

Lolo Pass Road Access Alternatives Project
OR CLACK 37005 (1)
Clackamas County, Oregon

September 2015 Alternatives Analysis Report
(Stakeholder and Public Review Draft)



Prepared for:

Western Federal Lands Highway Division
WFLHD Task Order No. T-14-002, DTFH70-10-D-00019

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ACRONYMS

AASHTO	American Association of State Highway and Transportation Officials
ADT	Average Daily Traffic
BMP	best management practice
BPA	Bonneville Power Administration
cfs	cubic feet per second
DEQ	Oregon Department of Environmental Quality
DOGAMI	Department of Geology and Mineral Industries
EPA	U.S. Environmental Protection Agency
FEMA	Federal Emergency Management Agency
FHWA	U.S. Department of Transportation Federal Highway Administration
GLO	General Land Office
LCR	Lower Columbia River
LID	low impact development
LIDAR	light detection and ranging
MEP	maximum extent practicable
MHNF	Mount Hood National Forest
MSE	Mechanically Stabilized Earth
NEPA	National Environmental Policy Act
NMFS	National Marine Fisheries Service
NRCS	U.S. Department of Agriculture Natural Resources Conservation Service
NRHP	National Register of Historic Places
NWI	National Wetlands Inventory
ORBIC	Oregon Biodiversity Information Center
RCRA	Resource Conservation and Recovery Act
RM	River Mile
SHPO	State Historic Preservation Office
US 26	U.S. Highway 26
USFWS	U.S. Fish and Wildlife Service
WFLHD	Western Federal Lands Highway Division

EXECUTIVE SUMMARY

The Western Federal Lands Highway Division (WFLHD) of the U.S. Department of Transportation, Federal Highway Administration (FHWA) and Clackamas County are evaluating options to provide safe, long-term access to public lands (including the Mount Hood National Forest [MHNH]) and private properties.

PURPOSE OF ALTERNATIVES ANALYSIS REPORT

The Lolo Pass Road Access Alternatives Study (study) assesses approaches to address long-term flooding and access issues on the portions of Lolo Pass Road that have been and will continue to be vulnerable to severe damage from major floods and ongoing river channel migration. The purpose of this Alternatives Analysis Report is to document the hydrologic and geomorphic, engineering, cost, and environmental analyses conducted for the following three alternatives:

- Modify and realign portions of existing Lolo Pass Road
- Construct new road in the Zigzag Mountain Corridor (two alignments are considered):
 - Zigzag Mountain West, originating near Autumn Lane
 - Zigzag Mountain East, originating near Mountain Drive

These three alternatives are compared with a No Action Alternative throughout this report. The study also considered building a new road in or adjacent to the Bonneville Power Administration (BPA) powerline corridor, but due to multiple concerns regarding feasibility, was not developed to the same level of detail as the three alternatives listed above.

SUMMARY OF COSTS AND IMPACT

Table ES- 1 summarizes the key features, impacts, and cost of the three build alternatives.

Table ES- 1. Key Features of Potential Build Alternatives

	Modify Existing Lolo Pass Road	Zigzag Mountain West: Originating Near Autumn Lane	Zigzag Mountain East: Originating Near Mountain Drive
Bridge Length	Two 200-foot bridges at existing crossing	800-foot bridge (four spans)	800-foot bridge (four spans)
Improvements to Existing Lolo Pass Road?	Yes – new bridge and reinforcements planned	Minor, south of Autumn Lane	Minor, south of Mountain Drive
Length of New/Improved Roadway	0.6 mile	1.6 miles	1.7 miles
Right-of-way (# of parcels)	10-18 parcels,	12-22 parcels,	25-26 parcels,

	Modify Existing Lolo Pass Road	Zigzag Mountain West: Originating Near Autumn Lane	Zigzag Mountain East: Originating Near Mountain Drive
affected, # of potential acquisitions)	4-5 potential displacements	1-2 potential displacements	1-2 potential displacements
Acres (Footprint)	5	23	25
Planning-Level Cost	\$8.7 M	\$23.6 M	\$27.2 M

INTRODUCTION

The Western Federal Lands Highway Division (WFLHD) of the U.S. Department of Transportation, Federal Highway Administration (FHWA) and Clackamas County (the County) are evaluating options to provide safe, long-term access to public lands (including the Mount Hood National Forest [MHNF]) and private properties. The Lolo Pass Road Access Alternatives Study (study) assesses approaches to address long-term flooding and access issues on the portions of Lolo Pass Road that have been and will continue to be vulnerable to severe damage from major floods and ongoing river channel migration. The purpose of this Alternatives Analysis Report is to document the hydrologic and geomorphic, engineering, cost, and environmental analyses conducted for the following three alternatives:

- Modify and realign portions of existing Lolo Pass Road
- Construct new road in the Zigzag Mountain Corridor (two alignments are considered):
 - Zigzag Mountain West, originating near Autumn Lane
 - Zigzag Mountain East, originating near Mountain Drive

A fourth alternative, to build a new road in or adjacent to the Bonneville Power Administration (BPA) powerline corridor, is also presented in this report, but due to multiple concerns regarding feasibility, was not developed further.

As shown in Figure 1, the Powerline Corridor and Sandy River Corridor study areas are located north of the intersection of U.S. Highway 26 (US 26) and Lolo Pass Road near Mt. Hood Village and Rhododendron, in Clackamas County, Oregon. WFLHD and Clackamas County conducted a previous study to develop a reconnaissance-level survey of the Sandy River Corridor Study Area (Figure 1b) area to help identify options for possible reasonable access alternatives. The reconnaissance report identified a new potential bridge location upstream of the existing Lolo Pass Road bridge that crosses the Sandy River. The reconnaissance report was shared with the public and stakeholders in late 2014, and is included in Appendix A.

PROJECT BACKGROUND

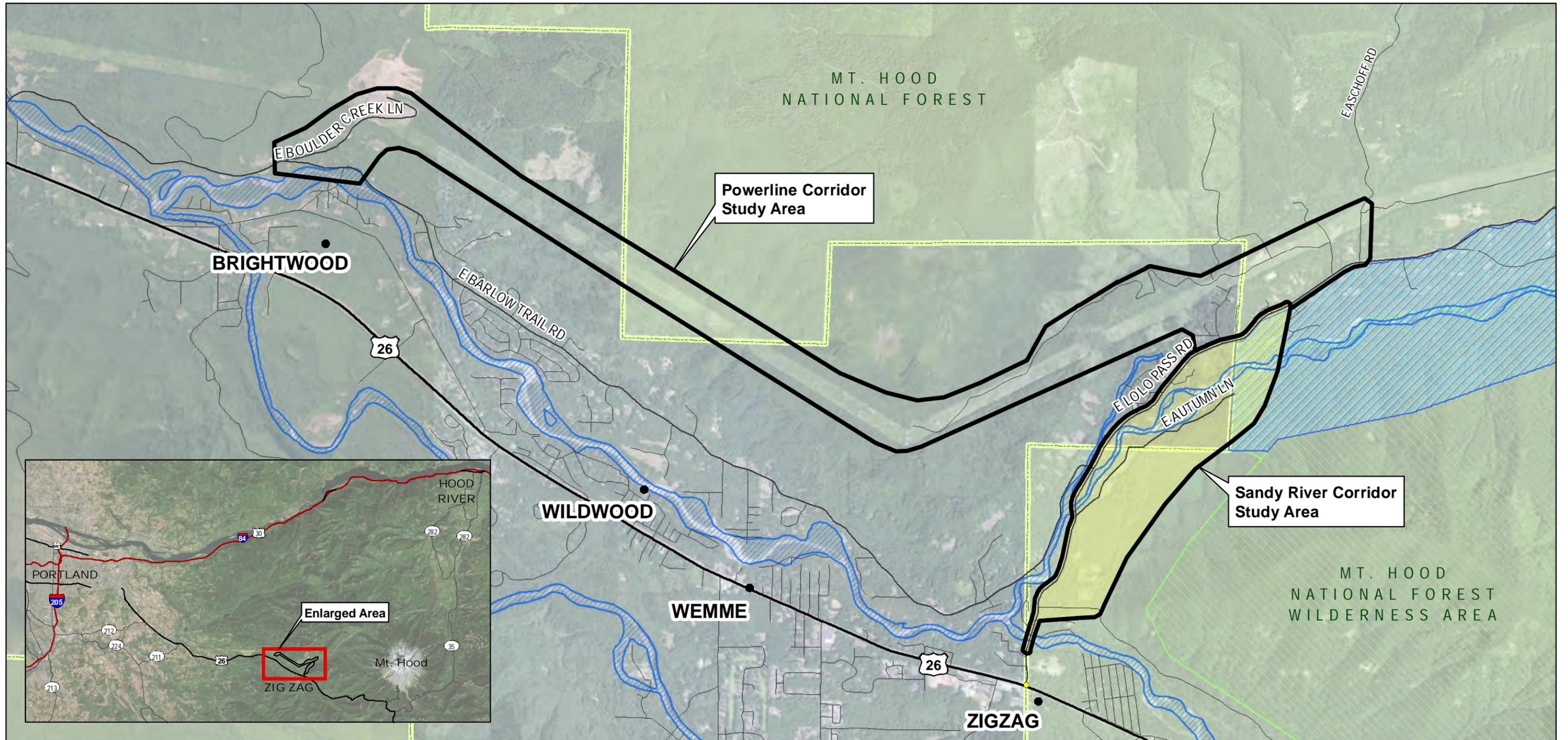
The Sandy River watershed in northwest Oregon extends from the west flank of Mount Hood to the Columbia River at Troutdale, Oregon. In the last 100 years, the Upper Sandy River, the section within the study area, has experienced several major floods that caused substantial flooding, bank erosion, and damages to infrastructure. From 1964 to 2014 alone, the river has experienced 8 of the 10 highest peak flows in its 100-year record of flows. The flood of record occurred in 1964 (61,400 cubic feet per second (cfs)), and completely destroyed the Sandy River bridge and several sections of the road in the study area. In addition to the 1964 event, very large and damaging flood flows also occurred in 1996 (48,100 cfs), and in 2011 (39,000 cfs), during which portions of the road upstream of the Sandy River bridge and within the study area were severely damaged. Figure 1b shows selected images of the river and surrounding features within the study area.

Over the course of the last several decades, the damages have required substantial repairs or total replacement of the roadway or bridges, and the tendency for damage to occur with high stage flows has warranted frequent maintenance, which causes the temporary loss of direct access to upstream residential properties and is costly.

In 2008, the County made emergency repairs on the Zigzag River (Lolo Pass Road at the southern end of the study area) Bridge approaches and installed riprap to protect it from further scour and erosion. The County repaired the damaged segments of road, rechanneled a section of the Sandy River, stabilized the banks with riprap and plantings, and added large woody debris for riparian and fish habitat.

During the January 2011 flood event, the Zigzag River undermined the south abutment of the Zigzag River (Lolo Pass Road) Bridge. The Sandy River washed out an approximately 300-foot-long segment of Lolo Pass Road approximately 0.23 mile north of its intersection with East Barlow Trail Road. Flood waters also eroded the roadway embankment north of the Sandy River (Lolo Pass Road) Bridge, and ran south along the roadway and ditch, causing erosion damage at the north bridge approach. During the 2011 event, several houses were destroyed due to the erosion of bank soils underlying house foundations, and a half-mile section of Lolo Pass Road, which serves hundreds of residents, was washed out.

Following the flood event in 2011, the County repaired the road, rechanneled a section of the Sandy River, and stabilized the banks with riprap, as well as added large woody debris for riparian and fish habitat restoration. Additionally, some adjacent property owners have also made modifications to the channel to add protection for their homes.

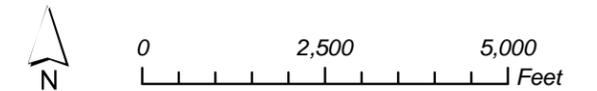


Lolo Pass Road Access Alternatives

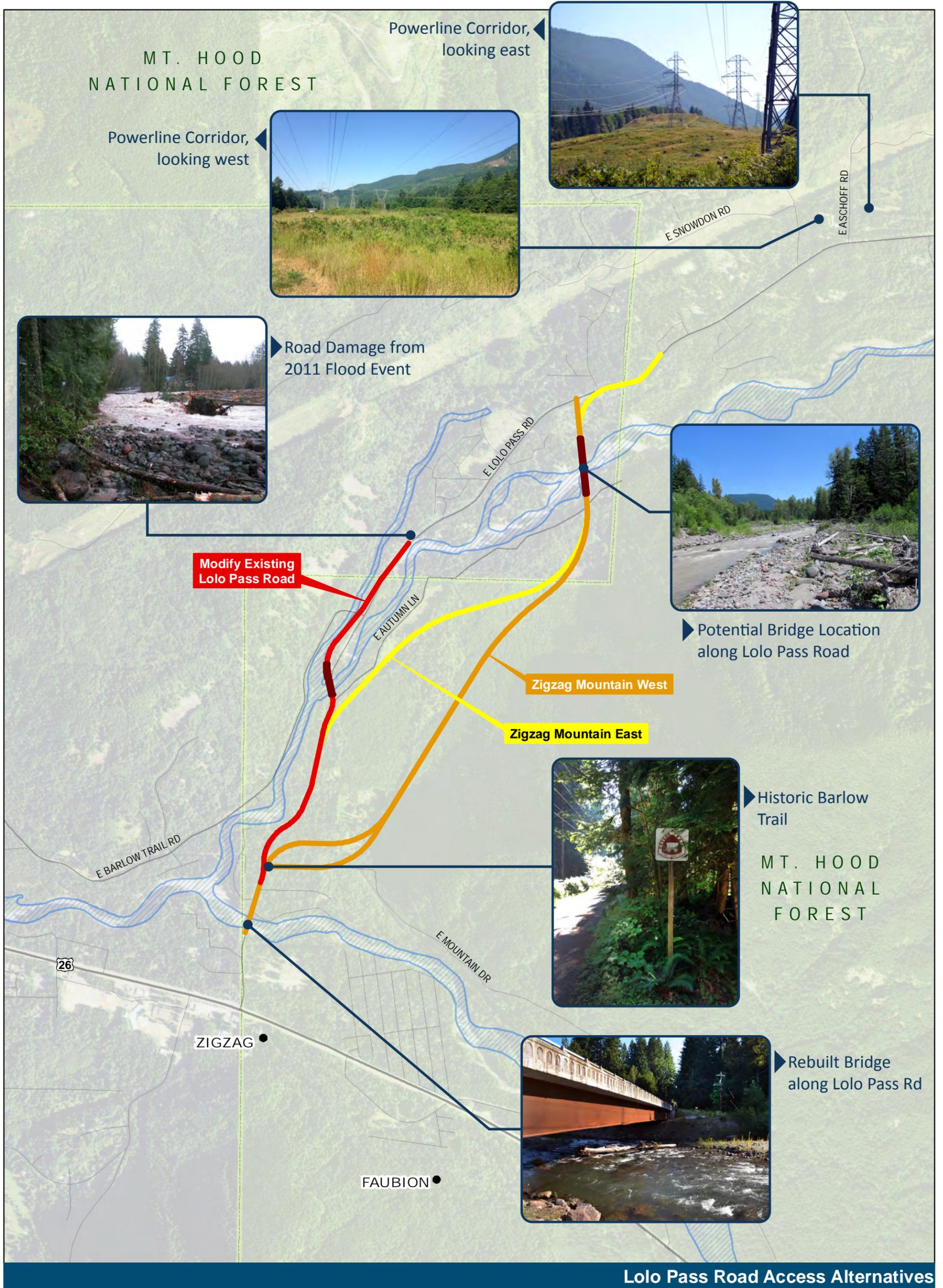
- Legend**
- Powerline Corridor Study Area
 - Sandy River Corridor Area
 - FEMA Floodway
 - Mt. Hood National Forest
 - Mt. Hood Wilderness
 - Wild & Scenic Sandy River (Recreation)

Powerline Corridor and Sandy River Corridor Study Areas

Figure 1. Areas of Study



Data Sources:
 ESRI, ArcGIS Online, World Imagery, 2010. Microsoft.



Lolo Pass Road Access Alternatives

Legend

- Study Area
- FEMA Floodway
- FEMA 100-Year Floodplain
- Mt. Hood National Forest

Alternatives

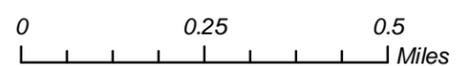
- Modify Existing Lolo Pass Road
- Zigzag Mountain East
- Zigzag Mountain West
- Bridge Deck

Sandy River Corridor Study Area

Figure 1b

Sandy River Corridor Study Area

Data Sources:
 ESRI, ArcGIS Online, World Imagery. 2010. Microsoft.
 FEMA. 2015.



ALTERNATIVES OVERVIEW

Five alternatives are described in this report: No Action Alternative, Modify Existing Lolo Pass Road Alternative, two Zigzag Mountain Alternatives (East and West), and a Powerline Corridor Alternative. The Zigzag Mountain and Powerline Corridor Alternatives would replace the existing Lolo Pass Road, and would become the primary route to provide access to residences and forest lands north of US 26. Under any of the potential new route options, Clackamas County would need to decide whether the County would continue to maintain the existing Lolo Pass Road as a local access road. As mentioned above, Figure 1 shows the project study area, which consists of the Sandy River Corridor Study Area and the Powerline Corridor Study Area. Figure 2 shows the three proposed alternatives in the Sandy River Corridor Study Area, Figure 2b shows a closer view of the Modify Existing Lolo Pass Road Alternative, and Figure 3 shows the Powerline Corridor Alternative.

The access alternatives were developed at a schematic planning or "sketch" level, and refined based on consideration and analysis of observed and mapped constraints, including environmental resources and engineering design criteria. For example, the Zigzag Mountain Alternatives were designed to achieve the following objectives:

- Develop a roadway substantially outside the channel migration zone
- Develop a roadway to allow continued access to residences and forest lands
- Avoid residential impacts
- Avoid wetland impacts
- Avoid direct impacts to National Forest Land and the Wild and Scenic section of the Sandy River

The Modify Existing Lolo Pass Road Alternative was developed after initial hydrologic and geomorphic analysis pointed to the existing bridge over the Sandy River as a considerable constriction to the river. This constriction causes localized erosion issues and puts the existing bridge, surrounding roadway, and nearby homes at risk in future events.

The alternatives presented in this report are at a conceptual engineering level, and are subject to refinement based on stakeholder and public input, and further study if needed. Table 1 below outlines some of the key features of each alternative; more detail is provided in the following discussion.

Table 1. Key Features of Potential Build Alternatives

	No Action	Modify Existing Lolo Pass Road	Zigzag Mountain West: Originating Near Autumn Lane	Zigzag Mountain East: Originating Near Mountain Drive	Powerline Corridor
Bridge Length	None	Two 200-foot bridges at existing crossing	800-foot bridge (four spans)	800-foot bridge (four spans)	Avoids Sandy River Crossing; multiple bridges anticipated
Improvements to Existing Lolo Pass Road?	No	Yes – new bridge and reinforcements planned	Minor, south of Autumn Lane	Minor, south of Mountain Drive	No
Length of New/Improved Roadway	0 miles	0.6 mile	1.6 miles	1.7 miles	5.5+ miles

Figure 2. Lolo Pass Road Access Alternatives Analysis Study

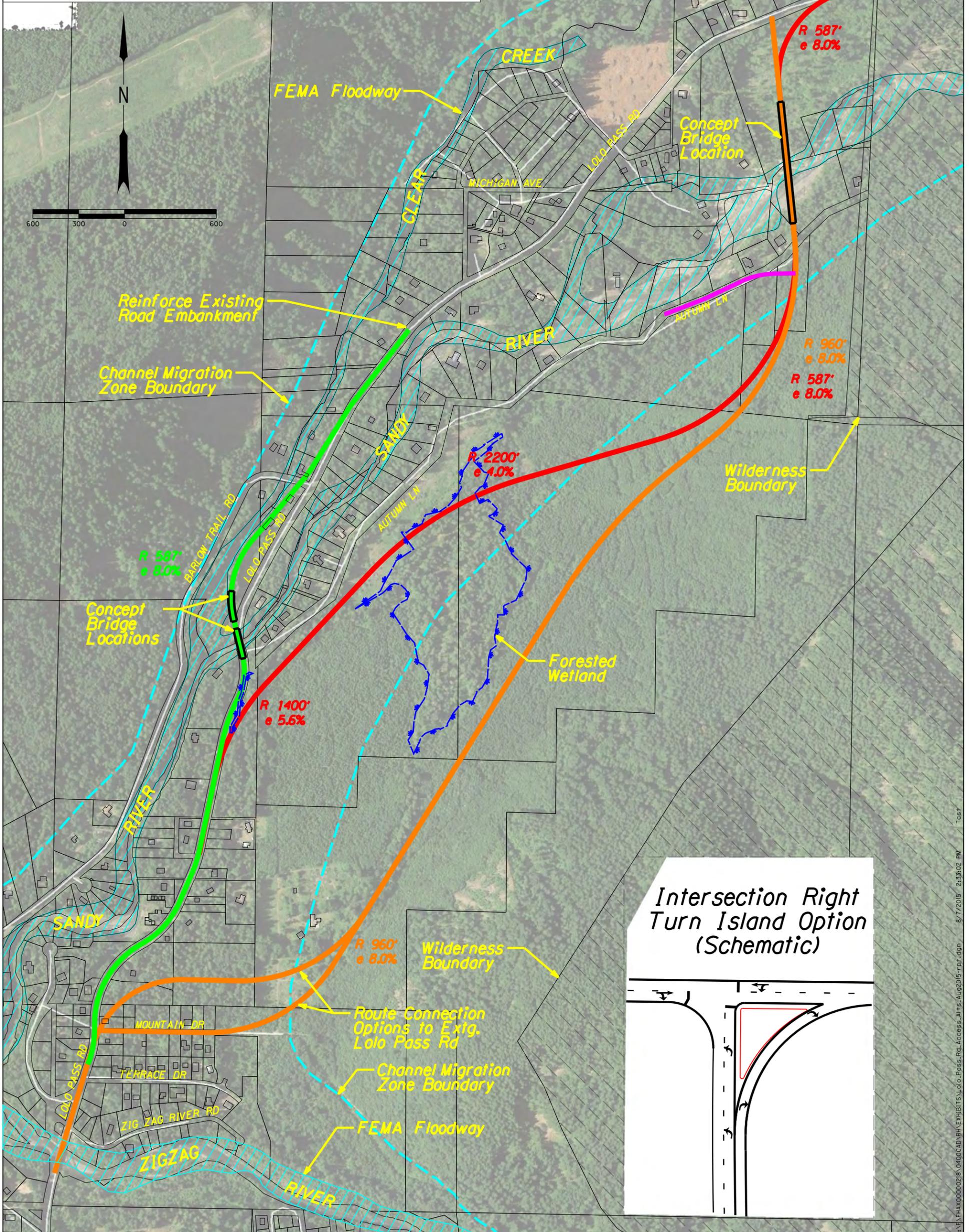
- DRAFT -

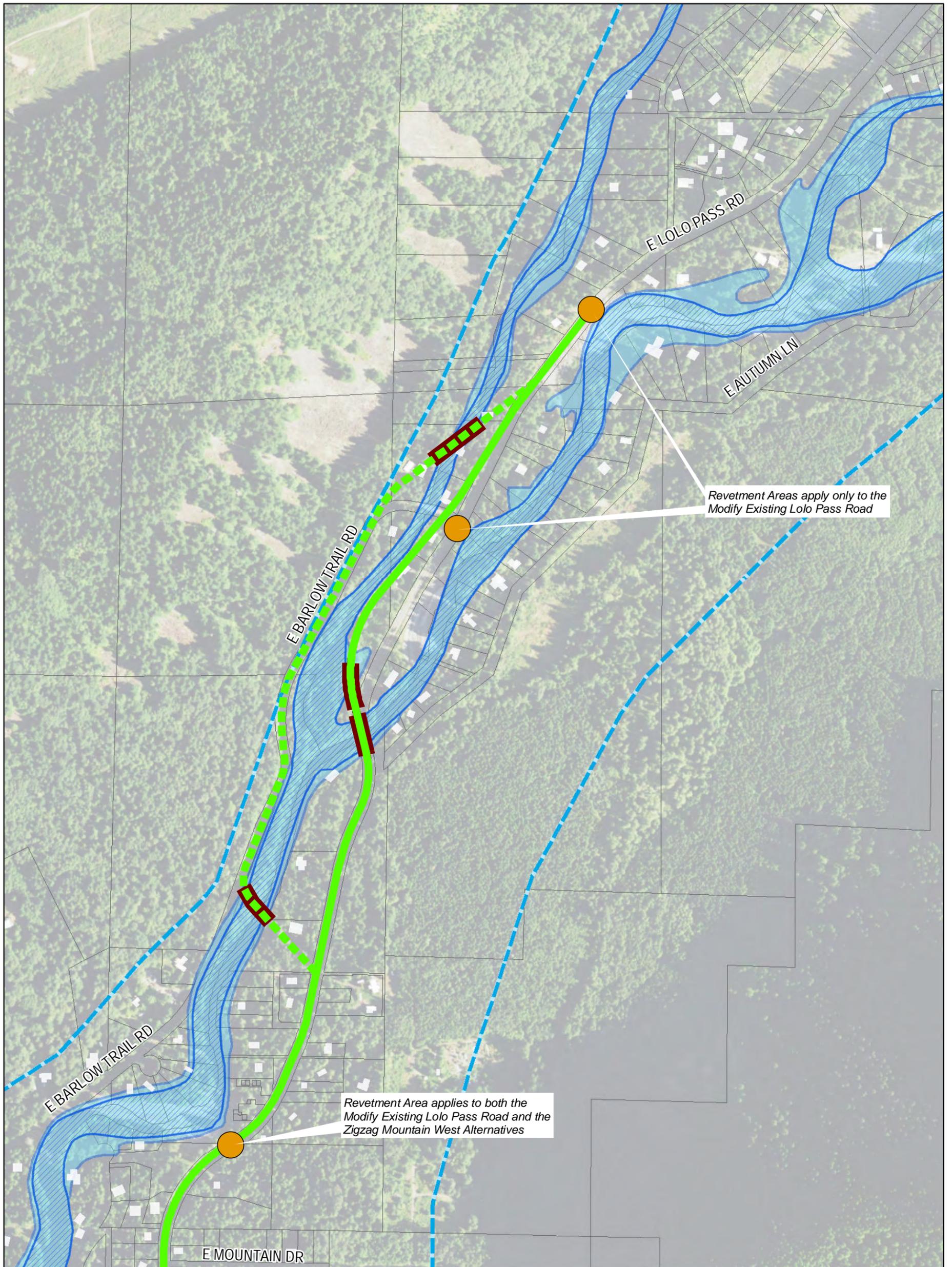
August 2015

Scale: 1"=600'

Alignment	Design Speed
— Modify Existing	45 mph
— Zigzag Mtn. West	45 mph
— Zigzag Mtn. East	55 mph
— Autumn Ln. Connection	25 mph

Preliminary alignments for planning study purposes only, and subject to change.





Lolo Pass Road Access Alternatives

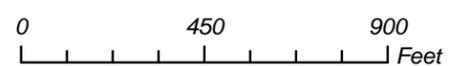
Sandy River Corridor Study Area

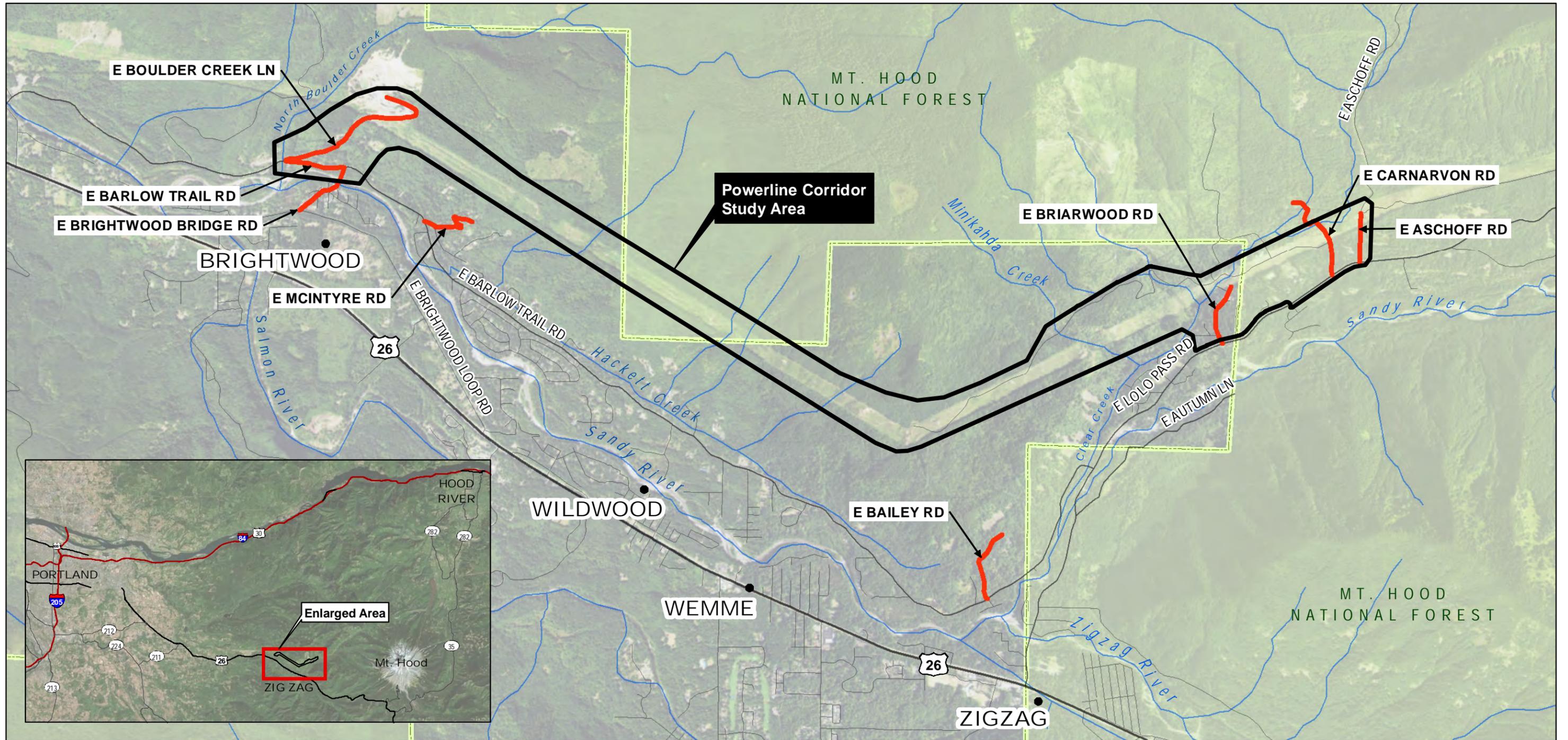
Figure 2b

Modify Existing Lolo Pass Road Alternative Detail and Option

- Study Area
- FEMA Floodway
- FEMA 100-Year Floodplain
- Channel Migration Zone
- Mt. Hood National Forest
- Revetment Area
- Alternatives**
- Modify Existing Lolo Pass Road
- Modify Existing Lolo Pass Road-Option
- Bridge Deck

Data Sources:
 ESRI, ArcGIS Online, World Imagery. 2010. Microsoft.
 FEMA. 2015.





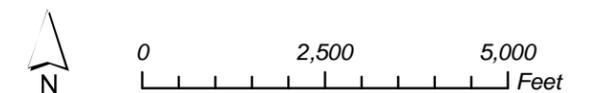
Lolo Pass Road Access Alternatives

- Legend**
- Study Area
 - Potential Connections
 - FEMA Floodway
 - Mt. Hood National Forest

Powerline Corridor Study Area

Figure 3.
Powerline Corridor Map

Data Sources:
 ESRI, ArcGIS Online, World Imagery. 2010. Microsoft.
 FEMA. 2015.



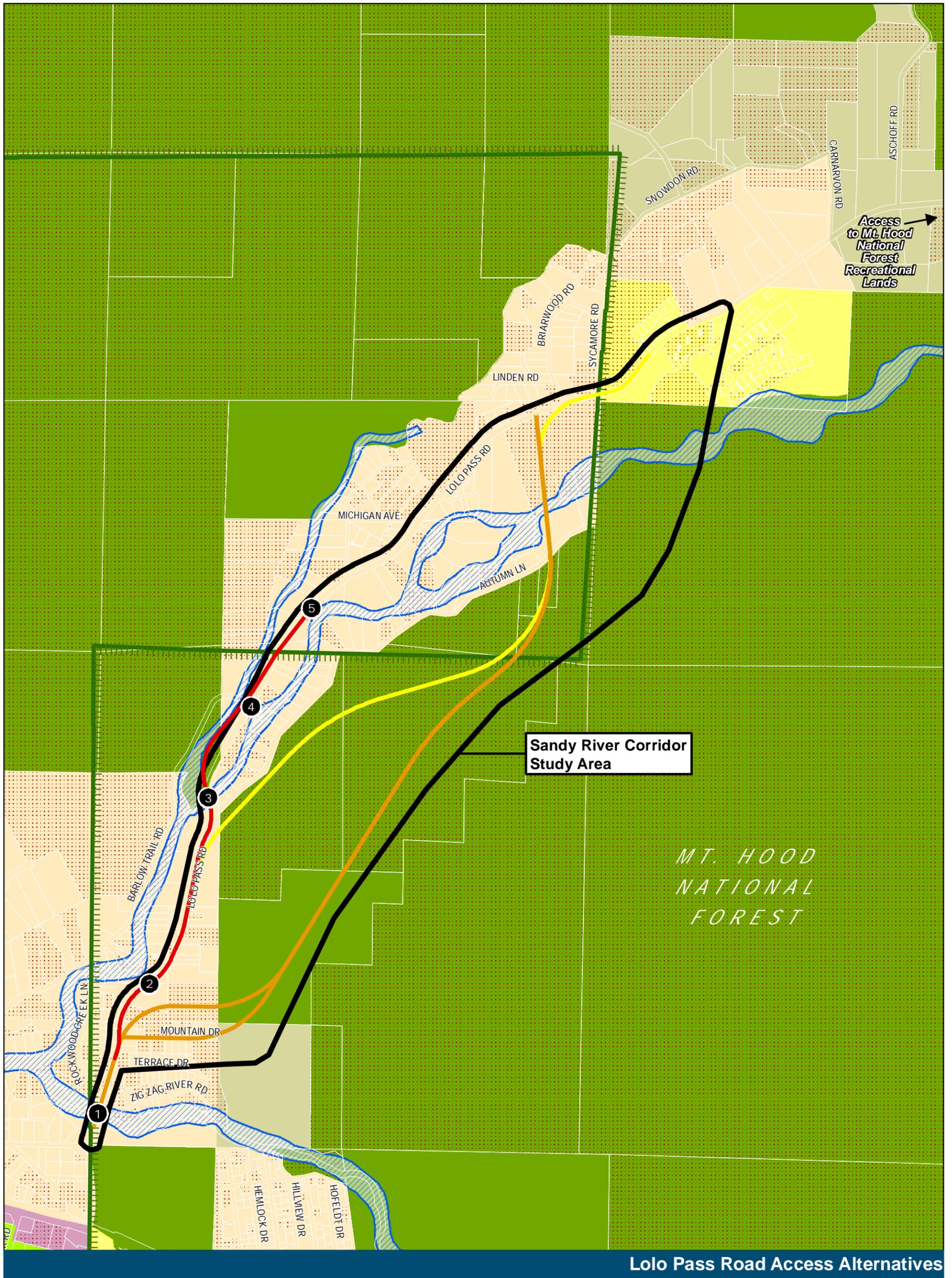
NO ACTION

Doing nothing to address imminent and ongoing damage from future natural events (no action) would leave Lolo Pass Road in its current state on the existing alignment. Storm and flooding events will continue to occur and will threaten the condition and function of roadway, particularly at bridges and in areas where the river currently abuts or historically crossed the roadway. Based on existing information, breaches or impassable damages to Lolo Pass Road would create access problems to hundreds of residences situated along and near Lolo Pass Road, and would restrict access to the MHNFR recreational lands to the northeast. Figure 4 shows the existing roadway and highlights some of the most vulnerable areas of the road to potential washout or other damage.

If Lolo Pass Road is damaged at or above (north of) East Barlow Trail Road (#4 on Figure 4), property access and egress from points north will become restricted. Under this condition, residents and visitors who rely on Lolo Pass Road would have two access route options: 1) follow Lolo Pass Road approximately 40 miles north to reach Hood River or 36 miles to reach the Columbia River Gorge near Cascade Locks (these routes are unplowed in the winter months and in sections are on forest roads), or 2) travel approximately 5.5 miles to use the unimproved gravel and dirt road accessed from Aschoff Road that BPA built for the purpose of maintaining its overhead power lines. (This route was used for emergency access by four-wheelers when Lolo Pass Road was severely damaged near the intersection with East Barlow Trail Road in January 2011.) Cars and trucks were not able to use this route for access. Neither the maintenance road nor the long detour route to the Columbia Gorge would be a durable year-round route for the current residents and visitors to the area.

If Lolo Pass Road is damaged below (south of) East Barlow Trail Road (below #4 on Figure 4), traffic from the points north (approximately 250 residences) of the damaged area would likely be detoured to East Barlow Trail Road and to the west approximately 4 miles through Brightwood before crossing the Sandy River to access US 26. Residents along Lolo Pass Road south of the damaged area (approximately 50 residences) would access US 26 as they do today, but with a detour totaling nearly 10 miles in order to proceed north on Lolo Pass Road (which would require backtracking on US 26 to Brightwood and returning to the area on East Barlow Trail Road).

In 1964, flood damage washed out the road near point #3 on Figure 4. A newspaper article describing that event stated that 200 homes were cut off from access to US 26. Development of residences above this point has continued over the past 50 years, such that hundreds of additional people would be adversely affected by a similar event today. See Appendix B, which contains an access memorandum, for more information.



Lolo Pass Road Access Alternatives

Legend

- Area of Potential Effect (APE)
- Vulnerable Areas
- FEMA Floodway
- Vacant/Unimproved Land
- Mt. Hood National Forest

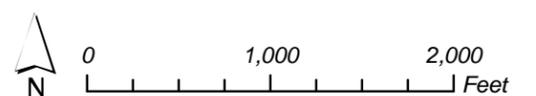
Alternatives

- Modify Existing Lolo Pass Road
- Zigzag Mountain East
- Zigzag Mountain West

Clackamas County Zoning Designations

- Hoodland Residential (HR)
- Mountain Recreational Resort (MRR)
- Open Space Management (OSM)
- Recreational Residential (RR)
- Rural Residential Farm Forest, 5-acre (RRFF5)
- Rural Commercial (RC)
- Rural Tourist Commercial (RTC)
- Timber District (TBR)

Figure 4
Sandy River Corridor
Property Access Analysis



Data Sources:
ESRI, ArcGIS Online, World Imagery, 2010, Microsoft.

MODIFY EXISTING LOLO PASS ROAD

An alternative was developed to assess the cost and impact of modifications needed to reduce the risk of roadway and bridge failures and retain the existing Lolo Pass Road as the long-term, primary access route through the area.

Figure 2 and Figure 2b show the conceptual alignment of this Modify Existing Lolo Pass Road Alternative. Figure 2b shows a second concept for this Alternative, which would use part of the existing East Barlow Trail Road. This concept would require two new bridges and would also result in property displacements. However, the concept would avoid two vulnerable locations of the existing road: near the intersection of Lolo Pass Road and East Barlow Trail Road, and the existing crossing of the Sandy River.

This alternative has the following features:

- Widen the channel and set back bank, resulting in the displacement of a residence on Lolo Pass Road to accommodate river dynamics.
- Replace the existing Sandy River bridge with two 200-foot bridges, allowing a reopening of the hydraulic opening for the river and moderating flows above and below the bridge, which currently constricts the river.
- Set back the road alignment north of the new bridge, connecting back to the existing Lolo Pass Road north of the intersection with East Barlow Trail Road.
- South of the Sandy River crossing, reinforce the existing roadway for about 800 feet to armor the roadway against high flows on the river.

The roadway realignment and improvements would require acquisition of new right-of-way from approximately ten to 18 properties. This alternative would likely result in four to five residential displacements, including one on the south bank of the bridge and three to accommodate the realigned roadway.

ZIGZAG MOUNTAIN ALTERNATIVES

The potential new roadway and Sandy River bridge crossing alignments to replace Lolo Pass Road are shown on Figure 2. Either of these potential alternatives would alleviate access concerns associated with future damage and closure of the existing roadway, and would provide a new crossing of the Sandy River north (upstream) of the existing crossing. The majority of the potential new roadway leading to the proposed new crossing would be outside the channel migration zone, in contrast with the existing Lolo Pass Road, which has multiple sections that are vulnerable to destruction from flooding and river channel migration. The Zigzag Mountain East Alternative (the alignment originating near Mountain Drive) would have a

longer distance outside of the channel migration zone than the Zigzag Mountain West Alternative (the alignment originating near Autumn Lane). Thus, these alternatives minimize the potential for future damage to the roadway, compared to the existing Lolo Pass Road.

For either of these alternatives, the new roadway would become the primary through route, and Clackamas County would maintain the existing road as a local access road, which would only receive minimal maintenance. If the road were washed out in the future, the County would need to decide whether to restore the road for continued use.

These Zigzag Mountain Alternatives have the following features:

- There would be a new bridge across the Sandy River of approximately 800 feet total length. This multi-span bridge would be on large vertical columns with foundations deeply embedded in solid rock.
- The bridge would cross both the existing and historic river channels with multiple spans. The multiple spans would allow river flows outside the existing channel.
- The bridge would extend over historic and potential future river channel areas, which could become the main stem of the river in the future.
- Substantial fill would be required for these alternatives, particularly at the northern end of the bridge, but the fill would be located outside the floodplain.
- Fill at the northeast end of the alignment (meeting the existing road) would need to be heavily armored, and the use of culverts might also be considered in order to provide overflow event relief.
- Connections between the potential new alignment and the existing Lolo Pass Road would be designed so that the new roadway would be the through movement. The design options considered to accommodate through travel for the primary route are:
 - T-intersection with free-flow right-hand turn channelization (shown with the alignment originating near Mountain Drive)
 - Through movement with curve (shown with the alignment originating near Autumn Lane)
- The connection to the existing Lolo Pass Road at the south end (near Autumn Lane or near Mountain Drive) would be designed to make the new roadway the through route. (The Zigzag Mountain East Alternative (originating near Mountain Drive) has two sub-

options for the connection (one along Mountain Drive and a second running north of Mountain Drive), as shown on Figure 2.¹)

- The new roadway would include an at-grade connection to Autumn Lane near its northeast section immediately east of the new bridge.

These alternatives would likely require acquisition of new right-of-way from 12 to 23 private properties and would result in one or two residential displacements.

POWERLINE CORRIDOR

One potential alternative would be to construct a new roadway along or adjacent to the BPA Powerline Corridor, a BPA power transmission facility. The Powerline Corridor has a dirt maintenance access road that meanders through most of the area, and a portion of that road was used as an emergency route when a section of Lolo Pass Road was destroyed in 2011.

Figure 3 (above) shows the Powerline Corridor Alternative. Connections between this corridor and Lolo Pass Road could be considered at the northern end at East Aschoff Road and at the southern end at McIntyre Road, Bailey Road, or at East Boulder Creek Lane, which connects to East Barlow Road and then connects to US 26 by a bridge over the Sandy River.

Review of the existing maintenance road revealed that its use as a primary access route would not be practical for a number of reasons. The road traverses over steep mountainous terrain which rises 800 feet above the valley floor. Improving this road from its current primitive condition to a primary access would require over six miles of road construction over hilly, forested terrain. It crosses over 2 miles of mapped landslide deposits and 11 significant drainage ravines, and stream crossings may be subject to fast-moving debris flows carrying significant amounts of sediment and entrained woody debris (material captured and carried by the stream). To traverse the terrain with a two-lane roadway would require large fills and bridges throughout the corridor and much of the roadway would have to be re-aligned to meet design safety standards. The new route would require an extensive amount of regular maintenance and snow removal during the winter months since it traverses hazardous and high elevation terrain. In addition to these challenges, a major constraint is the locations of the

¹ These options both appear on Figure 2; however, only the original alignment along the existing Mountain Drive is included in the cost estimate analysis presented later in this report.

transmission towers themselves; the corridor is traversed by three powerlines that follow a BPA easement.

Projects within a BPA easement require special clearances and requirements. If the alternative would be in any part of the BPA easement, the project would need to submit a land use application, and the engineering drawings would need to go through BPA's engineer reviews. BPA would likely:

- Restrict how close any work or improvements can be to BPA's towers or poles (usually a 50-foot minimum distance).
- Evaluate each proposed project element for height restrictions (e.g., any signs, illumination, planting, guardrails, road grade).
- Assess whether any project components could pick up a stray current, and apply location restrictions if appropriate.

Figure 5 and Figure 6 present examples of the terrain in the existing Powerline Corridor. Lolo Pass Road is downslope of the corridor.

Figure 5. Powerline Corridor Showing Existing Maintenance Road and Terrain, Looking North

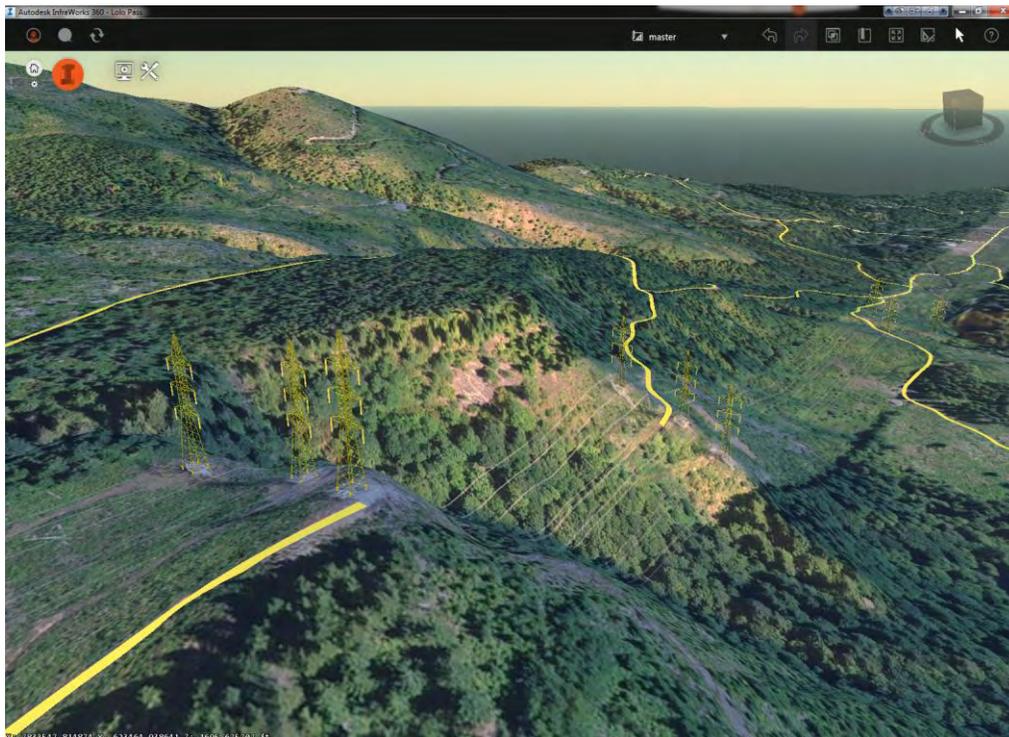
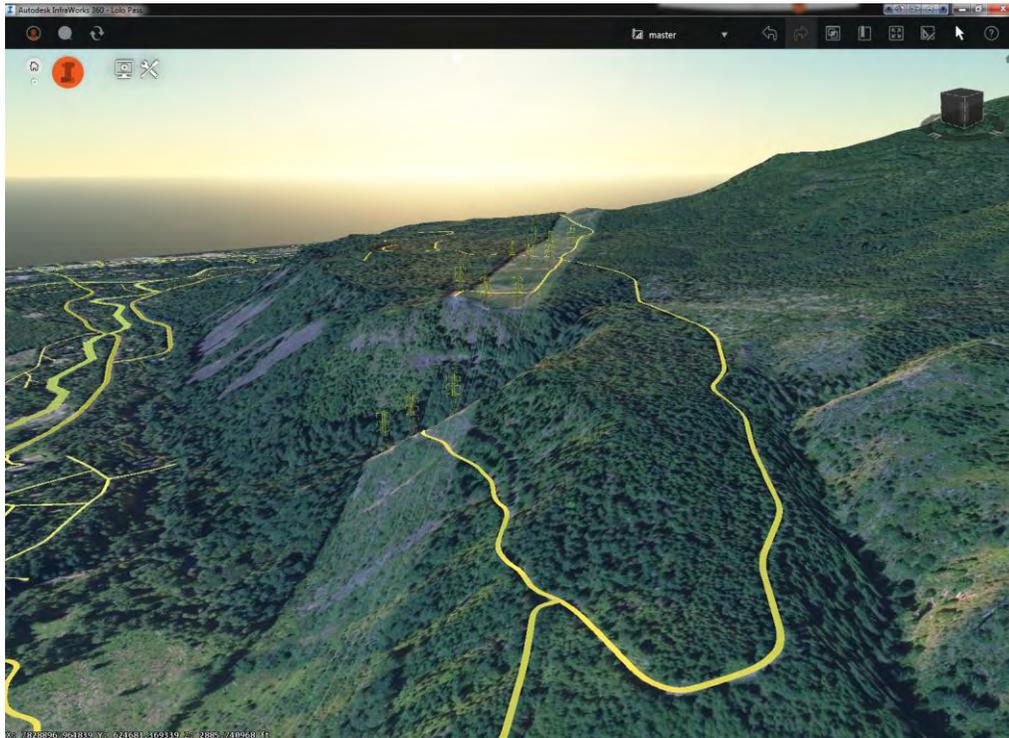


Figure 6. Powerline Corridor Looking South; note BPA towers (yellow) and mountainous terrain



As described and shown above in Figure 5 and Figure 6, the Powerline Corridor Alternative alignment is characterized by significant variations in terrain elevations, large areas with slope instability, and numerous water resources areas, as well as substantial challenges related to the existing BPA corridor. Additionally, the reconnaissance report (Appendix A) documented the presence of sensitive environmental resources and hazard areas including active landslides. Even if right-of-way could be secured, construction would be extremely difficult and costly, and connections for existing residences and other roadway users would require substantially longer routes than currently exist. Thus, the Powerline Corridor Alternative does not appear to be a reasonable or feasible option and was not included in the additional design and cost analysis described in the remainder of this report.

CONTENTS OF THIS REPORT

The remainder of this report consists of eight sections plus appendices. The first three sections address the analysis of the potential build alternatives in the context of a Geomorphic and Hydrologic Assessment of most reasonable bridge crossing locations, and in consideration of Engineering Issues and multiple Environmental Resources, including:

- Streams and Wetlands

- Threatened and Endangered Species
- Geological Hazards
- Floodplains
- Cultural Resources
- Hazardous Materials

A Cost Analysis section that provides comparative conceptual-level costs follows the Environmental Resources section. The alternatives analysis and cost estimating was conducted at a level of detail sufficient to compare broadly the alternatives with one another. It is a greater level of analysis detail than typically used in comprehensive land use and transportation planning, but is a substantially less detailed analysis than expected in analyzing the specific impacts of a proposed project design where more exact right-of-way lines, construction limits, and facility geometry and design features are known. A summary Evaluation Matrix section completes the analysis portion of this report.

The last three sections of the main body of this report consist of:

- Public Involvement Summary
- Narrative on Future Project Development that identifies potential next steps, including studies needed to support selection of a preferred alternative
- References used to develop this report

Finally, Appendices A through F provide additional background and supporting technical documentation that was used to inform the development of this report.

GEOMORPHIC AND HYDROLOGIC ASSESSMENT

This section presents a summary of the geomorphic and hydrologic conditions in the study area, and focuses on the two bridge crossing areas: the existing Sandy River Bridge crossing on Lolo Pass Road, and a new bridge crossing upstream of the existing crossing (See Figure 2). A memorandum summarizing the geomorphic and hydrologic assessment is attached in Appendix C.

The Sandy River and its tributaries originate high on the western slopes of Mount Hood from the Sandy, Palmer, Reid and Zigzag glaciers. The Sandy River transports large amounts of sediment during the spring and summer months, and during large floods. The sediment supplied by the glaciers and the surrounding steep, erodible slopes can migrate downstream in waves, resulting in localized rise and then fall of the channel bed elevations. As the river evolves, channel erosion and hillside erosion also contribute to the development of debris torrents and localized deposition along segments of the river. High flood waters, combined