



DEPARTMENT OF
NATURAL RESOURCES

FOREST RESOURCES DIVISION
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December 1, 2023

TO: Bruce Schmitz, Forester, Cascade District, Northwest Region, DNR

FROM: Noah Dudley, LEG # 19110609, QE, Forest Resources Division, DNR
Zach Click, LEG # 19110583, Forest Resources Division, DNR

SUBJECT: Geologic Memorandum for the Bologna Timber Harvest, Snohomish County, Washington

This letter documents our observations and interpretations of potentially unstable slopes around the Bologna timber harvest (proposed harvest). This letter documents rule-identified landform interpretations, key observations used to make those interpretations, and the proposed mitigations and recommendations. It is not intended to document the full engineering geologic review that we conducted for this harvest, nor is it intended to satisfy the requirements for a Class IV special Forest Practices Application.

Project Description

The proposed harvest is located east of Roesiger Lake within the Pilchuck River Watershed Analysis Unit (WAU). Proposed forest management activities include variable retention harvest and road construction. DNR proposes using ground based, tethered, and cable harvest methods.

The proposed harvest area is located on gentle to steep slopes. Rule-identified landforms around the proposed harvest include bedrock hollows, inner gorges, and outer edge of meander bends within a channel migration zone. The timber harvest boundary excludes rule-identified landforms, therefore there is a low potential for these landforms to deliver sediment to a public resource or impact public safety.¹

Scope of Services

The scope of services included:

- Review of Washington State Department of Natural Resources (DNR) GIS data including:
 - Digital orthophotographs from the 1990's, 2002, 2003, 2004, 2006, 2007, 2009, 2011, 2013, 2015, 2017, 2019, 2021-2022
 - Historic aerial photographs from: 1941, 1954, 1970, 1972, 1983

¹ Washington Forest Practices Board, 2016, Washington Forest Practices Board manual: Washington Forest Practices Board, 1 v.

- Light detection and ranging (lidar) data acquired in 2017
- 1:100,000-scale geologic mapping²
- Washington Geological Survey (WGS) Landslide Inventory
- Forest Practices Landslide Inventory (LSI) and Hazard Zonation (LHZ) mapping
 - LSI and LHZ not available for this area
- Nearby forest practice applications (FPA's)
 - Kitten Kaboodle and Saddle Up
- Field reconnaissance on:
 - October 18th, 2023 – Noah Dudley (State Lands Geologist, Licensed Engineering Geologist (LEG), Qualified Expert (QE)), Zach Click (State Lands Geologist, LEG), Jack Armstrong (State Lands Forester), Bruce Schmitz (State Lands Forester), Jeremy Westra (State Lands Engineer)
 - November 7th, 2023 – Zach Click, Bruce Schmitz

Noah Dudley and Zach Click prepared this report. Noah Dudley is a “qualified expert” for timberland slope stability evaluations.

Geologic Setting

We reviewed the Sauk River 30- by 60-minute quadrangle, 1:100,000-scale geologic map by Tabor, 2002 (Figure 3). The published geologic map indicates that the site is underlain by Cretaceous-aged metasedimentary (Kjmm(w)) and metavolcanic (KJmv(w)) rocks, and Jurassic-aged gabbro and diorite (Jigbd(w)). The bedrock is capped with glacial outwash (Qgo) deposits in of Units 1 through 5 and Quaternary-aged glacial till (Qgt) and glacial drift (Qgpc) in the vicinity of Units 6, 7, and 8. Quaternary-aged alluvium (Qa) is also mapped in the site vicinity along the Pilchuck River north of Unit 5.

During the most recent ice age, termed Vashon, glacial ice advanced across the project area. The Puget lobe of the Cordilleran Ice Sheet shaped the landscape of the Puget Sound and the surrounding hillslopes. Glaciers deposited glacial till over the landscape. Glacial till consists of a low-permeability, very dense mixture of sand, silt, clay, gravel, and boulders.

In the field, we primarily observed intact metasedimentary and metavolcanic bedrock with instances of highly weathered bedrock observed in stream channels, as well as bedrock colluvium, and occasional thin glacial sediment deposits. We observed discontinuous deposits of glacial till, glacial outwash, glacial drift, and glacial outwash mantling the local bedrock. Glacial deposits appeared to be thickest near Unit 5.

No landslide deposits were mapped in the project vicinity by Tabor; however, the Washington Geological Survey landslide inventory provides data for remotely mapped landslides. Landslides are discussed further in the following sections.

² Tabor, R. W.; Booth, D. B.; Vance, J. A.; Ford, A. B., 2002, Geologic map of the Sauk River 30- by 60-minute quadrangle, Washington: U.S. Geological Survey Geologic Investigations Series Map I-2592, 2 sheets, scale 1:100,000, with 67 p. text.

Washington Geological Survey Landslide Inventory

The WGS mapped landslide deposits in and around the proposed harvest.

The table below summarizes WGS data and our observations for the landslide deposits mapped in and around the harvest area. Figure 3 shows additional polygons, but these are separated from the management area by topographic and hydrologic barriers.

Table 1. WGS Landslide Inventory Table – Landslide Deposits

Inventory Metadata				
LSI ID#	Movement	WGS Confidence	Field Verified by WGS?	Our Observations and Interpretations
10626	Complex	Moderate	No	Intact bedrock observed in head scarp and body. Smooth scarp to body transition. Generally planar body. Old and second growth stumps observed to be vertical/not displaced. Intact bedrock or weathered bedrock observed in stream channels within mapped polygon. We do not interpret this landslide polygon as active, but dormant-indistinct/relict.
14207	Slide-Rotational	Low	No	Small convergent area on terrace riser above Pilchuck River. Shallow landslide or bedrock hollow. Outside proposed harvest in RMZ.
14208	Slide-Rotational	Moderate	No	Smooth, arcuate break in terrace riser above floodplain with hummocky terrain below. Likely an old shallow landslide. Outside proposed harvest in RMZ.
14209	Complex	Moderate	No	Shallow landslide deposit from bedrock hollow above. Mapped deposit terminates at road grade below. Hollow is excluded from proposed harvest area.
14211	Slide-Translational	Low	No	Steep area an outer edge of creek below. Appears to reflect shallow landslide processes on inner gorge. Outside proposed harvest.
14212	Slide-Translational	High	No	Appears to be an oversteepened inner gorge bank in LiDAR. Outside proposed harvest.
14218	Complex	Moderate	No	Steep convergent topography. Several hollows with bare soil and undermined roots below existing road. Road will be rerouted to south side of ridge to avoid impacting this shallow landslide prone area. We not observe evidence of deep-seated landslide movement. Outside proposed harvest.
14219	Complex	Moderate	No	Shallow landslide. We observe rapid groundwater seepage at a consistent elevation band corresponding to a sand-clay contact. Shallow slope failures and erosion appear common below this contact. We not observe evidence of deep-seated landslide movement. Outside proposed harvest.
14223	Complex	Moderate	No	Not a landslide – see discussion below
14298	Complex	Moderate	No	Steep terrace riser with arcuate scarp. Shallow landslide or inner gorge. Outside proposed harvest.
14299	Slide-Rotational	Moderate	No	Terrace fragment with broadly arcuate riser. Same elevation as terrace to north. Outside proposed harvest.
14306	Complex	Moderate	No	Shallow landslide on outer edge of meander bend. Outside proposed harvest.
14307	Complex	Moderate	No	Shallow landslide on outer edge of meander bend. Outside proposed harvest.
14308	Complex	Moderate	No	Shallow landslide. Separated from proposal area by topographic and drainage divide.

14310	Complex	Low	No	Vertical conifers, upright old growth stumps, planar slopes. Smooth topography. Likely terrace riser. Unclear why this section of slope was included as a landslide polygon and not other nearby, similar looking sections.
14311	Complex	Moderate	No	Possible landslide or terrace riser. Separated from proposal area by topographic and drainage divide. Outside proposed harvest.
14312	Complex	Moderate	No	Shallow landslide. We observe rapid groundwater seepage at a consistent elevation band corresponding to a sand-clay contact. Shallow slope failures and erosion appear common below this contact. We not observe evidence of deep-seated landslide movement. Outside proposed harvest.

Washington Geological Survey Alluvial Fan Inventory

The WGS mapped alluvial fans in and around the proposed harvest area (Figure 3). Table 2 provides WGS inventory metadata for mapped alluvial fans that we identified during remote review of potential channel migration zones and sensitive sits.

Table 2. WGS Alluvial Fan Inventory Table – Alluvial Fan Deposits

Alluvial Fan ID#	WGS Confidence	WGS Relative Fan Age	Field Verified by WGS?	Our Observations and Interpretations
9228	High	Pre-historic (>150 years)	No	Inner gorge stream banks above are vegetated with conifer and upright old growth stumps. Old growth stumps along margin of main channel. We did not observe secondary channels on fan surface. Main channel is well-developed. Relict alluvial fan.
9259	Low	Pre-historic (>150 years)	No	Smooth, vegetated topography. Mature conifer and old growth stumps on fan surface. No evidence of recent deposition beyond existing channel.
9260	Low	Pre-historic (>150 years)	No	Mapped apex includes rail grade through cut. Smooth, vegetated topography. Mature conifer and old growth stumps on fan surface. No secondary channels. No evidence of recent deposition beyond existing channel. Well-developed stream.
9261	Moderate	Pre-historic (>150 years)	No	Broadly fan shaped. Source area is small. Lacks confined stream network above.
9271	Moderate	Pre-historic (>150 years)	No	Inner gorge stream banks above are vegetated with conifer and upright old growth stumps. Old growth stumps along margin of main channel. We did not observe secondary channels on fan surface. Main channel is well-developed. Relict alluvial fan.
9272#	Low	Pre-historic (>150 years)	No	Inner gorge stream banks above are vegetated with conifer and upright old growth stumps. Old growth stumps along margin of main channel. We did not observe secondary channels on fan surface. Main channel is well-developed. Relict alluvial fan.

Dormant-Indistinct/Relict Bedrock DSLs

The WGS remotely identified landslide deposits #10626 and #14223 using 1-meter resolution 2017 LiDAR. The WGS did not field verify the landslides discussed in this report. Both landslides are within the proposed management area. In our opinion, polygon #10626 is a deep-seated landslide and #14223 is not a deep-seated landslide.

Field and remote observations of WGS polygon #14223 include:

- Lidar hill shade shows glacial drumlins trending east-west across the head scarp and body of the polygon
- Intact bedrock in mapped scarp, body, along stream channels, and mapped lateral margin
- Bedrock derived soil in mapped head scarp and body
- Upright old growth and second growth stumps and vertical conifers on scarps, body, and indistinct toe
- Planar, smooth, and rolling/undulated landslide body
- Did not observe seeps, springs, wet ground, or hydrophytic vegetation outside of mapped streams
- Did not observe internal scarps, grabens, or category E features indicative of deep-seated landslide movement

Based on the above observations, we interpret that WGS polygon #14223 is not a landslide. Glacial drumlins visible in lidar are continuous across the head scarp and body of the polygon. Conifers, old growth, and second growth stumps appear to have remained vertical since their harvest, generally planar topography, and the presence of established stream channels support this interpretation. The intact bedrock and bedrock in the head scarps, body, margins, and stream channels further suggest that WGS polygon #14223 is not a bedrock deep-seated bedrock landslide.

If polygon #14223 were a landslide, it would be relict to the point where it cannot be distinguished in the field or lidar. Relict deep-seated landslides are not rule-identified landforms because they formed under different geologic and climatic conditions and are highly unlikely to reactivate³.

Field and remote observations of WGS polygon #10626 include:

- Intact bedrock in head scarps, body and along stream channels at the lateral margins and within body
- Vegetated, arcuate head scarp lateral margins
- WGS polygon disrupts the glacial drumlins observed in lidar which were observed to be continuous across WGS polygon #14223

³ Forest Practices Board Manual – Section 16

- Intact bedrock exposures on intact ground between #10626 DSL #14225
- Highly weathered bedrock derived landslide debris in stream channels within the body west of Unit 8
- Upright old growth and second growth stumps and vertical conifers on scarps, body, and indistinct toe
- Smooth, undulating to hummocky landslide body
- Seepage along stream channel wall south of Unit 8 and wet ground at the western boundary of Unit 8
- Established stream channels across scarp, body, and toe
- Did not observe internal scarps, grabens, or apparent block movement
- Polygon disrupts east-west trending glacial drumlins

Based on the above observations, we interpret WGS polygon #10626 as a dormant-indistinct to relict, bedrock deep-seated landslide. In the absence of toes steeper than 65% and category E combined signs of instability, dormant-indistinct to relict, bedrock DSLs are not rule-identified landforms. In our opinion, the proposed forest practices are unlikely to reactive the DSL.

Pilchuck River Channel Migration Zone

The Pilchuck River flows east to west, around units 1, 2, 3, and 4 (Figure 5). Multiple terraces above the current floodplain are visible in the field and lidar, reflecting a history of channel incision and abandonment. We confirmed the presence of a Channel Migration Zone along this reach of the Pilchuck River based on the following observations:

- The valley floor is more than twice the width of the Pilchuck River
- Secondary channels are visible on the low terraces and floodplain
- Change in vegetation from conifer to deciduous trees and lack of old growth stumps on lower terraces
- Gravel bars in air photos and in the field

Based on our review of aerial photos ranging from 1954 to 2021, the Pilchuck River channel appears to have remained relatively stable during this time. Small avulsions occurred during this time, which are visible as low areas near the current channel elevation (Figure 6). Figure 5 shows our delineation of the Historic Migration Zone (HMZ).

We used a relative elevation raster as a first pass to identify likely avulsion pathways (Figure 6). We expanded the avulsion hazard area to include parts of a terrace below Unit 1. This terrace is 6 to 10 feet above the current channel. On this terrace, we observed a vegetative type change and lack of old growth stumps.

We initially screened an outer edge meander bend as a possible Erosion Hazard Area (EHA) that would require an increased buffer (Figure 4, sheet 1). We determined an EHA was not present based on the following observations:

- We did not observe measurable bank retreat in the 67 year aerial photo record
- We observed shallow landslides on the outer edge meander bend slopes

- Old growth stumps and mature conifer above the slope break
- Lack of tension cracks, undermined roots, stretched roots, or other Category E indicators that would indicate active bank retreat

Based on the stable HMZ, and vertical relief of terrace risers, the glacial terraces appear to be resistant to erosion.

In our opinion, the proposed buffers provide adequate protection for Pilchuck River's desired future condition in the 140-year near term.

Bedrock hollows and Inner Gorges

We and the Forester identified several bedrock hollows and inner gorges around the proposed harvest area. These are excluded from the proposed harvest through timber sale boundary tags. Refer to Appendix D of the FPA for additional slope stability information.

Conclusion

The Bologna timber harvest excludes potentially unstable rule-identified landforms. The DNR excluded these features with harvest boundary tags. In our opinion, because the proposed harvest excludes potentially unstable rule-identified landforms, there is a low likelihood that the proposed forest practices will cause or contribute to movement on these landforms.

Limitations

This field summary is intended to summarize landform interpretations in and around the proposed Bologna timber harvest to DNR's foresters and engineers. This letter is not intended to document the full engineering geologic analysis conducted for this proposed timber harvest, instead it is intended to document the primary observations that form the basis of the rule-identified landform interpretations that are present, or interpreted to not be present, in or around the proposed forest practices activities.

Mitigation recommendations presented in this report were developed collaboratively with the forester. While forest practices inherently involve risk, the mitigations presented in this memorandum are intended to minimize adverse impacts on slope stability due to forest practices activities. Conclusions are based on professional judgement and do not guarantee slope stability or absolute absence of risk.

The conclusions presented in this report were developed using limited information, including office-based screening tools and surficial geologic observations, as they existed at the time of the field visits. Actual geologic conditions may differ from those presented in this report. Site conditions can change with time and additional geologic information may become available. If this occurs, geologic interpretations and recommendations may require modification. It is not possible to fully define the geologic conditions of the site based on this limited investigation; however, the work was performed using practices consistent with geologic and geotechnical industry standards for forest slope stability in the region, at the time of this report. It is not possible to predict slope movement with certainty with the available scientific knowledge.

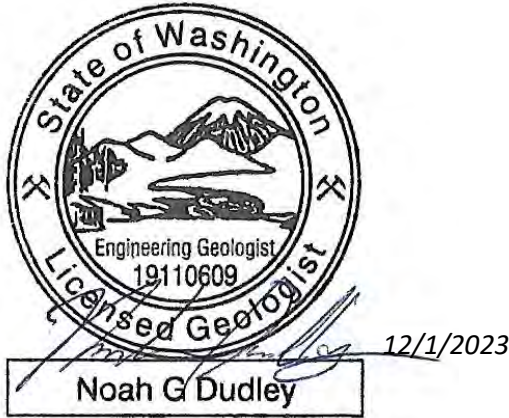
Do not rely on the interpretations or conclusions presented in this memorandum for any activities other than those evaluated for the proposed Bologna timber harvest. If any changes in the proposed FPA or road plan are formulated or carried out differently in the field than currently proposed, conclusions and recommendations shall not be considered valid unless those changes are reviewed in writing by the author or author's representative. No one other than the DNR should rely on this report.

- ATTACHMENTS:**
- Figure 1, Vicinity Map
 - Figure 2, Geologic Map
 - Figure 3, WGS Inventory Map (4 sheets)
 - Figure 4, Geomorphology Map (4 Sheets)
 - Figure 5, Pilchuck River CMZ Map
 - Figure 6, Relative Elevation Map



12/1/2023

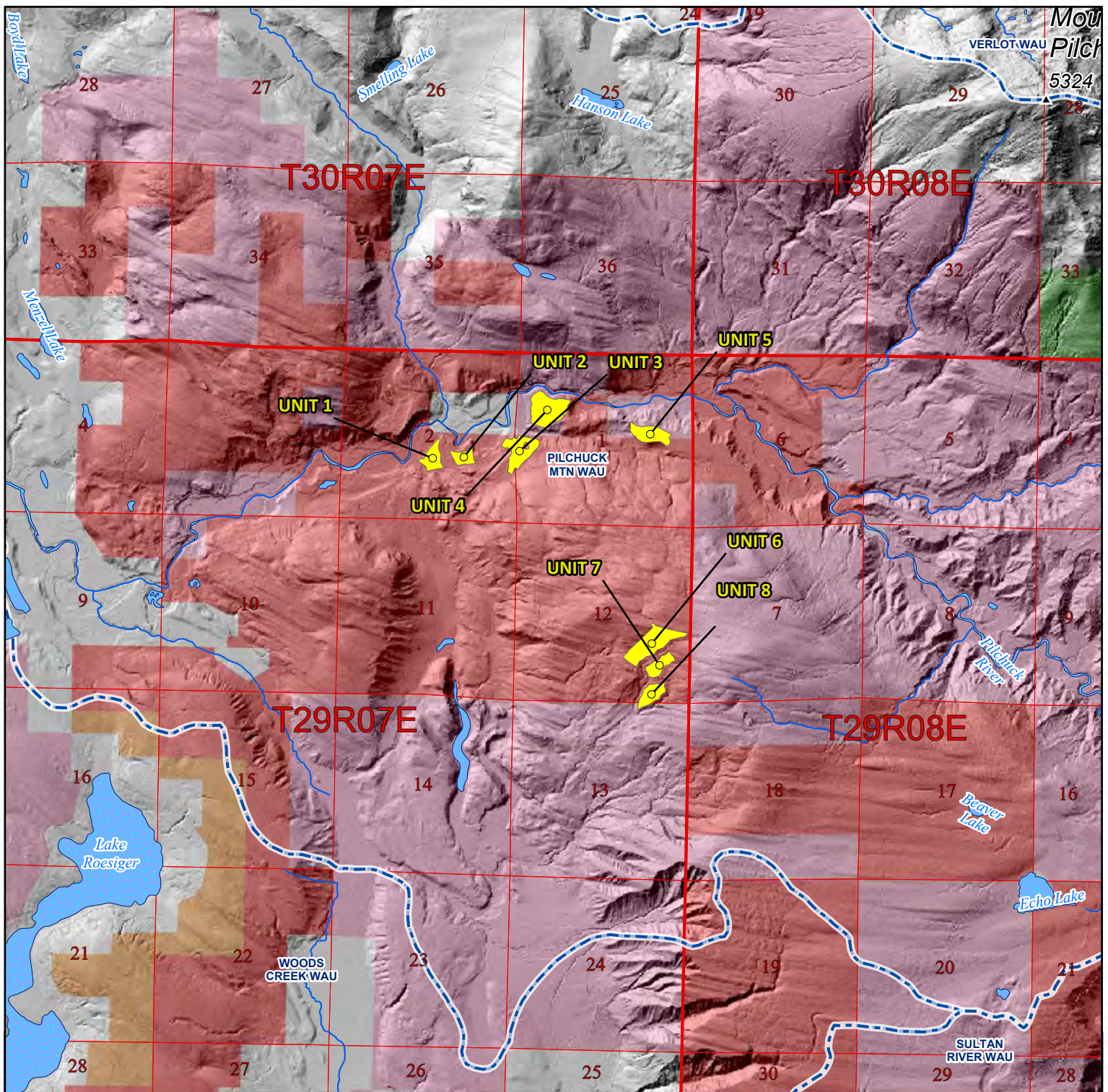
Zach Click, LEG # 19110583
State Lands Geologist



12/1/2023

Noah G Dudley

Noah Dudley, QE, LEG # 19110609
State Lands Geologist

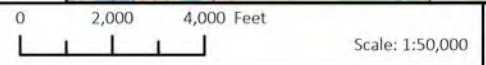


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|-------------------------------------|--|
| Bologna Unit Boundary | Administrative - DNR-Managed (Surface) Lands (4 Categories) |
| Watershed Administrative Unit (WAU) | Granted Trust Lands |
| Major Stream | Forest Board Trust Lands |
| Open Freshwater | NAP / NRCA |
| | Other DNR-Managed Lands |



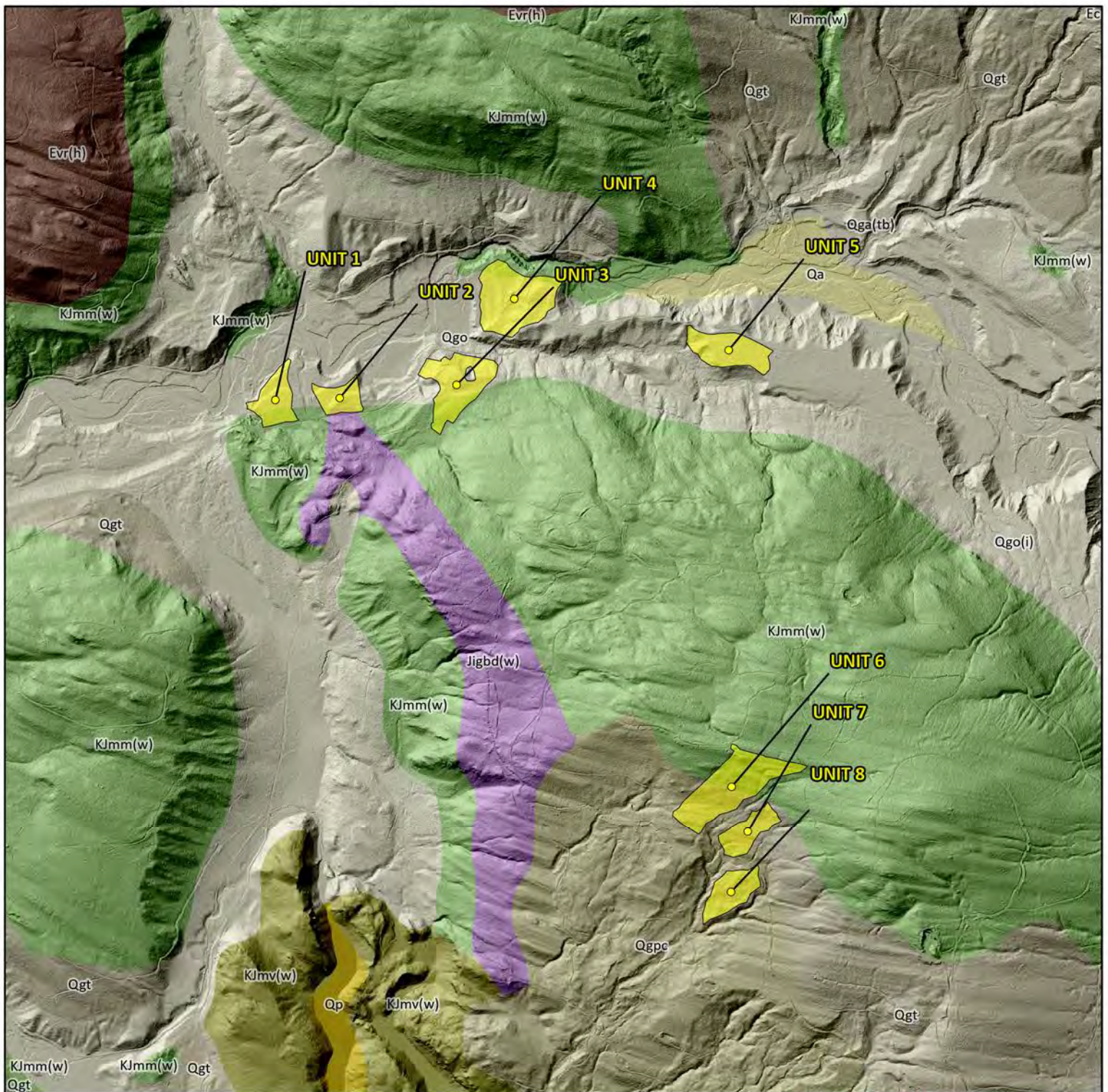
Fig. 1

VICINITY MAP
Bologna Timber Sale



Washington State Department of Natural Resources





<p> Bologna Unit Boundary</p> <p>1:100,000 Geologic Units</p> <ul style="list-style-type: none"> Ec, continental sedimentary deposits or rocks Evr(h), rhyolite flows Jigbd(w), gabbro and diorite KJmm(w), marine metasedimentary rocks KJmv(w), metavolcanic rocks 	<ul style="list-style-type: none"> Qa, alluvium Qga(tb), advance continental glacial outwash, Fraser-age Qgo, continental glacial outwash, Fraser-age Qgo(i), continental glacial outwash, Fraser-age Qgpc, continental glacial drift, pre-Fraser, and nonglacial deposits Qgt, continental glacial till, Fraser-age Qp, peat deposits
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Modified after: Tabor, R. W.; Booth, D. B.; Vance, J. A.; Ford, A. B., 2002, Geologic map of the Sauk River 30- by 60-minute quadrangle, Washington: U.S. Geological Survey Geologic Investigations Series Map I-2592, 2 sheets, scale 1:100,000, with 67 p. text.

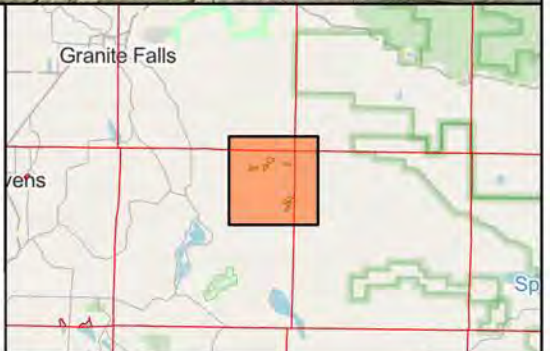
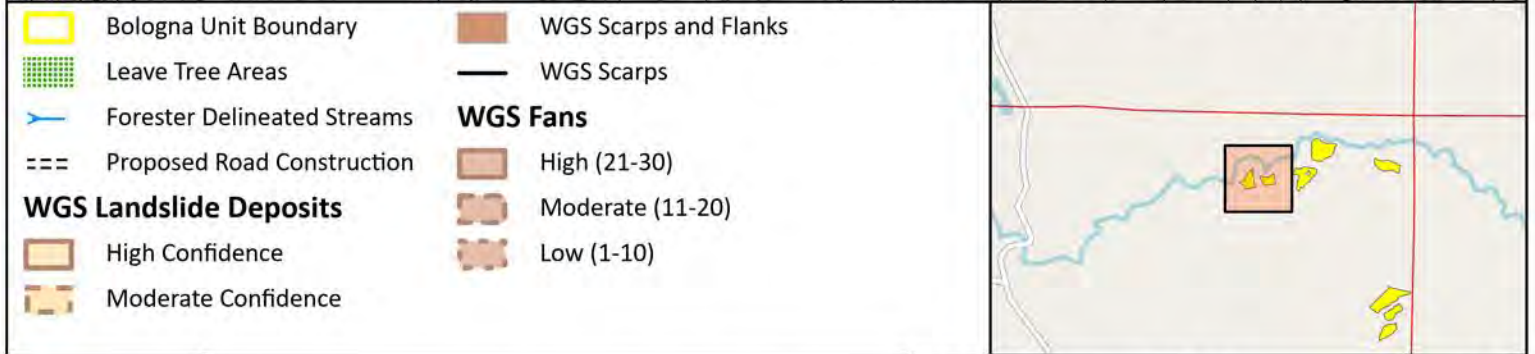
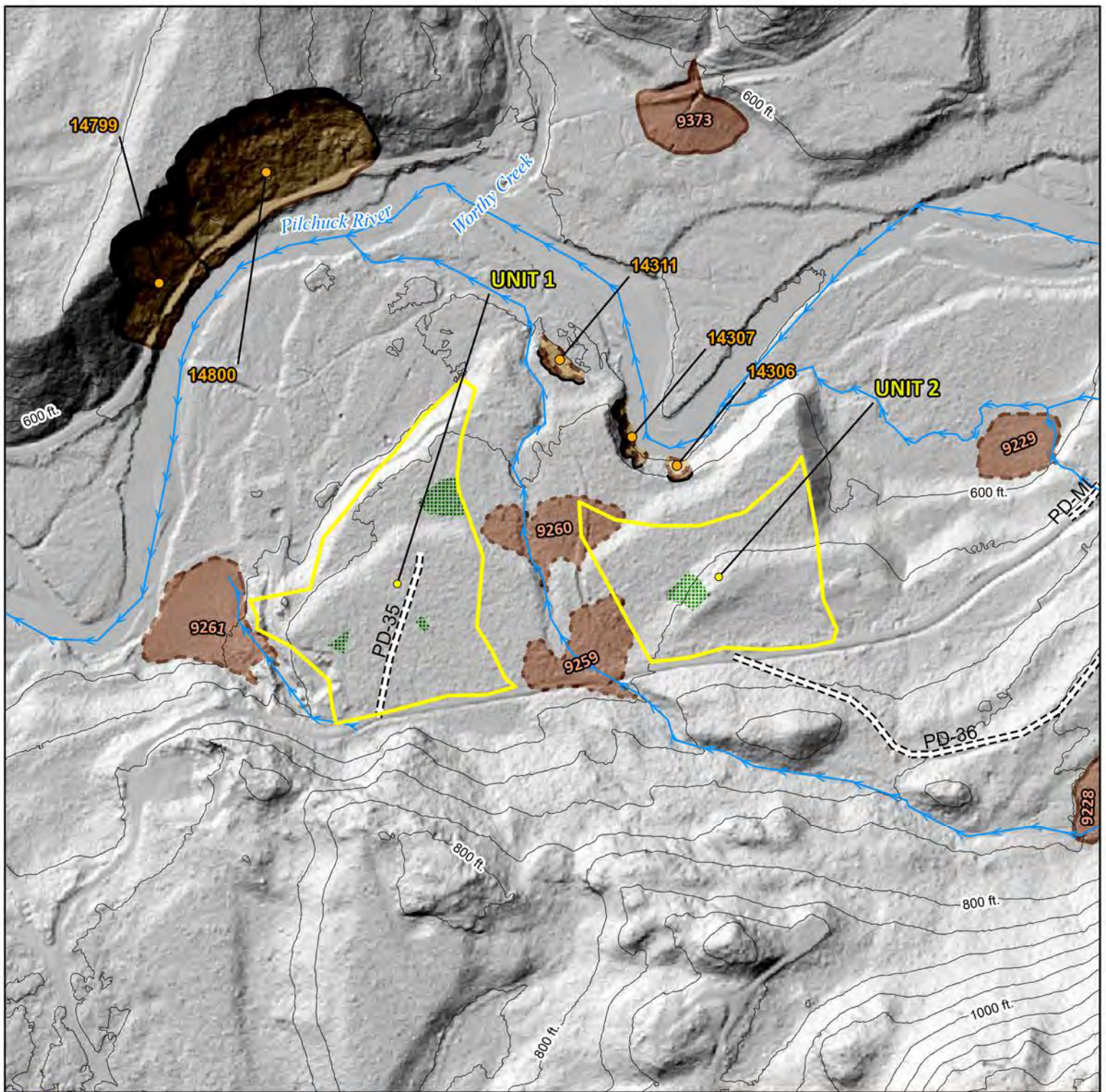


Fig. 2	<p>1:100,000 GEOLOGIC MAP</p> <p>Bologna Timber Sale</p>	<p>0 980 2,000 Feet</p> <p>Scale: 1:24,000</p>	<p>N</p>
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<p>Fig. 3 Sheet 1 of 4</p>	<p>WGS INVENTORY MAP Bologna Timber Sale</p>	<p>0 250 500 Feet Scale: 1:4,800</p>	
		<p>Washington State Department of Natural Resources</p>	

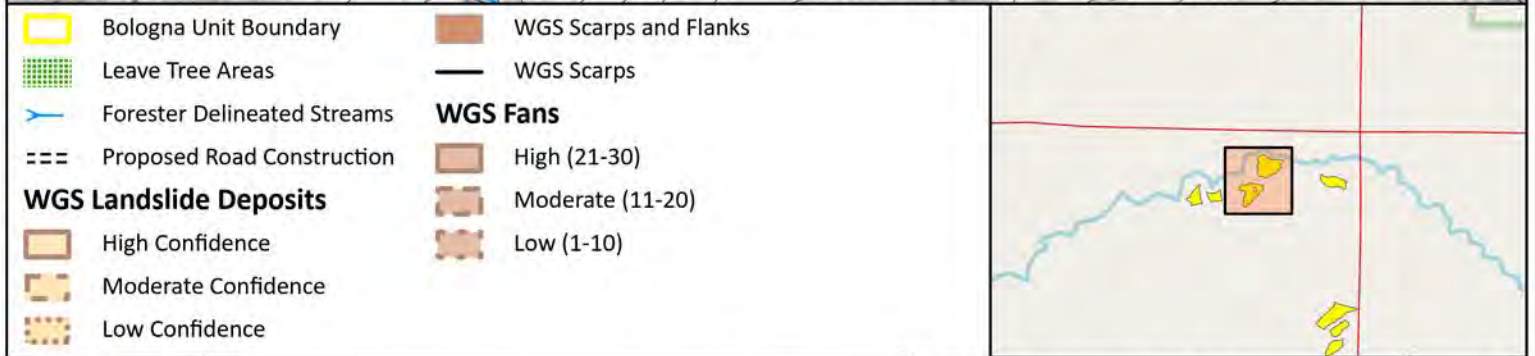
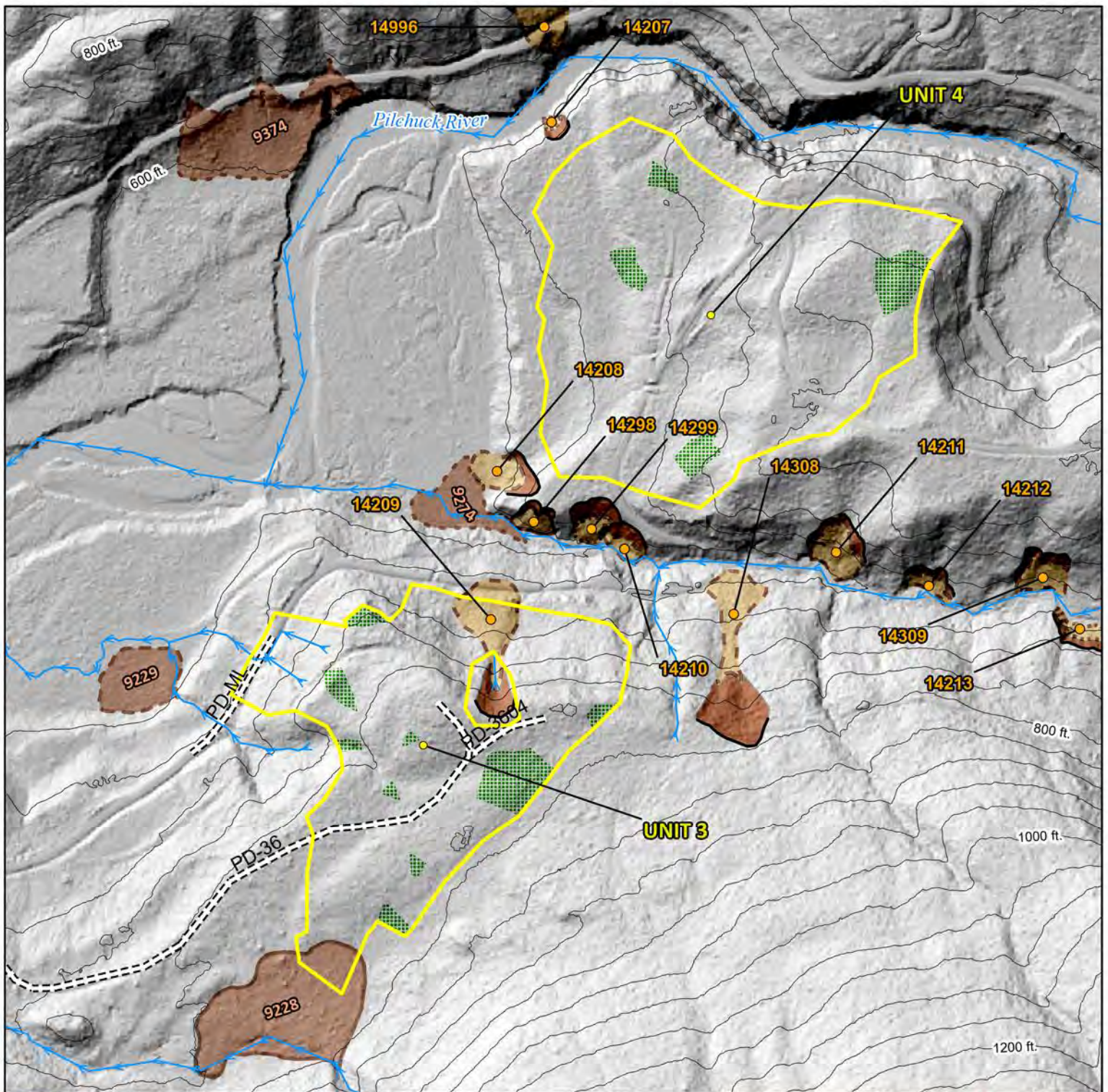


Fig. 3
Sheet 2 of 4

WGS INVENTORY MAP
Bologna Timber Sale

0 250 500 Feet Scale: 1:4,800

Washington State Department of Natural Resources

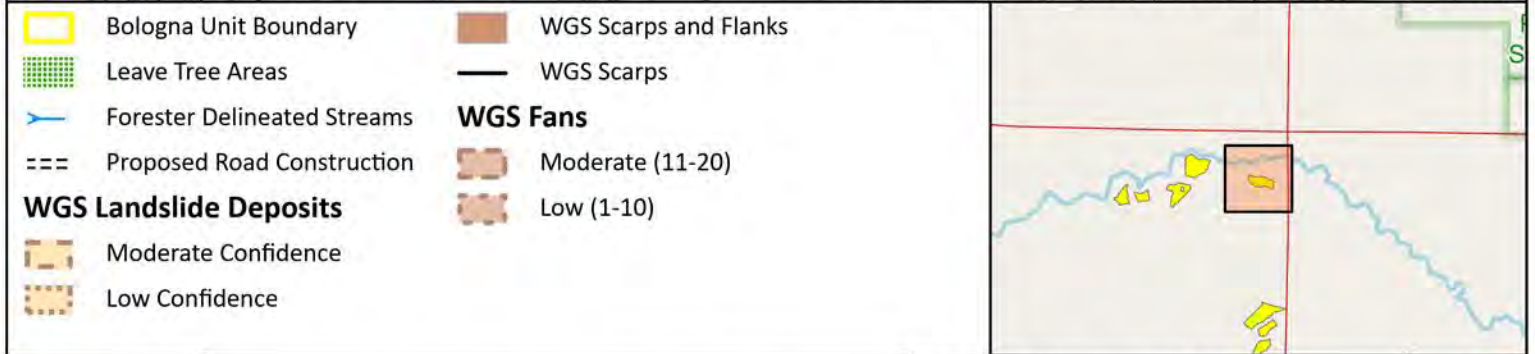
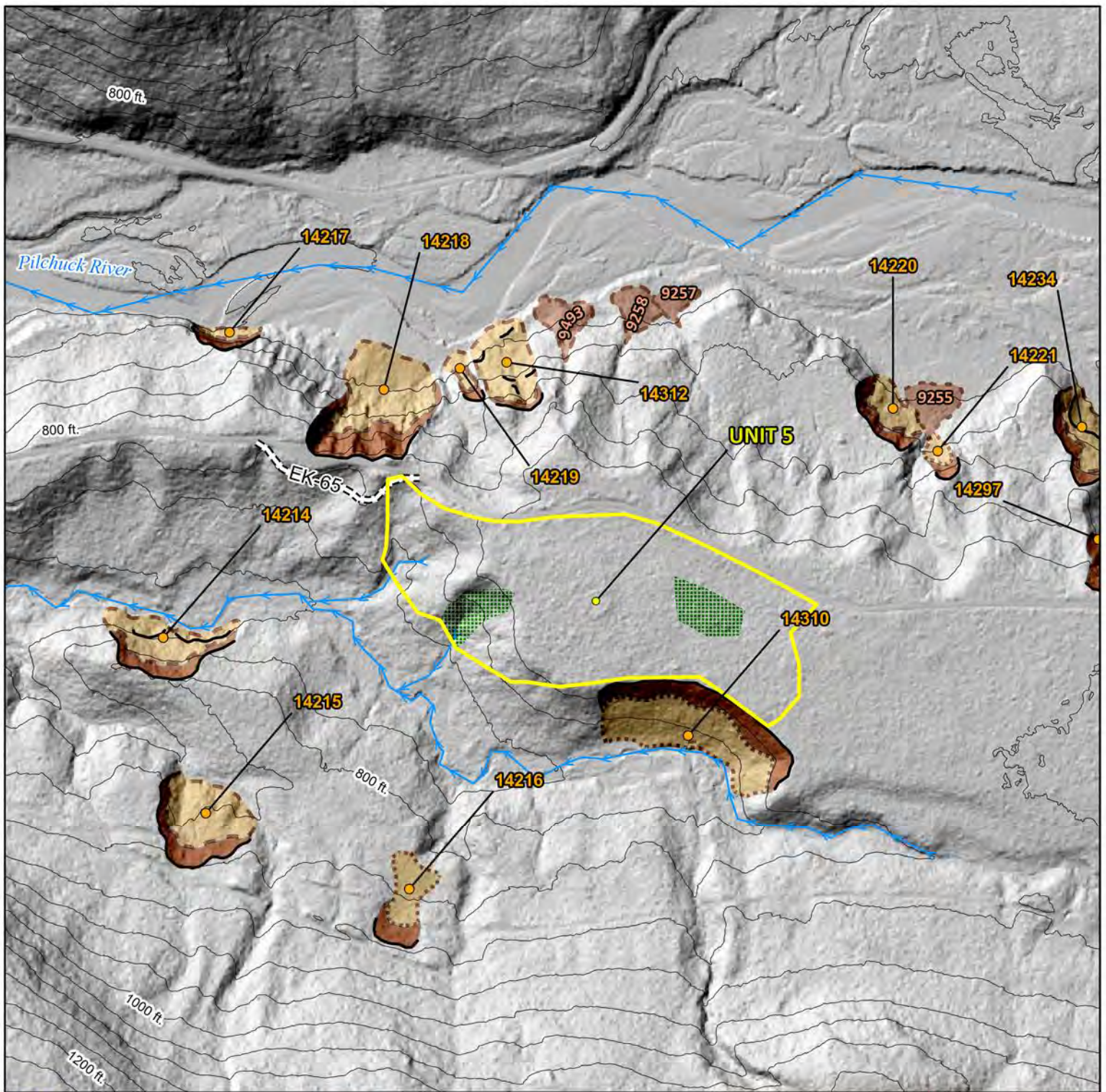
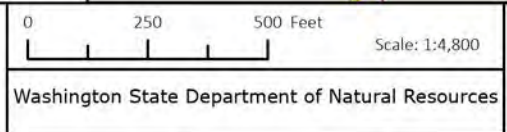


Fig. 3
Sheet 3 of 4

WGS INVENTORY MAP
Bologna Timber Sale



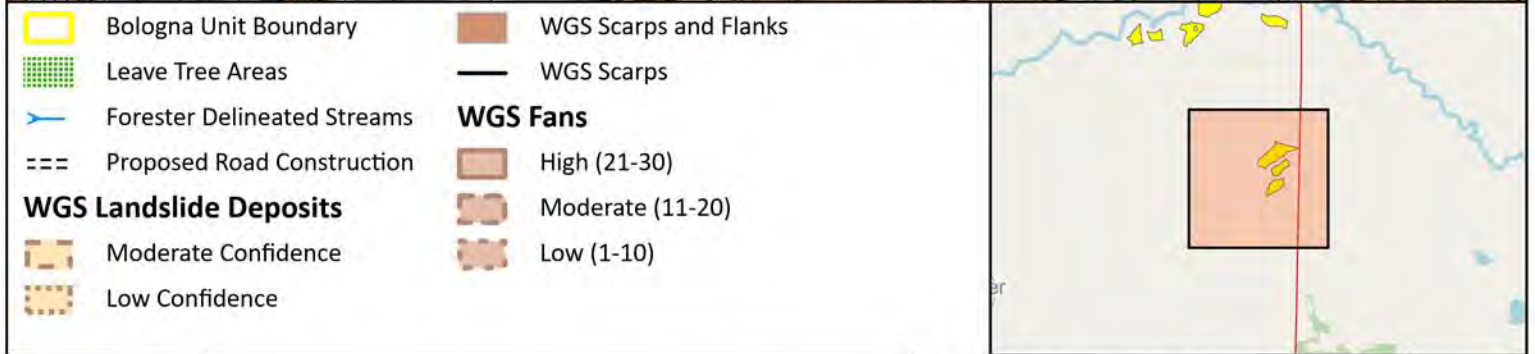
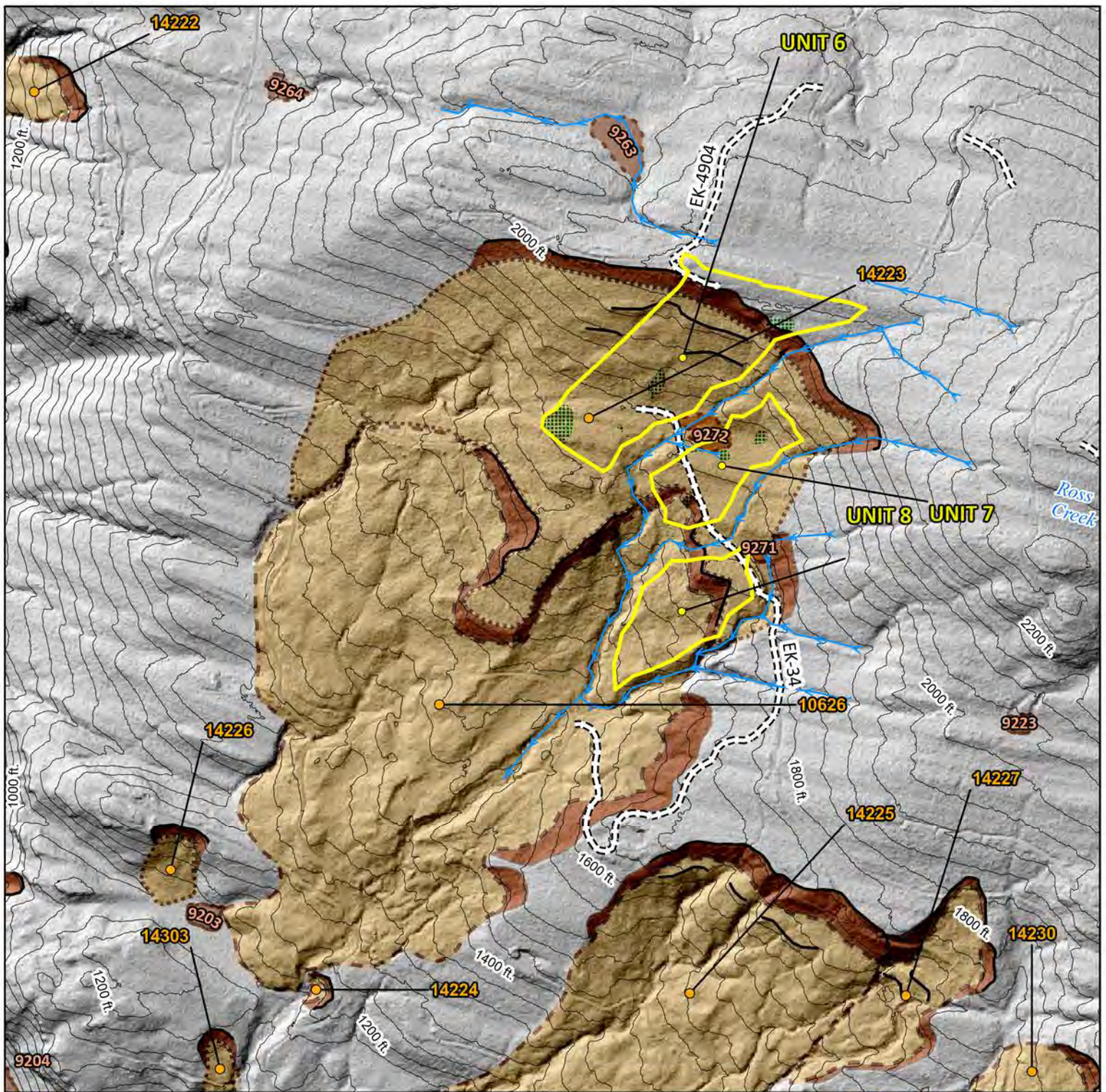
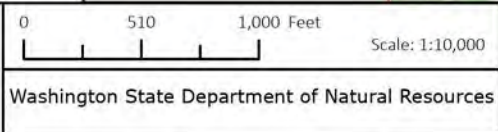


Fig. 3
Sheet 4 of 4

WGS INVENTORY MAP
Bologna Timber Sale



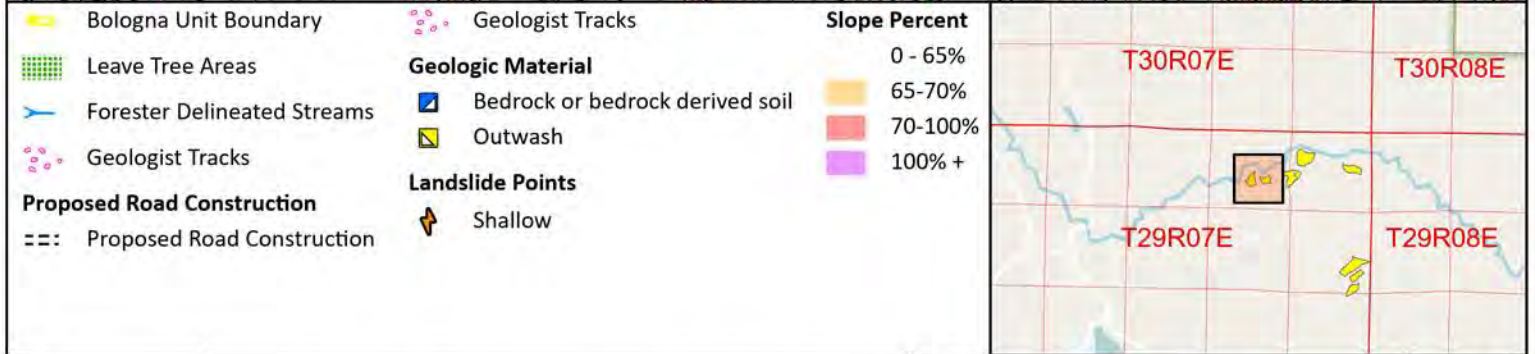
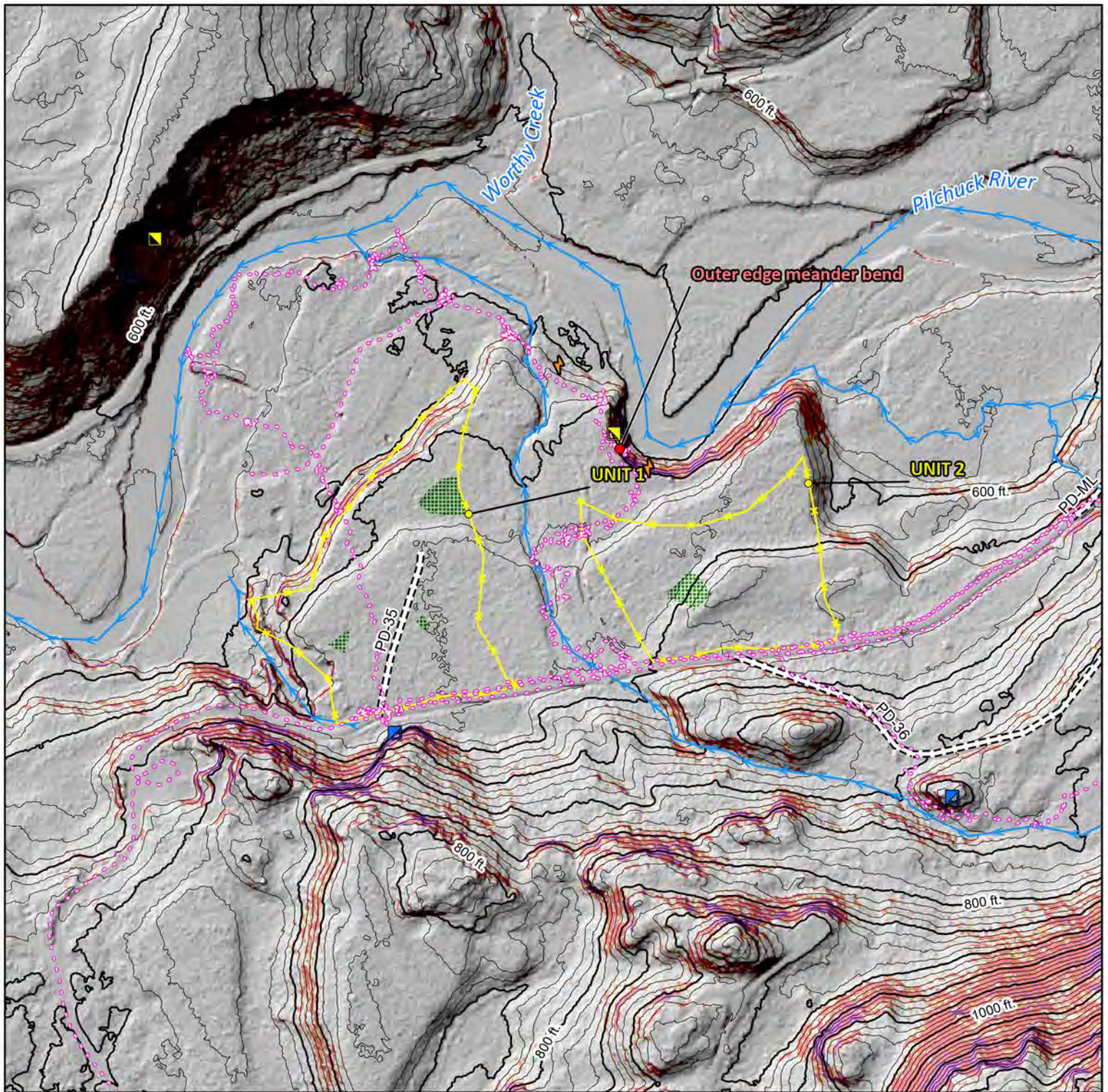
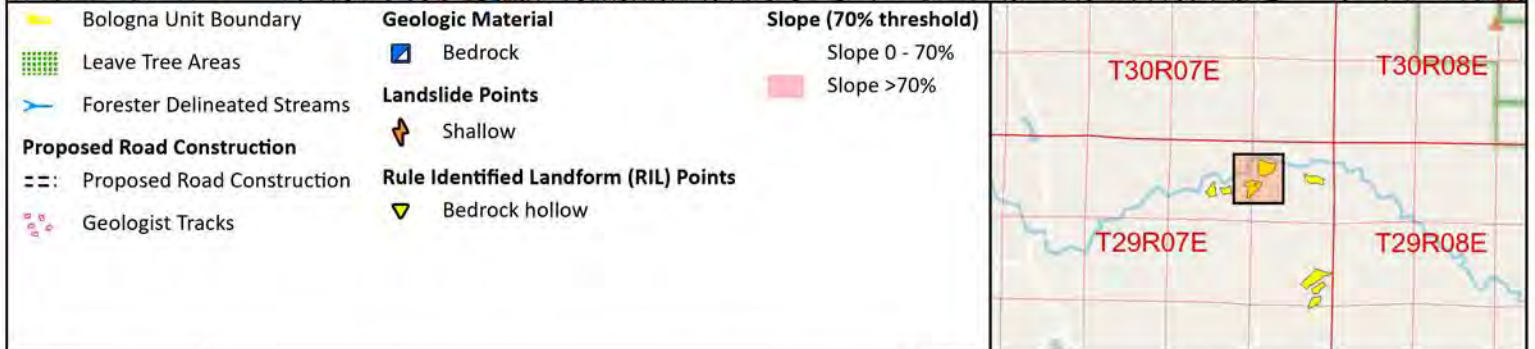
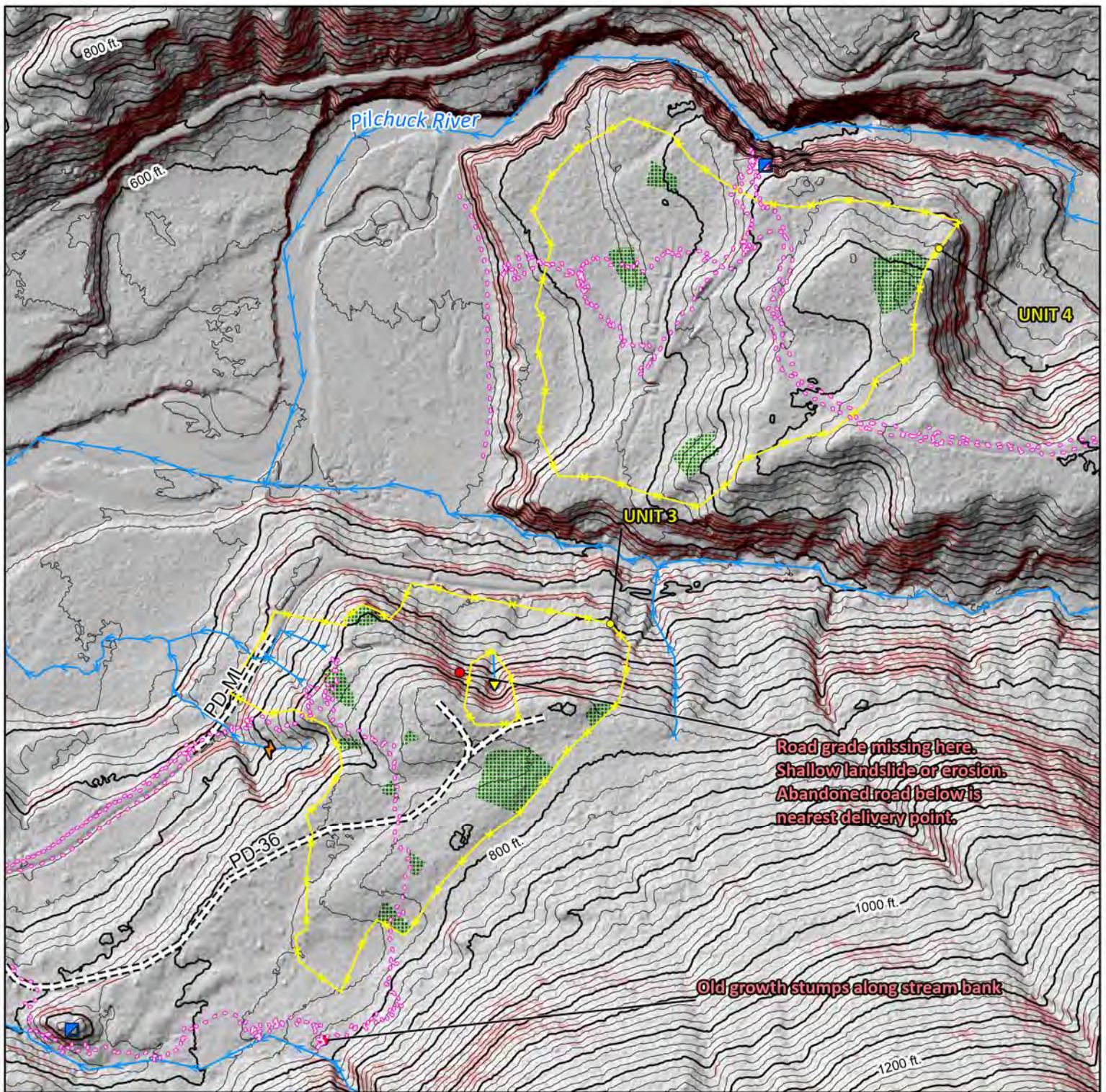


Fig. 4
Sheet 1

GEOMORPHOLOGY MAP
Bologna Timber Sale

0 260 520 Feet
Scale: 1:4,800
Washington State Department of Natural Resources



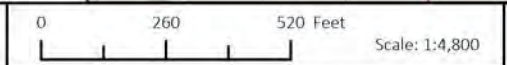


Road grade missing here.
Shallow landslide or erosion.
Abandoned road below is
nearest delivery point.

Old growth stumps along stream bank

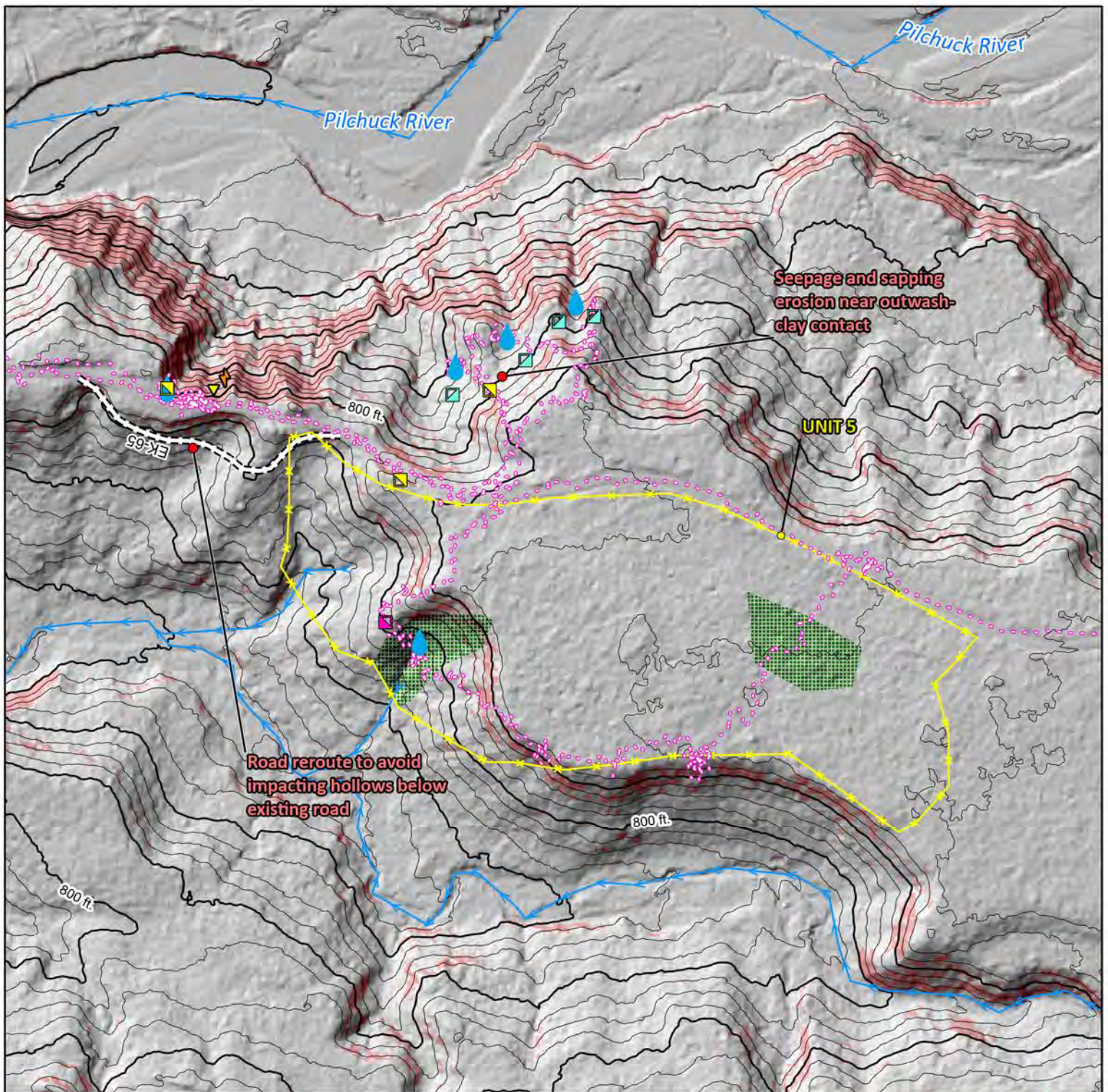
Fig. 4
Sheet 2

GEOMORPHOLOGY MAP
Bologna Timber Sale



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Seepage and sapping erosion near outwash-clay contact

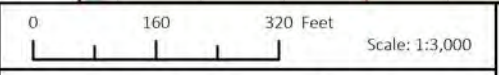
UNIT 5

Road reroute to avoid impacting hollows below existing road

<ul style="list-style-type: none"> — Bologna Unit Boundary Leave Tree Areas — Forester Delineated Streams ••• Geologist Tracks Proposed Road Construction Proposed Road Construction 	Geologic Material <ul style="list-style-type: none"> Glacial Till Glaciolacustrine Outwash 💧 Seepage Landslide Points ➡ Shallow 	Rule Identified Landform (RIL) Points <ul style="list-style-type: none"> ▼ Bedrock hollow Slope (70% threshold) Slope 0 - 70% Slope >70% 	
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Fig. 4
Sheet 3

GEOMORPHOLOGY MAP
Bologna Timber Sale



Washington State Department of Natural Resources



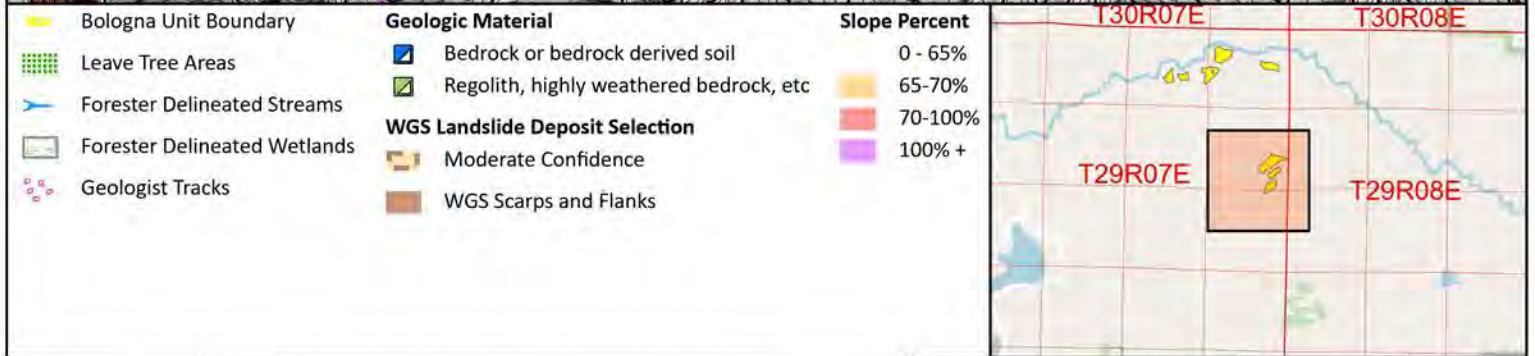
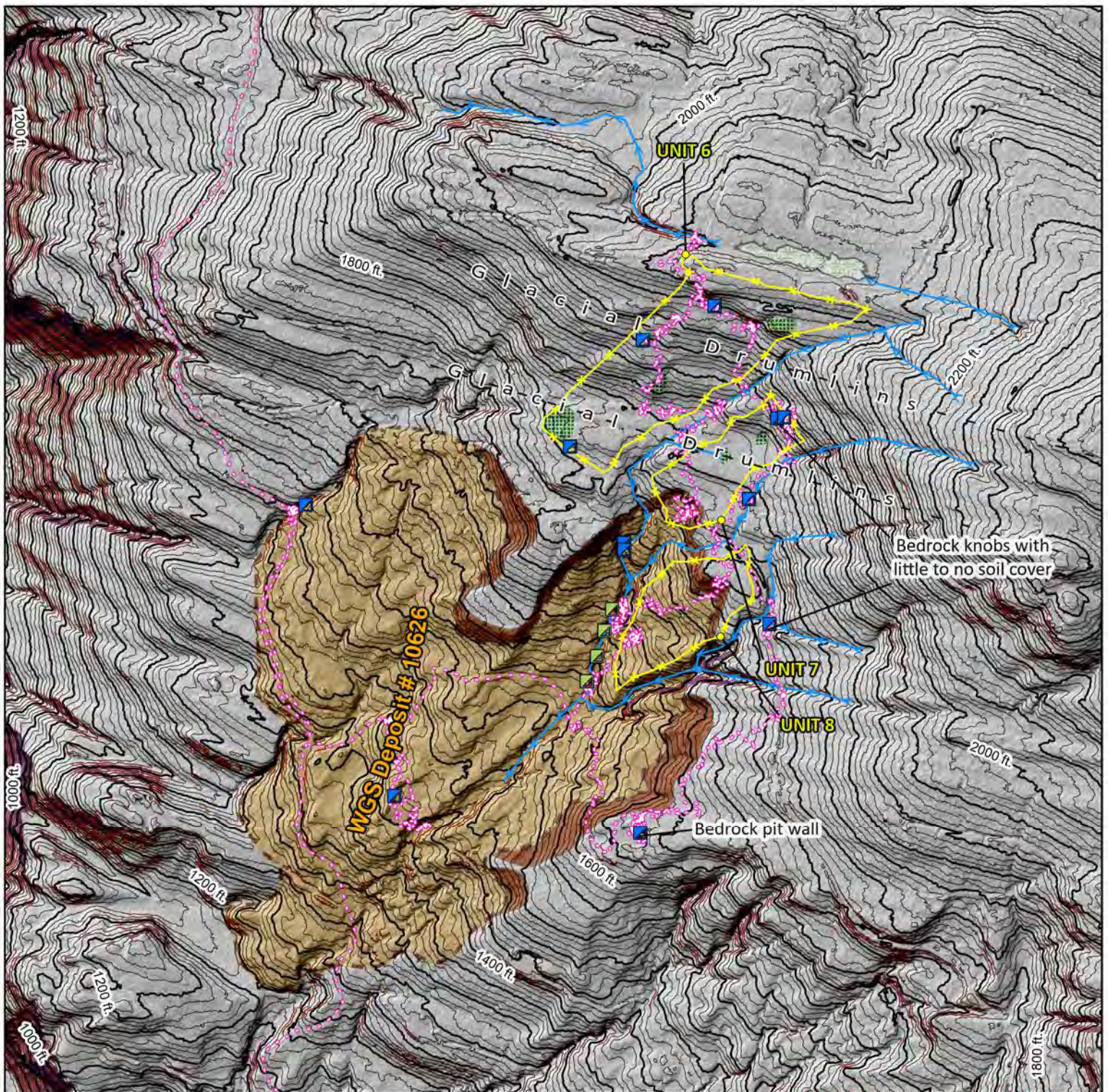
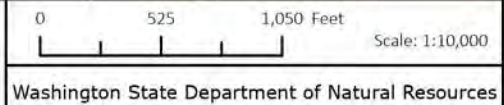
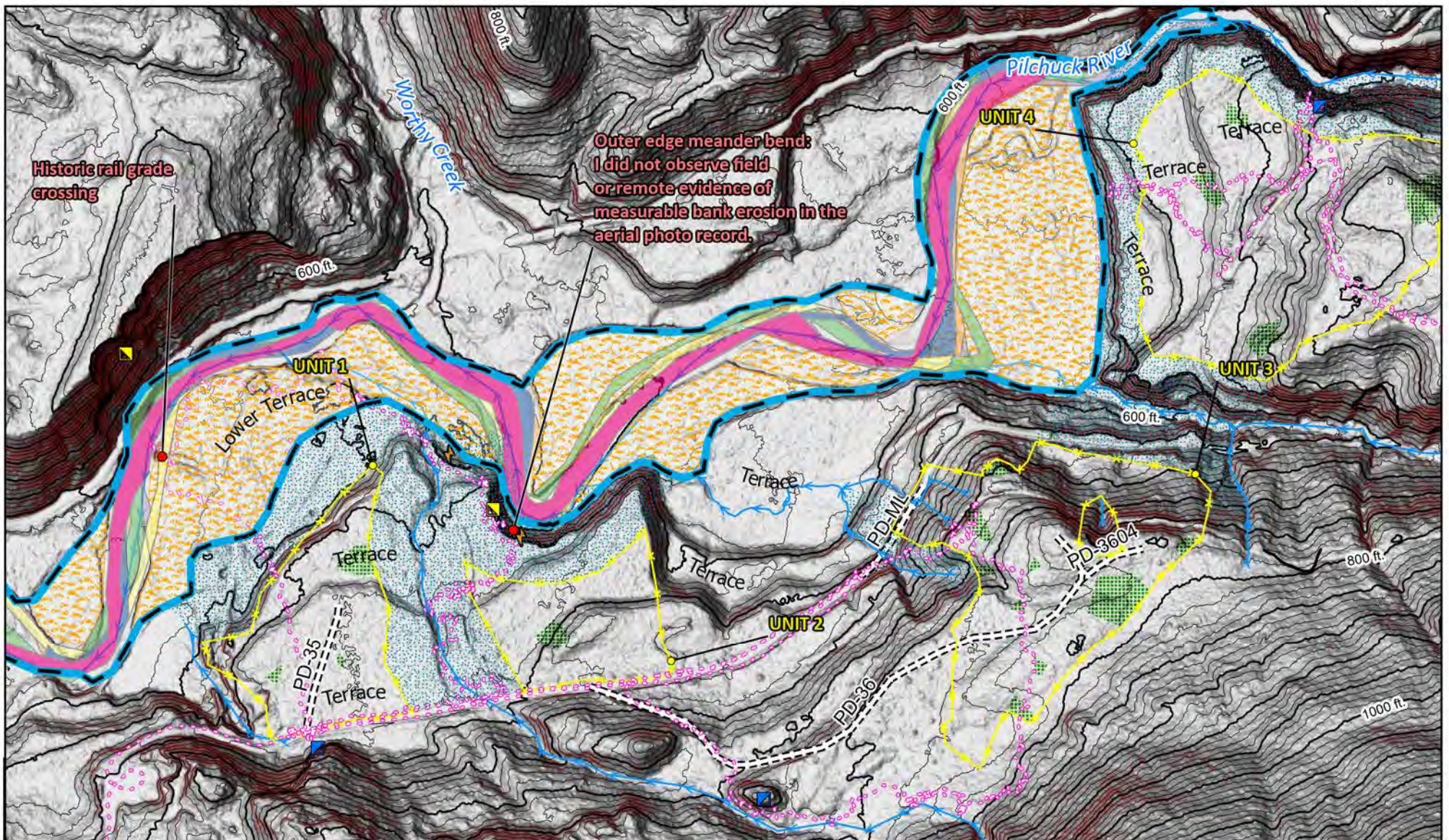


Fig. 4
Sheet 4

GEOMORPHOLOGY MAP
Bologna Timber Sale





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|-----------------------------|--------------------------|------------------------------|--------------------------------|------------------------|
| Bologna Unit Boundary | Geologic Material | Slope (70% threshold) | Historic Migration Zone | Avulsion Hazard Zone |
| Leave Tree Areas | Bedrock | Slope 0 - 70% | 1954 | Channel Migration Zone |
| Forester Delineated Streams | Outwash | Slope >70% | 1970 | Riparian Mgt Zone |
| Proposed Road Construction | Landslide Points | | 1983 | |
| Geologist Tracks | Shallow | | 1990 | |
| | | | 2002 | |
| | | | 2021 | |

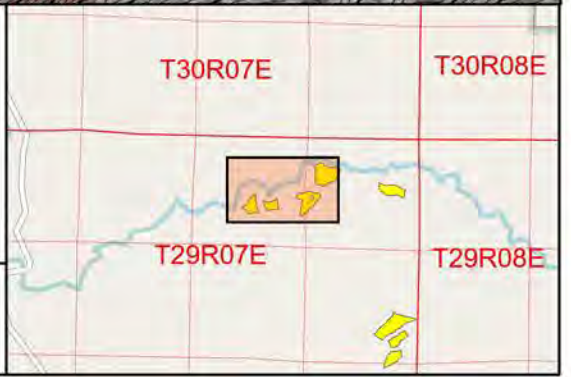
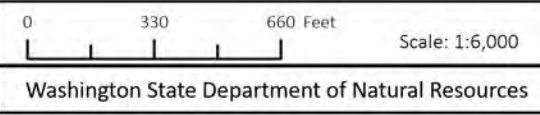


Fig. 5 **CHANNEL MIGRATION ZONE MAP**
Bologna Timber Sale



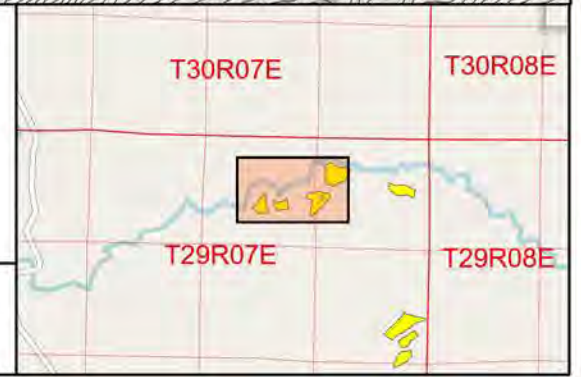
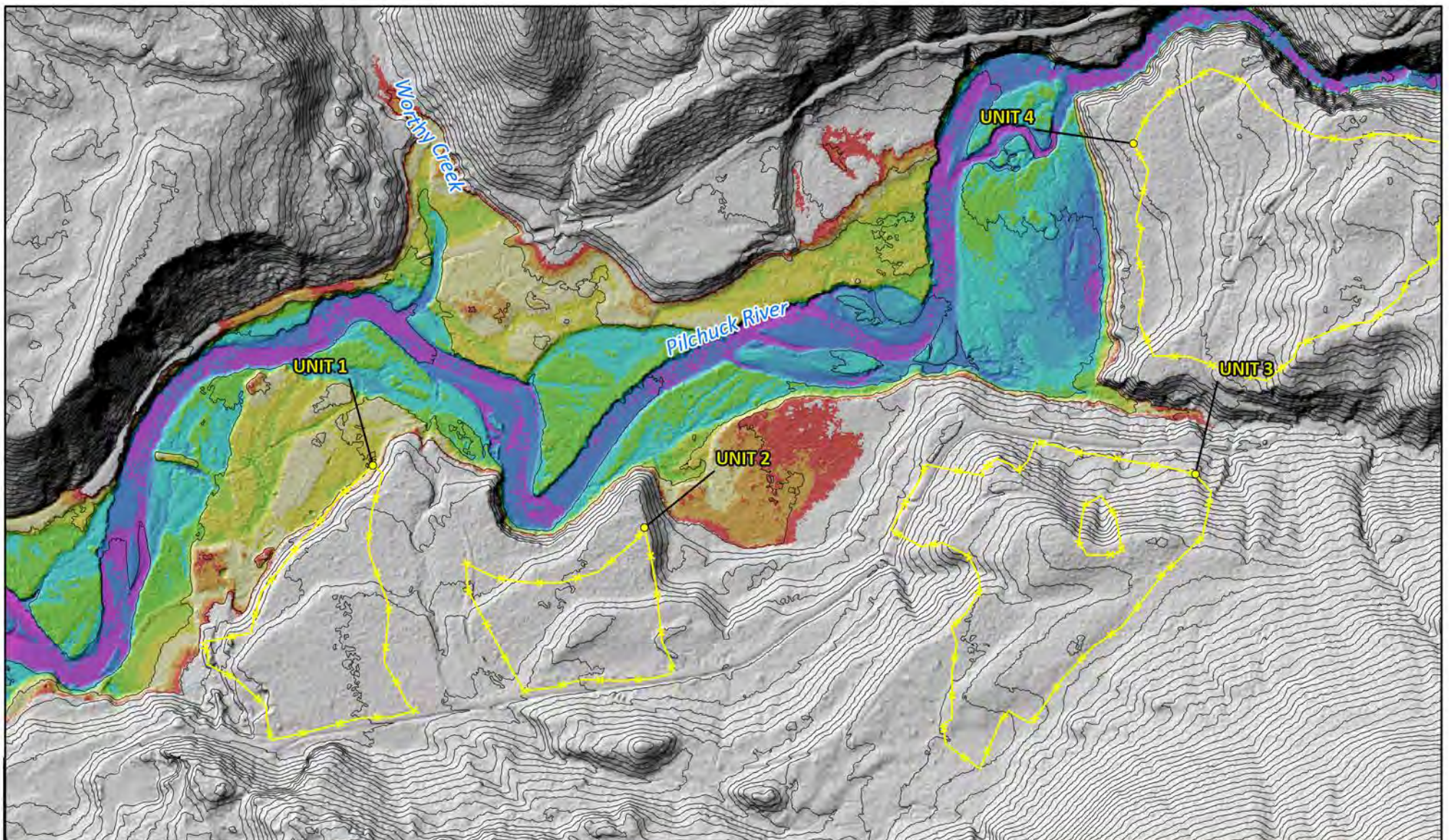


Fig. 6

RELATIVE ELEVATION RASTER MAP
Bologna Timber Sale

