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February 23, 2018

TO: Kody Beesley, Forester, Baker District, Northwest Region

FROM: Jennifer Parker, LEG #2892, Forest Resources Division
Casey Hanell, LEG #2771, Forest Resources Division

SUBJECT: Slope Stability Information for the Firefly CH Timber Harvest, Skagit County, Washington

This memorandum documents potentially unstable slopes in and around the proposed Firefly CH timber sale (sale) to supplement the forest practices application (FPA) to the Washington State Department of Natural Resources (DNR).

A portion of the sale is located in and around an area with features indicating the presence of potential slope instability, commonly referred to as "category E" landforms. The sale excludes areas with the most prominent signs of instability and that have the potential to deliver sediment to typed streams. Harvest is proposed on a portion of the slope that exhibits some signs of instability, but there are no public resources or threats to public safety immediately downslope.

The scope of our services included:

- Review of DNR GIS data including:
  - Digital orthophotographs from the 1990's, 2006, 2009, 2011, 2013, and 2015.
  - Light detection and ranging (LiDAR) data.
  - Forest Practices Landslide Inventory (LSI) mapping.
- Review of pertinent published geologic maps.
- Review of historic aerial photographs from 1969, 1978, 1983, 1987, and 1995.
- Field reconnaissance on January 3, 2018 by Jennifer Parker (Licensed Engineering Geologist (LEG)) and Kody Beesley (Forester). Weather during the field visit was overcast.
- Forest Practices pre-application field review on January 24, 2018 with Jennifer Parker, Garth Anderson (Forest Practices geologist), David Klingbiel (Forest Practices forester), Kody Beesley, and Chris Hankey (Baker District Manager). Weather during the field visit was overcast. ICN # 130598 documents the discussion and conclusions reached during the field visit.
- Preparation of this memorandum.

The sale is within the Samish Bay Watershed Administration Unit (WAU). Landslide Hazard Zonation (LHZ) and landslide inventory (LSI) mapping are not available for the Samish Bay WAU.

Jennifer Parker, a licensed engineering geologist (LEG #2892) prepared this memorandum under the direct supervision of Casey Hanell (LEG #2771). Casey Hanell is a "qualified expert" for timberland slope stability evaluation, as designated by the DNR.

Site and Project Description

The proposed Firefly CH timber sale is located in Skagit County, near the crest of Chuckanut Mountain (Figure 1). A portion of the sale area burned in the Burnout Road Fire in August 2017. The fire was actively contained using wildland firefighting methods. The burned area is shown on Figures 2 and 3. The nearest structures are houses located on the flanks of Chuckanut Mountain, southeast of the sale, and at the base of the mountain to the southwest (Figure 1). Larabee State Park is due west of the sale (Figure 1).

The sale includes both variable retention harvest (Unit 1 VRH) and variable density thinning in riparian management zones (Units 1 VDT) (Figure 2). The DNR proposes using ground based, cable, and/or tethered logging harvest methods. Three optional spur roads are proposed in the FPA (Figure 2).

Geologic Setting

Chuckanut Mountain is composed of the Bellingham Bay member of the Chuckanut Formation. The Chuckanut Formation consists of sandstone, siltstone, conglomerate, and coal[1]. The formation has undergone post-deposition folding. The tight folds are easily distinguished in LiDAR (Figures 1 and 3). Resistant sandstone outcrops form the steep, prominent ridges. The intervening valleys formed in less-resistant beds, such as siltstone.

Potentially Unstable Landform Discussion

Washington's Forest Practices rules define potentially unstable landforms (rule-identified landforms (RIL)) for purposes of classifying and reviewing forest practice applications and regulating in those areas[2]. Areas containing features indicating the presence of potential slope instability are considered RILs. These areas are commonly referred to as "category E" landforms. The forester and I delineated two areas with "category E" features (Figure 3). Area A has the potential to deliver sediment to a typed stream. Area A was excluded from the sale using timber sale boundary tags. Area B drains to a flat bench and dry swale, therefore there are no public resources or threats to public safety immediately downslope of Area B. In addition, there

[1] Lapen, Thomas J., 2000, Geologic map of the Bellingham 1:100,000 quadrangle, Washington: Washington Division of Geology and Earth Resources Open File Report 2000-5, 36 p., 2 plates, scale 1:100,000.
[2] WAC 222-16-050 (1)(d)(i)

were fewer indicators of slope instability within Area B. Area B remains in the proposed variable retention harvest (VRH) (Figure 3).
During my field and office review, I observed other steep slopes within the sale. Some of these steep (>70%) slopes are adjacent to low-gradient streams and wetlands. These steep slopes are the result of folded, resistant layers of the bedrock geology. I did not observe evidence of inner gorge erosion or other instability within the sale.

Observations about Areas A and B follow:

Area A
Area A is about 1.3 acres and encompasses a 70 to 100 percent slope with signs of shallow debris slides and soil creep. The timber sale boundary provides at least two tree canopy widths buffer around the area that exhibits indications of instability. In addition, the lower gradient slope toe is included in the protected area. If shallow debris slides continue to occur on the slope, the downslope trees will help reduce debris slide mobility. Area A observations include:

- The 2017 fire burned the understory vegetation and forest duff, exposing soil at the surface. Soil is composed of loose, brown silt and fine sand.
- Fine roots are visible at the surface in places, an indication of shallow erosion from sheet flow and/or raindrop impact.
- Three shallow colluvial hollows formed from debris slides. The hollows range in size from 5 to 25 feet wide, and 1 to 5 feet deep. The debris slides have burned sword ferns within their scars, therefore the debris slides occurred before the fire. I observed a damaged tree about 100 feet downslope of the largest colluvial hollow but otherwise, it was difficult to identify the runout from the debris slides. However, I did not observe evidence that they resulted in long runout debris flows.
- Two, 1-inch wide, 5-foot long cracks at about the same elevation as the colluvial hollows. These cracks may be indications of incipient shallow debris slides.
- Area A is primarily vegetated with hardwoods. The few conifers on the slope have curved trunks.
- I did not observe evidence of debris slides or debris flows in Area A in the reviewed aerial photographs (Figures 4 through 8).
- The 1969 aerial photographs shows part of Area A was harvested, but several trees were left standing within the area (Figure 4).
- I did not observe old growth stumps on the steep slope in Area A.
- I did not observe evidence of seeps, springs, or flowing water within Area A during my two January field visits.
- The nearest public resource is a seasonal, low-gradient stream that disappears into the subsurface in a flat bench below Area A. The stream reappears downslope, as shown on Figures 2 and 3.

In my opinion, there is a moderate potential that debris slides will continue to occur within Area A, with or without timber harvest. In my opinion, there is a low potential for these debris slides

to deliver sediment to the lower stream that connects to other streams downslope. The potential for instability is currently inflated because the area has burned. The fire removed understory vegetation and reduced the soil cohesion from shallow root systems. If debris slides occur, they will likely stop on the lower gradient slope toe within Area A. I did not observe indicators of groundwater or surface water that would cause debris slides to fluidize and flow long distances. However, because of the moderate to high potential for debris slides, and the proximity of a stream, I recommend excluding Area A from harvest, yarding, or other activities that could cause soil disturbance.

The long-term stability of Area A may benefit from low-impact revegetation activities. In my opinion, forest activities such as planting and conifer release may benefit the slope stability by improving the winter canopy cover and root strength.

During the field visit with Forest Practices, we discussed my interpretations and mitigation recommendations related to the landforms and delivery potential from Area A. Forest Practices agreed with my interpretations and mitigation proposal, as documented in ICN #130598.

Area B

Area B is about 1.2 acres within the proposed VRH timber harvest. Area B also has 70 to 100 percent slopes, however it lacks some of the indications of instability that I observed in Area A. Most importantly, Area B drains to a flat bench and a dry swale. The nearest stream is low-gradient and more than 350 feet away. Area B observations include:

- The 2017 fire burned the understory vegetation and forest duff similar to Area A.
- No clear evidence of shallow colluvial hollows in Area B. The slope is more planar and smooth compared with Area A.
- Area B is primarily vegetated with conifers. Many of the conifer trunks are curved, likely from soil creep.
- Burned old growth stumps within Area B.
- Area B is harvested in the 1978 imagery (Figure 5).
- No evidence of debris slides or debris flows in Area B in the reviewed aerial photographs (Figures 4 through 8).
- No evidence of seeps, springs, or flowing water within Area B.
- The ridge crest of Area B has resistant sandstone outcrops. The sandstone ridge is visible in the 1983 aerial imagery. The ridge crest along Area A does not have sandstone outcrops. The presence of a sandstone cap at the top of the slope may be one reason the slope appears to be more stable than Area A.

In my opinion there is a low to moderate potential that debris slides will occur within Area B following timber harvest. Like Area A, the potential for instability is currently inflated because the area has been burned, removing understory vegetation and soil cohesion from shallow root systems. If debris slides occur, they will likely stop on the flat bench downslope. Like Area A, I did not observe indicators of groundwater or surface water that would cause debris slides to

fluidize and flow long distances. In addition, there are no public resources or threats to public safety near Area B.

During the field visit with Forest Practices, we discussed my interpretations and mitigation recommendations related to the landforms and delivery potential from Area B. Forest Practices agreed with my interpretations and mitigation proposal, as documented in ICN #130598.

Potential Ground Disturbance During Harvest

I observed in the field that forest duff and understory vegetation was burned within the Burnout Road fire area, leaving patches of mineral soil exposed at the surface. The mineral soil appears to have eroded from sheetwash and/or raindrop impact. In my opinion, the fire has caused the soil to be more sensitive to disturbance from ground-based equipment. I understand that the timber harvest contract places restrictions on ground-based harvest operations within the burned area including, tracked equipment only (no rubber tire vehicles), no tethered logging equipment, and skidding is restricted to slopes less than 15%. In my opinion, these restrictions are appropriate to mitigate ground disturbance within the burned area.

Forest Practice Rule Statements

The following are the Forest Practice Rule statements addressing WAC 222-10-030 (1) (a,b,c). These responses are based on the data and discussion presented above.

(a) *The likelihood that the proposed forest practices will cause movement on the potentially unstable slopes or landforms, or contribute to further movement of a potentially unstable slope or landform:*

In my opinion, there is a low likelihood that proposed forest practices will cause movement in Area A, because the area has been excluded from the proposal with a buffer around potentially unstable slopes. However, in my opinion, there is a moderate potential that debris slides will occur naturally within Area A because of the reduced soil cohesion caused by the forest fire.

In my opinion there is a low to moderate potential that debris slides will occur within Area B following timber harvest.

(b) *The likelihood of delivery of sediment or debris to a public resource, or in a manner that would threaten public safety:*

In my opinion, there is a low potential for debris slides from Area A to reach the stream that connects to other streams downslope. The potential is low because I did not observe indicators of groundwater or surface water that would cause debris slides to fluidize and flow long distances, and the debris would need to cross a 220-foot wide, low-angle slope. We have further reduced the likelihood of sediment delivery by excluding Area A from forest practices activities.

There are no public resources or threats to public safety downslope of Area B.

(c) *Any possible mitigation for the identified hazards and risks:*

The primary mitigation measure for the identified hazards and risks is avoidance. We recognized features within Area A as potentially unstable with the potential to deliver to a public resource. This area has been excluded from the sale.

I understand that the timber harvest contract places restrictions on ground-based harvest operations within the burned area including, tracked equipment only (no rubber tire vehicles), no tethered logging equipment, and skidding is restricted to slopes less than 15%. In my opinion, these restrictions are appropriate to mitigate ground disturbance within the burned area.

Limitations

This memorandum is intended to be additional information submitted with the forest practices application (FPA) for the Firefly CH timber harvest to document licensed engineering geologist and qualified expert involvement in the timber sale process. The conclusions presented in this memorandum are based on observed site conditions as they existed at the time of the field visit. 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 in the region for forest slope stability. It is not possible to predict slope movement with certainty with the available scientific knowledge.

ATTACHMENTS:

Figure 1, Vicinity map
Figure 2, Site map
Figure 3, Geomorphology map
Figure 4, 1969 Aerial Imagery
Figure 5, 1978 Aerial Imagery
Figure 6, 1983 Aerial Imagery
Figure 7, 2006 Aerial Imagery
Figure 8, 2015 Aerial Imagery

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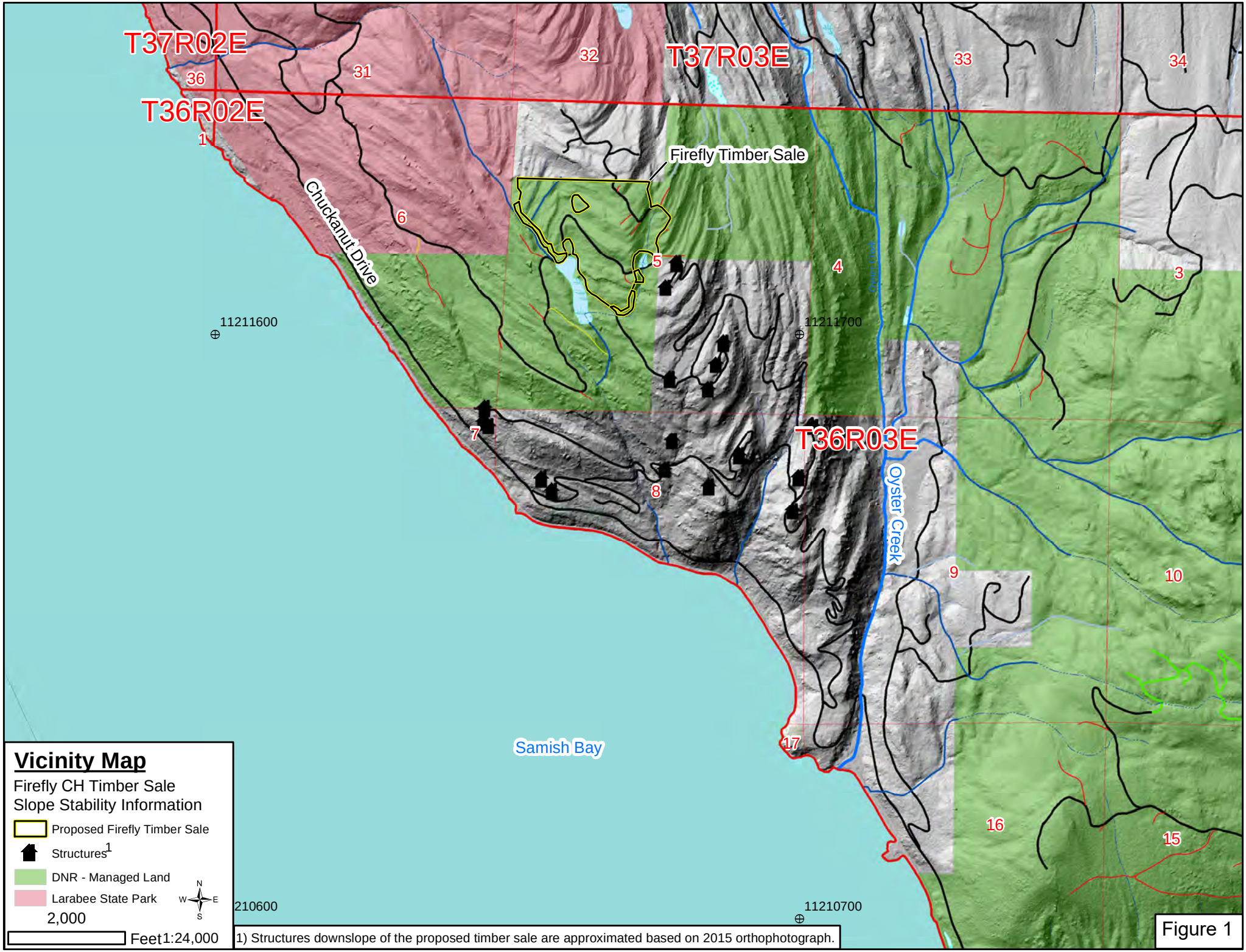
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T37R03E
T36R02E
T36R03E
36
31
32
33
34
1
6
5
4
3
7
8
9
10
15
16
17
Firefly Timber Sale
Chuckanut Drive
Oyster Creek
Samish Bay
11211600
11211700
210600
11210700
Vicinity Map
Firefly CH Timber Sale
Slope Stability Information
Proposed Firefly Timber Sale
Structures[1]
DNR - Managed Land
Larabee State Park
N
W
E
S
2,000
Feet
1:24,000
1) Structures downslope of the proposed timber sale are approximated based on 2015 orthophotograph.
Figure 1

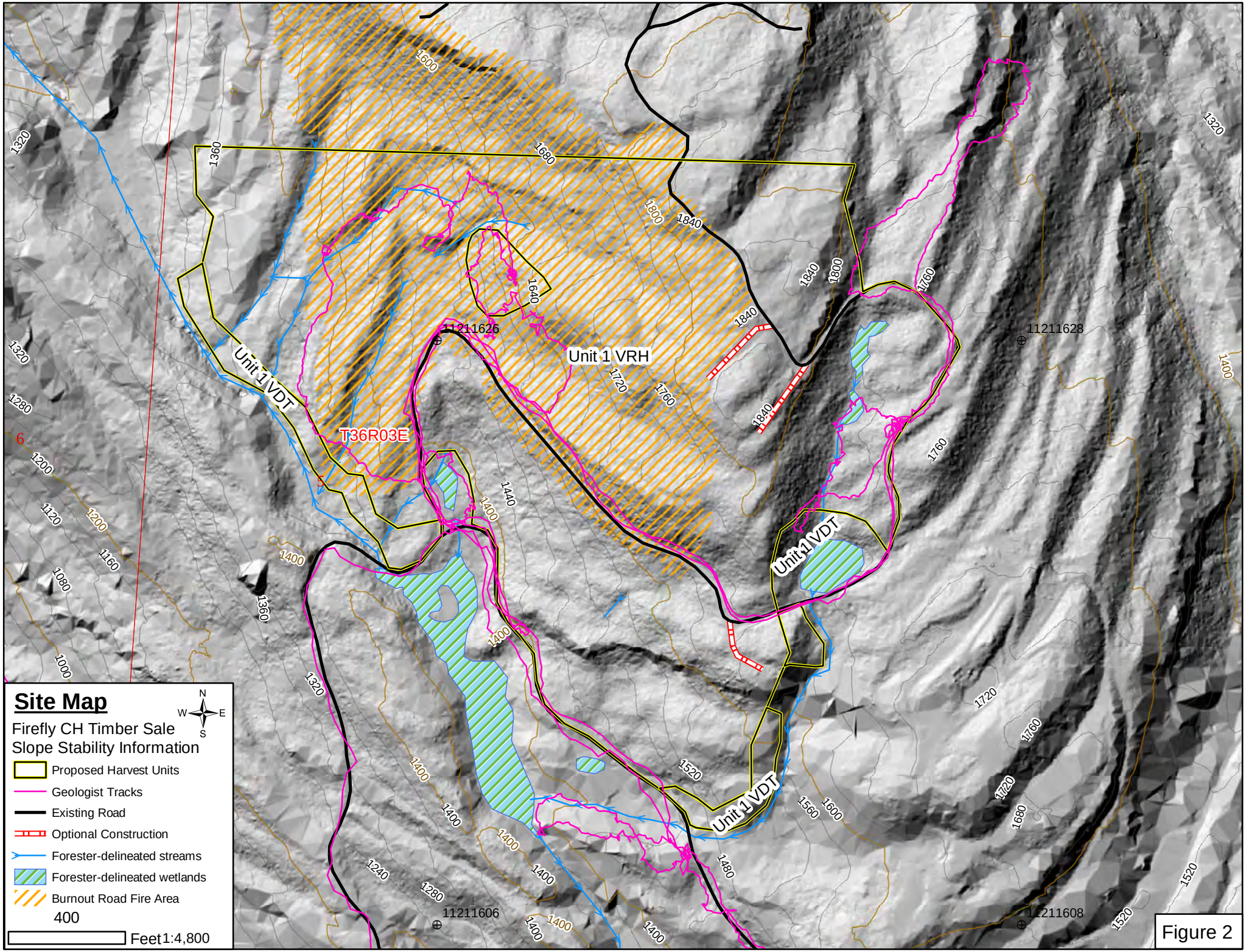
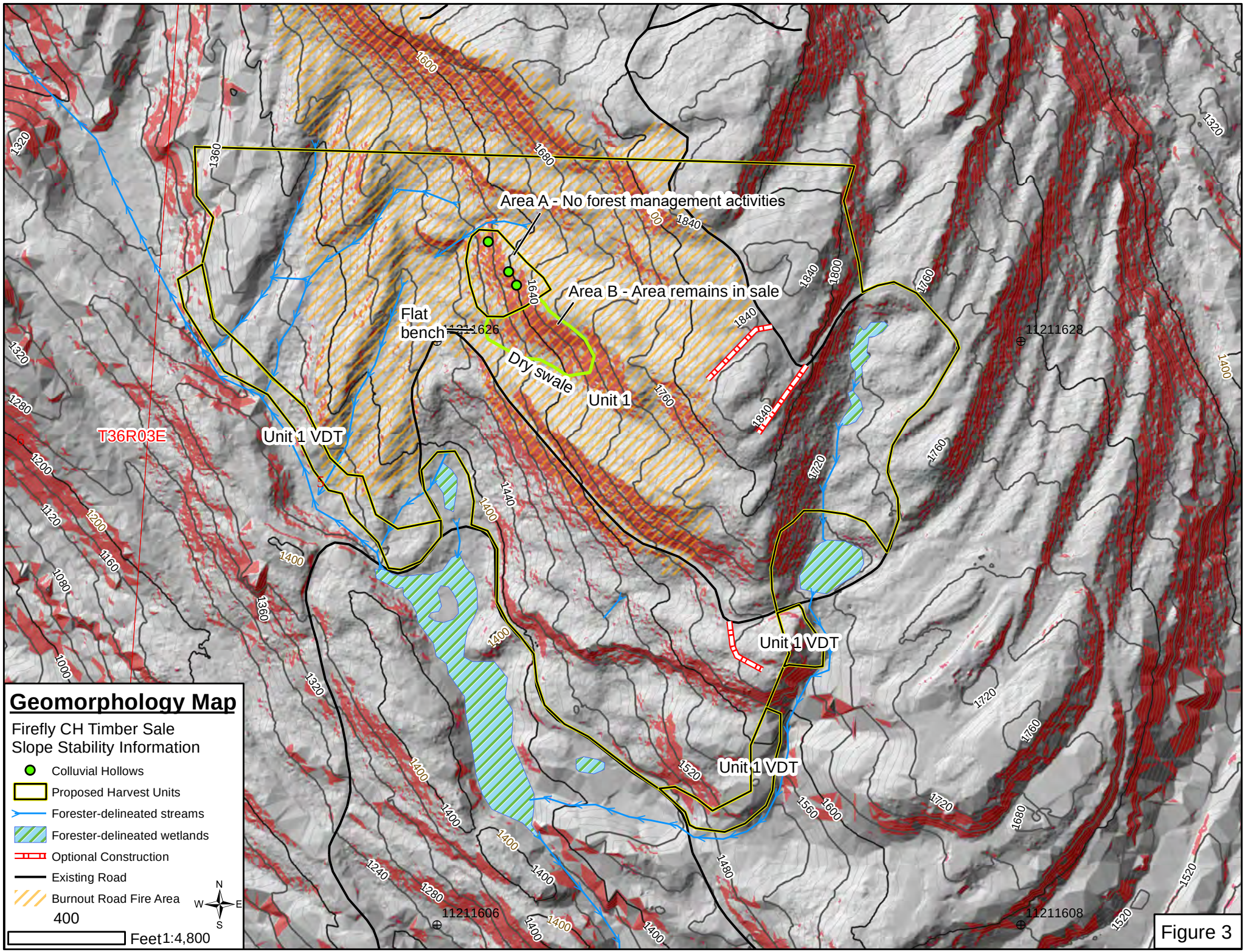

Site Map
Firefly CH Timber Sale
Slope Stability Information
Proposed Harvest Units
Geologist Tracks
Existing Road
Optional Construction
Forester-delineated streams
Forester-delineated wetlands
Burnout Road Fire Area
400
Feet1:4,800
N
W
E
S
Unit 1 VRH
Unit 1 VDT
Unit 1 VDT
Unit 1 VDT
T36R03E
11211626
11211628
11211606
11211608
1320
1360
1680
1800
1840
1640
1720
1760
1440
1400
1200
1120
1160
1080
1000
1240
1280
1520
1560
1600
1480

Figure 2


Geomorphology Map
Firefly CH Timber Sale
Slope Stability Information
Colluvial Hollows
Proposed Harvest Units
Forester-delineated streams
Forester-delineated wetlands
Optional Construction
Existing Road
Burnout Road Fire Area
400
Feet
1:4,800
N
W
E
S
Area A - No forest management activities
Area B - Area remains in sale
Flat bench
Dry swale
Unit 1
Unit 1 VDT
Unit 1 VDT
Unit 1 VDT
T36R03E
11211626
11211628
11211606
11211608
Figure 3

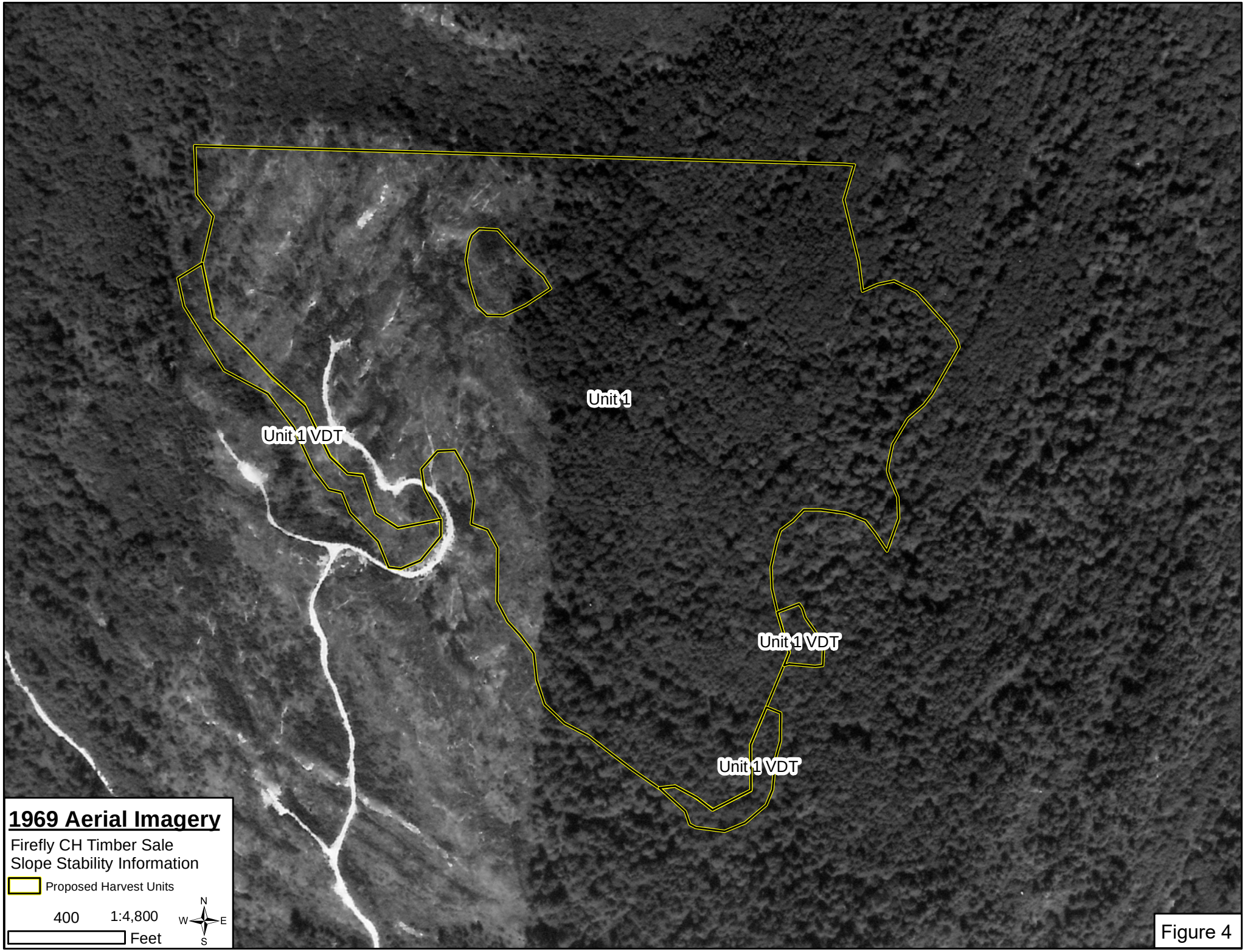
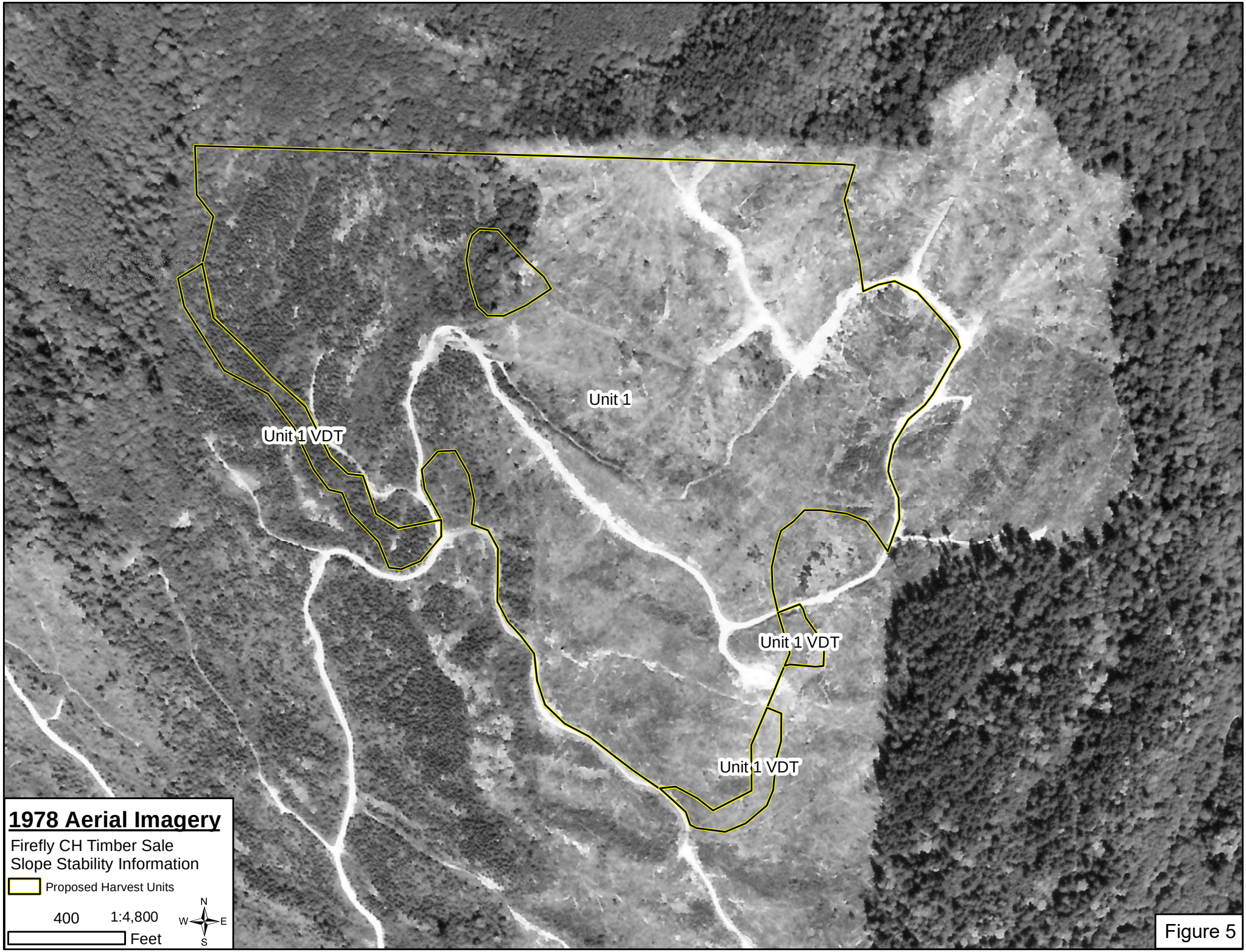

Unit 1
Unit 1 VDT
Unit 1 VDT
Unit 1 VDT
1969 Aerial Imagery
Firefly CH Timber Sale
Slope Stability Information
Proposed Harvest Units
400
1:4,800
Feet
N
W
E
S

Figure 4


Unit 1
Unit 1 VDT
Unit 1 VDT
Unit 1 VDT
1978 Aerial Imagery
Firefly CH Timber Sale
Slope Stability Information
Proposed Harvest Units
400
1:4,800
Feet
N
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E
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Figure 5

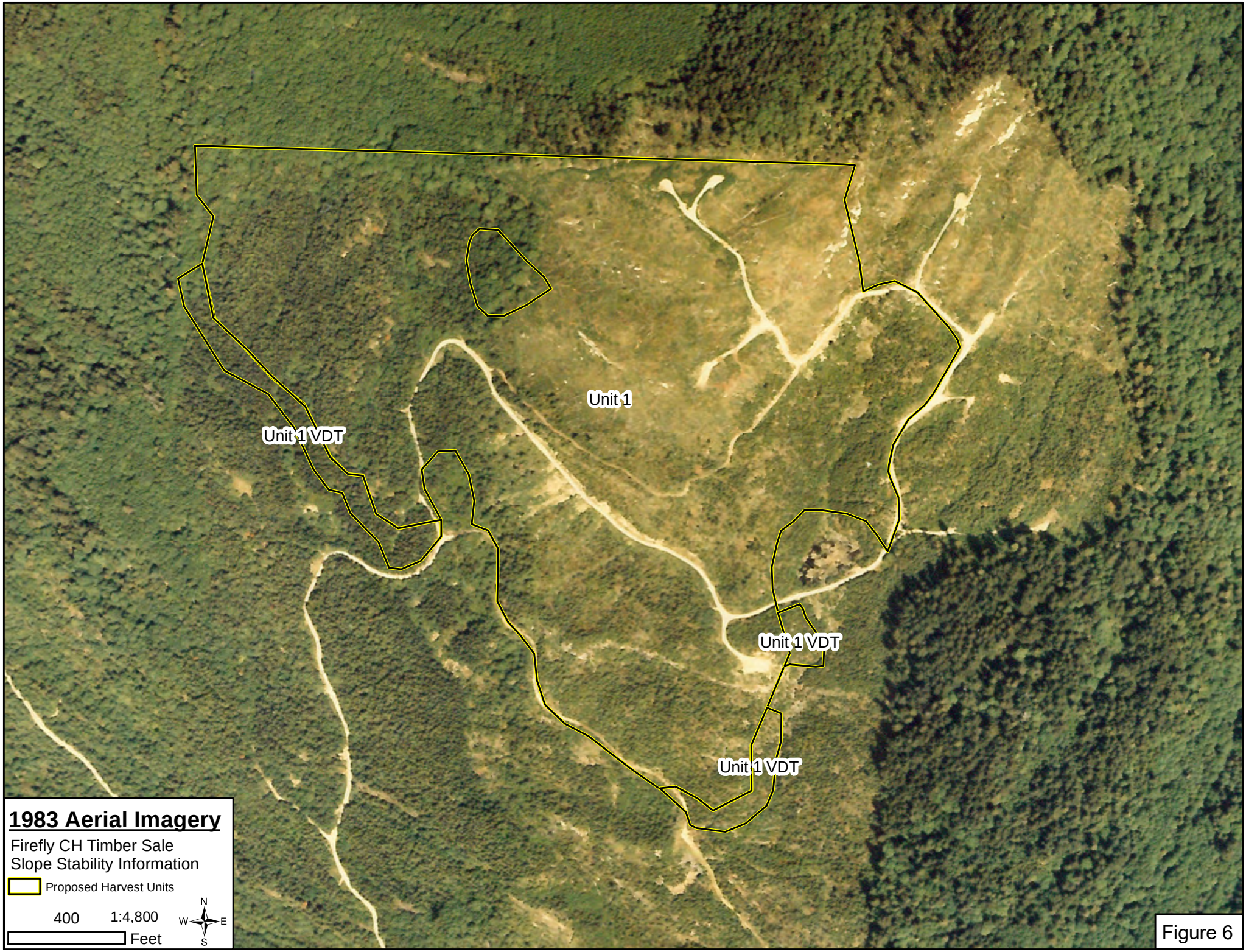
Unit 1
Unit 1 VDT
Unit 1 VDT
Unit 1 VDT
1983 Aerial Imagery
Firefly CH Timber Sale
Slope Stability Information
Proposed Harvest Units
400
1:4,800
Feet
N
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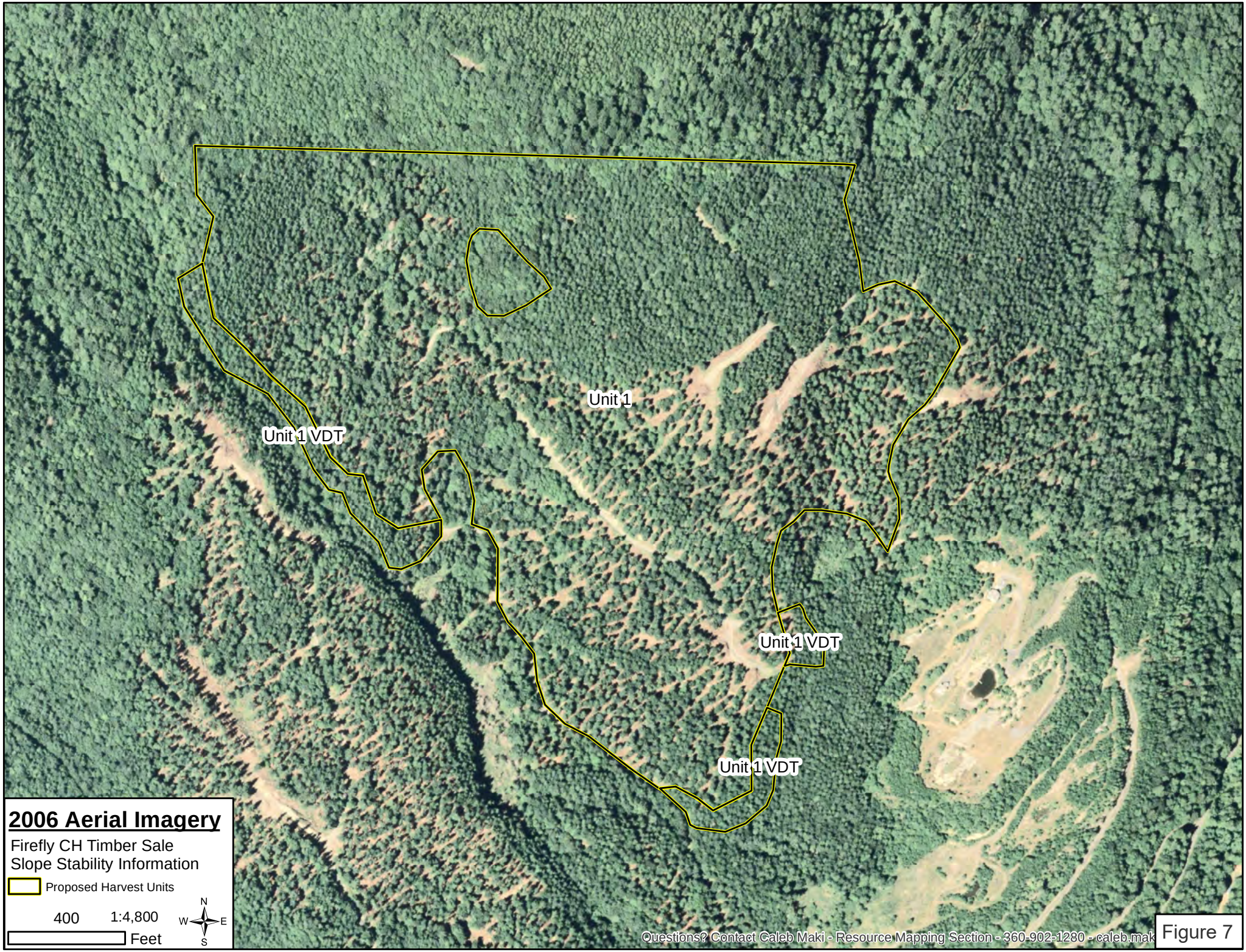
Figure 6


Unit 1
Unit 1 VDT
Unit 1 VDT
Unit 1 VDT
2006 Aerial Imagery
Firefly CH Timber Sale
Slope Stability Information
Proposed Harvest Units
400
1:4,800
Feet
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Questions? Contact Caleb Maki - Resource Mapping Section - 360-902-1280 - caleb.mak

Figure 7

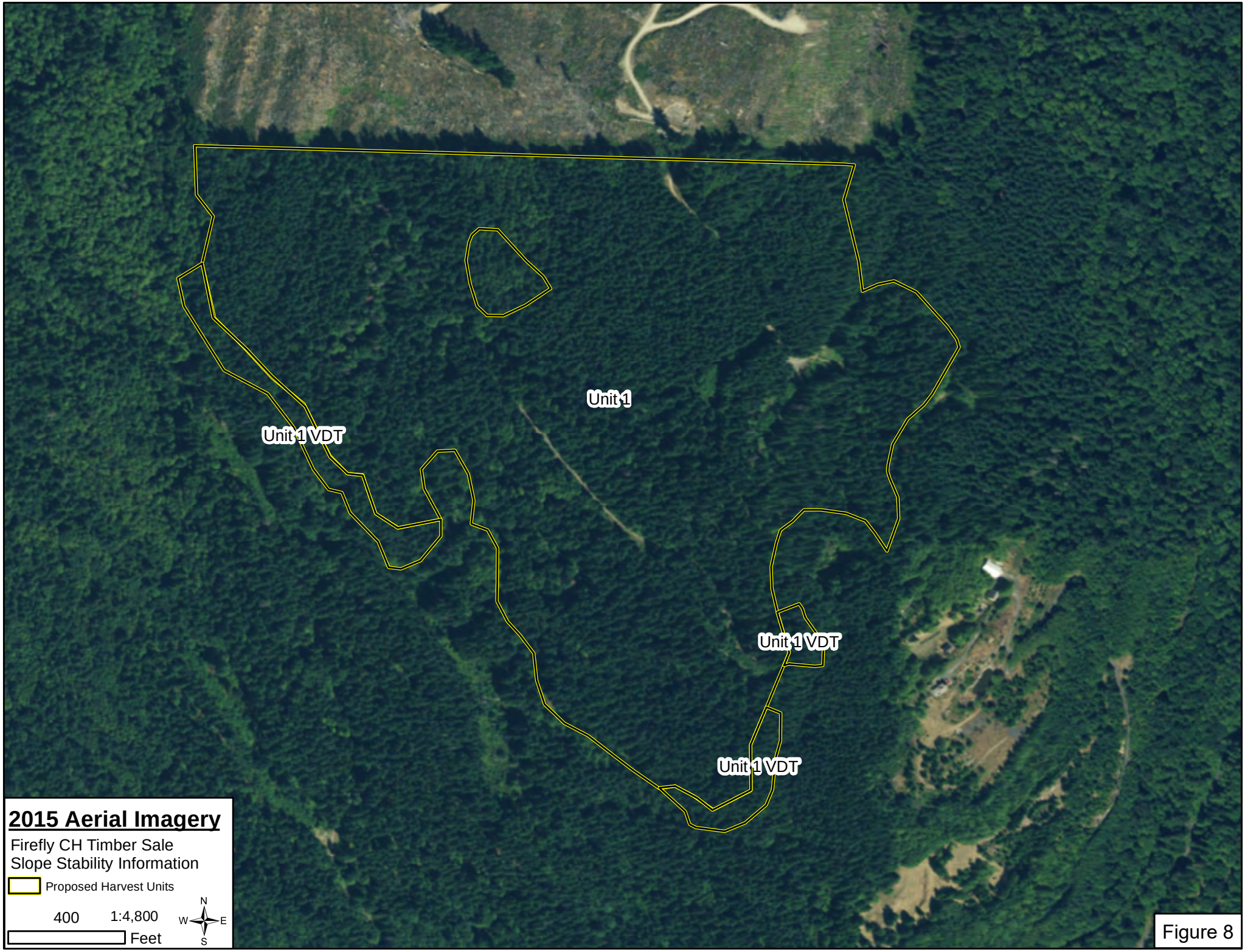
Unit 1
Unit 1 VDT
Unit 1 VDT
Unit 1 VDT
2015 Aerial Imagery
Firefly CH Timber Sale
Slope Stability Information
Proposed Harvest Units
400
1:4,800
Feet
N
W
E
S

Figure 8