FUSS & O'NEILL

May 20, 2019

Ms. Juliet T.H. Walker, AICP
Planning Director
Planning Department
1 Junkins Avenue
Portsmouth, NH 03801

RE: Response to Cate Street Extension Roadway Design Peer Review

Dear Ms. Walker,

The Peer Review Comments from TEC have been restated below in *bold italicized font*. The responses to these comments have been issued below in normal font.

Horizontal Alignment and Roadway Plan Review:

1. *Please confirm the intended design speed of Cate Street / Cate Street Extension. It appears that most, but not all, design parameters are consistent with a design speed of 30 mph.*

   The design speed for the Cate Street Extension is 25 mph.

   It should be noted that the City preferred alignment at the intersection of Cate Street and Bartlett Street will not support a design speed too much above 20 mph. The maximum centerline radius that can be fit to the City Right of Way and Easements provided by the adjacent approved, under construction, Townhouse project prior the rail Road bridge to the south is a radius of 110-ft.

   According to AASHTO's Policy For Geometric Design Section 5.3, Local Streets in Urban Areas, Table 3-7, a minimum radius of 110-ft will support a design speed between 20 and 25 mph. We employed a radius of 155-ft to round up. See Attached excerpt from AASHTO.

2. *Label radii of horizontal curves on baseline alignment.*

   The curve data has been added to the baseline alignment. Please refer to sheets CS-101 through CS-104 of the Roadway Plans.

3. *The proposed alignment of Cate Street Extension at the Route 1 Bypass / Borthwick Avenue intersection causes the westbound through movement to approach the existing raised median island within Borthwick*

5 Fletcher Street, Suite 1
Kennebunk, ME 04043
207.363.0669

www.fando.com

California
Connecticut
Maine
Massachusetts
New Hampshire
Rhode Island
Vermont

Avenue at an angle. Consider revising the alignment of Cate Street Extension at this intersection to provide a better alignment for through traffic (refer to attached markup of Sheet CS-101).

Eric Eby had a similar concern at the last TAC Work Session. Shortly after that meeting we made alignment corrections to the Cate Street Extension to better align the through movements.

Please refer to Sheet CS-101 of the Roadway Plans.

4. *Per Section VI of the City of Portsmouth Subdivision Rules & Regulations, a minimum 25' radius should be provided at all street corners (e.g. northeast corner of Cate Street Extension / US Route 1 Bypass, driveway at Station 4+00 right, Cate Street at Station 8+00 left, driveway at Station 9+50 right, and driveway at Station 13+15 right).*

   The radii for the intersections are as follows:

Route 1 Bypass / Cate Street Extension	Northeast = 20-ft, Southeast = 50-ft
Driveway Station 4+00 Right	radii=20-ft
Cate Street / Cate Street Extension	800+00 left = 20-ft, 9+50 right = 20-ft (slated to become pedestrian way, possibly)
Driveway Station 13+15 Right	R1=15-ft, R2=25-ft

   The 20-ft radii at the Cate Street Extension / Route 1 Bypass is 20-ft in order to provide more protection / separation to the Traffic signal mast arm. It can be changed to 25-ft if necessary. However the 50-ft radius suggested in #5 below will require a relocation of the Traffic Light Mast Arm. Turning movement checks at this intersection show that a larger radius is unwarranted.

   It should be notes that the radii at the driveways of the adjacent townhouse project are 15-ft. The driveway radii throughout the project are sufficient to allow for ingress and egress of delivery vehicles and more importantly emergency vehicles.

5. *Consider revising the proposed 20-foot radius at the northeast corner of the Cate Street Extension / Route 1 Bypass intersection to a 50-foot radius. It is noted that the existing traffic signal mast arm foundation is at the edge of pavement and is a design constraint. However, if the northern curb line of Cate Street Extension were re-aligned and shifted to the south as suggested (refer to attached markup of Sheet CS-101), a 50-foot radius curve may fit while*

maintaining the existing traffic signal mast arm and guardrail. At minimum this curve radius should be 25' (see Comment #4).

As stated above, the 20-ft radius was used at the northwest corner of Cate Street Extension and Route 1 Bypass in order to provide more protection to the Traffic Light Mast Arm. A 25-ft radius will fit without interfering with the guardrail or Mast Arm, however a larger radius of 25-ft will reduce the separation from the travel lane and the Mast Arm. A 50-ft radius will require a replacement of the Mast Arm entirely and the turning movements at the intersection show this would be unwarranted. In the event that the City desires a larger radius at the intersection a 25-ft radius can be revised into the design.

6. *The Cate Street Extension westbound approach to US Route 1 Bypass appears to be excessively wide. Consider revising the approach layout to consist of an exclusive left-turn lane, a through lane, and an exclusive right-turn lane (refer to attached markup of Sheet CS-101).*

   The Traffic Study by Stephen Pernaw recommends delineation of the westbound approach with a shared left-through-right lane and an exclusive right-turn lane. This is what the design reflects.

7. *Consider revising the 15' wide receiving lane on Cate Street Extension eastbound to be comprised of an 11' wide lane and a 4' wide shoulder.*

   A complete re-working of the Cate Street Extension / Route 1 Bypass / Borthwick Avenue intersection has taken place to address concerns voiced by Eric Eby, City Traffic Engineer and echoed by Peer Review comment #3 and this comment #7.

   The revisions to the intersection allow eastbound traffic form Borthwick Avenue entering Cate Street Extension to smoothly cross Route 1 Bypass. The revisions also allow Traffic proceeding westbound from Cate Street Extension to Borthwick Avenue to make a smooth movement while crossing Route 1 Bypass.

8. *Provide turning movement simulations for the intended design vehicle entering / exiting Cate Street Extension from US Route 1 Bypass. Utilize WB-67 design vehicle, if applicable (Sheet CT-103).*

   The design vehicle and turning movements have been updated.

9. *The existing guardrail at the northeast corner of US Route 1 Bypass / Cate Street Extension will need to be modified to provide a gap for the shared use path, with appropriate crash worthy end terminals for vehicular traffic.*

The guardrail at the Northeast corner of Cate Street Extension at the intersection with Route 1 Bypass will be modified as ultimately discussed with and approved by NHDOT.

Discussions regarding the Traffic Study and subsequent design are ongoing with NHDOT. The decided upon guardrail detail will be added to the plans. As of yet the desired guardrail termination has not been decided.

The necessary gap will be provided to allow the shared use path to be accessed and ultimately extended across Route 1 Bypass and along Borthwick Avenue as outlined in the Seacoast Greenway Master Plan.

10. *Consider extending the raised median island on Cate Street Extension from Station 1+60 to Station 3+50 (refer to attached markup of Sheet CS-101). While this would restrict the U-Haul driveway access to right-in / right-out only, allowing left turns at this intersection may be a safety concern, given its proximity to the signalized US Route 1 Bypass intersection. It is understood that U-Haul may have requested full access to this intersection; however, further coordination should be conducted to ensure the long-term operational safety at this driveway access.*

    The raised median cannot be extended further down Cate Street Extension while still honoring the terms of the easement that the U-Haul possesses for access. The Easement in favor of U-Haul allows for full access onto the existing driveway where the Cate Street Extension will be constructed.

11. *Remove the horizontal angle point in the proposed alignment at Station 4+50.47 (Sheet CS-101). Utilize a horizontal curve at this location with radius and length appropriate for the intended design speed of the roadway.*

    The angle point has been removed.

12. *Revise the horizontal curve located at Station 9+73.3 (Sheet CS-102). Currently the curve is too sharp/short and should be revised to meet NHDOT minimum curve length for the intended design speed of the roadway.*

    The horizontal curve length has been revised to be the prescribed length for the design speed. AASHTO Guidance, which NHDOT has adopted, recommends lengths equal to or greater than 3 times the design speed. In the case of Cate Street Extension, the design speed is 25 mph as controlled by the reverse curves as you approach Bartlett Street. Therefore, all curves should be 75-ft in length or greater and they now are.

13. *The currently proposed horizontal reverse curves at Station 11+46 and Station 13+94 appear to have radii of approximately 150'. Per AASHTO Green Book Table 3-13, for a roadway with normal crown (-2.0%), the minimum radius should be 198' and 333' for design speeds of 25 mph and 30 mph, respectively. While impacts to the proposed site layout and abutting properties may be deemed too significant to accommodate a 30 mph design speed at this location, at minimum, recommend revising the reverse curves consistent with a design speed of 25 mph.*

The Horizontal Curves nearer to Bartlett Street on Cate Street Extension are 155-ft radius curves. Per AASHTO's Policy For Geometric Design Section 5.3, Local Streets in Urban Areas, Table 3-7 states a minimum radius of 154.3-ft is acceptable for a design speed of 25-mph. We employed a radius of 155-ft to round up. See Attached excerpt from AASHTO.

The sizing of the radii was not taken lightly. Linda Greer, PE, PTOE of Fuss & O'Neill and Stephen G. Pernaw, PE, PTOE were both consulted and concluded for a street of this nature, utilizing the guidance of section 5.3, table 3-7 was appropriate. This is also in line with the City's desires for calmer streets.

14. *Recommend increasing the roadway width through the horizontal reverse curves at Station 11+46 and Station 13+94 to accommodate off-tracking of tractor trailers. Depending on the horizontal radius selected (see Comment #13), a typical section consisting of 11' lanes and 4' shoulders may be appropriate to accommodate two WB-62 vehicles passing along the curves. Also consider if this typical section should be utilized for the entire roadway for consistency.*

The additional, 3-ft recommended has been added to the shoulders in the curves as you approach Bartlett Street.

The curves have had the WB-62 vehicles driven through and a supporting exhibit will be prepared.

15. *The Cate Street baseline alignment approaching the Cate Street / Bartlett Street intersection does not appear to properly transition to the proposed roadway layout depicted, which is associated with the adjacent townhouse development. Further, City staff has advised that realignment of the Cate Street / Bartlett Street intersection (such that the easterly leg of Bartlett Street is the minor approach under stop control), as discussed in prior peer reviews of the project's Traffic Impact and Access Study, should be implemented by the Applicant.*

The Alignment and subsequent design of the intersection has been provided in accordance with this comment, earlier discussions at TAC Work Sessions with Eric Eby, PE, City Traffic Engineer, and with the recommendations in Stephen G. Pernaw's Traffic Study. Converting Cate Street Extension to the through street and Bartlett Street to Stop control is represented on the Roadway Plans.

Vertical Alignment Review:

16. *At Station 14+00, consider revising the sag vertical curve to have a minimum K value of 37 to reflect the 30 mph design speed accommodated by all other proposed vertical curves.*

    The K Values at all vertical curves will be re-evaluated to provide appropriate vertical curves for the design speed of 25 mph or better.

Pedestrian and Bicycle Accessibility Review:

17. *Provide construction details for tip-downs / curb ramps with maximum slopes and minimum dimensions for ADA compliance.*

    Construction Details for tip-downs / curb ramps with maximum slopes and minimum dimensions for ADA Compliance will be added to the plans.

18. *Consider adding a tip-down with ADA detectable warning panel to the southeast corner of the Cate Street Extension / US Route 1 Bypass intersection for future pedestrian accessibility.*

    There is no sidewalk to the south of the Cate Street Extension / Route 1 Bypass intersection for quite a distance. It is unlikely that sidewalk will be installed without a NHDOT project being undertaken along the southern portion of the Bypass.

    In the interest of limiting confusion at the intersection with a busy road, a tip down and ADA warning panel has not been added. In the event sidewalk extends to the south in the future it can be added at that time.

19. *A call-out for the tip-down of the side path with detectable warning panels at the northeast terminus of the side path appears to be missing.*

    A callout for the tip down of the side path and detectable warning panels at the northeast terminus of the side path will be added.

Traffic Control Review:

20. *Consider revising the proposed U-Haul egress to be a right-in / right-out only driveway. The proposed design presents a potential safety concern for left turns onto Cate Street Extension. Consider extending the proposed median island east to prohibit left turns onto Cate Street Extension (see Comment #10).*

    As addressed in the response to comment #10, there is an existing easement in favor of U-Haul allowing them full access onto the driveway that is becoming Cate Street Extension. It is not possible to limit the left turns at this entrance with the current easement in place.

21. *The proposed painted median island on the westbound approach to US Route 1 Bypass, ending at Station 4+24, does not provide enough width for a turning vehicle to wait. Consider extending the raised median island to prohibit left turns into / out of the U-Haul driveway (see Comment #10).*

    As addressed in the response to comment #10, there is an existing easement in favor of U-Haul allowing them full access onto the driveway that is becoming Cate Street Extension. It is not possible to limit the left turns at this entrance with the current easement in place.

22. *Consider whether a marked crosswalk is warranted across Cate Street Extension at the terminus of the side path at US Route 1 Bypass. Note that a crosswalk would be required if a tip-down is added per Comment #18. We would also recommend installation of pedestrian-actuated signals for this crosswalk. This would need to be coordinated with NHDOT.*

    As discussed in the response to comment #18, a tip down to the southeast of Cate Street Extension can be added at a future date. Currently there is no sidewalk on the southern portion of Route 1 Bypass.

    A pedestrian actuated signal will be added for a crosswalk that will be needed to cross Route 1 Bypass and the extension of the Side path to Borthwick Avenue. The need for a tip down and pedestrian actuated signal will be addressed with NHDOT and revisions will be made to the plans accordingly.

23. *Consider providing intersection approach warning signage or markings on the proposed 10' wide bituminous side path prior to roadway crossings.*

    Appropriate warning signage will be added for users of the side path at the approaches to intersections.

24. *Recommend providing pedestrian / bicycle crossing warning signs at (and possibly in advance of) all proposed mid-block crosswalks (Sheet CS-101, Station 4+35 and Sheet CS-103, Station 13+90). Also consider warning devices (e.g. rectangular rapid flashing beacons) at these locations, particularly Station 13+90, where the side path terminates.*

    Pedestrian / bicycle crossing warnings will be added ahead of all crosswalks crossing Cate Street Extension.

25. *Add stop lines on all driveway approaches to Cate Street / Cate Street Extension and consider a short length of double yellow line.*

    Stop lines and signage has been added at all driveway intersections with Cate Street Extension.

26. *The centerline and edge line pavement markings do not appear to properly transition to meet the proposed pavement markings associated with the adjacent townhouse development modifications at Station 14+73.*

    Centerline and edge line pavement markings will be reviewed and corrected to ensure appropriate transition at the adjacent Townhouse project.

27. *Consider signing and/or pavement markings to indicate that westbound bicyclists in the on-road bike lane should transition onto the sidewalk path at approximate Station 13+85.*

    Signage will be added to ensure safety of westbound bicyclists and to prepare them to transition to the side path.

28. *Impacts to the existing traffic signal at US Route 1 Bypass should be addressed in the plan set. This includes replacement of the loop detectors, adjustment or relocation of pullboxes, pedestrian signal equipment (see Comment #22) and any necessary timing or phasing modifications.*

    The Route 1 Bypass improvements are being treated as a separate project with NHDOT. Full plans for signal improvements, replacement of loop detectors and adjustments to pull boxes, and addition of pedestrian signal equipment will be prepared and provided to NHDOT for approval. The construction of the Route 1 Bypass improvements and intersection improvements will be incorporated into the plan set or referenced on the plan set as appropriate once completed.

Pavement Section Review:

29. *The proposed pavement design shown on the Roadway Typical Sections of 5"-HBP, 12"- Crushed Gravel, and 12"-Gravel appears to be adequate for the class of roadway and anticipated volume and composition of traffic.*

    Noted.

30. *Per Section VII of the City of Portsmouth Subdivision Rules & Regulations, sidewalk subbase shall consist of a minimum of 12" bank-run gravel. Current design for the side path of 6" processed aggregate base shown on Sheet CD-540 is not adequate.*

    This detail has been corrected.

31. *Per Section VII of the City of Portsmouth Subdivision Rules & Regulations, bituminous concrete for sidewalks shall be placed in two (2) courses consisting of 1-1/2" base and 1-1/2" top, for a total nominal thickness of 3". Current design for the side path of 2" bituminous concrete on Sheet CD-540 is not adequate.*

    This detail has been corrected.

General Comments:

32. *To improve plan readability, include street names on all plan sheets for all major roadways. (e.g. Cate Street, Cate Street Extension, Bartlett Street, Borthwick Avenue, US Route 1 Bypass.)*

    As plans are completed the Street names will be added to all major roadways where they are not already present.

33. *The slope arrows for the multi-use trail on the Typical Sections, Sheet CS- 001, are pointing in the wrong directions; revise as appropriate. The trail should drain toward the roadway rather than onto abutting properties.*

    The direction of the slope arrows have been corrected.

34. *Include dimensions of all lane and shoulder widths, where appropriate. Some seem to be missing at the Cate Street Extension intersection with US Route 1 Bypass. Dimensions along Cate Street / Cate Street Extension and parking lot driveway access points onto Cate Street / Cate Street Extension also appear to be missing.*

Dimensions of all lane and shoulder widths have been added.

35. *On many plan sheets, the Graphic Scale within the border / title block is missing the number values indicating the plan scale (i.e. 20- or 30-scale).*

    The graphic scale will be corrected on all plan sheets where the plan is to scale.

36. *Add additional relevant existing conditions survey information to site plans, specifically the existing guardrail and utility/signal infrastructure at the Cate Street Extension / US Route 1 Bypass intersection and Hodgson Brook bank limits.*

    Existing conditions information regarding the guardrail and utility signal infrastructure will be added to / supplemented with information form NHDOT reference plans where survey information is not available.

37. *Include match-line sheet continuation notes on all plan sheets (i.e. "See Sheet XXXX").*

    Match line sheet continuation notes will be added on all plan sheets.

38. *Include and label all proposed curbing tip downs on Site Plans.*

    Curbing tip downs not already labelled will be on the Site Plans.

39. *Remove sewer text from roadway profile sheets (Sheet CS-102 & CS-103).*

    Roadway Profiles will be edited to only present vertical alignment data.

40. *Label grades on profiles at intermediate 50-foot stations.*

    Grades will be labelled on 50-ft stations.

41. *Consider expanding plan coverage to show Borthwick Avenue and the intersection with US Route 1 Bypass on the plans (e.g. Sheet CS-101).*

    Offsite Improvements to Route 1 Bypass are being designed as a separate project and will be presented on a separate plan set. This is an approach that has been discussed with the City and NHDOT and both are allowing for the Offsite Improvements to Route 1 Bypass to be designed separately as a separate project or phase.

42. *On Sheet CU-100, add label to indicate "See Inset Above for Continuation".*

    A label indicating "See Inset Above for Continuation" will be added.

43. *On Sheet CD-511, proposed cast iron cover for Bioretention Inlet Structure Detail should be labeled "DRAIN". It currently shows "SEWER".*

    The Inlet structure has been fully detailed and replaced by a Pretex unit.

    The Outlet Structure has been further detailed as well.

    Cover labels where present will reflect "DRAIN".

44. *On Sheet CD-511, label inlet structure on Bioretention System Typical Section Detail.*

    The Bioretention Inlet and Outlet Structures are more clearly labelled.

45. *Label all proposed drainage structures on Grading, Drainage & Erosion Control Plans, including subsurface infiltration basins (SSIBs).*

    Drainage Structures have been labelled on the Grading, Drainage & Erosion Control Plans.

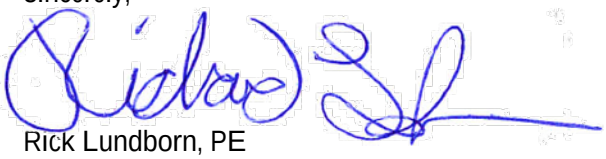
46. *The Applicant should provide an update on status of coordination with NHDOT District 6 regarding the Driveway Permit that will be required for work within the NHDOT Right-of-Way at US Route 1 Bypass.*

    Coordination with NHDOT is still on-going. The NHDOT is allowing the Offsite Improvements design and permitting to proceed separately from the Site and Cate Street project. As more information becomes available regarding the design of Route 1 Bypass improvements it will be provided to the City of Portsmouth.

Thank you for your time and efforts in review of this project.

Should you have additional questions/comments, please do not hesitate to contact me.

Sincerely,



Rick Lundborn, PE
rlundborn@fando.com
207-363-0669 x2314

RL/bh

c: file

track is also needed for drivers of stopped vehicles to decide when it is safe to proceed across the tracks. For further information on railroad–highway grade crossings, see Section 9.12.

The roadway width at all railroad crossings should be the same as the width of the approach roadway. Crossings that are located on bicycle routes that are not perpendicular to the railroad may need additional paved shoulder for bicycles to maneuver over the crossing. For further information, see the AASHTO *Guide for the Development of Bicycle Facilities* (*6*).

5.2.2.11 Traffic Control Devices

Signs, pavement and other markings, and, where appropriate, traffic signal controls are essential elements for all local roads and streets. Refer to the MUTCD (*12*) for details of the devices to be used and, for some conditions, warrants for their use.

5.2.2.12 Drainage

Drainage, both on the pavement and from the sides and subsurface, is an important design consideration. Inadequate drainage can lead to high maintenance costs and adverse operational conditions. In areas of significant snowfall, roadways should be designed so that there is sufficient storage space outside the traveled way for plowed snow and proper drainage for melting conditions. Further guidance can be found in the AASHTO *Drainage Manual* (*7*).

5.2.2.13 Erosion Control and Landscaping

Consideration should be given to the preservation of the natural groundcover and the growth of shrubs and trees within the right-of-way when designing local roads in rural areas. Shrubs, trees, and other vegetation should be considered in assessing the sight distance available to the driver and the lateral offset to roadside objects. Seeding, mulching, sodding, or other acceptable measures for covering slopes, swales, or other erodible areas should be considered in the local road design in rural areas.

For further information about erosion control and landscaping, see Section 3.6.1, "Erosion Control and Landscape Development."

5.2.2.14 Design of Local Streets in the Rural Town Context

The design of local streets in the rural town context is similar to the design of local streets in the suburban and urban contexts, which is addressed in Section 5.3.

5.3 LOCAL STREETS IN URBAN AREAS

This section presents guidance on the design of local streets in urban areas. Local streets in urban areas are designed with a flexible approach to meet the needs of the suburban, urban, and urban core contexts. Local streets generally have lower traffic volumes than collectors and

arterials and lower speeds are appropriate because the emphasis is on serving the adjacent developments. A flexible and balanced design approach to serve all transportation modes appropriately should be applied. The balance among transportation modes may differ between projects based on the demand flows for each transportation mode and established neighborhood plans. The design guidance given below should be adapted to the context and needs of each individual neighborhood and street.

5.3.1 General Design Considerations

A local street in an urban area is a public roadway that serves motor vehicles, transit, pedestrians, and bicyclists. The street includes the entire area within the right-of-way and usually accommodates public utility facilities within the right-of-way. The development or improvement of streets should be based on a functional street classification that is part of a comprehensive community development plan. The design criteria should be appropriate for the ultimately planned development.

Local streets in urban areas fall within three functional classifications: arterials, collectors, and local access routes, which are discussed in Chapter 1. Geometric design guidance is provided for collector streets in Chapter 6 and for arterial streets in Chapter 7. This chapter does not present a complete discussion of all design criteria that apply to local streets. However, where there are substantial differences from the criteria used in design of other functional classes, specific design guidance is given below.

The design features of local streets in urban areas are constrained by practical limitations to a greater extent than those of similar roads in rural areas. The two major design controls are:

- the type and extent of urban development, which often limit the available right-of-way, and
- zoning or regulatory restrictions.

Some streets serve primarily to provide access to adjacent residential development areas. In such cases, the overriding consideration is to foster a community environment whereas the convenience of the motorist is secondary. Other local streets not only provide access to adjacent development but also serve limited through traffic. Traffic operational performance may be an important concern on such streets.

On streets serving industrial or commercial areas, the vehicle dimensions, traffic volumes, and vehicle loads differ greatly from those on residential streets, and different dimensional and structural design values are appropriate. The major design controls for such streets are intended to provide efficient operations. Where a particular design feature varies depending on the area served (e.g. residential, commercial, or industrial), different design guidelines are presented for each condition. The designer should be apprised of local ordinances and resolutions that affect certain design features.

5.3.1.1 Design Speed

Design speed is not a major factor for local streets in urban areas because in the typical street grid, the closely spaced intersections usually limit vehicular speeds. For consistency in design elements, design speeds ranging from 20 to 30 mph [30 to 50 km/h] may be used, depending on available right-of-way, terrain, anticipated use by pedestrians and bicyclists, adjacent development, and other area controls. Since the function of local streets is to provide access to adjacent property, all design elements should be consistent with the character of activity on and adjacent to the street, and should encourage speeds generally not exceeding 30 mph [50 km/h].

5.3.1.2 Design Traffic Volume

Traffic volume is not usually a major factor in determining the geometric criteria to be used in designing residential streets. Traditionally, such streets are designed with a standard two-lane cross section, but a four-lane cross section may be appropriate in certain urban areas, as governed by traffic volume, administrative policy, or other community considerations.

Traffic volume is a major factor for streets serving industrial or commercial areas. The ADT projected to some future design year should be the design basis. It usually is difficult and costly to modify the geometric design of an existing street unless provision is made at the time of initial construction. Design traffic volumes in such areas should be forecast for at least 10 years, and preferably 20 years, into the future.

5.3.1.3 Levels of Service

Procedures for estimating the traffic operational level of service for particular highway designs are presented in the *Highway Capacity Manual* (HCM) (*17*), which also presents a thorough discussion of the level-of-service concept. Although the choice of an appropriate design level of service is left to the highway agency, designers should provide the highest level of service practical and consistent with the project context. Level-of-service characteristics are discussed in Section 2.4.5 and summarized in Table 2-2.

5.3.1.4 Alignment

Alignment in residential areas should closely fit with the existing topography to minimize the need for cuts or fills. The function of local streets in residential areas is to provide land access, and therefore these streets should be designed to discourage through traffic. Street alignment in commercial and industrial areas should be commensurate with the topography but should be as direct as practical.

The minimum radius for horizontal curves should be the greater of 100 ft [30 m] or the minimum radius for the applicable design speed shown in Table 3-7.

5.3.1.5 Grades

Grades for local residential streets should be as level as practical, consistent with the surrounding terrain. Grades for local residential streets should be less than 15 percent. Where grades of 4 percent or steeper are needed, the drainage design may become critical. On such grades, special care should be taken to prevent erosion on slopes and open drainage facilities.

Streets in commercial and industrial areas should have grades less than 8 percent, and flatter grades should be encouraged.

To provide for proper drainage, the desirable minimum grade for streets with outer curbs should be 0.50 percent, but a minimum grade of 0.30 percent may be used. Further guidance can be found in the AASHTO *Drainage Manual* (7)

5.3.1.6 Cross Slope

Pavement cross slope should be sufficient to provide proper drainage. Normally cross slopes range from 1.5 to 2 percent for paved surfaces and 2 to 6 percent for unpaved surfaces where there are flush shoulders. Where there are outer curbs, cross slopes steeper than the guidelines given above by about 0.5 to 1 percent are desirable for the lane adjacent to the curb.

For unpaved surfaces, such as stabilized or loose gravel or stabilized earth surfaces, a cross slope of at least 3 percent is desirable. For further information on pavement cross slope, see Section 4.2.2.

Where shoulders are intended to be used as pedestrian facilities, the shoulder must be accessible to and usable by individuals with disabilities (*19, 21*). For additional guidance, refer to the *Proposed Guidelines for Pedestrian Facilities in the Public Right-of-Way* (*18*).

5.3.1.7 Superelevation

Superelevation on horizontal curves may be advantageous for local street traffic operations in specific locations, but in built-up areas the combination of wide pavement areas, proximity of adjacent development, control of cross slope, profile for drainage, frequency of cross streets, and other urban features often combine to make the use of superelevation impractical or undesirable. Therefore, superelevation usually is not provided on local streets in residential and commercial areas; it may be considered on local streets in industrial areas to facilitate operation.

If superelevation is used, horizontal curves should be designed for a maximum superelevation rate of 4 percent. If terrain dictates sharp curvature, a maximum superelevation rate of 6 percent may be justified if the curve is long enough to provide an adequate superelevation transition. Minimum lengths of superelevation runoff and a detailed discussion of superelevation are found in Section 3.3.8.2.

Table 3-7. Minimum Radius Using Limiting Values of *e* and *f*

U.S. Customary					
Design Speed (mph)	Maximum *e* (%)	Maximum *f*	Total (*e*/100 + *f*)	Calculated Radius (ft)	Rounded Radius (ft)
10	4.0	0.38	0.42	15.9	16
15	4.0	0.32	0.36	41.7	42
20	4.0	0.27	0.31	86.0	86
25	4.0	0.23	0.27	154.3	154
30	4.0	0.20	0.24	250.0	250
35	4.0	0.18	0.22	371.2	371
40	4.0	0.16	0.20	533.3	533
45	4.0	0.15	0.19	710.5	711
50	4.0	0.14	0.18	925.9	926
55	4.0	0.13	0.17	1186.3	1190
60	4.0	0.12	0.16	1500.0	1500
10	6.0	0.38	0.44	15.2	15
15	6.0	0.32	0.38	39.5	39
20	6.0	0.27	0.33	80.8	81
25	6.0	0.23	0.29	143.7	144
30	6.0	0.20	0.26	230.8	231
35	6.0	0.18	0.24	340.3	340
40	6.0	0.16	0.22	484.8	485
45	6.0	0.15	0.21	642.9	643
50	6.0	0.14	0.20	833.3	833
55	6.0	0.13	0.19	1061.4	1060
60	6.0	0.12	0.18	1333.3	1330
65	6.0	0.11	0.17	1656.9	1660
70	6.0	0.10	0.16	2041.7	2040
75	6.0	0.09	0.15	2500.0	2500
80	6.0	0.08	0.14	3047.6	3050
10	8.0	0.38	0.46	14.5	14
15	8.0	0.32	0.40	37.5	38
20	8.0	0.27	0.35	76.2	76
25	8.0	0.23	0.31	134.4	134
30	8.0	0.20	0.28	214.3	214
35	8.0	0.18	0.26	314.1	314
40	8.0	0.16	0.24	444.4	444
45	8.0	0.15	0.23	587.0	587
50	8.0	0.14	0.22	757.6	758
55	8.0	0.13	0.21	960.3	960
60	8.0	0.12	0.20	1200.0	1200
65	8.0	0.11	0.19	1482.5	1480
70	8.0	0.10	0.18	1814.8	1810
75	8.0	0.09	0.17	2205.9	2210
80	8.0	0.08	0.16	2666.7	2670

Metric					
Design Speed (km/h)	Maximum *e* (%)	Maximum *f*	Total (*e*/100 + *f*)	Calculated Radius (m)	Rounded Radius (m)
15	4.0	0.40	0.44	4.0	4
20	4.0	0.35	0.39	8.1	8
30	4.0	0.28	0.32	22.1	22
40	4.0	0.23	0.27	46.7	47
50	4.0	0.19	0.23	85.6	86
60	4.0	0.17	0.21	135.0	135
70	4.0	0.15	0.19	203.1	203
80	4.0	0.14	0.18	280.0	280
90	4.0	0.13	0.17	375.2	375
100	4.0	0.12	0.16	492.1	492
15	6.0	0.40	0.46	3.9	4
20	6.0	0.35	0.41	7.7	8
30	6.0	0.28	0.34	20.8	21
40	6.0	0.23	0.29	43.4	43
50	6.0	0.19	0.25	78.7	79
60	6.0	0.17	0.23	123.2	123
70	6.0	0.15	0.21	183.7	184
80	6.0	0.14	0.20	252.0	252
90	6.0	0.13	0.19	335.7	336
100	6.0	0.12	0.18	437.4	437
110	6.0	0.11	0.17	560.4	560
120	6.0	0.09	0.15	755.9	756
130	6.0	0.08	0.14	950.5	951
15	8.0	0.40	0.48	3.7	4
20	8.0	0.35	0.43	7.3	7
30	8.0	0.28	0.36	19.7	20
40	8.0	0.23	0.31	40.6	41
50	8.0	0.19	0.27	72.9	73
60	8.0	0.17	0.25	113.4	113
70	8.0	0.15	0.23	167.8	168
80	8.0	0.14	0.22	229.1	229
90	8.0	0.13	0.21	303.7	304
100	8.0	0.12	0.20	393.7	394
110	8.0	0.11	0.19	501.5	501
120	8.0	0.09	0.17	667.0	667
130	8.0	0.08	0.16	831.7	832

Table 3-7. Minimum Radius Using Limiting Values of e and f (Continued)

U.S. Customary						Metric					
Design Speed (mph)	Maximum e (%)	Maximum f	Total (e/100 + f)	Calculated Radius (ft)	Rounded Radius (ft)	Design Speed (km/h)	Maximum e (%)	Maximum f	Total (e/100 + f)	Calculated Radius (m)	Rounded Radius (m)
10	10.0	0.38	0.48	13.9	14	15	10.0	0.40	0.50	3.5	4
15	10.0	0.32	0.42	35.7	36	20	10.0	0.35	0.45	7.0	7
20	10.0	0.27	0.37	72.1	72	30	10.0	0.28	0.38	18.6	19
25	10.0	0.23	0.33	126.3	126	40	10.0	0.23	0.33	38.2	38
30	10.0	0.20	0.30	200.0	200	50	10.0	0.19	0.29	67.9	68
35	10.0	0.18	0.28	291.7	292	60	10.0	0.17	0.27	105.0	105
40	10.0	0.16	0.26	410.3	410	70	10.0	0.15	0.25	154.3	154
45	10.0	0.15	0.25	540.0	540	80	10.0	0.14	0.24	210.0	210
50	10.0	0.14	0.24	694.4	694	90	10.0	0.13	0.23	277.3	277
55	10.0	0.13	0.23	876.8	877	100	10.0	0.12	0.22	357.9	358
60	10.0	0.12	0.22	1090.9	1090	110	10.0	0.11	0.21	453.7	454
65	10.0	0.11	0.21	1341.3	1340	120	10.0	0.09	0.19	596.8	597
70	10.0	0.10	0.20	1633.3	1630	130	10.0	0.08	0.18	739.3	739
75	10.0	0.09	0.19	1973.7	1970						
80	10.0	0.08	0.18	2370.4	2370						
10	12.0	0.38	0.50	13.3	13	15	12.0	0.40	0.52	3.4	3
15	12.0	0.32	0.44	34.1	34	20	12.0	0.35	0.47	6.7	7
20	12.0	0.27	0.39	68.4	68	30	12.0	0.28	0.40	17.7	18
25	12.0	0.23	0.35	119.0	119	40	12.0	0.23	0.35	36.0	36
30	12.0	0.20	0.32	187.5	188	50	12.0	0.19	0.31	63.5	64
35	12.0	0.18	0.30	272.2	272	60	12.0	0.17	0.29	97.7	98
40	12.0	0.16	0.28	381.0	381	70	12.0	0.15	0.27	142.9	143
45	12.0	0.15	0.27	500.0	500	80	12.0	0.14	0.26	193.8	194
50	12.0	0.14	0.26	641.0	641	90	12.0	0.13	0.25	255.1	255
55	12.0	0.13	0.25	806.7	807	100	12.0	0.12	0.24	328.1	328
60	12.0	0.12	0.24	1000.0	1000	110	12.0	0.11	0.23	414.2	414
65	12.0	0.11	0.23	1224.6	1220	120	12.0	0.09	0.21	539.9	540
70	12.0	0.10	0.22	1484.8	1480	130	12.0	0.08	0.20	665.4	665
75	12.0	0.09	0.21	1785.7	1790						
80	12.0	0.08	0.20	2133.3	2130						

Note: Use of e_{max} = 4.0% should be limited to urban areas.

3.3.3.4 Effects of Grades

On long or fairly steep grades, drivers tend to travel faster in the downgrade than in the upgrade direction. Additionally, research (*16, 66*) has shown that the side friction demand is greater on both downgrades (due to braking forces) and steep upgrades (due to the tractive forces). Research (*66*) has also shown that, for simple horizontal curves, the maximum superelevation rate on steep downgrades of 4 percent or more should not exceed 12 percent. If considering a maximum superelevation rate on a horizontal curve in excess of 12 percent, a spiral curve tran-