolerate long-term settlement; generally requires high quality wall backfill soil; wide base width required (70% of wall height); typically requires a settlement delay period during construction	Applicable primarily to fill situations; maximum height of 33 ft for routine designs; heights over 33 ft require a special design
Steel soil reinforcement with welded wire face only	Can tolerate large long-term settlements; low cost	Aesthetics, unless face plantings can be established; generally requires high quality backfill; wide base width required (70% of wall ht.)	Applicable primarily to fill situations; maximum height of 33 ft for routine designs; heights over 33 ft require a special design

Table 1(a)
Summary of mechanically stabilized earth (MSE) gravity wall/slope options available.

Specific Wall Type	Advantages	Disadvantages	Limitations
Segmental masonry concrete block faced walls, generally with geosynthetic soil reinforcement	Low cost; flexible enough to handle significant settlements	Internal wall deformations may be greater than for steel reinforced systems but are still acceptable for most applications; generally requires high quality backfill; wide base width required (70% of wall height)	Applicable primarily to fill situations; in general, limited to wall height of 20 ft or less; greater wall heights may be feasible by special design in areas of low seismic activity and when geosynthetic products are used in which long-term product durability is well defined. (See Qualified Products List.)
Geosynthetic walls with a shotcrete or cast in place concrete face	Very low cost, esp. with shotcrete face; can tolerate large short-term settlements	Internal wall deformations may be greater than for steel reinforced systems but are still acceptable for most applications; generally requires high quality backfill; wide base width required (70% of wall height)	Applicable primarily to fill situations; in general, limited to wall height of 20 ft or less unless using geosynthetic products in which long-term product durability is well defined. (See Qualified Products List.) For qualified products, heights of 33 ft or more are possible.
Geosynthetic walls with a welded wire face	Very low cost; can tolerate large long-term settlements	Internal wall deformations may be greater than for steel reinforced systems but are still acceptable for most applications; generally requires high quality wall backfill soil; wide base width required (70% of wall height)	Applicable primarily to fill situations; in general, limited to wall height of 20 ft or less unless using geosynthetic products in which long-term product durability is well defined. (See Qualified Products List.) For qualified products, heights of 33 ft or more are possible.

Table 1(a) continued

Specific Wall Type	Advantages	Disadvantages	Limitations
Geosynthetic walls with a geosynthetic face	Lowest cost of all wall options; can tolerate large long-term settlements	Internal wall deformations may be greater than for steel reinforced systems but are still acceptable for most applications; generally requires high quality backfill; wide base width required (70% of wall height); durability of wall facing	Applicable primarily to fill situations; use only for temporary applications due to durability of facing; can be designed for wall heights of 40 ft or more
Soil nail walls	Relatively low cost; can be used in areas of restricted overhead or lateral clearance	Soil/rock must have adequate standup time to stand in a vertical cut approximately 6 ft high for at least 1 to 2 days; not feasible for bouldery soils; may require an easement for the nails	Applicable to cut situations only; not recommended in clean or water bearing sands and gravels, in bouldery soils that can interfere with nail installation, or in landslide deposits, especially where deep potential failure surfaces are present; maximum wall heights of 35 ft are feasible, though greater wall heights are possible in excellent soil/rock conditions. A special design is always required.

Table 1(a) continued

Specific Wall Type	Advantages	Disadvantages	Limitations
Concrete crib walls	Relatively low cost; quantity of high quality backfill required relatively small; relatively narrow base width, on the order of 50% to 60% of the wall height; can tolerate moderate settlements	Aesthetics	Applicable to cut and fill situations; reinforced concrete can typically be designed for heights of up to 33 ft and unreinforced concrete up to 16 ft; not used to support bridge or building foundations
Metal crib walls	Quantity of high quality backfill required relatively small; relatively narrow base width, on the order of 50% to 60% of the wall height; can tolerate moderate settlements	Relatively high cost; aesthetics	Applicable to cut and fill situations; can be designed routinely for heights up to 35 ft; not used to support bridge or building foundations
Timber crib walls	Low cost; minimal high quality backfill required; relatively narrow base width, on the order of 50% to 60% of the wall height; can tolerate moderate settlements	Design life relatively short, aesthetics	Applicable to cut and fill situations; can be designed for heights up to 16 ft; not used to support structure foundations
Concrete bin walls	Relatively low cost; narrow base width, on the order of 50 to 60% of the wall height; can tolerate moderate settlements	Aesthetics	Applicable to cut and fill situations; can be designed routinely for heights up to 25 ft; not used to support bridge or building foundations
Gabion walls	Relatively narrow base width, on the order of 50 to 60% of the wall height; can tolerate moderate settlements	Relatively high cost, depending on proximity to source of high quality angular rock to fill baskets	Applicable to cut and fill situations; can be designed routinely for heights up to 15 ft, and by special design up to 21 ft; not used to support structure foundations

Table 1(b) Summary of prefabricated modular gravity wall options available

Specific Wall Type	Advantages	Disadvantages	Limitations
Mortar rubble masonry walls	Quantity of high quality backfill required is relatively small	High cost; relatively wide base width, on the order of 60% to 70% of the wall height; cannot tolerate settlement	Applicable mainly to fill situations where foundation conditions consist of very dense soil or rock; due to expense, only used in areas where other mortar rubble masonry walls are present and it is desired to match aesthetics; typically, can be designed for maximum heights of 25 ft
Unreinforced concrete gravity walls	Quantity of high quality backfill required is relatively small	High cost; relatively wide base width, on the order of 60% to 70% of the wall height; cannot tolerate settlement	Applicable mainly to fill situations where foundation conditions consist of very dense soil or rock; due to expense, only used in areas where other concrete gravity walls are present and it is desired to match aesthetics; typically, can be designed for maximum heights of 25 ft
Reinforced concrete cantilever walls	Relatively narrow base width on the order of 50% to 60% of the wall height; can be used to support structure foundations by special design	High cost; cannot tolerate much settlement; relatively deep embedment might be required on sloping ground due to toe in front of wall face	Applicable to cut and fill situations; can be routinely designed for heights up to 35 ft
Reinforced concrete counterfort walls	Relatively narrow base width on the order of 50% to 60% of the wall height; can be used to support structure foundations by special design	High cost; cannot tolerate much settlement; relatively deep embedment might be required on sloping ground due to toe in front of wall face	Applicable to cut and fill situations; can be routinely designed for heights up to 50 ft; proprietary versions typically 33 ft max

Table 1(c) Summary of rigid gravity and semigravity wall options available

Specific Wall Type	Advantages	Disadvantages	Limitations
Soldier pile wall	Very narrow base width; deep embedment to get below potential failure surfaces relatively easy to obtain	Relatively high cost	Applicable mainly to cut situations; maximum feasible exposed height is on the order of 10 ft; difficult to install in bouldery soil or soil with water bearing sands
Sheet pile wall	Low to moderate cost; very narrow base width	Difficult to get embedment in dense or bouldery soils; difficult to protect against corrosion	Applicable mainly to cut situations in soil; maximum feasible exposed height is on the order of 10 ft
Cylinder pile wall	Relatively narrow base width; can produce stable wall even if deep potential failure surfaces present	Very high cost	Applicable mainly to cut situations; max. feasible exposed height is on the order of 20 to 25 ft, depending on passive resistance available; can be installed in bouldery conditions, though cost will increase
Slurry wall	Relatively narrow base width; can produce stable wall even if deep potential failure surfaces present	Very high cost; difficult construction	Applicable mainly to cut situations; maximum feasible exposed height is on the order of 20 to 25 ft, depending on passive resistance available

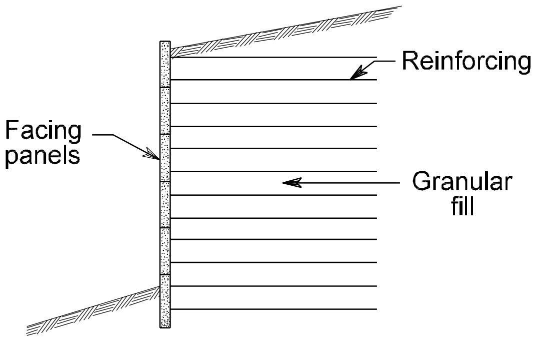
Table 1(d) Summary of nongravity wall options available

Specific Wall Type	Advantages	Disadvantages	Limitations
All nongravity cantilever walls with tiebacks	Relatively narrow base width; can produce stable wall even if deep potential failure surfaces present	Very high cost; difficult to install in areas where vertical or lateral clearance is limited; easements may be necessary; installation activities may impact adjacent traffic	Applicable only to cut situations; can be designed for heights of 50 ft or more depending on the specifics of the structure of the wall
All nongravity cantilever walls with deadman anchors	Relatively narrow base width; can produce stable wall even if deep potential failure surfaces present	Moderate to high cost; must have access behind wall to dig trench for deadman anchor; may impact traffic during deadman installation; easements may be necessary	Applicable to partial cut/fill situations; can be designed for wall heights of approximately 16 ft

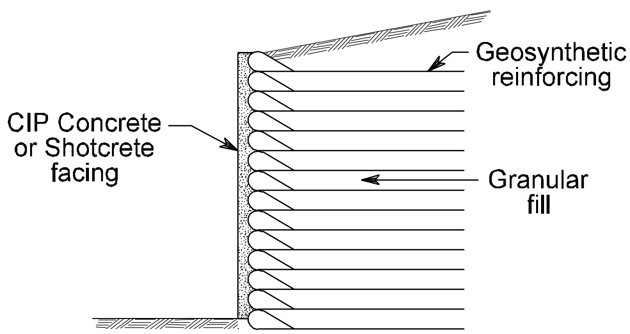
Table 1(e) Summary of anchored wall options available

Wall/Slope Classification	Specific Wall Type	Advantages	Disadvantages	Limitations
Rockeries	Only variations are in rock sizes used and overall wall dimensions	Low cost; narrow base width on the order of 30% of the wall height required	Slope must be at least marginally stable without rockery present; cannot tolerate much settlement	Applicable to both cut and fill situations; max. feasible height in a cut even for excellent soil conditions is approx. 16 ft and 8 ft in fill situations
Reinforced slopes	Only variations are in geosynthetic products used and in erosion control techniques used on slope face	Low cost; can tolerate large settlements; can adapt well to sloping ground conditions to minimize excavation required; high quality fill is not a requirement	Must have enough room between the right of way line and the edge of the shoulder to install a 1H:1V slope	Best suited to sloping fill situations; max. height limited to 30 ft unless geosynthetic products are used in which long-term product durability is well defined. Certain products can be used in critical applications and for greater slope heights on the order of 60 ft or more but consider need, landscaping maintenance, and the reach of available maintenance equipment.

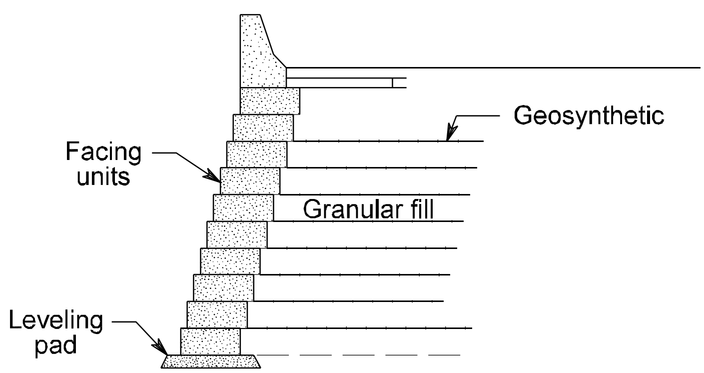
Table 1(f) Other wall/slope options available



MSE Wall with Modular Precast Concrete Facing Panels

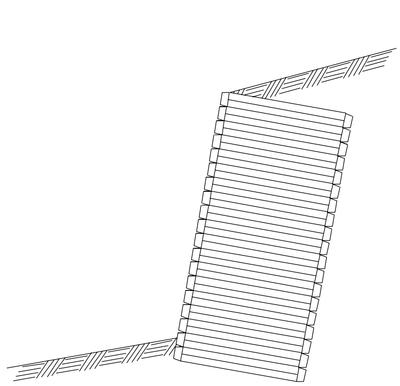


MSE Wall with Geosynthetic Reinforcement and CIP Concrete or Shotcrete Facing

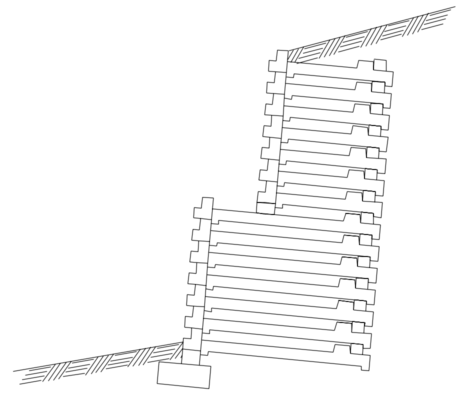


MSE Wall with Segmental Concrete Block Facing

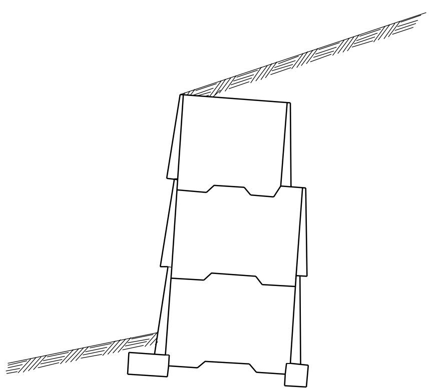
Typical Mechanically Stabilized Earth Gravity Walls
Figure 1130-1a



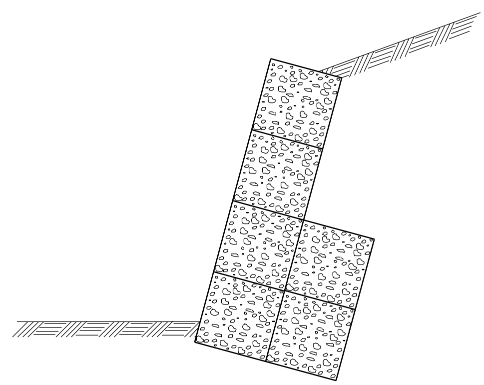
Metal Bin Wall



Precast Concrete Crib Wall



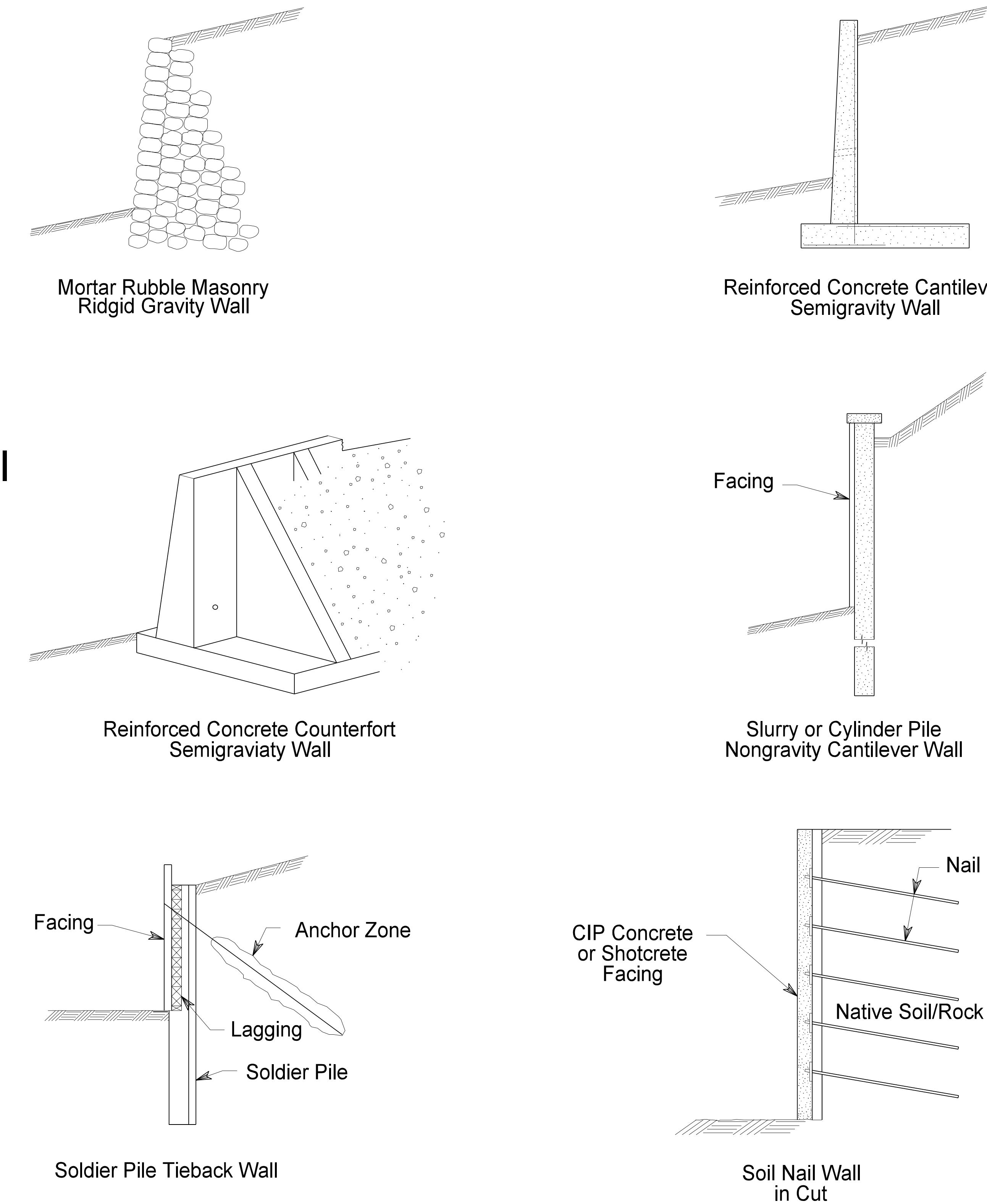
Precast Concrete Bin Wall



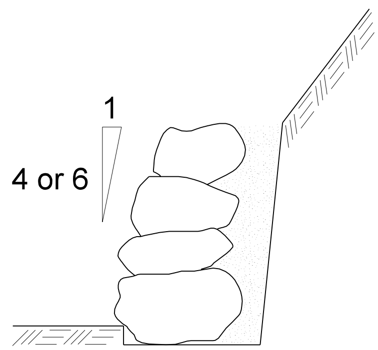
Gabion Wall

Typical Prefabricated Modular Gravity Walls

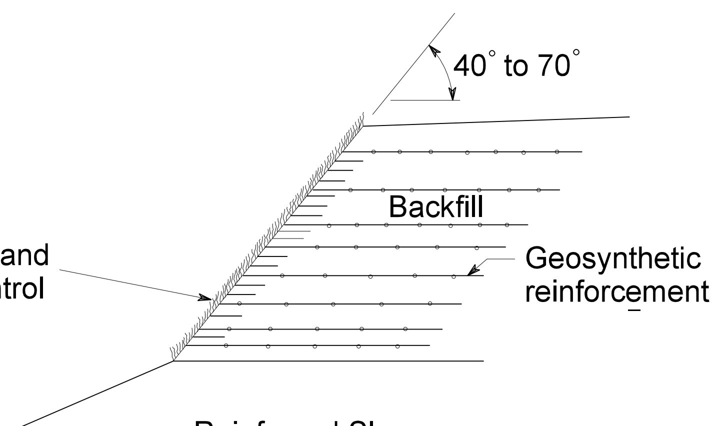
Figure 1130-1b



Typical Rigid Gravity, Semigravity Cantilever, Nongravity Cantilever, and Anchored Walls
Figure 1130-1c

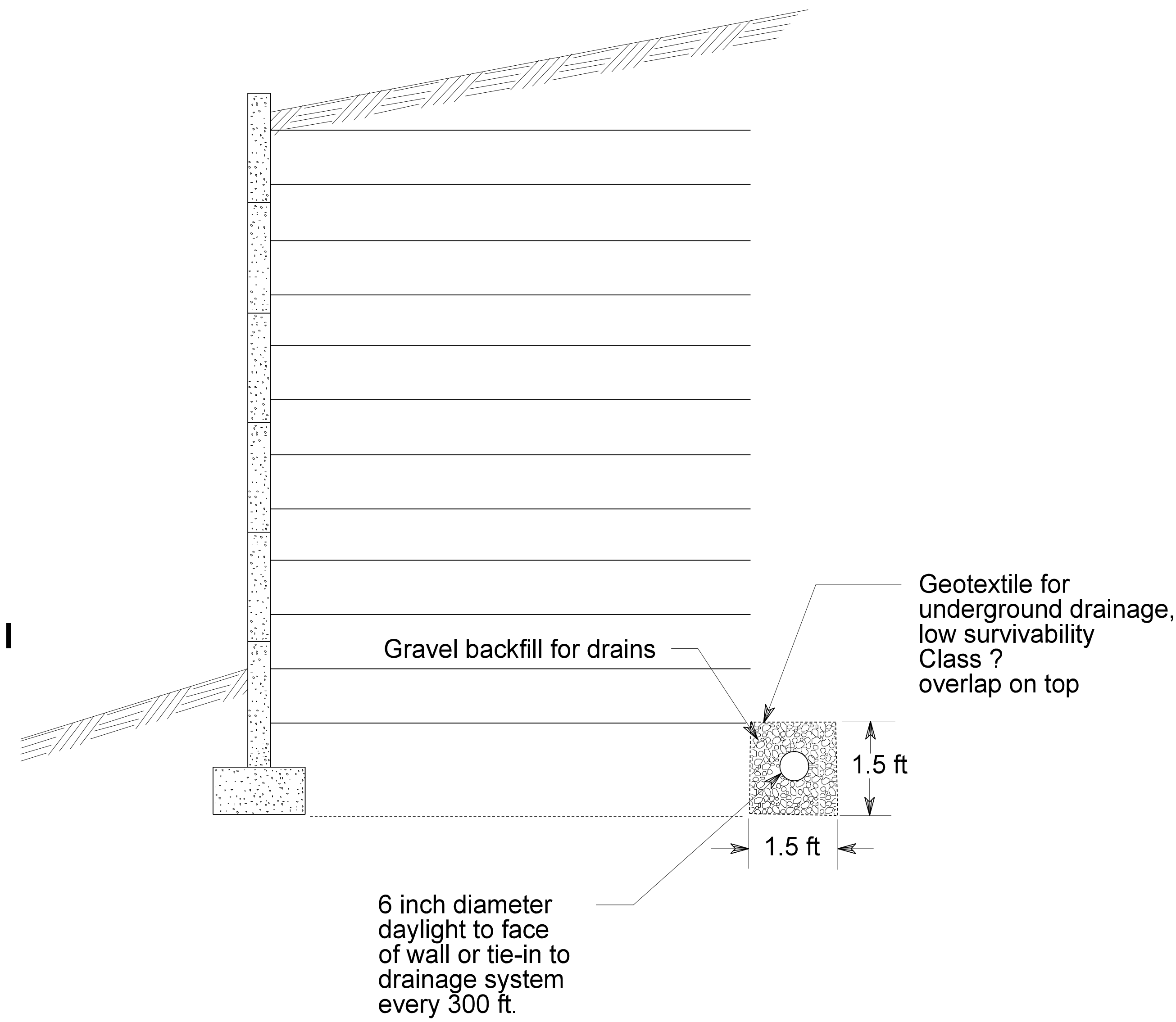


Rockery

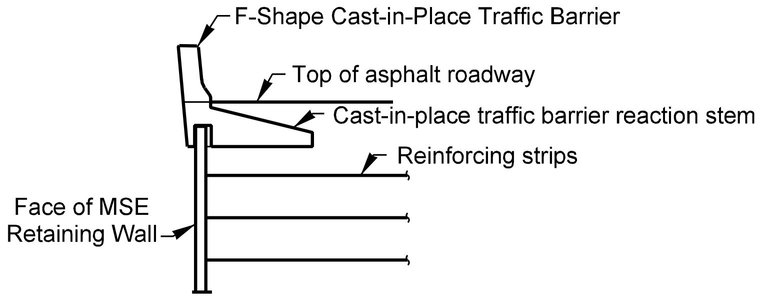


Reinforced Slope

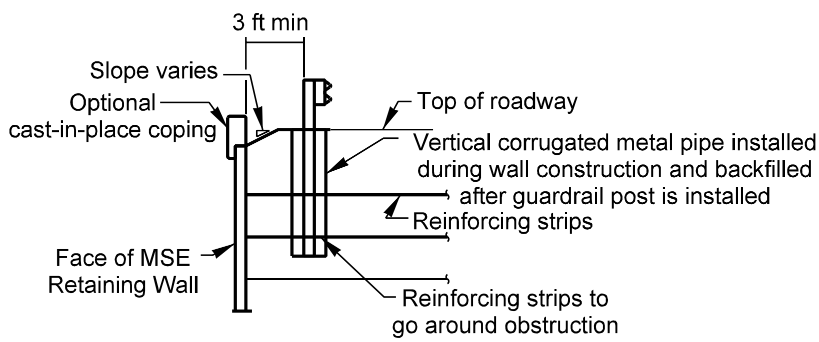
Typical Rockery and Reinforced Slope
Figure 1130-1d



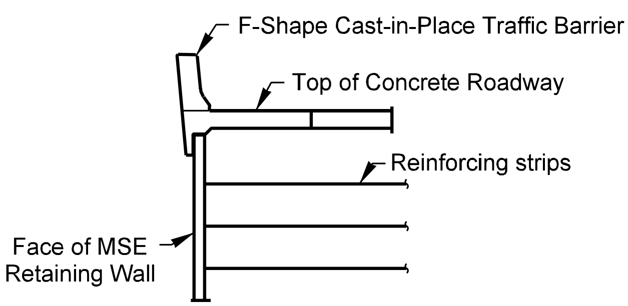
MSE Wall Drainage Detail
Figure 1130-2



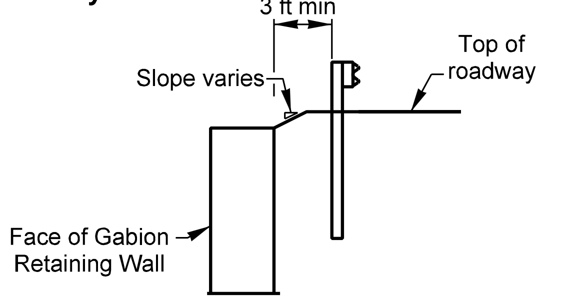
Concrete Traffic Barrier with Asphalt Roadway



Beam Guardrail on Top of MSE Retaining Wall

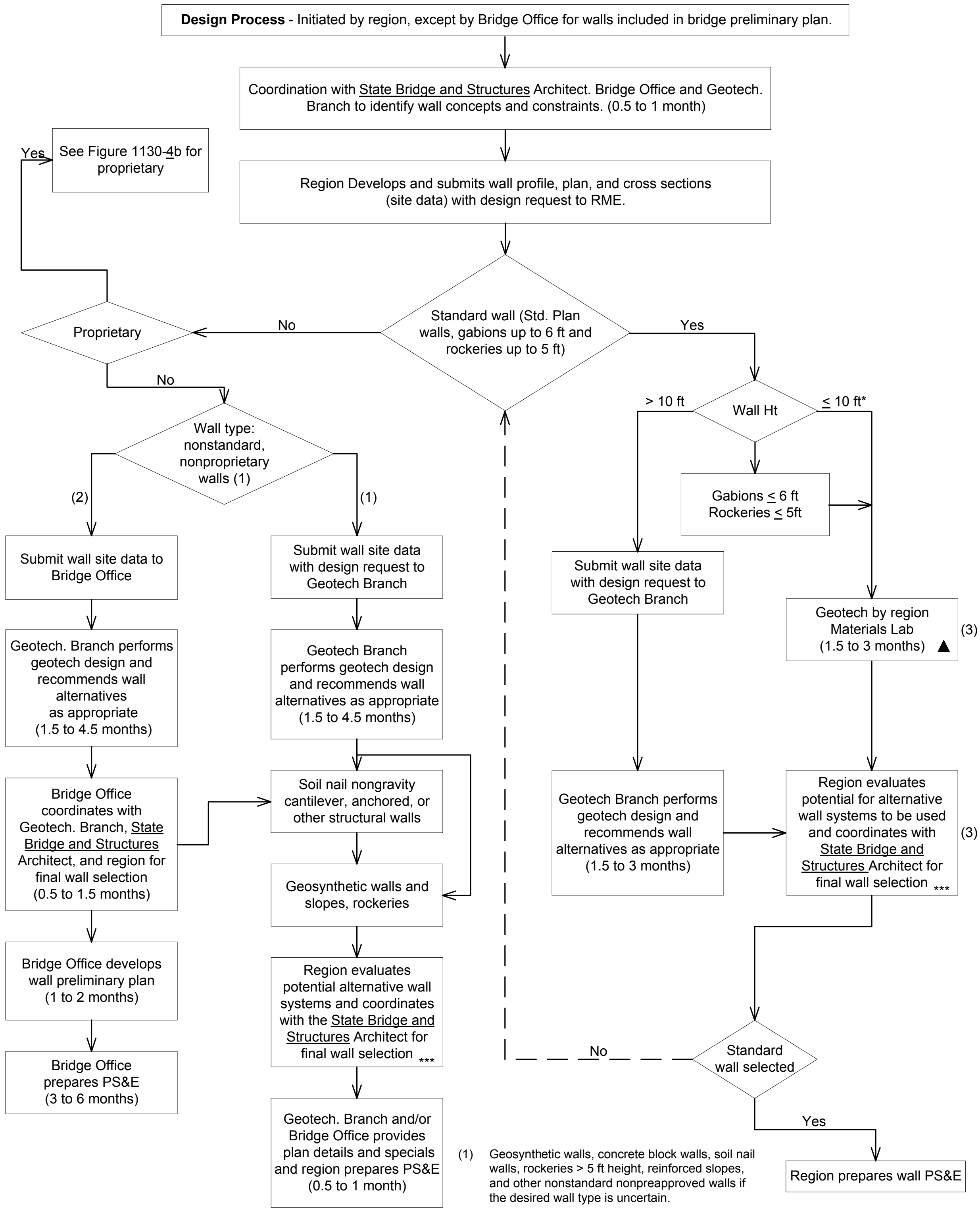


Concrete Traffic Barrier with Concrete Roadway



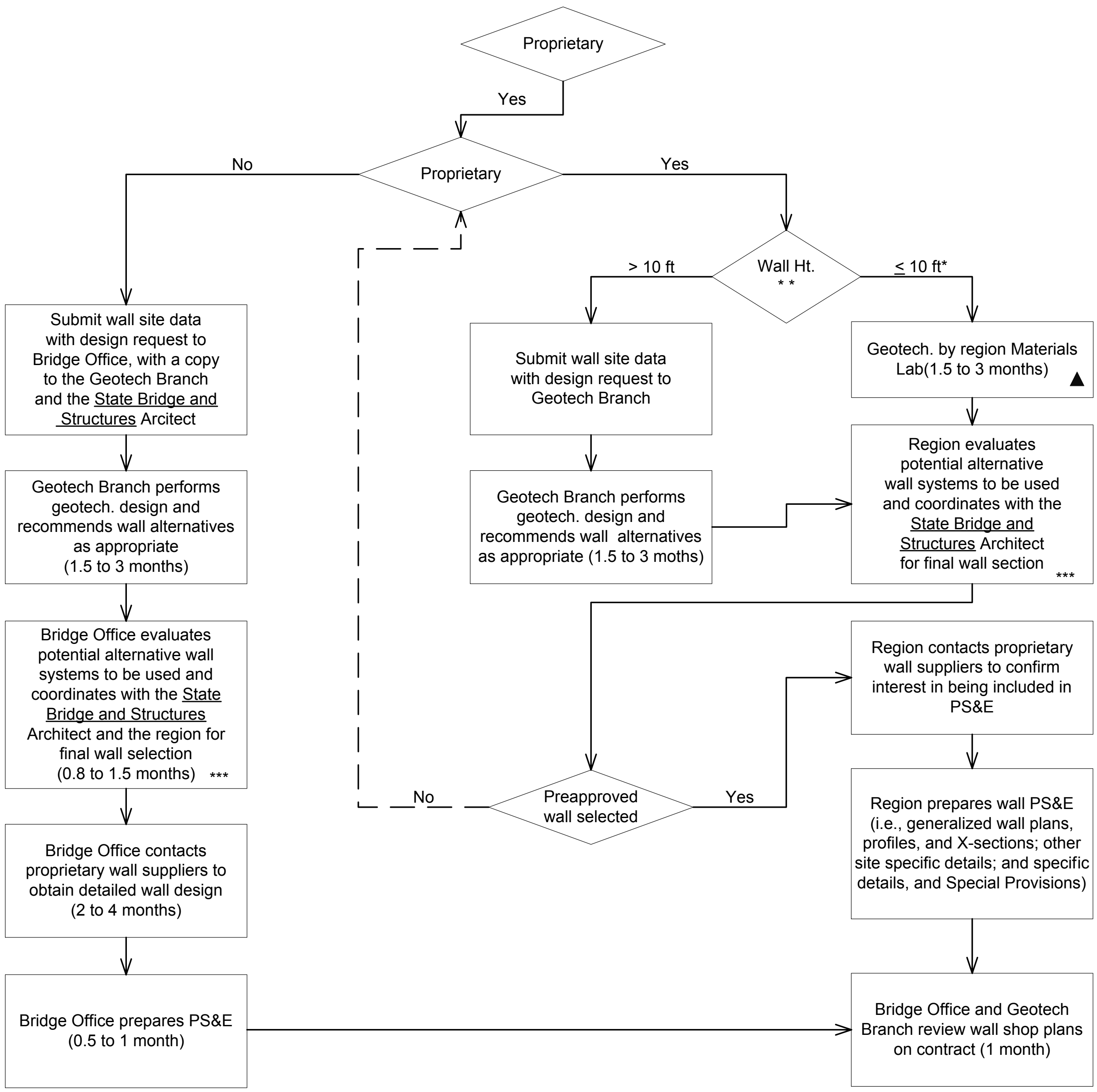
Beam Guardrail on Top of Gabion Wall

Retaining Walls With Traffic Barriers
Figure 1130-3



(1) Geosynthetic walls, concrete block walls, soil nail walls, rockeries > 5 ft height, reinforced slopes, and other nonstandard nonpreapproved walls if the desired wall type is uncertain.
(2) All other nonstandard, nonproprietary walls
(3) See notes and legend on Figure 1130-4b

Retaining Wall Design Process
Figure 1130-4a



Notes:

The "Bridge Office" refers to the WSDOT Bridge and Structures Office in Headquarters.

The "Geotech Branch" refers to the WSDOT Geotechnical Services Branch in Headquarters.

The "State Bridge and Structures Architect" refers to the WSDOT Architecture Section of the Bridge and Structures Office in Headquarters.

Regarding time estimates:

- Assumes no major changes in the wall scope during design.
- Actual times may vary depending on complexity of project.
- Contact appropriate design offices for more accurate estimates of time.

Legend:

▲ Region provides courtesy coy of region's geotechnical report to Geotechnical Branch

* Assumes soft or unstable soil not present and wall does not support other structures.

** The preapproved maximum wall height is generally 33 ft. Some proprietary walls might be less. (Check with the Bridge and Structures Office.)

*** If the final wall selected is a different type than assumed, go back through the design process to ensure that all steps have been taken.

Retaining Wall Design Process - Proprietary

Figure 1130-4b

Ht (ft)	Maximum Soil Pressure (psf) for Reinforced Concrete Retaining Walls											
	Type 1 ①		Type 2 ②		Type 3 ③		Type 4 ④		Type 5 ③		Type 6 ④	
	Static	Earth-quake	Static	Earth-quake	Static	Earth-quake	Static	Earth-quake	Static	Earth-quake	Static	Earth-quake
5	1611	781	1607	770	630	1033	641	1115	702	971	611	798
6	1838	976	1842	974	705	1254	865	1661	908	1322	746	1141
7	1876	1137	1891	1150	797	1558	882	1904	1179	1782	882	1420
8	2178	1431	2213	1465	995	2047	1025	2323	1510	2419	1246	2091
9	2255	1646	2305	1703	1104	2402	1040	2473	1632	2666	1587	2692
10	2492	2078	2492	2063	1216	2786	1065	2651	1924	3224	1635	2918
11	2693	2474	2713	2482	1197	2787	1174	2907	2046	3475	1795	3233
12	2643	2666	2682	2702	1308	3172	1277	3351	2345	4063	1873	3282
13	2732	2999	2693	2923	1458	3560	1304	3158	2384	4041	1955	3377
14	2972	3508	3065	3624	1539	3790	1444	3643	2683	4611	2269	3941
15	3100	3886	3358	4281	1620	4019	1645	4205	2766	4664	2349	4036
16	3166	4128	3420	4552	1752	4305	1748	4466	2818	4715	2668	4603
17	3247	4372	3472	4795	1833	4534	1849	4723	3149	5293	2846	4927
18	3301	4577	3559	5067	2104	5223	2072	5246	3373	5625	2924	5021
19	3399	4825	3405	4877	2217	5457	2208	5534	3691	6417	3175	5551
20	3570	5205	3724	5585	2461	5983	2312	5822	3685	6422	3405	6103
21	3677	5453	3617	5423	2507	6197	2478	6111	3650	6403	3556	6406
22	3752	5659	3696	5664	2635	6473	2610	6547	3778	6672	3737	6741
23	3866	5910	3810	5939	2715	6693	2650	6729	4110	7280	3889	7046
24	4049	6294	3912	6180	2844	6972	2785	7071	4159	7293	4071	7383
25	4166	6544	4058	6457	2973	7252	2949	7462	4492	7894	4228	7689
26	4250	6752	4172	6698	3103	7532	3047	7711	4664	8241	4410	8031
27	4372	7004	4318	6976	3265	7986	3093	7928	4786	8507	4391	8040
28	4496	7258	4463	7254	3394	8264	3106	8115	4956	8832	4575	8385
29	4621	7512	4609	7533	3524	8544	3241	8402	4920	8819	4724	8693
30	4666	7480	4535	7371	3653	8824	3376	8690	4892	8824	4752	8760
31	4795	7734	4682	7648	3816	9280	3536	9130	5068	9158	4901	9068
32	4924	7988	4828	7926			3707	9422	5194	9433	5088	9415
33	5055	8244	4975	8204			3872	9901	5293	9513	5263	9723
34	5186	8500	5122	8483					5328	9603	5191	9536
35	5318	8757	5269	8763					5456	9877	5378	9880

Notes

① 2 ft surcharge or traffic barrier with vertical front face.

② 2 ft surcharge or traffic barrier with sloping front face.

③ 2H:V1 backslope with vertical front face.

④ 2H:1V backslope with sloping front face.

Retaining Wall Bearing Pressure
Figure 1130-5

1140.01 General

The function of a noise barrier is to reduce traffic noise levels at adjoining areas. The noise abatement decisions are made during the environmental stage of the project development process. This is a highly interactive process. Before a noise barrier is designed, the department must be confident that there is significant need, a cost effective and environmentally acceptable noise barrier, a source of funds, and acceptance by adjacent property owners, local governmental agencies, and the general public.

The designer will find the following preliminary design information in the noise report:

- Sources of noise
- Noise receiver locations
- Predicted level of noise reduction
- Locations of existing and future noise impacts along the project corridor
- Barrier location and height recommendations based on what is feasible and reasonable

Design of a noise barrier project is the result of a team effort coordinated by the project engineer.

This chapter addresses the factors that are considered when designing a noise barrier and the associated procedures and documentation requirements.

1140.02 References

Environmental Procedures Manual, M 31-11, WSDOT

Guide Specifications for Structural Design of Sound Barriers, AASHTO

Roadside Manual, M 25-30, WSDOT

Standard Plans for Road, Bridge, and Municipal Construction (Standard Plans), M 21-01, WSDOT

1140.03 Design

The two basic types of noise barriers are the earth berm and the noise wall. An earth berm can be constructed to the full height required for noise abatement or to partial height in conjunction with a noise wall to reach the required height. A noise wall can be made of concrete, masonry, metal, wood, or other approved innovative products, and can be supported by spread, pile, shaft, or trench footings.

Consideration of the noise report and the visual characteristics of adjacent land forms, vegetation, and structural elements (such as buildings, bridges, and retaining walls) will determine whether a proposed noise barrier might be berm, wall, or both.

An earth berm <u>is</u> the primary alternative if the visual and environmental quality of the corridor <u>will</u> be preserved or enhanced and materials and right of way widths are available. See the *Roadside Manual* for criteria for determining if a vegetated earth berm is appropriate.

The region uses the noise report and other environmental documents (see the *Environmental Procedures Manual*) to help determine the location, exposure conditions, length, and heights of the proposed noise barrier.

To design and locate a noise barrier of any kind, consider the following:

- Desired noise abatement
- Future right of way needs
- Cost and constructibility
- <u>Neighborhood character</u>
- Visual character and quality of the corridor
- Future maintenance of the noise barrier and the whole right of way
- Wind

- Supporting soil
- Earthquakes
- Ground water
- Existing drainage systems and water courses
- Exposure to vehicular impacts
- Potential vandalism
- Existing vegetation and roadside restoration required
- Access for maintenance equipment and enforcement, traffic service, and emergency vehicles
- Access to fire hydrants from both sides
- Pedestrian and bicycle access
- Available and attainable width of right of way for berms
- Aesthetic and structural characteristics of available wall designs
- Visual compatibility of each wall design with other transportation structures within the corridor
- Construction limits for footings
- Locations of existing survey monuments
- Access to, and maintenance of, right of way behind a wall, including drainage structures
- Use of right of way and wall by adjacent property owners
- Drainage and highway runoff
- Drainage from adjacent land
- Existing utilities and objects to relocate or remove
- Water and electricity; needs, sources, and access points

A noise barrier must not have anything (such as bridge columns, light fixtures, or sign supports) protruding in such a way as to present a potential for snagging vehicles.

(1) Earth Berm

(a) Berm slopes are a function of the material used, the attainable right of way width, and the desired visual quality. Slopes steeper than 2H:1V (3H:1V for mowing) are not recommended. Design the end of the berm with a lead-in slope of 10H:1V and curve it toward the right of way line.

(b) See Chapter 710 and the Standard Plans for guidance on redirectional land forms if the berm is to function as a traffic barrier.

(c) See the *Roadside Manual* for guidance regarding vegetation on berms and redirectional land forms.

(2) Noise Wall

(a) When feasible, to encourage competitive bidding, include several alternate noise wall designs in the contract and permit the contractor to submit alternate designs under the value engineering specification.

(b) There are standard noise wall designs in the Standard Plans manual. Additional designs are in various stages of development to become standard plans. The draft-standard design sheets and other preapproved plans are available from the Bridge and Structures Office. The Bridge and Structures Office also works with the regions to facilitate the use of other designs as bidding options.

(c) When a noise wall has ground elevations that are independent of the roadway elevations, a survey of ground breaks (or cross sections at 25-ft intervals) along the entire length of the wall is needed for evaluation of constructibility and to assure accurate determination of panel heights.

(d) Size of openings (whether lapped, door, or gated) depends on the intended users. Agencies such as the local fire department can provide the necessary requirements. Unless an appropriate standard plan is available, such openings must be designed and detailed for the project.

(e) When a noise wall is inside the Design Clear Zone, design its horizontal and vertical (ground elevation) alignment as if it were a rigid concrete traffic barrier. See Chapter 710 for maximum flare rates.

(f) Provide a concrete traffic barrier shape at the base of a new noise wall constructed 12 ft or less from the edge of the nearest traffic lane. The traffic barrier shape is optional at the base of the new portion when an existing vertical-faced wall is being extended (or the existing wall may be retrofitted for continuity). Standard Concrete Barrier Type 4 is recommended for both new and existing walls except when the barrier face can be cast as an integral part of a new wall. Deviations may be considered but require approval as prescribed in Chapter 330. For deviations from the above, deviation approval is not required where sidewalk exists in front of the wall or in other situations where the wall face is otherwise inaccessible to traffic.

See Chapter 710, "Traffic Barriers," for flare rates and approach slopes for concrete barriers.

(g) To designate a standard noise wall, select the appropriate general special provisions and state the standard plan number, type, and foundation type. For example: Noise Barrier Standard Plan D-2a, Type 1A, Foundation D1.

Wall type is a function of exposure and wind speed. See Figure 1140-1.

A geotechnical report identifying the angle of internal friction f and the allowable bearing pressure is needed for selection of a standard foundation. The standard spread footing designs require an allowable bearing pressure of 1 Tsf. The standard trench and shaft footing designs require a f of at least 32° for D1 and 38° for D2.

A special design of the substructure is required for noise walls on substandard soil, where winds exceed 90 mph, and for exposures other than B1 and B2 as defined in Figure 1140-1.

(h) For maintenance of the surface of a tall wall (10 ft or more), consider harness tie-offs for the fall protection required by the Department of Labor and Industries.

	Exposure				
	B1		B2		C
Wind Speed	80 mph	90 mph	80 mph	90 mph	
Wall Type	A	B	C	D	Special Design*

Wind speed is according to Figure 1-2.1.2.A of the (AASHTO) *Guide Specifications for Structural Design of Sound Barriers*. Assume the wind to be perpendicular to the wall on both sides and design for the most exposed side.

Exposure is determined by the nature of the immediately adjacent ground surface and the extension of a plane at the adjacent ground surface elevation for 1,500 ft to either side of the noise wall:

Exposure B1 = Urban and suburban areas with numerous closely spaced obstructions having the size of single-family dwellings or larger that prevail in the upwind direction from the noise barrier for a distance of at least 1,500 ft.

Exposure B2 = Urban and suburban areas with more open terrain not meeting the requirements of Exposure B1.

Exposure C = Open terrain, with scattered obstructions, that includes flat, open country; grasslands; and elevated terrain.

*For a noise wall with Exposure C, on a bridge or overpass, or at the top of a slope, consult the Bridge and Structures Office, as a special design will probably be necessary.

Standard Noise Wall Types
Figure 1140-1

1140.04 Procedures

The noise unit notifies the Project Engineer's Office when a noise barrier is recommended in the noise report.

The Project Engineer's Office is responsible for interdisciplinary teams, consultation, and coordination with the public, noise specialists, maintenance, construction, region's Landscape Architecture Office (or the Roadside and Site Development Services Unit), right of way personnel, Materials Laboratory, State Bridge and Structures Architect (in the Bridge and Structures Office), Bridge and Structures Office, CAE Support Team, Access and Hearings Engineer, consultants, and many others.

The region evaluates the soils (see Chapters 510 and 1110) and, if a noise wall is contemplated, obtains a list of acceptable wall design options by sending information pertaining to soils and drainage conditions, the alignment, and heights of the proposed wall to the State Bridge and Structures Architect.

If a vegetated earth berm is considered, see the *Roadside Manual* for procedures.

The State Bridge and Structures Architect coordinates with the Bridge and Structures Office, Hydraulics Design Branch, Geotechnical Branch, and the region to provide a list of acceptable standard, draft-standard, and preapproved-proprietary noise wall designs, materials, and finishes that are compatible with existing visual elements of the corridor. Only wall designs from this list may be considered as alternatives. Design visualizations of the highway side of proposed walls (available from the CAE Support Team in Olympia) must be limited to options from this list. The visual elements of the private-property side of a wall are the responsibility of the region unless addressed in the environmental documents.

After the noise report, any changes to the dimensions or location of a noise barrier must be reviewed by the appropriate noise unit to determine the impacts of the changes on noise abatement.

On limited access highways, any opening in a wall or fence (for pedestrians or vehicles) must be coordinated with the Access and Hearings Engineer and approved by the State Design Engineer.

On nonlimited access highways, an access connection permit is required for any opening (approach) in a wall or fence.

The Bridge and Structures Office provides special substructure designs to the regions upon request; reviews contract design data related to standard, draft-standard, and preapproved designs; and reviews plans and calculations that have been prepared by others. (See Chapter 1110.)

Approval of the Bridge and Structures Office and the Architecture Office is required for any attachment or modification to a noise wall and for the design, appearance, and finish of door and gate type openings.

Approval of the State Bridge and Structures Architect is required for the final selection of noise wall appearance, finish, materials, and configuration.

1140.05 Documentation

A list of the documents that are required to be preserved in the Design Documentation Package (DDP) or the Project File (PF) is on the following web site:

http://www.wsdot.wa.gov/eesc/design/projectdev/

A

B

C

H

M

T

U

V

W

Z