

How does tolerance and resolution work in ArcGIS?

See the topics below for information about tolerance and resolution within ArcGIS Pro.

<https://pro.arcgis.com/en/pro-app/help/data/geodatabases/overview/feature-class-basics.htm>

<https://pro.arcgis.com/en/pro-app/help/data/geodatabases/overview/the-properties-of-a-spatial-reference.htm>

How can I configure measure tolerance and resolution for ArcGIS Roads and Highways?

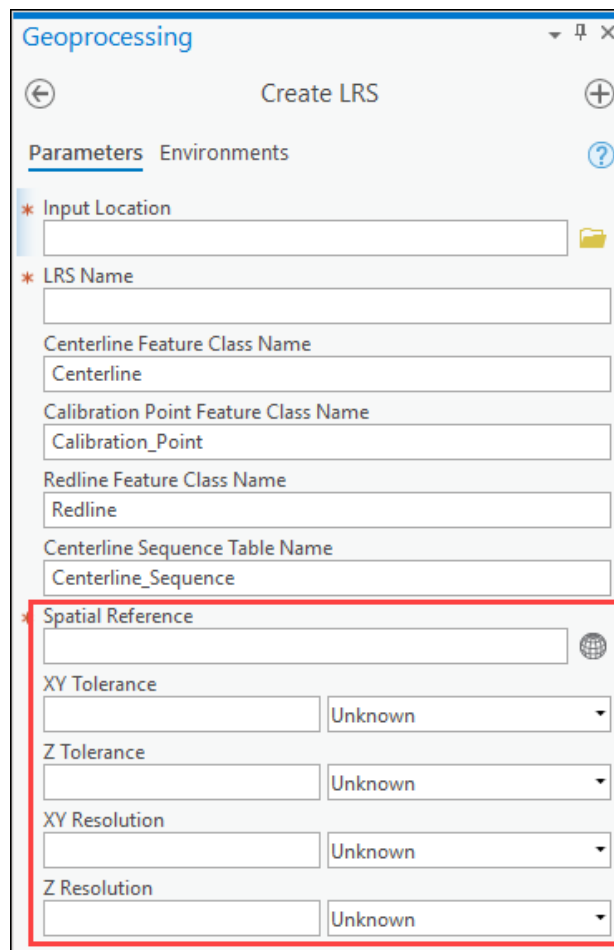
Step 1 – Configuring XY tolerance and spatial reference of centerline

When creating the LRS, you must specify the XY tolerance and spatial reference to use for the

Centerline feature class (you can also use a pre-created Centerline feature class where the XY tolerance and spatial reference is already configured) within Roads and Highways.

<https://pro.arcgis.com/en/pro-app/tool-reference/location-referencing/createlrs.htm>

<https://pro.arcgis.com/en/pro-app/tool-reference/location-referencing/create-lrs-from-existing-dataset.htm>



The screenshot shows the 'Create LRS' tool interface in ArcGIS Pro. The 'Parameters' tab is active. The 'Spatial Reference' section is highlighted with a red box. The parameters are as follows:

Parameter	Value
Input Location	[Empty field]
LRS Name	[Empty field]
Centerline Feature Class Name	Centerline
Calibration Point Feature Class Name	Calibration_Point
Redline Feature Class Name	Redline
Centerline Sequence Table Name	Centerline_Sequence
Spatial Reference	[Empty field]
XY Tolerance	Unknown
Z Tolerance	Unknown
XY Resolution	Unknown
Z Resolution	Unknown

Create LRS geoprocessing tool

Once the desired spatial reference is specified, the units of measure for the spatial reference are set by ArcGIS as they are a property of the spatial reference. While users can select any spatial reference they'd like, including a geographic coordinate system, many Roads and Highways users use a state plane or UTM coordinate system which enforces that the XY coordinate system unit of measure is feet or meters. The ArcGIS default XY tolerance for a meter coordinate system is 0.001, but you may change it when creating the feature class. Once the tolerance and resolution for a feature class are set, the values can't be changed in ArcGIS.

Once you specify the XY tolerance for the centerline, Roads and Highways will calculate a value $1/10^{\text{th}}$ the tolerance to use as the resolution of the XY coordinate system for the centerline. For example, if the tolerance is set to 0.001 meters, the resolution is set to 0.0001 meters.

Note that these are the default values; users can set the resolution to be any value at least two times smaller than the tolerance. It is recommended that users use the suggested $1/10^{\text{th}}$ ratio for tolerance/resolution that ArcGIS suggests.

Roads and Highways will propagate the XY tolerance, resolution, and spatial reference settings from the Centerline feature class to the Calibration Point and Redline feature classes. All LRS Network feature classes will also inherit the same XY tolerance, resolution, and spatial reference of the Centerline. Any Event and Intersection feature classes that are created by Roads and Highways will also have the same XY tolerance, resolution, and spatial reference.

If the user wants a custom configuration for XY tolerance and resolution for the "Centerline" feature class that does not align with the defaults for the chosen spatial reference, they have the option to pre-create the "Centerline" feature class, "Centerline Sequence" table, "Calibration Point" feature class, and "Redline" feature class and can configure Roads and Highways to use those elements instead of the defaults.

For additional information, see: <https://pro.arcgis.com/en/pro-app/help/production/roads-highways/lrs-data-model.htm> and <https://pro.arcgis.com/en/pro-app/help/production/roads-highways/tolerance-and-resolution-settings-for-the-lrs.htm>

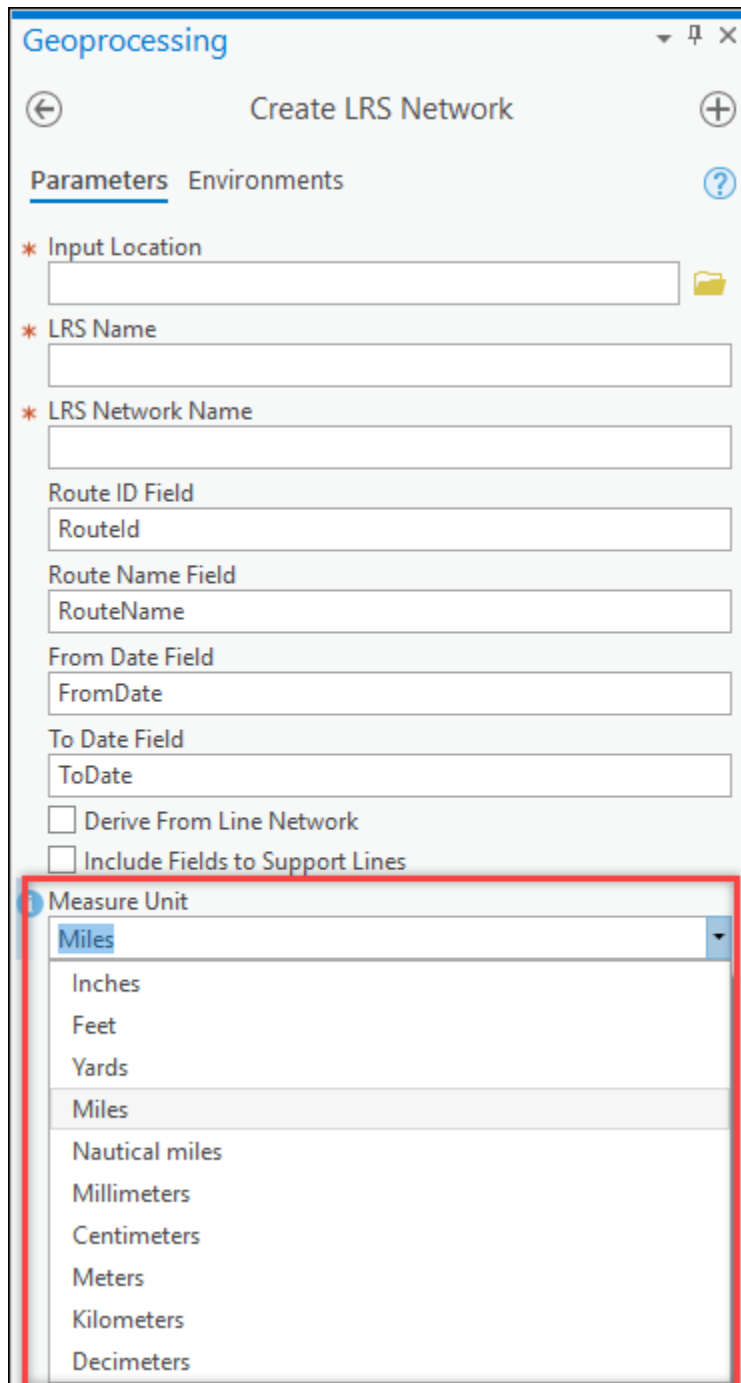
Note the centerline does not store measures, so at this step measure tolerance is not specified.

Step 2 – Specify the unit of measure for the network

At LRS Network creation time, you are prompted to specify the units of measure for the LRS network. Many organizations use miles, but any of the available units in the drop down for the tool are supported.

<https://pro.arcgis.com/en/pro-app/tool-reference/location-referencing/create-lrs-network.htm>

<https://pro.arcgis.com/en/pro-app/tool-reference/location-referencing/create-lrs-network-from-existing-dataset.htm>



Create LRS Network geoprocessing tool

Once you specify the unit of measure, Roads and Highways will calculate the required M tolerance and resolution for the network feature class that will align the XY tolerance with that of the M tolerance. The XY and Z tolerance and resolution for the network will come from the centerline of the LRS.

An example of this calculation is shown below. If the XY tolerance is 0.001 meters and the LRS Network unit of measure will be miles, the M tolerance ends up needing to be 0.000000621369949. This is because:

0.001 meters \approx 0.000000621369949 miles

ArcGIS stores the measure values of a PolylineM enabled feature class on each vertex of the polyline. This is the geometry model that ArcGIS and Roads and Highways is based on.

If the XY and M tolerances did not align, and the M tolerance was made larger, say 0.001 miles, it would be possible for neighboring vertices to have the same measure value. This would result in multiple locations with the same measures. This would create measure ambiguity for any system using the PolylineM in ArcGIS and would also result in non-monotonic routes.

If a user wishes to model their LRS Network feature class in advance, they will need to set the M tolerance and resolution values correctly based on the calculation from the XY tolerance and resolution.

Roads and Highways takes the XY and M tolerances and resolutions and propagates this configuration to all events that are registered under the LRS Network if Roads and Highways creates the event feature class using the Create LRS Event tool.

<https://pro.arcgis.com/en/pro-app/tool-reference/location-referencing/createlrsevent.htm>

<https://pro.arcgis.com/en/pro-app/tool-reference/location-referencing/create-lrs-event-from-existing-dataset.htm>

Like with the LRS Network, the LRS Event feature classes can be modeled in advance, but would need to have the same XY, Z, and M tolerances and resolutions as the LRS Network the event will be associated with.

What can I expect with 0.001 meters XY tolerance and using miles as my M unit of measure?

Remember that 0.001 meters \approx 0.000000621369949 miles and Roads and Highways does not want to produce an LRS with measure ambiguity (multiple locations or route vertices with the same measures) or create non-monotonic routes as a recommended practice. Given this, any measures derived by ArcGIS or Roads and Highways on an LRS Network with this configuration will yield measures that are 7 digits past the decimal place.

If you identify on a route, the number of decimal places Roads and Highways will produce is up to 7 decimal places.

If Roads and Highways suggests a measure based on geometry length of the centerlines for an LRS edit activity, up to 7 decimal places may be displayed.

If you wish to derive a measure in the Event Editor by clicking on the map, up to 7 decimal places may be displayed.

How can I configure my M tolerance to be 0.001 miles?

The way to achieve this is to configure the XY tolerance of the "Centerline" feature class to 10.0 meters, because:

10.0 meters \approx 0.00621369949 miles

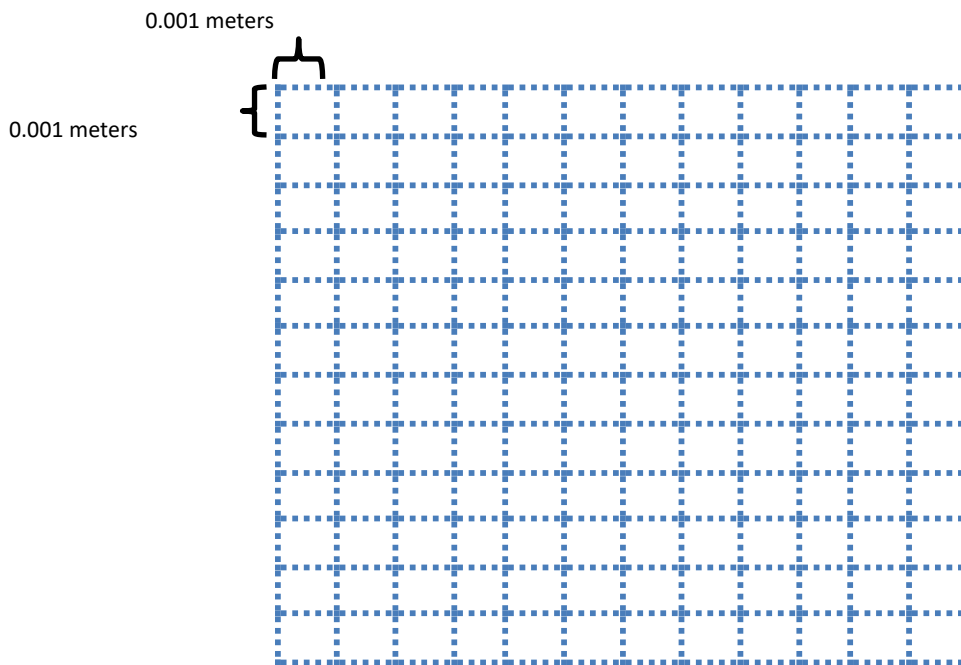
However, this will result in very imprecise geometry...but the imprecision will match the desired imprecision of the measures.

Implications to having imprecise centerlines include:

- LRS data may not spatially align with other spatial data maintained by the state or provided by outside sources.
- Geographic location imprecision for routes (no 2 route vertices are closer than 10 meters apart)
- Jagged route geometry
- Maps will not be cartographically accurate to imagery due to jagged geometry

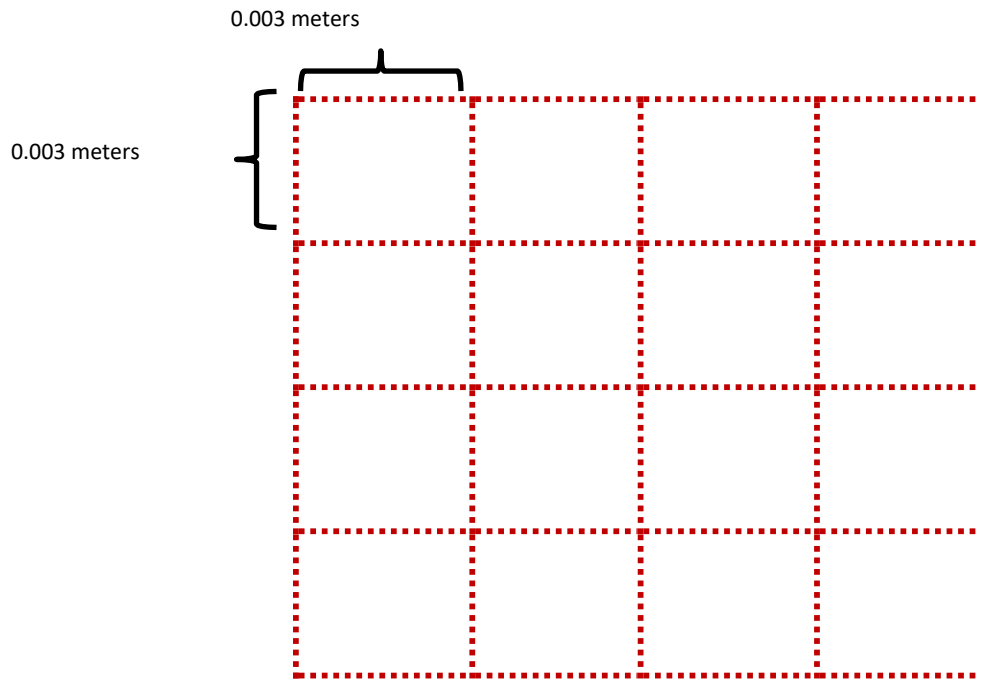
Can you illustrate why M tolerance and XY tolerance should align with an example?

For example, with an XY tolerance of 0.001 meters, any value of the X or Y that has a decimal place smaller than 0.001 meters is rounded to the nearest 0.001-meter value and snapped to a logical coordinate grid. See the 0.001-meter grid below. Any coordinate not on the grid with decimal places smaller than 0.001 meters will be snapped to the closest corner of a cell on the grid. So, a coordinate of 127.34534534, 97.993934393 would be snapped and rounded to 127.345, 97.994.



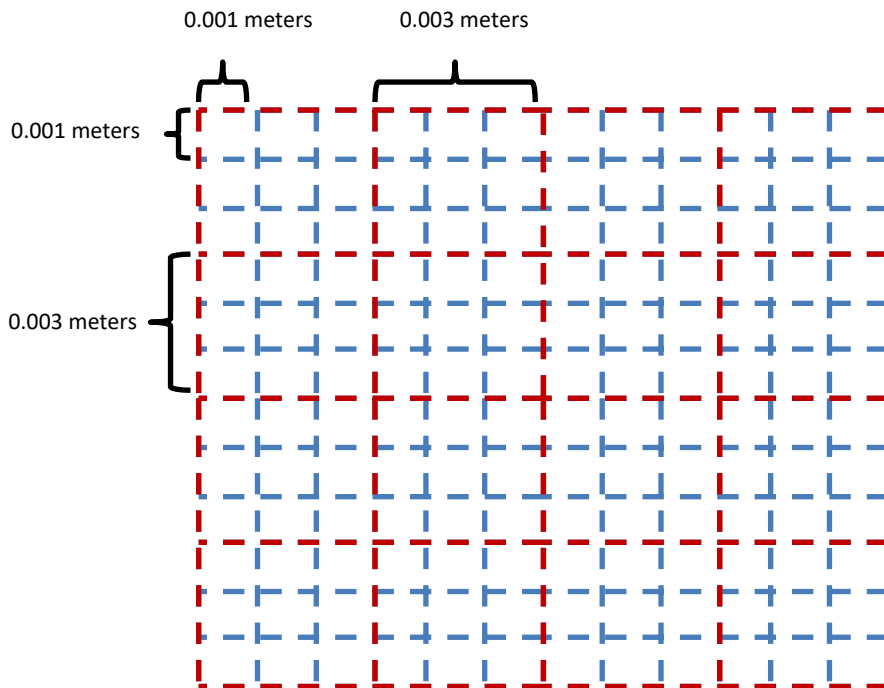
0.001-meter XY coordinate grid

In the case where the desire is to have an XY tolerance of 0.001 meters and a measure tolerance of 0.001 miles, the tolerances are over 1000 times apart from one another after unit of measure conversion. To illustrate what this can cause, let's choose a simpler example where the coordinate tolerances between measures and XY are only 3 times apart from one another. See the below measure tolerance grid of 0.003 meters.



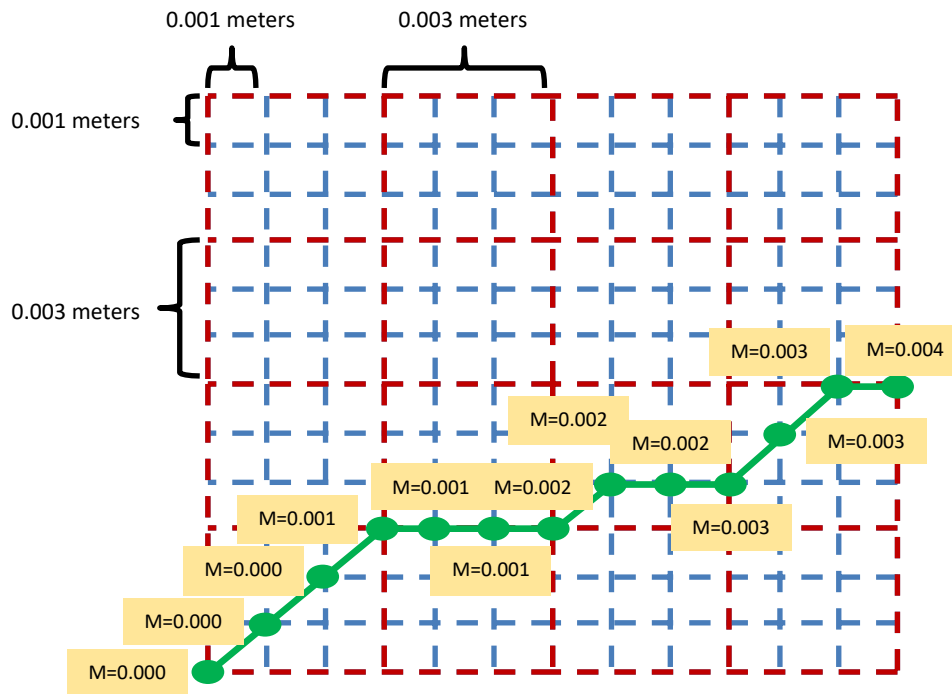
0.003-meter measure grid

Now, if you overlay them, you get the grid representation below:



0.003-meter measure grid on top of 0.001-meter XY grid

Now if you draw a PolylineM (in green) on the grid, you get a representation like below:

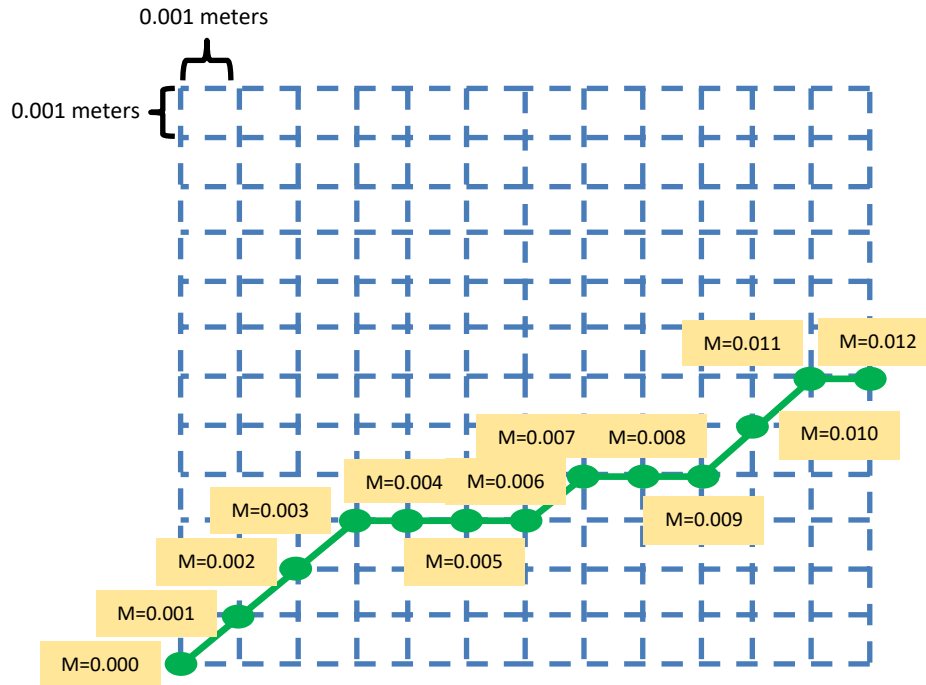


PolylineM drawn on coordinate and measure grid

XY Tolerance 0.001, M Tolerance 0.003

The problem with such a configuration is that all the vertices of the PolylineM on the blue coordinate grid that fall within the same measure grid cell have the same measure value. In the case of a XY tolerance of 0.001 meters and a measure tolerance of 0.001 miles, you could have over a thousand coordinates in the same measure grid cell having the same measure (this is a worst-case scenario to illustrate the issue). If PolylineMs have the same measure, this creates measure location ambiguity and non-monotonic routes.

What is desired is that each vertex on a route has a unique measure such that there is no location/measure ambiguity and non-monotonic routes are avoided. See below.



PolylineM drawn on coordinate and measure grid XY Tolerance 0.001, M Tolerance 0.001 (equal)

How will workflows change if my m tolerance is 7 decimal places when I'm used to 3 (i.e. 0.001 miles)?

If you wish to keep the XY tolerance at 0.001 meters and have the LRS Networks in Roads and Highways store measures as miles, then up to 7 decimal places could be displayed in Roads and Highways for some measures.

How will I experience this when I edit routes?

In Roads and Highways, when using the Roads and Highways editing toolbar and LRS edit activities such as "Create Route", "Extend Route", "Reassign Route", etc., Roads and Highways will suggest measures based on shape length of the centerlines involved in the edit. Under this workflow, routes can have ending measures that have more than 3 decimal places due to the precision of the route/centerline geometry.

You can still enter in only 3 decimal places for measures if you wish. Roads and Highways only suggests measures based on either geometry length based on the XY tolerance of the data or by where you clicked on the map.

If you wish to round the Roads and Highways suggested measures on a route edit such as Create Route, Reassign Route, and Extend Route for the end of the route; you can. One reason you may wish to do this is if you want to force route end measures to be only to 3 decimal places, with the remaining decimal places being 0. This will make route measures less accurate but may conform better to previous business practices with older LRS systems. If this is done, you should round the measure up to not create a route that is shorter than geometry length. Creating a route that is shorter than the geometry length could result in non-monotonic portions of the route where multiple adjacent vertices have the same measure.

How will I experience this when editing events using Event Editor?

When editing events using Event Editor, if you click on the map to derive a measure at a location for an event edit, the measures will be provided up to the number of decimal places the M tolerance is configured for.

You may still manually enter measures to only 3 decimal places if the source of the measures is something other than the location clicked on the map. You should be aware though that if they are providing measures manually from a source that has less precision than the LRS, care should be taken when entering event measures at the route start and route end.

For example, if a route is based on geometry length for measures and starts at 0 but ends at 1.5468889 miles, but the end measure from field data for an event has a measure of 1.546 miles. Roads and Highways “Detect Event Gaps” geoprocessing tool will detect a gap on the route between 1.546 and 1.5468889. This is a gap of 0.0008889 miles. These can be ignored if they are no concern to the user and their business rules, but if they are, there are ways to prevent this.

To prevent this, editor may wish to snap events to the route start or end to ensure no very small gaps are created at the route start or end. The Event Editor provides 2 ways to achieve this:

First, the EE has a feature on the event editing widgets to “Use the Route Start” or “Use the Route End”, which will derive the route start or end measures to the precise precision.

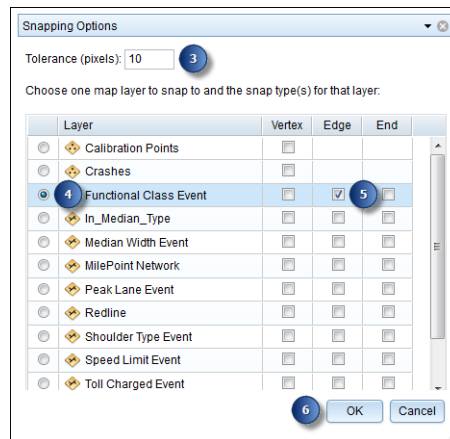
<https://enterprise.arcgis.com/en/roads-highways/latest/event-editor/adding-linear-events-by-route-and-measure.htm>

The screenshot shows the 'Add Linear Events' dialog box. It includes fields for Network (LRM), Route ID, From/To sections with Method and Measure dropdowns, Dates section with Start/End Date fields and checkboxes, and a list of checkboxes for 'Retire overlaps', 'Merge coincident events', and 'Prevent measures not on route'. A red box highlights the 'Measure:' input fields, and a tooltip menu is open over them, showing 'Use the Route Start' and 'Use the Route End' options.

Event Editor Add Linear Event Widget “Use Route Start” and “Use Route End”

Second, in EE you can use snapping to click on a route start or route end to derive a precise measure for the route start or route end.

<https://enterprise.arcgis.com/en/roads-highways/latest/event-editor/configuring-snapping.htm>



Event Editor Snapping Options Dialog

How will I experience this for data referencing intersections?

If event data references measures derived from intersection location, and the measure location of the intersection is rounded to the nearest 0.001 mile due to historical, pre-Roads and Highways practices, events may plot on the map up to 5.3 feet off the location of an intersection generated in Roads and Highways against a high precision coordinate system (0.001 meters XY tolerance).

When plotting the events on the map against Roads and Highways generated intersections, the event data may render on the map off the actual, more precise XY location of the intersection, by up to 0.001 miles which is roughly 5.3 feet.

Roads and Highways offers a new model to reference events directly to the spatial location (and offset if desired) of an intersection for event data. This model ties event data directly to intersection locations on the map and can render it with high precision.

https://pro.arcgis.com/en/pro-app/help/production/roads-highways/events-data-model.htm#ESRI_SECTION1_1FC23CA9691A49BD9B9BDD8B8EBE12D

<https://enterprise.arcgis.com/en/roads-highways/latest/event-editor/adding-linear-events-by-reference-offset-and-locations.htm>

How will I experience this for external systems?

If you need to provide the Roads and Highways external system measure updates through external system integration, the data integrator can round the provided measures to the desired precision.

If you have external system that provides measures to a precision that is lower than the M precision configuration in Roads and Highways, the data will still map on routes in ArcGIS. The only thing to note is that the route geometry is more precise in location than the measures from the external system.

If the source data has a tolerance of 0.001 miles and the Roads and Highways network has a measure tolerance of 0.0000001 miles, then the location of plotted events may not locate exactly up to 0.0009999 miles or 5.28 feet. That is a byproduct of the accuracy of the external measures.