Waldo Canyon Fire – Burned Area Emergency Response

Geology Resource Assessment Documentation

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July 15, 2012

Waldo Canyon Fire, Mountain Shadows

Executive Summary – Geological Resource Condition Documentation:

The Waldo Canyon Fire burned 18,247 acres west of Colorado Springs, CO. An Inter-Agency BAER Team Assessed the incident and found the overall soil burn severity to be 5% unburned, 41% low, 40% moderate, and 19% high. The high and moderate severity classes have evidence of severe soil heating in patches, including moderate to high water repellency; these areas have long-term soil damage and high erosion hazard. Geologic hazard analysis was performed by the U.S. Geological Society and will be a separate stand-alone document evaluating the effects of the Waldo Canyon Fire on known geologic hazards. This report gives general geologic background data to familiarize the reader on the potential hazards present in the Waldo Canyon Fire to better understand the U.S. Geological Society geologic hazard analysis.

1 General Situation Report

1.1 Waldo Canyon Inter-Agency BAER Team

An Inter-Agency BAER team was formed to address the effects of the Waldo Canyon Fire, the range of concerns, values at risk, and potential treatments across ownerships to coordinate efforts and maximize treatment effectiveness within whole watershed units at several scales.

Geology concerns were addressed by U.S. Geological Society and by the State of Colorado Geological Society.

1.2 Summary of Geological Conditions

The Cascade quadrangle covers the southern end of the Rampart Range part of the Front Range uplift. The Rampart Range fault zone forms the range-bounding structure and a tectonic boundary with the Colorado Piedmont to the east. The fault juxtaposes Precambrian rocks on the west against steeply dipping Paleozoic and Mesozoic rocks to the east. The Rampart Range consists mainly of Precambrian crystalline rocks, with Phanerozoic cover rocks limited to its southern end. These rocks lie within the structural and topographic reentrant of the Manitou Springs embayment, where displacement along the Rampart Range fault zone is transferred to the Ute Pass fault zone. The "Great Unconformity" (i.e. the nonconformity between Precambrian crystalline rocks and Phanerozoic sedimentary rocks) is well exposed in deep canyons of the southern Rampart Range, with the sedimentary Cambrian Sawatch Sandstone overlying Proterozoic plutonic igneous and metamorphic rocks. Coarse clastic sediments of Tertiary and Quaternary age are widespread along the mountain front, resting in angular unconformity upon strata of Cretaceous or older age. At higher elevations, dissected remnants of Tertiary gravels cover the gently rolling topography of the Rampart erosion surface that was cut into less resistant granitic bedrock probably during the late Eocene and Miocene (Steven and others, 1997). The Colorado Piedmont (Leonard, 2002; McMillan and others, 2002) contains tributaries of the Fountain Creek watershed of the Arkansas River system (see Appendix A for geologic map and map key).

STRUCTURAL GEOLOGY - Two major fault zones transect the Cascade quadrangle. These are the northwest-striking Ute Pass fault zone in the southwestern part of the quadrangle, and the generally north-striking Rampart Range fault zone along the eastern edge of the map area. High-angle, north-northwest- to north-northeast-striking faults are abundant within the Precambrian units of the Rampart Range. Some of these high-angle faults are sub-parallel to and associated with the major fault zones. The Fountain Creek drainage (a conduit for part of the Colorado Springs culinary water supply) and State Highway 24 follows the Ute Pass fault zone. North-south-trending hogback ridges and strike valleys were eroded upon steeply dipping strata in the downthrown block east of the Rampart Range fault zone. The U.S. Air Force Academy lies along the Rampart Range fault zone, as do many of the new housing subdivisions.

ALLUVIAL DEPOSITS — Silt, sand, and gravel deposited in stream channels, on flood plains, on pediments, and as sheetwash along Fountain and Monument Creeks and associated tributary drainages. Terrace alluvium and related pediments along these mainstem creeks were deposited mostly during late-glacial and early interglacial stages. The approximate terrace heights reported for each unit are the elevation differences measured between the creek bed and the top of the original or remnant alluvial surface near the creek edge of the terraces. Thickness is measured on the maximum exposed thickness of the unit.

PEDIMENT GRAVELS (MIDDLE PLEISTOCENE TO LATE PLIOCENE) — Partially dissected remnants of four levels of older gravel deposits are preserved along Fountain and Monument Creek and the piedmont. Finlay (1916) recognized two of these "mesa gravels" on the basis of on their distinctive topographic form and suggested a fluvial origin. Varnes and others (1967) identified a third partially dissected gravel deposit at lower elevation and from youngest to oldest formally named them the Pine Valley Gravel, Lehman Ridge Gravel, and Douglass Mesa Gravel (Table 2). They classed them as "pediment gravels." Scott and Wobus (1973) referred to all three deposits as "alluvial terrace or pediment gravel" and correlated them with similar deposits in the Denver area that were formally named the Slocum Alluvium, Verdos Alluvium, and Rocky Flats Alluvium by Scott (1960, 1963b).

ALLUVIAL AND COLLUVIAL DEPOSITS — Gravel, sand, and silt in alluvial fans, stream channels, flood plains, tributary stream channels, and lower parts of hillslopes. Alluvial processes are predominant in stream

channels and flood plains, whereas colluvial and sheetwash processes are predominant on alluvial fans and along the hillslope-valley floor boundary.

MASS-WASTING DEPOSITS — Earth materials that were transported downslope primarily by gravity and not within or under another medium, such as water or ice. Some of these deposits have moved by creep, which is a slow, gradual, progressive downslope movement of earth materials.

1.3 Geologic Hazards

Past geologic hazards are mapped and presented in summary form taken from State of Colorado Geological Society: Many different types of geologic hazards, such as landslides, debris flows, swelling soils and rockfall, are present within the Cascade quadrangle. Landslides and swelling soils are the most common and most costly hazards in the eastern urbanized area, potentially accounting for millions of dollars in property loss and damage (Noe and others, 1997; Himmelreich and Noe, 1999; Himmelreich, 1996; and City of Colorado Springs Office of Emergency Management Homepage, 2003).

LANDSLIDES

Many landslides are located in the Cascade quadrangle. The largest one lies along Highway 24, about 0.25 mi southeast of the town of Cascade along the eastern margin of French Creek. This large, complex pre-historic slide-flow deposit covers an area of at least 0.42 mi and is outside the fire perimeter.

Both prior to and as a result of the 1999 storms, landslide damage has occurred in the Cedar Heights subdivision, west of Garden of the Gods Park , here the Glen Eyrie Shale Member of the Fountain Formation is accountable for both old and active landslides.

The Mountain Shadows subdivision is built upon shale, limestone, and sandstone overturned by Laramide movement on splays of the Rampart Range fault zone that pass beneath the neighborhood. This area was previously mapped as earthflow, colluvium, and landslide deposits (Trimble and Machette, 1979; Scott and Wobus, 1973; Himmelreich and Essigmann, 1980).

North of the Mountain Shadows subdivision, landslides in the Pierre Shale locally affect Qg2 gravels. Numerous landslides have occurred in the Pikeview Quarry as a result of mining operations exposing dipping carbonate layers of the Manitou Limestone (Himmelreich, oral communic. to Pikes Peak Ranger District, 2001).

Most of the landslides mapped in the Peregrine subdivision are derived from the Pierre Shale and other Cretaceous rocks (Himmelreich, unpublished maps). In addition, other small (not mapped) landslides occur in the quadrangle, and soil slumps have developed on road cuts along Woodmen Road near Dry Creek in the Peregrine subdivision (J. White, oral comm., 2003).

Two landslides located along the westernmost boundary of the U.S. Air Force Academy are also derived from the Pierre Shale. They contain cobbles and boulders of Qg2 gravels, subrounded fragments of Pikes Peak Granite, and buff-colored fragments of Dawson Formation. These landslides themselves, contain localized debris flows and slumps.

DEBRIS FLOWS

Debris flows are heterogeneous mixtures of mud, rock fragments, and plant materials that commonly form in the lower parts of tributary streams as they enter a large valley (Rogers and others, 1974). As the debris flow moves down its valley, unconsolidated surficial material is incorporated into the flow until the suspended sediment is no longer confined and is released as a fan-shaped deposit at the mouth of the tributary stream. Debris flows are the result of torrential rainfall or very rapid snowmelt runoff, where sediment supply is abundant and easily mobilized (Selby, 1993). Hazard analysis should take into account denuded forest conditions, such as after a wildfire (FEMA, 1999; White, 1999). Such conditions may exist in areas mapped as alluvial fans (Qf), colluvium and sheetwash (Qcs), and landslides (Qls), or in areas where crystalline bedrock units are weathered to grus.

Deposits formed by debris-flow activity have been recognized and reported within the quadrangle in the Mountain Shadows and Peregrine subdivisions (Bass and Himmelreich, 1987; Himmelreich and Essigmann, 1983; Himmelreich, 2000). Several techniques are available for the mitigation of debris flows. These include construction

of debris basins (to be cleaned after each flow event), channelization and/or diversion of runoff, protective structures, debris-catching devices, and structures with significant clearance.

ROCKFALL

Rockfall deposits are grouped into the colluvium and sheetwash deposits (Qcs) on the accompanying geologic map. While rockfall deposits were not very extensive or of great thickness, they represent a significant hazard in the map area where hogbacks are located near urban development. Sections of U.S. Highway 24, where Fountain Creek passes through Precambrian Pikes Peak Granite and forms steep-walled cliffs, are in an area of significant rockfall hazard. These slopes carry a "high" rating in the Colorado Department of Transportation Rockfall Rating System (J. White, personal communic., 2003). Very large granite boulders, some exceeding 15 ft in diameter, are found along the highway, along with smaller boulders, cobbles, and fan deposits.

2 Geology Inventory

Geologic coverage was obtained from the State of Colorado Geological Society, which incorporates USGS geology information and mapping. The fire areas covered by 2 separate geology surveys, with 154 soil map units in total within the fire perimeters. Corresponding map unit data and interpretations were obtained for further analyses. This provided the basic information for making interpretations of fire effects upon the various geologic formations, particularly as many areas were not field visited due to access and time constraints.

3 Values at Risk – Threats to Downstream Infrastructure

The combination of burning, soil types, steep slopes, and lack of soil cover will create watershed responses with erosion and sedimentation, the degree depending upon the severity of the coming winters over the next 2-4 years. Off-site effects due to sedimentation and stream bulking are downstream, and include potential adverse effects to facilities (roads, buildings, reservoirs), water quality deterioration and human use, and risk to human life and property from potential flooding, mudslides, increased landslide, rock-falls, and debris flows.

4 Emergency Determination

Effects of the fire on the soils have created emergency conditions, posing hazards to downstream values at risk. Soils naturally prone to flashy runoff and erosion have been affected by the fire with complete removal of soil cover and water repellency. This will significantly increase peak flows, runoff, stream bulking, flooding and debris flow hazard, and downstream sedimentation.

5 Treatments to Mitigate the Emergency

Specific mitigations will be site specific and based on the U.S. Geologic Society geologic hazard findings.

6 References

Geologic Map of the Cascade Quadrangle, El Paso County, Colorado By Matthew L. Morgan1, Christine S. Siddoway2, Peter D. Rowley3, Jay Temple4, John W. Keller1, Bonny Hawkins Archuleta2 and John W. Himmelreich Jr.5, 1 Colorado Geological Survey, Denver, CO, 2 Colorado College, Colorado Springs, CO, 3 Geologic Mapping Inc., New Harmony, UT, 4 Consulting Geologist, Woodland Park, CO, 5 Himmelreich and Associates, Colorado Springs, CO, Colorado Geological Survey, Denver, Colorado / 2003

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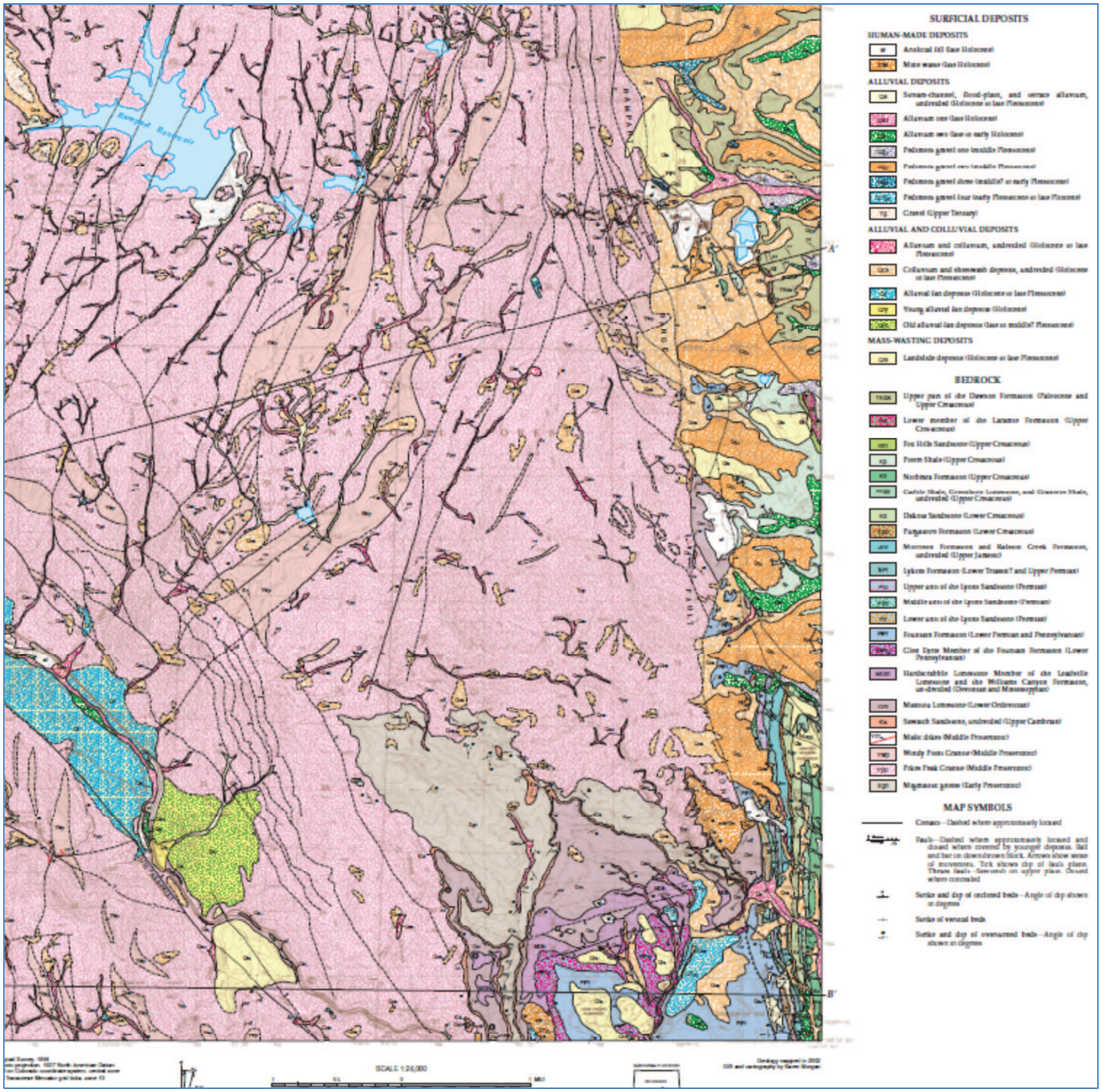
USDA Forest Service, Effects of Fire on Soil, National Fire Effects Workshop, GTR WO-7.

APPENDIX A: Bedrock Geology Map Unit Inventory

Table A1. Bedrock Geology Map Unit Descriptors

Map Unit	Map Unit Description
23	Chawanakee family, 60 to 80 percent slopes.
24	Chawanakee-Chaix families complex, 40 to 60 percent slopes.
27	Chawanakee family-Rock outcrop complex, 60 to 80 percent slopes.
32	Deadwood family, 40 to 60 percent slopes.
33	Deadwood family, 60 to 80 percent slopes.
35	Deadwood-Neuns families complex, 40 to 60 percent slopes.
36	Deadwood-Neuns fasmilies complex, 60 to 80 percent slopes
63	Etsel family-Rock outcrop complex, 50 to 80 percent slopes.
80	Goulding family, 40 to 60 percent slopes.
109	BARPEAK-SHEETIRON COMPLEX, 50 TO 90 PERCENT SLOPES
110	BEARGULCH-SKYROCK COMPLEX, 50 TO 75 PERCENT SLOPES
125	CHOOP FINE GRAVELLY LOAMY COARSE SAND, 50 TO 75 PERCENT SLOPES
126	CHOOP-ROCK OUTCROP COMPLEX, 50 TO 90 PERCENT SLOPES
148	HAPLOXEROLLS, 2 TO 9 PERCENT SLOPES
162	INDLETON-CARIS-HOOSIMBIM COMPLEX, 50 TO 75 PERCENT SLOPES
175	MILLSHOLM LOAM, 5 TO 9 PERCENT SLOPES
176	MILLSHOLM-AZULE COMPLEX, 15 TO 30 PERCENT SLOPES
177	MINERSVILLE SANDY LOAM, 50 TO 75 PERCENT SLOPES
178	MINERSVILLE VARIANT-CHOOP COMPLEX, 50 TO 75 PERCENT SLOPES
179	MUSSERHILL GRAVELLY LOAM, 15 TO 30 PERCENT SLOPES
183	MUSSERHILL-WEAVERVILLE-URBAN LAND COMPLEX, 9 TO 30 PERCENT SLOPES
195	SKYROCK VARIANT-ROCK OUTCROP COMPLEX, 30 TO 50 PERCENT SLOPES
199	TALLOWBOX-MINERSVILLE COMPLEX, 50 TO 75 PERCENT SLOPES
203	VALCREEK-MINERSVILLE COMPLEX, 30 TO 75 PERCENT SLOPES
204	VALCREEK-MINERSVILLE-CHOOP COMPLEX, 30 TO 75 PERCENT SLOPES
206	VANVOR-HOOSIMBIM COMPLEX, 50 TO 75 PERCENT SLOPES
259	Rock outcrop-Goulding family complex, 40 to 80 percent slopes.
162tw	INDLETON-CARIS-HOOSIMBIM COMPLEX, 50 TO 75 PERCENT SLOPES
AlD	Auberry fine sandy loam, 8 to 30 percent slopes
AlF	Auberry fine sandy loam, 30 to 70 percent slopes
AnD	Auburn loam, 8 to 30 percent slopes
ArD	Auburn very stony loam, 8 to 30 percent slopes
ArDsh	Auburn very stony loam, 8 to 30 percent slopes
AtE2	Auburn very stony clay loam, 30 to 50 percent slopes, eroded
AuF2	Auburn very rocky clay loam, 50 to 70 percent slopes, eroded
BeD	Behemotosh very stony loam, 8 to 30 percent slopes
BeE2	Behemotosh very stony loam, 30 to 50 percent slopes, eroded
BeE2sh	Behemotosh very stony loam, 30 to 50 percent slopes, eroded
BhF2	Behemotosh very rocky loam, 50 to 70 percent slopes, eroded
BhF2sh	Behemotosh very rocky loam, 50 to 70 percent slopes, eroded
BkE	Boomer gravelly loam, 30 to 50 percent slopes
BkEsh	Boomer gravelly loam, 30 to 50 percent slopes
BlF	Boomer very stony loam, 50 to 70 percent slopes
BlFsh	Boomer very stony loam, 50 to 70 percent slopes
BoE3	Boomer very stony clay loam, 30 to 50 percent slopes, severely eroded
BoF3	Boomer very stony clay loam, 50 to 70 percent slopes, severely eroded
CaE3	Chaix coarse sandy loam, 30 to 50 percent slopes, severely eroded
CaF3	Chaix coarse sandy loam, 50 to 70 percent slopes, severely eroded
CbD2	Chaix sandy loam, 5 to 30 percent slopes, eroded
CbE	Chaix sandy loam, 30 to 50 percent slopes
CbF	Chaix sandy loam, 50 to 70 percent
CdE	Cohasset loam, 30 to 50 percent slopes
CdF	Cohasset loam, 50 to 65 percent slopes
CeA	Churn gravelly loam, 0 to 3 percent slopes
Ch	Cobbly alluvial land
CkF	Colluvial land, volcanic rocks
ClF	Colluvial land, sedimentary rocks
CmD	Cohasset stony loam, 0 to 30 percent slopes
CnF	Cohasset very stony loam, 50 to 70 percent slopes
CsF	Colluvial land
CsFsh	Colluvial land
CxE	Corbett loamy coarse sand, 15 to 50 percent slopes
CxF3	Corbett loamy coarse sand, 30 to 70 percent slopes, severely eroded
CxG	Corbett loamy coarse sand, 50 to 80 percent slopes
CyG	Corbett very rocky loamy coarse sand, 30 to 80 percent slopes
DgE2	Diamond Springs very rocky sandy loam, 30 to 50 percent slopes, eroded
DgE3	Diamond Springs very rocky sandy loam, 30 to 50 percent slopes, severely eroded
GaC	Gaviota fine sandy loam, 3 to 15 percent slopes
GaD	Gaviota fine sandy loam, 15 to 30 percent slopes
GbD	Gaviota very rocky sandy loam, 0 to 30 percent slopes
GbE2	Gaviota very rocky sandy loam, 30 to 50 percent slopes, eroded
GeE2	Goulding very rocky loam, 30 to 50 percent slopes, eroded
GeE2sh	Goulding very rocky loam, 30 to 50 percent slopes, eroded
GeF2	Goulding very rocky loam, 50 to 70 percent slopes, eroded
GeF2sh	Goulding very rocky loam, 50 to 70 percent slopes, eroded
GgF	Goulding stony loam, 50 to 65 percent slopes
HaF	Henneke very rocky loam, 15 to 60 percent slopes
HcE	Holland sandy loam, 15 to 50 percent slopes
HcF	Holland sandy loam, 50 to 70 percent slopes
HmE	Hillgate-Lodo complex, 3 to 50 percent slopes
HuE	Hugo gravelly sandy loam, 30 to 50 percent slopes
HuF	Hugo gravelly sandy loam, 50 to 65 percent slopes
HvF	Hulls gravelly loam, 50 to 65 percent slopes
JbD	Josephine gravelly loam, 10 to 30 percent slopes
JbE	Josephine gravelly loam, 30 to 50 percent slopes
JbF	Josephine gravelly loam, 50 to 70 percent slopes
JdD	Josephine gravelly loam, moderately deep, 10 to 30 percent slopes
JdE	Josephine gravelly loam, moderately deep, 30 to 50 percent slopes
JoD	Josephine gravelly loam, 10 to 30 percent slopes
JoF2	Josephine gravelly loam, 50 to 65 percent slopes, eroded
JsF	Josephine-Sheetiron complex, 50 to 70 percent slopes
KbC	Kanaka sandy loam, 3 to 15 percent slopes
KcD	Kanaka rocky sandy loam, 5 to 30 percent slopes
KcE	Kanaka rocky sandy loam, 30 to 50 percent slopes
KcF2	Kanaka rocky sandy loam, 50 to 70 percent slopes, eroded
KgF2	Kidd very rocky loam, 10 to 60 percent slopes, eroded
KgF2sh	Kidd very rocky loam, 10 to 60 percent slopes, eroded
LbE	Lodo shaly loam, 10 to 50 percent slopes
LbF3	Lodo shaly loam, 50 to 70 percent slopes, severely eroded
LdE2	Lodo and maymen shaly loams, 30 to 65 percent slopes, eroded
MaE	Marpa gravelly loam, 30 to 50 percent slopes
MaEsh	Marpa gravelly loam, 30 to 50 percent slopes
MaG	Marpa gravelly loam, 50 to 75 percent slopes
MaGsh	Marpa gravelly loam, 50 to 75 percent slopes
MbG2	Maymen very stony loam, 30 to 80 percent slopes, eroded
MbG2sh	Maymen very stony loam, 30 to 80 percent slopes, eroded
McD	Millsap loam, 5 to 30 percent slopes
McE	Millsap loam, 30 to 50 percent slopes
MeD	Millsholm gravelly loam, 3 to 30 percent slopes
MeE	Millsholm gravelly loam, 30 to 50 percent slopes
MeG	Millsholm gravelly loam, 50 to 75 percent slopes
MfE2	Millsholm very rocky loam, 30 to 50 percent slopes, eroded
MfE2sh	Millsholm very rocky loam, 30 to 50 percent slopes, eroded
MfF2	Millsholm very rocky loam, 50 to 70 percent slopes, eroded
MfF2sh	Millsholm very rocky loam, 50 to 70 percent slopes, eroded
MtD	Millsholm clay loam, 10 to 30 percent slopes
MtE	Millsholm clay loam, 30 to 50 percent slopes
MtF	Millsholm clay loam, 50 to 65 percent slopes
NdE	Neuns very stony loam, 8 to 50 percent slopes
NdG	Neuns very stony loam, 50 to 80 percent slopes
NdGsh	Neuns very stony loam, 50 to 80 percent slopes
NeE2	Newtown gravelly loam, 30 to 50 percent slopes, eroded
NfE2	Newtown stony loam, 8 to 50 percent slopes, eroded
PaD	Parrish gravelly loam, 10 to 30 percent slopes
PaE	Parrish gravelly loam, 30 to 50 percent slopes
PaF	Parrish gravelly loam, 50 to 65 percent slopes
PcD	Parrish loam, 8 to 30 percent slopes
PcE	Parrish loam, 30 to 50 percent slopes
PcF	Parrish loam, 50 to 70 percent slopes
RtF	Rockland
Rw	Riverwash
RxF	Rockland
RxFsh	Rockland
ScE	Sehorn clay and Clay loam, 30 to 50 percent slopes
SgE	Sheetiron very stony loam, 30 to 50 percent slopes
SgF	Sheetiron very stony loam, 50 to 75 percent slopes
SgG	Sheetiron very stony loam, 75 to 90 percent slopes
SgGsh	Sheetiron very stony loam, 75 to 90 percent slopes
SmB	Sierra sandy loam, 3 to 8 percent slopes
SmC	Sierra sandy loam, 8 to 15 percent slopes
SmD	Sehorn-Millsholm complex, 10 to 30 percent slopes
SmD3	Sierra sandy loam, 15 to 30 percent slopes, severely eroded
SmE	Sehorn-Millsholm complex, 30 to 50 percent slopes
SnE	Sheetiron gravelly loam, 30 to 50 percent slopes
SnF	Sheetiron gravelly loam, 50 to 65 percent slopes
SsE	Stonyford very stony loam, 30 to 50 percent slopes
SsG	Stonyford very stony loam, 50 to 75 percent slopes
StE	Stonyford stony loam, 30 to 50 percent slopes
StF	Stonyford stony loam, 50 to 65 percent slopes
TaA	Tehama loam, 0 to 3 percent slopes
TaD	Tailings and placer diggings
Tb	Tehama gravelly loam, 0 to 3 percent slopes
TbA	Tehama loam, 0 to 3 percent slopes
TcE	Toomes very rocky loam, 0 to 50 percent slopes

Table A2. Waldo Canyon Fire Surficial Deposits and Bedrock Geology Map



APPENDIX B: Geomorphology Map
(see State of Colorado Geological Society)